Modeling Spatial Inequalities in Health in Cities of Developing Countries: The Case of Child Mortality in Accra, Ghana

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Abstract

Mortality levels in sub-Saharan Africa remain among the highest in the world, even after several decades of decline. Urban-rural differences persist, but even in urban areas, life expectancy remains relatively low. As the population in the region grows increasingly urban and dependent upon city-based economic development, the health of the urban population becomes a more compelling concern. Little is known, however, about intra-urban spatial and socioeconomic inequalities in health in cities of developing nations. We contribute to closing this gap in the literature through an innovative process of linking spatially extensive data from the 2000 census of Ghana with substantively intensive data from the Ghana Demographic and Health Surveys for the same time period. Following models of the urban health transition, we calculate expected levels of child mortality for neighborhoods in Accra, and then compare those expectations with observed data based on direct measures of child mortality. The surprising result is that the observed pattern does not follow the expected pattern, apparently because of the spatially disparate impact of programs to reduce child mortality in high-risk neighborhoods. Additional spatial analysis reveals that clusters of high child mortality do still exist in parts of the city, and are explained both by biological and spatial factors.

INTRODUCTION AND BACKGROUND

Despite a half century of improvement in life expectancy, levels in sub-Saharan Africa remain among the lowest in the world. Almost three decades ago Farah and Preston (1982) noted that "mortality levels in sub-Saharan Africa are the highest in the world and are the object of substantial national and international concern" (p. 381). That conclusion has been repeated over time (Ewbank and Gribble 1993; Balk et al. 2004), and it is still true. Furthermore, it may be at least partly responsible for the relatively slow decline in fertility in sub-Saharan Africa as well as the slow rate of economic growth (Montgomery and Cohen 1998). Among west African countries, Ghana has the lowest mortality (Balk et al. 2004), and the World Health Organization estimates that life expectancy in Ghana is 56.6 years for both sexes combined (World Health Organization 2009). This is an improvement over the estimate of 43.5 years in 1950 (United Nations Population Division 2009), but in the United States life expectancy has been higher than 56.6 since 1928 (Arias 2007). Hill (1993) estimates that in 1936 the probability of a child in Ghana dying before age five was .371, compared to .080 in the US at that time (Arias 2007). By 1980 it had dropped to .164, and the 2003 Ghana Demographic and Health Survey (GDHS) estimated a rate of .111 (Ghana Statistical Service, Noguchi Memorial Institute for Medical Research, and ORC Macro 2004).

The general pattern in Ghana, then, as in other parts of sub-Saharan Africa, is that mortality is much lower than it used to be, but by world standards it is still very high and the improvement seems to have stalled (Johnson, Rutstein, and Govindasamy 2005). In East and Southern Africa, the HIV/AIDS epidemic clearly accounts for much of the reversals or stalling in mortality improvements but in West Africa, this factor is not so important. In West Africa, as in almost every other part of the world, chances of survival for children and adults is higher in cities than in rural areas (Balk et al. 2004), but the differences between urban and rural areas are not huge, and the health of people in urban areas is an increasingly important development issue. 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 economic and 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 (López-Casasnovas, Rivera, and Currais 2005; Bloom, Canning, and Sevilla 2001). 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 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. Economic development was once thought to be the precursor to improved nutrition, but there is now recognition that improved nutrition and health can in fact help to promote economic development (World Bank 2005). 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.

Health status measurement in urban areas of developing countries is complex (Montgomery 2009), partly because they are characterized by wide differentials (Montgomery and Hewett 2005) and also because of the widely varying exposures both within the city and over the life course. Many African city-dwellers, for example, were brought up in rural areas. Songsore (2004) has proposed that the complexity of urban health can be best conceptualized through a combination of the urban environmental transition model of McGranahan et al. (2001), and the environmental risk transition model proposed by Smith and Lee (1993). At the heart of these models is the core idea of the overall health and mortality transition that is part of the broader demographic transition—that in high mortality societies people die young from acute communicable disease and in low mortality societies people die at increasingly older ages from degenerative disease (Weeks 2008). The reasons for the transition are related to improved nutrition, improved public health infrastructure, and improved medical care, all of which are linked to the higher use of resources per capita that we know as economic development. Since urban environments are the places where incomes rise earliest and fastest and wealth accumulates most prolifically, it is in the cities of developing nations where the health transition is likely to be fastest and most visible.

Low-income cities in developing nations are apt to have high mortality relative to richer cities because children, in particular, are dying from acute communicable disease related to living in poor families with inadequate nutrition, and related as well to living in an unhealthy environment of unsafe water and poor sanitation (Cameron and Williams 2009), along with poor air quality (Boadi and Kuitunen 2005). Some of these risks at the household level can be at least partially overcome by public, private and voluntary programs aimed at immunizing children, providing nutritional supplements (such as vitamin A and iron), and providing bed-nets as protection from mosquitoes in malaria-prone areas such as most of sub-Saharan Africa. As income and wealth rise in the context of an improving economy, they will almost certainly do so in an unequal fashion, leading to a small, but potentially growing, group of people who survive through adulthood to be afflicted at older ages by degenerative disease. With increased wealth the risk profile of poor nutrition, poor water and sanitation, and inadequate medical care transitions to a profile of over-nutrition (see, for example, Popkin 2002), good water and sanitation threatened by toxic waste from resource-intensive product use and abuse, and increasingly expensive high-technology-oriented medical care designed to extend life expectancy at the older ages. In between these end points of the transition, child mortality associated with acute illness will continue to be a concern even as the population faces a new set of risks associated with degenerative disease.

Cities in richer countries have, of course, already traversed this urban health transition. "Interest in the effects of the local environment on human health is not new. It has been manifest for some 2,500 years and reached its peak during the public health movements of the mid to late nineteenth century in Europe and America. *Interest waned with improvement in basic living conditions (the provision of clean water and air, better housing, sanitation, etc.) and the epidemiologic transition that rendered infectious diseases apparently less important than chronic diseases*" (MacIntyre and Ellaway 2003: 38 [emphasis added]). But there is an important difference between the transitions now and those of one hundred years ago, which relates to the dramatic improvement in global health knowledge and in our ability to transfer that knowledge. In Europe and the United States it was clearly the poorer neighborhoods where death rates were the highest (MacIntyre and Ellaway 2003; Gordon 2003), and that assumption has been applied directly to cities of developing nations, where slums are often assumed to be the lowest income areas and therefore the areas with the poorest health outcomes (UN Habitat 2005, 2006). That may be broadly true but at a finer scale, "upper-class inner-city areas, industrial zones, slums and low-income housing estates often border one another and are interconnected in many ways" (Obrist et al. 2006:320). This is part of the complexity noted by Montgomery and Hewett (2005). Global knowledge of the linkages between health and the environment allows governments and non-governmental organizations to improve health in given neighborhoods without necessarily directly improving the income levels of the people affected by those environmental changes.

RESEARCH OBJECTIVES

The potential complexity of urban health dynamics suggests to us that we should not automatically assume that the urban health transition of cities in developing nations will be identical to those of the now rich cities. At the same time, the data available to test these ideas are very scarce, and there is almost no literature on the spatial inequalities in morbidity and mortality differentials within cities of developing nations. In this research, we develop an innovative way to create direct measures of child mortality by linking the substantively detailed Demographic and Health Survey data to the spatially detailed census data for the city of Accra, Ghana.

Our principal objectives in this paper are (1) to identify the nature of neighborhood-level (place) differentials in health—measured in terms of child mortality rates--within a reasonably data-rich city of a developing nation, so that we can ultimately model the spatial distribution of mortality in other cities of developing nations; and (2) to test the hypothesis that observed differences are the joint result of inequalities in the status of individuals and their neighborhood environments.

Our decision to focus solely on the mortality of children is based on the practical reason that the Demographic and Health Surveys focus on this aspect of health, derived from the urban health transition perspective discussed above which posits that in poorer cities the greatest health risks are found among children. Our decision to focus our attention on the probability of dying between birth and age five (5q0) is based on the practical reason that we are examining data for relatively small geographic areas—neighborhoods within a city—and thus we are using the death rate available to us that has the largest denominator (children up to the age of five), because that increases the statistical power of comparisons between neighborhoods.

DATA AND METHODS

The Study Site

The study site for this project is Accra, the capital of Ghana, located on the Gulf of Guinea coast (see Figure 1). Accra falls within the Greater Accra region (first administrative level in the country), but our focus is on the district (second administrative level) within that region, which is the Accra Metropolitan Area (AMA). Responsibility for the health, welfare and governance of this population rests with the Accra Metropolitan Assembly (AMA) and the Accra Regional Directorate of Health. The metropolitan area comprised 1.6 million people and 365,550 households according to the March 2000 census, and it is estimated to have reached 2 million by 2009. The Ghana Statistical Service delimits several levels of geography within the Accra district: 13 sub-metro areas, which are further divided into 43 localities, and then into 1,731 Enumeration Areas (EAs). The latter represent the basic geographic building blocks for our analysis, and EAs are roughly comparable to census tracts in the United States. As part of our research, we have created the first digital boundary file of those EAs, working from paper maps that are not-to-scale along with a high spatial resolution satellite imagery to do so.

FIGURE 1 ABOUT HERE

Importantly for our purposes, the Ghana Statistical Services has also defined a set of 88 agglomerations of EAs which we call “vernacular neighborhoods,” by which we mean neighborhoods that are broadly recognized and agreed to by residents of 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, primarily because there is no comprehensive street address system for the city. The 88 neighborhoods are shown in Figure 2. A few of the neighborhoods are special purpose areas, such as the presidential palace (Flagstaff House), the juvenile facility (Borstal Institute), the Police Training Depot, the Military Hospital, the International Trade Fair Center, and the University of Ghana, Legon. Most, however, are residential or mixed commercial/ retail/residential and they average 20 EAs per neighborhood, with a minimum of one and a maximum of 85.

FIGURE 2 ABOUT HERE

Several studies have suggested that there are important inequalities in urban health in Ghana in general and in Accra more specifically (Songsore and McGranahan 1998; Stephens et al. 1994; Taylor et al. 2002). An analysis of existing health data and a household survey in the 1990s by Songsore and Goldstein (1995) revealed stark contrasts between the better off neighborhoods and the slum areas of the city. Agyei-Mensah (2006) notes that these studies helped lead to the enactment of the 2003 Ghana Poverty Reduction Strategy. At the same time, Accra seems generally typical of the coastal cities of West Africa. Twenty-first century Greater Accra is a sprawling urban area of 2 million people and the neighborhoods reflect multiple strands of history, including (1) a directive-based urban development policy in the colonial period; (2) the development of elite areas, including military cantonments, populated largely by foreigners and diplomats; (3) older villages dominated by different ethnic groups and which are now incorporated into the larger city; (4) and parts of the city that have been reception areas for migrants into the metropolis. Urban planning and development control have been lax, leading to wide disparities in neighborhood formality and infrastructure (Harvey and Brand 1974; Parker 2000; Brand 1972; Acquah 1958). These are features shared by many West African coastal cities, thus increasing the possibilities of generalization from Accra to other cities. Accra is the western end of what Davis (2006) calls a "vast West African conurbation rapidly coalescing along the Gulf of Guinea" with Lagos as its fulcrum. By 2020 it could have a total population of more than 60 million inhabitants and "tragically, it probably will also be the biggest single footprint of urban poverty on earth" (p. 6).

At independence in 1957 Accra had fewer than 250,000 residents, but by the 2000 census that had mushroomed to 1.6 million. A Master Plan of Accra was produced in 1958, but it was not fully implemented. Planning schemes were prepared for pockets of land, resulting in a series of disconnected plans which fragmented the orderly development of the city--Accra has no coherent, consistent spatial development strategy (Agyei-Mensah and Owusu 2009; Parker 2000). This complexity is compounded by the incessant population growth, with Greater Accra growing by nearly 4% per year between the 1984 and the 2000 censuses, a pace that almost certainly has continued since the census was taken (United Nations Population Division 2008).

In Accra, the negative health impacts of urban poverty are at least partly associated with an uneven pattern of infrastructure which is a consequence of weak planning controls in the era since independence during which the city has increased dramatically in population. To be sure, Parker (2000:xxvii) has commented that [t]he perception that Accra represents what one historian called ‘a jungle of intractable complexities’ has remained remarkably persistent.” Yet, as Parker shows, the complexities are not actually intractable once you dig into the history of the city. Indeed, they are not dissimilar from other post-colonial cities in Africa such as Lagos, Nigeria (Olayiwola, Adeleye, and Oduwaye 2005) and Asia, such as Jakarta (Ford 1993).

The fact that a majority of Accra’s residents live in neighborhoods that would be called slums by UN-Habitat definitions (Weeks et al. 2007) has quite naturally led Ghanaian health officials to focus their efforts on trying to ameliorate conditions in urban environments that promote communicable disease and thus add a heavy burden to the local population. For example, in 2006 the government launched a national campaign to protect the lives of children through immunizations and the distribution of insecticide-treated bed-nets (UN Office for the Coordination of Humanitarian Affairs 2006). Consistent with the urban health transition perspective, the focus of these programs is children, especially those under five, but there is increasing evidence that the chronic diseases associated with richer cities, such as diabetes and hypertension, are showing up in Accra (Hill et al. 2005; Hill et al. 2007). This too is consistent with the urban health transition framework..

Indirect and Direct Measures of Child Mortality

The spatially most complete set of data from which child mortality can be calculated is the 2000 census, for which we have microdata (individual records without any personal identifiers) georeferenced to the enumeration area (EA). Although the census did not include a set of questions asking about a woman’s complete pregnancy history, each woman was asked how many children she had ever borne alive, and how many of those children were still alive at the time of the census. These are the basic questions required to calculate indirect measures of child mortality using the methods developed originally by Brass (1971) specifically for application to Africa, but now widely used in all settings where census and/or survey data are superior in quality to vital statistics data.

These methods are described in the United Nations Population Division Manual X (1983), and are implemented in the software MORTPAK, developed by the UN Population Division. The census includes data for 482,790 women aged 15-49, with a reported total of 795,631 births among them.

The indirect method of calculating child mortality assumes a set of empirical relationships between age of mother, number of children ever born, children surviving and a resulting age pattern of death among children after birth. Direct measures, by contrast, use the reported date of birth and date of death of each child listed in a pregnancy history, and then generate measures of exposure to the risk of death based on the time that had elapsed between a child's birth and death and the survey date. Hill (1991) has noted that the data from complete maternal histories generally yield excellent mortality data, although the training involved to obtain the data accurately from each respondent to a survey is fairly time-consuming.

While the direct measures of mortality are likely to be the most accurate, the calculations themselves involve a synthetic cohort approach that requires a fairly large number of deaths in order to generate meaningful estimates of the probability of dying in infancy and childhood (Curtis 1995). This limits the ability of survey data to be used for the direct calculation of childhood mortality rates in sub-regional areas, including even a city, much less zones within a city. The 2003 Ghana Demographic and Health Survey (GDHS) included a total of 5,691 women aged 15-49, but the largest sample size for any one of the ten regions in the country was 927 women in Ashanti region. The Greater Accra Region included 835 women, but within the Accra Metropolitan Area (our study site) the number of respondents was only 443, with a total of 691 reported births. Curtis (1995) analyzed a large set of Demographic and Health Surveys and concluded that the standard error around measures of childhood mortality [5q0—the probability of dying before the fifth birthday] stabilized at between four and eight percent of the mortality rate when the number of births exceeds 4,500.

“Matching” Census Records with Survey Data

In order to combine the detailed information provided by complete maternal histories in the GDHS with the spatial detail afforded by nearly a half million women enumerated in the census, we employed a matching technique developed by Kenneth Hill and Livia Montana (citations to follow), whereby each woman in the census was paired up with a respondent in the GDHS who shared her characteristics. The concept itself is not unlike the “hot-deck” imputations used by the U.S. Census Bureau to fill in information for respondents when data are missing (Rubin 1987; Bishop, Formby, and Thistle 2003). The difference is that we are not filling in missing data for some respondents; rather, we are filling in missing categories of data for all respondents. In this case, we are imputing birth histories to women in the census, based on the matching of characteristics between women in the census and those in the GDHS.

As noted above, the sample size of the 2003 GDHS was small in Accra. Therefore, we pooled the 2003 GDHS with two other data sources: (1) the 1998 GDHS in which there were 501 women in Accra, with a total of 828 births; and (2) a special “slum” supplement to the 2003 GDHS that was administered in Accra under the auspices of UN-Habitat, and included 807 women aged 15-49 in Accra and 1,102 births to those women. Overall, the pooled data set included 1,551 women aged 15-49 and 2,621 children ever born to those women. However, only 917 of the women had ever given birth to a child, indicative of the fact that fertility in Accra is kept low at least partly by delayed marriage, in combination with the use of abortion (Oliveras 2005). In the combined GDHS samples, 41 percent of women 15-49 reported no children ever born, slightly lower than the 45 percent in the 2000 census.

Each of the three surveys sampled respondents from different EAs within Accra, so the probability is close to zero that there are duplicates in the pooled data. Although the dates are obviously not identical, the surveys bracket the time period of the census. Furthermore, 1998-2003 was a period of stability in fertility rates in Ghana (Ghana Statistical Service, Noguchi Memorial

Institute for Medical Research, and ORC Macro 2004) and the estimates of childhood mortality were also essentially unchanged in Ghana from 1998 to 2003, according to the respective surveys.

The matching proceeded as follows: (1) match on age (coded in five-year age groups because of the relatively small number of women in the combined DHS sample); (2) then match on number of children ever born; (3) then match on number of children surviving (with the caveat that an apparently lower number of children surviving in the census than expected—see discussion below--would lead to a match of n or n + 1 children surviving from the census compared to the DHS). If no match is found on (3), then accept a match on (1) and (2). If no match is found on either (2) or (3) then match on (1). If there is more than one valid match, one is chosen at random. Note that no attempt was made to match on geographic variables, since there were too few cases in the DHS to allow for that additional matching criterion. The matching program was implemented in a Python script that is available on request.

The caveat above regarding the third matching step for the number of children surviving refers to the fact that, for unknown reasons, the census listing includes fewer surviving children than would be expected on the basis of results from GDHS (Ghana Statistical Service 2005). The average number of children ever born to women by age in Accra is nearly identical in the census and in the combined GDHS surveys, but at every age the number of children surviving is less in the census than in the survey results, with an average of 0.17 children fewer surviving per woman in the census than in the surveys. The matching obviously cannot account for fractions of children, so the decision rule was to allow sufficient fuzziness that a woman in the census who, for example, reported five children born and only three children surviving could be matched with a woman in the survey with five children born of whom either three or four were surviving.

An analysis of the matched data showed that there was 100 percent agreement on the age group, which was the first and the mandatory matching criterion. The second matching element was the exact number of children ever born and there was 96 percent agreement on this criterion, with part of the error being due to the fact that the greatest number of children born to any women in the GDHS was 10, whereas in the census there were women within the 15-49 age group who reported as many as 18 children ever born. The third and last matching element was the number of surviving children, and there was 89 percent agreement on the exact number of children surviving, and 90 percent agreement on either the exact number or one more children surviving in the GDHS than in the census. Overall, 89 percent of the matches were in agreement on all three matching variables, and only three percent were not in agreement of either children ever born or children surviving. We compared complete matches with incomplete matches and found that the latter were disproportionately young, single women, and also higher parity women. This is likely the result of the typical bias of a sample, which is to miss the extreme cases and thus to exhibit less variability than exists in the population from which the sample came. There were no observable differences by religion, ethnicity, education, or area of the city. We calculated the child mortality rate (5q0) without the women who did not match completely and resulting rate of 67 deaths per 1,000 was identical to the rate calculated with those women included. Thus, we concluded that the relatively small number of non-exact matches was not introducing a bias into the analysis and, for the sake of completeness, we kept all records for analysis.

An Alternative Index of Child Mortality

The direct and indirect measures of mortality are aggregate measures, for which the denominator is the number of live births. These mortality indices can then be related to neighborhood or other contextual data in an effort to understand the variability over space and time. Another way to approach the data is from the perspective of the mother, in terms of the proportion of her children who have died relative to what we would expect for a woman her age with her number of live births in her region. To control for these two key determinants of exposure—age and parity—we calculated the proportion of each woman's children who had died as a standard score (PDz). Thus, each woman's score represents her standard distance from the average for all women in Accra of her age and parity. This produces a variable that can be used at the individual level, but can also be aggregated to varying spatial scales. This measure has a very high correlation at the neighborhood level with the proportion of a mother's children who have died among women aged 30-34, which has been used in the literature as a surrogate for 5q0 (see, for example, Weeks et al. 2006), but which has the obvious disadvantage that it ignores women of other ages and thus limits the scope of the analysis. Although PDz accounts for age and parity, our analysis revealed that there was a very high correlation (+.85) between PDz and the simpler dichotomy of whether or not a woman of any age or parity had lost at least one child. Indeed, 95 percent of women who had lost one or more children were in the top quartile of PDz.

By creating indices of mortality at what amounts to the household level, we may be better able to understand the determinants of childhood mortality, defining "determinant" as a "variable that would change a population's mortality level if its own value were altered…Many of the determinants of child mortality are properties of the household in which the child is located…other determinants are properties of the 'community' of households" (Farah and Preston 1982: 368). This approach has been codified by Mosley and Chen (1984) into their well-known analytic framework for studying child survival in developing countries, to which we return below.

RESULTS

Comparison of Death Rates Calculated From Different Approaches

We first compare the estimates of child mortality drawn from both direct and indirect estimates. Table 1 summarizes the comparisons for Ghana and for Accra, from which several conclusions can be drawn. It is clear that the indirect measures of child mortality are consistently higher than the direct measures, thus leading us to prefer the direct measures, which presumably are more accurate. It is also evident in the table that, as noted above, the census data tend to overestimate child mortality when based on the comparison of indirect measures, assuming that the data collected by the Demographic and Health Surveys are of higher quality than data collected in the census and that discrepancies are the fault of the census, not the survey. It can also be seen that, as expected, child mortality is lower and the implied life expectancy is higher in Accra than in the country as a whole. Using these direct rates for Accra as a baseline, we were able to evaluate whether or not there are areas within Accra in which children are more or less at risk of death than the average for the city.

TABLE 1 ABOUT HERE

Table 2 summarizes the differences in child mortality according to education of the mother, which is known to be one of the strongest predictors of child survival, and data from the GDHS and other surveys have shown that this holds for Ghana as it does for most places (see, for example, Agyei-Mensah 1999). Yet, the results in Table 2 show a surprising similarity by educational level, with little discernible trend. Although the highest rate is found among those women with no education and the lowest rate is found among those with the highest education, and even though that difference is statistically significant, the magnitude of the difference is very small. To see if this lack of differential might be due to the matching process, we compared these direct measures with the indirect measures for each educational group. As can be seen in Table 2, the indirect measures only add a layer of confusion, since they suggest that child mortality is actually highest among the most well-educated. As a third approach, we calculated the average PDz for each level of education. This measure of child mortality from the mother's perspective also suggests that there is a positive relationship between education and child mortality. The age-parity standardized proportion of children who have died is once again highest for the most educated, and women without an education seem to have better outcomes than do women with some education. We also calculated the PDz by education for mothers in the pooled GDHS (not shown), and found that none of the differences was statistically significant. The slight differences and lack of consistent pattern of child mortality by education in Accra may be explained by the fact that the more educated women in Accra have a greater likelihood of being childless and thus not being at risk yet of losing a child. In the 2000 census, illiteracy was found among 24 percent of those with at least one child, but only 14 percent of the childless. At the other extreme, only 29 percent of mothers had at least a secondary education, whereas 40 percent of childless women had a secondary level education.

TABLE 2 ABOUT HERE

The second panel of Table 2 conveys differences for another well-established determinant of child mortality—the marital status of the mother. Here the results are as expected. In particular, married women are much less likely than single women to experience a death among their children. This pattern is repeated closely by the PDz measure, but less precisely for the indirect measure of 5q0. As can be seen, it is true with all measures that being married or living together reduces the risk of a woman having a child die before age five. For the direct measure and PDz the fact that the highest rate is among single women is clear, but that is not exactly true for the indirect measure, for which being separated produces the highest estimate of child mortality, followed by being single.

The third panel of Table 2 compares women on the basis of labor force status. Women have been an integral part of Accra's economy for many decades (Parker 2000) and 73 percent of women aged 15-49 reported being in the labor force at the time of the census. We compared those not in the labor force with those in the labor force and in either high status occupations (professional, administrative, or clerical) or in lower status occupations and also in the private informal sector. These distinctions scarcely do justice to the complexity of Accra's economic landscape, but they provide useful comparisons. The comparisons indicate that women who are not in the labor force are slightly more likely to have experienced the loss of a child, but among women in the labor force there is no difference according to the occupational status of their work.

Expected Spatial Distribution of Child Mortality

Our major interest in this paper is to see if there is a discernible pattern of child mortality by neighborhood within Accra, focusing especially on the 88 "vernacular" neighborhoods shown in Figure 2. The Mosley-Chen (1984) framework for the determinants of child survival provides us with a way of modeling the expected spatial distribution of child mortality rates in Accra, by identifying, as best we can within the limits of the census data, the proximate determinants of deaths to children (or, alternatively, survival). We measure the biological factors as age and parity, although we are missing data on birth intervals. The environmental contaminants are inferred by proxy variables such as "the intensity of household crowding (persons per room); water contamination can be scaled by source of supply (ditch, pond, open well, hand-pump, piped supply); household food contamination, by cleaning, cooking, and storage practices; and potential fecal contamination, by the presence of latrines or toilets, or the use of soap and water" (Mosley and Chen 1984:33). On the other hand, we have no way of measuring nutrient deficiency, injury, or personal illness control from the census data. We have limited measures of socioeconomic status, largely education of the mother. We also have information on her labor force status, recognizing that its effect on child health is expected to be conditioned by the woman's economic status. A lower income mother who works may leave the child with a less able caregiver, whereas a higher income mother who works may hire a more capable caregiver.

Since an important objective was to identify neighborhoods where the risk of child mortality is highest, we operationalized all variables at the neighborhood level. As indices of the intensity of childbearing (which would conceptually link higher parity with shorter birth intervals) we measure the average number of children born to women in the neighborhood. With respect to environmental factors, we measure the proportion of homes in a neighborhood that are crowded (3+ persons per room), the proportion without piped water in the house, the proportion that are not connected to a sewer, the proportion without their own toilet, the proportion without their own bath, the proportion who use charcoal as cooking fuel, the proportion of women who are illiterate, and the proportion of women who work in the private informal sector (which in all likelihood includes only lower income women). A higher proportion on any one of these indices of the proximate determinants should increase the risk that the neighborhood will have a higher than average level of child mortality. Table 3 shows the descriptive statistics at the neighborhood level for each of these proximate determinants of child mortality.

TABLE 3 ABOUT HERE

We used principal components analysis to deal with multicollinearity among these proximate determinants. The variables loaded onto two components with eigenvalues over one, explaining 78 percent of the overall variance. The first component, with an eigenvalue of 5.7, included (in order of importance) lack of own toilet, lack of sewerage, using charcoal to cook, lack of own bath, lack of inside piped water, working in the private informal sector, and illiteracy. This component seemed clearly to be associated with Socioeconomic Status. The second component included the number of children born per mother and the number of people per room. This variable seemed clearly to be associated with Parity. Since we assume that the risk of child mortality is associated with both Status and Parity, we created a multiplicative risk index by adding a constant to both scores to eliminate negative values and then multiplying Status times Parity. We then divided the resulting score by the mean of the distribution to produce a relative risk for each neighborhood, which ranged from a low of .02 (in Legon—the University of Ghana) to a high of 2.02 in Greefe (the Salt Ponds). We noted above that our estimate of child mortality in Accra based on the direct calculation from our matched census and GDHS data set was 67 deaths per 1,000 live births. Our estimate of the expected 5q0 for each neighborhood was thus a neighborhood's relative risk times 67, leading to a range from 1 in Legon to a high of 136 in Greefe.

Greefe (Salt Ponds) has the highest expected 5q0, but it is a large area with a small population (only 434 women of childbearing age in 2000), so the "real" neighborhood with the highest risk of a child death is Nima, home to nearly 11,000 women of childbearing age, with an expected 5q0 of 135. Nima sprang up after World War II as a village outside of the city limits where soldiers, especially Muslims, returning from the war could establish residences as they sought employment in Accra. In 1958 Nima was officially designated as a slum needing remediation (Harvey and Brand 1974). This has made it Accra's most famous slum, thus drawing a great deal of attention to the area, with positive consequences for the health of its children, as we note below. Most of the other neighborhoods with high expected levels of child mortality are well-known as slums with higher than average levels of fertility, including Chorkor, Ussher Town, South Teshie, Sabon Zongo, Avenor, Mamobi, and Accra Central. At the other extreme, the "real" neighborhoods with low expected levels of child mortality are the elite, embassy-laden areas of Ringway Estates, Airport Residential, Cantonments, and Roman Ridge. Figure 3 is a map of the neighborhoods by expected 5q0, with the actual numbers listed in Table 4. Consistent with the idea that neighborhoods in Accra are distinct entities, we found no pattern of spatial autocorrelation among neighborhoods in terms of child mortality (z(I) = 1.25).

FIGURE 3 ABOUT HERE

TABLE 4 ABOUT HERE

Observed Spatial Pattern of Child Mortality

We sought to calculate a direct measure of child mortality for each vernacular neighborhood, but some neighborhoods have too few mothers with imputed recent births and thus the requisite calculations of risk and exposure were not possible. Therefore, we calculated rates on three different bases. First, we calculated the average of 5q0 for the ten years prior to the census, where rates for that time period were available. Secondly, we calculated the average for all periods prior to the census for those places where complete rates were not available (note that the correlation coefficient between this and the rates for just the ten years prior to the census is +.91). And, thirdly, for the neighborhoods without any direct measure of 5q0, we estimated the rate based on a linear regression equation that predicted 5q0 in a neighborhood from the PDz for that neighborhood, based on the relationship between PDz and the direct rates for all neighborhoods for which we had those direct rates. We then controlled the observed rates to an overall average of 67 deaths per 1,000, in order to maintain the same order of magnitude as our expected results. This adjustment does not influence our analysis, since at this intra-urban level we are interested in the relative rates among neighborhoods as much as in the absolute levels.

The results of the observed levels of child mortality are shown in Figure 4 and Table 4, where it can be seen by comparison with Figure 3 that there is a striking difference between the expected and observed levels of child mortality. For example, three neighborhoods that are regarded as being among the worst slums in Accra, and for which there was an expectation of high child mortality—Nima, Chorkor, and Sabon Zongo—turn out to be among the neighborhoods with the lowest level of child mortality. Although our evidence is thus far only observational and anecdotal, the explanation for this is almost certainly that public and private not-for-profit health delivery systems in Accra have targeted those neighborhoods where the numerically greatest risks of death among children exist. The average woman of reproductive age in Accra in 2000 had given birth to three children and had lost 0.50 children—thus one child in six born to women of reproductive age had died. As a general rule, those neighborhoods with the greatest number of children being born to women are also the places where the greatest number of children can be expected to be at risk of dying. Indeed, this is precisely the group of neighborhoods that had the highest expected level of child mortality. Those are the natural targets for intervention and comparing the columns in Table 4 suggests that this has been a successful strategy.

FIGURE 4 ABOUT HERE

The observed death rates by neighborhood are negatively associated with the total number of children ever born to women in a neighborhood (r = -.57), and negatively associated with the total number of births born to women in the twelve months prior to the census (r = -.55). This is indirect evidence, then, that Ghana Health Service and NGOs have focused attention on those areas where the delivery of maternal and child health services (including vaccinations, vitamin A and iron supplements, and bed nets to lower the risk of malaria) will reach the greatest number of mothers. We have not been able to find direct evidence to confirm this, however (Ghana Health Service - Greater Accra Region 2007).

Overall, the correlation between the expected and the observed levels of child mortality is very low (+.04), and so there is a new set of neighborhoods with "unexpectedly" high mortality. Only one neighborhood, Avenor, is in the highest category shown in Figures 3 and 4 with respect to both expected and observed child mortality. Avenor is a low-income community with a higher-than-average percentage of migrants that has grown up in the open spaces of the commercial sector that lines the Odaw River just north of central Accra. It is an area that is notoriously flood-prone, and it falls within an urban zone identified by Stoler et al. (2009) as having elevated levels of self-reported malaria.

Since the expected and observed levels of child mortality are so loosely correlated, it is obvious that the socioeconomic status and parity of women in neighborhoods will not predict the observed levels. We examined every possible variable that could be summarized from the census to the neighborhood level, including housing characteristics, family structure, ethnicity, and religion. We also calculated the number of health clinics within a 1, 2, and 3 kilometer distance from the center of each neighborhood. There were seven variables that had statistically significant relationships to the observed level of child mortality, only two of which were positively related to the child mortality rate—(1) the percentage of women who had been born outside of Accra, and (2) the number of births per woman in the year prior to the census. Along with this was a negative relationship between child mortality and the number of health clinics within 1 km of the neighborhood. The other four variables reflected the apparent emphasis of Ghana Health Services on the demographically largest neighborhoods, since observed child mortality went down as the number the mothers went up, as the number of children went up, as the number of surviving children went up, and as the number of births in the year prior to the census went up.

These results may also help us understand the somewhat puzzling lack of association found above between education and the direct measures of child mortality. In essence, the apparently selective nature of interventions in Accra has meant that lower status women have had their child mortality rates lowered relative to higher status women, and that has helped to narrow the impacts of the educational gap within Accra. This may also mean that the influence of neighborhoods on child mortality is greater than might otherwise be imagined, and not discernible from statistical tests such as a multilevel regression analysis.

Neighborhood "Clusters"

To better understand the unexpected pockets of apparently high child mortality within Accra, we looked more closely within those neighborhoods by aggregating data for the enumeration areas within each vernacular neighborhood and, in some instances, examining data for specific women in neighborhoods that were covered by the GDHS. For each EA, we have calculated the average PDz as the measure of child mortality. Two important findings emerge when we analyze data at the EA level: (1) in higher status vernacular neighborhoods that had unexpectedly high child mortality as shown in Table 4, there tends to be one or only a small number of EAs that account for the pattern that is attributed to the entire neighborhood. We hypothesize, but do not have the data to confirm, that these are areas within the more elite neighborhoods that are more likely to be populated by workers who service the wealthier families, or by people living informally in the areas of open land that exist in the more elite neighborhoods. They may be women of higher-than-average risk of losing a child, but are not living in a neighborhood that has been targeted for maternal and child services by the health ministry, nor are they in an area with much neighborhood social capital for people in their situation and thus they have worse outcomes than similar women living in some of the lower status areas in Accra.

The analysis at the EA level also reveals the existence of discernible clusters of high child mortality in several parts of Accra. We used the Getis-Ord Gi* statistic (Getis and Ord 1992; 1996) to analyze clusters of contiguous EAs with similar levels of child mortality, and the results are shown in Figure 5. The "strong" areas of high child mortality are in the vicinity of two of the vernacular neighborhoods that exhibited high child mortality as shown previously in Figure 4—Accra Central and Nii Boi Town. Accra Central is an area that historically was open space between the Ga village at Ussher Town and the Ga village at Osu. However, during the British colonial period it emerged as a center of commercial activity and is the site of Salaga Market (the first major market in Accra) and the central bus station. The cluster includes not only Accra Central, but also Ministries, parts of Osu, Ringway Estates, parts of Ridge Estates, all of Tudu, all of Adabraka, and the northern part of Korle Dudor-Agbogbloshie.

FIGURE 5 ABOUT HERE

The other cluster of high child mortality as shown in Figure 5 is centered on Nii Boi Town, but includes the northern portion of Kwashieman and the central portion of Abeka. Kwashieman was one of the earlier suburbs of Accra and was developed just before World War II. However, Nii Boi Town and Abeka are post-Independence suburbs and are generally deficient in infrastructure, especially water. This is also an area identified by Stoler et al. (2009) as having clusters of high levels of self-reported malaria.

Overall, there were 104 EAs that fell within clusters of high child mortality, and 152 EAs that fell within clusters of low child mortality. We looked at the profiles of these two groups, along with the remaining EAs that were not clustered, to see if there were discernible differences. The following variables produced statistically significant bivariate differences between the three groups: (1) hot spots were less likely to have inside water than cold spots; (2) hot spot residents were more likely to be insecure in their residence tenure; (3) hot spot residents tended to have the lowest quality roofing material (this refers to housing, not commercial buildings); (4) the average mother in hot spots had fewer children than the average mother in cold spots; (5) the average woman in hot spots was more likely to have been born outside of Accra; and (6) the average residence in hot spots was more likely to be a hut, or kiosk, or something else besides a house or apartment. We entered these variables into a discriminant analysis to see how well they could predict whether an EA was a cold spot, hot spot, or not clustered. The results were mixed. They correctly predicted only 5 percent of the hot spot EAs, although none of the hot spots was incorrectly classified as a cold spot. Instead, most hot spots were incorrectly classified as not clustered. The combination of variables correctly predicted 33 percent of the cold spot EAs, and once again it did not incorrectly classify any EA as being a hot spot. In general, the picture emerges of the at-risk group of women being newer migrants to the city, and living in poor housing with poor infrastructure in heavily commercial areas, e.g., in newer informal settlements.

The Interaction of Neighborhoods and Child Mortality at the Individual Level

Does living in a neighborhood that is clustered around low or high child mortality predict an individual woman's experience with child mortality? We examine this question with a logistic regression model in which the binary dependent variable is whether or not a mother has lost at least one of her children. The data represent all 265,287 mothers aged 15-49 in the 2000 census in Accra. Following the Mosley-Chen model as best we can given the data available, we first enter a woman's age and parity (number of children born to date) as predictors. As can be seen in Table 5, age is negatively related to the probability of having lost a child; the younger the woman, the more likely she is to have lost a child, controlling for her parity. At the same time, the higher the parity, the higher the probability of having lost a child, controlling for age. Those relationships do not change as other variables are entered into the model.

TABLE 5 ABOUT HERE

The second model introduces social and economic variables including marital status, education, and employment in the private informal sector. Being a never-married mother increases the odds of having lost a child by almost 70 percent—the biggest effect of any variable in any of the models in Table 5. The educational differences are slight and only the effect for a level of education beyond secondary is statistical significant and it is in the wrong direction, with the suggestion that more education slightly increases the odds of losing a child, even when controlling for age, parity, and marital status. Similarly, working in the private informal sector slightly lowers the odds of having lost a child, which is contrary to the expectation. These relationships do not change as other variables are entered into the model.

The third model introduces variables relating to the environmental context. Having no piped water in the house slightly increases the odds of losing a child, as does not having a toilet in the house, and having insecure tenure ("perching") at the residence. On the other hand, crowdedness and having less than a good roof unexpectedly lowered the odds of losing a child. These relationships do not change as other variables are entered into the model. The fourth model introduces cultural background variables including ethnicity, religion, place of birth and type of housing. Here we see that relative to the Akan, the Ga have a slightly higher risk of losing a child, consistent with an earlier study by Weeks et al (2006). Having been born outside of Accra slightly increases the risk of losing a child, as does being non-Christian, as does living in compound housing.

The final model introduces the fixed parameter of living in a hot spot, cold spot or non-clustered area with respect to child mortality. At first glance, this seems circular—trying to predict having lost a child by asking whether a woman lives in a neighborhood identified according to a particular pattern of losing children. But, in fact, we have controlled for the major compositional, contextual and personal effects that could likely influence the loss of a child if a woman were randomly distributed in the city. Here we ask whether being in a particular type of neighborhood makes a difference, even after controlling for other risk factors. The answer is yes and the results are in the expected direction. Relative to living in a cold spot neighborhood, living in a hot spot neighborhood increases the odds of losing a child by about 20 percent.

Finally, we can glimpse greater detail on child health in the clustered neighborhoods by examining women included in the combined GDHS data set. Among the 1,543 women, 195 live in EAs that are within the cold spot clusters and 127 of them had given birth to at least one child. There were 113 women living within the hot spot clusters, and 60 of them had given birth to a child. The GDHS asks about health attributes of children born in the five years prior to the survey and in the 2003 survey, 13.6 percent of children in urban areas in Ghana had experienced diarrhea during the two weeks prior to the survey (Ghana Statistical Service, Noguchi Memorial Institute for Medical Research, and ORC Macro 2004). In the Accra data set, we found that 8.3 percent of children in cold spot neighborhoods had experienced diarrhea, compared to 11.0 percent in non-clustered areas, and 18.2 percent in hot spot neighborhoods. The differences are in the expected direction, and despite the small sample size, the difference between cold spot and hot spot neighborhoods was statistically significant at the .10 level. There was a smaller difference in terms of fever in the prior two weeks, but again the differences were in the expected direction, with 21 percent in cold spot neighborhoods and 24 percent in hot spot neighborhoods.

CONCLUSION

We have employed a set of innovative methods to estimate child mortality at the neighborhood level to show that the spatial pattern of child mortality is very different than would be expected based on widely-accepted risk factors. The combination of biological and environmental characteristics led us to expect to find the highest rates of child mortality in neighborhoods that are locally known as slums, with the lowest rates in the more elite residential areas of the city. However, we found that the slum neighborhoods had dramatically lower levels of child mortality than expected, while there were small pockets of high mortality within some of the more elite neighborhoods.

This type of finding has been anticipated by Entwisle (2007:697), who notes that: "[t]hrough their behavior, people can change the characteristics of neighborhood contexts. They may do this indirectly, as just discussed, and also directly by intervening to change neighborhood conditions. Direct effects may involve political activity, attempts to organize residents to make improvements of some sort (e.g., traffic calming), and the like. The intervention that has attracted the attention of demographers, however, is the potential endogeneity of program placement (e.g., Angeles, Guilkey, and Mroz 1998). Health clinics and family planning outlets, for example, are often placed in areas of need, not distributed randomly as is assumed in a standard analysis. This complicates the study of their impact. In the cross section, it is even possible to find a 'counterintuitive' relationship between service availability and the behavior or outcome those services were intended to address. The forces leading to a particular distribution of services need to be taken explicitly into account. The endogeneity of neighborhood characteristics occurs in many ways and at many levels." This "counterintuitive" relationship is, of course, exactly what we have found in Accra.

We do not have specific program placement information in Accra, but our anecdotal knowledge of the work of the Ghana Health Ministry and a variety of NGOs does suggest that the explanation for the discrepancy between the expected and observed rates of child mortality has to do with the direct efforts to reduce these rates in the neighborhoods where they were expected to be highest. More than two decades ago Hill and David (1988) pointed out the difficulty of knowing whether health interventions are having an impact on child mortality, but we have somewhat serendipitously done that in this analysis by comparing the spatial distribution of expected child mortality with the observed distribution. Most of the highest risk neighborhoods seem clearly to have been impacted by these efforts, although our spatial analysis also identified two parts of the city—one in the central area and one in the northern peri-urban area—where high child mortality tends to be spatially clustered. An individual-level analysis, using as the dependent variable whether or not a mother had lost any of her children, revealed that even after controlling for biological and socioeconomic predictors of child loss, women living in these high mortality clusters had an elevated risk of losing a child. Furthermore, by gathering some details from the Ghana Demographic and Health Surveys, we found that their living children were also more likely to have recently suffered from diarrhea and fever.

The apparent effectiveness of campaigns to lower child mortality in some of Accra's neighborhoods may auger well for the success of continuing to expand that coverage, unless it turns out that the health interventions thus far have been undertaken in those places where it was easiest to bring down high rates, and thus moving forward it may be more difficult, time-consuming, and expensive to improve rates beyond their current levels. Optimistically, though, as greater proportions of children survive to adulthood, the urban health transition perspectives suggest that the health and mortality focus will shift to the problems posed by increasing levels of chronic disease, and we are working on the spatial analysis of that phenomenon.

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Figure 1. Study Site of Accra, Ghana

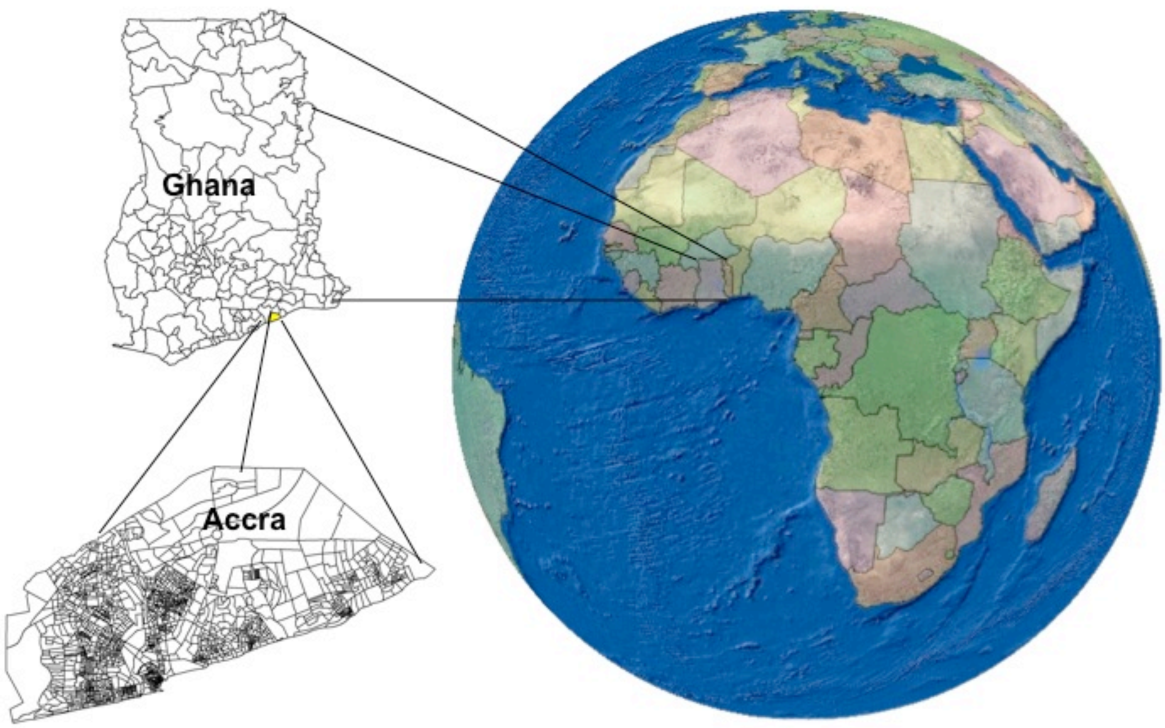

Figure 2. "Vernacular" Neighborhoods of Accra

Table 1. Estimates of the Child Mortality Rate (5q0) based on Indirect and Direct Calculations From Different Sources: Ghana and Accra

		Indirect		Direct	
Data for:	**Source**	**Deaths before age 5 per 1000 live births**	**Implied life expectancy at birth (both sexes)**	**Deaths before age 5 per 1000 live births**	**Implied life expectancy at birth (both sexes)**
Ghana	1998 GDHS	136	55	115	59
	2003 GDHS	128	56	114	59
	2000 Census	177	50	n/a	
Accra Metropolitan Area	Pooled 1998, 2003 and 2003 supplement GDHS	87	62	75	64
	Matched Census and Pooled GDHS file	175	50	67	65

Notes: 2000 Census data for Ghana are from a 10 percent sample obtained from international.ipums.org at the Minnesota Population Center, using data made available by Ghana Statistical Services; life table values are estimated by interpolation from Coale-Demeny "north" model life tables.

Maybe stick with West as the average but I'd defer to ken on this.

Table 2. Child Mortality Rates by Characteristics of Mothers

Characteristic	**Direct 5q0**	**Indirect 5q0**	**PDz**
Education			
No education	68	181	-0.01
Primary	66	176	-0.12
Secondary	67	177	0.01
Beyond Secondary	65	195	0.05
Marital Status			
Married	60	168	-0.04
Living together	65	170	-0.01
Separated	68	220	0.03
Divorced	72	194	0.03
Widowed	74	184	0.02
Single	114	211	0.18
Labor Force Status			
Not in labor force	77	161	0.02
Not high status occupation and employed in private informal sector	64	175	-0.01
High status occupation*	65	176	0.01

See text for definitions of variables

*Defined as professional, administrative, or clerical

Table 3. Expected Determinants of Child Mortality at the Neighborhood Level

Variable	**Neighborhood Mean**	**Standard Deviation**
Proportion who cook with charcoal	.54	0.17
Proportion illiterate	.17	0.08
Proportion with no inside piped water	.51	0.18
Proportion not connected to a sewer	.77	0.21
Proportion with 3+ persons per room	.38	0.10
Proportion employed in the private informal sector	.59	0.12
Proportion with no inside toilet	.65	0.24
Proportion with no bath	.67	0.18
Children ever born	2.97	0.18

N = 88 “vernacular” neighborhoods (see Figure 1)

Figure 3. Expected Levels of Child Mortality by Vernacular Neighborhood, Accra, Ghana, 2000

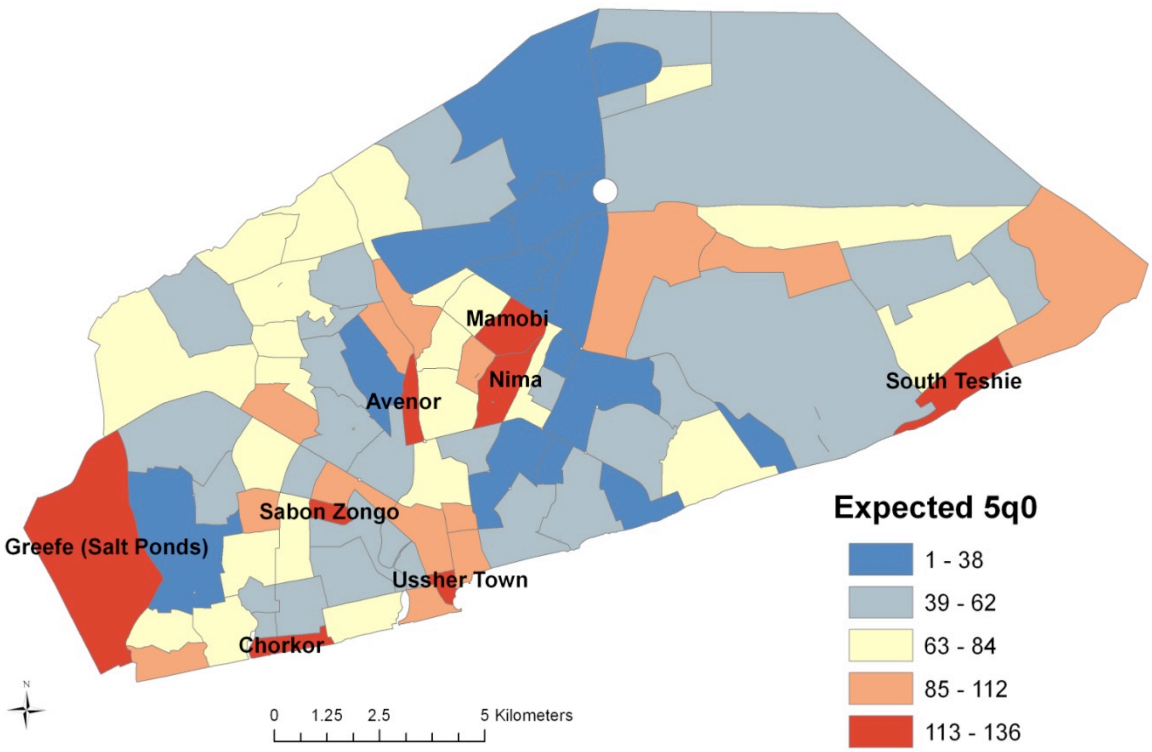

Table 4. Expected and Observed Levels of Child Mortality, by Vernacular Neighborhood, Accra, Ghana, 2000

Sorted by Expected 5q0				Sorted by Observed 5q0			Sorted by Difference Between Observed and Expected	
Neighborhood Name	**Expected 5q0**	**Observed 5q0**	**Observed minus Expected**	**Neighborhood Name**	**Expected 5q0**	**Observed 5q0**	**Neighborhood Name**	**Observed minus Expected**
Greefe	136	50	-85	Avenor	124	129	Borstal Institute	71
Nima	135	45	-89	Martey Tsuru	87	129	East Cantonments	61
Chorkor	134	48	-86	Accra Central	112	123	Ringway Estates	61
Ussher Town	132	66	-66	Nii Boi Town	69	118	Legon	59
South Teshie	130	81	-49	Motorway Industrial Area	72	113	Military Hospital	57
Sabon Zongo	129	53	-76	East Cantonments	46	108	Asylum Down	51
Avenor	124	129	5	Darkuman	72	93	Cantonments	49
Mamobi	124	56	-68	Airport	94	92	Nii Boi Town	49
Accra Central	112	123	11	Asylum Down	40	91	Martey Tsuru	41
Gbegbeyise	109	68	-42	Borstal Institute	20	91	Motorway Industrial Area	41
Russia	101	51	-50	Hedzoleman_Teshie	52	89	North Industrial Area	41
James Town	100	70	-30	Alajo	99	82	Abelenkpe	41
Alajo	99	82	-18	South Teshie	130	81	South Labadi	40
Bubuashie	97	52	-45	Mpoase	84	81	Hedzoleman_Teshie	38
Korle Dudor_Agbogbloshie	97	68	-29	Apenkwa	56	81	Airport Residential	35
Accra New Town	97	66	-31	Kotobabi	71	80	Sahara	33
Airport	94	92	-2	Adedenkpo_Old Fadama	56	80	Ridge_E _ W	32
Abossey Okai	89	34	-54	North Kaneshie	52	80	Roman Ridge	31
Police Training Depot	88	80	-8	Ringway Estates	19	80	Ministries	30
Martey Tsuru	87	129	41	Police Training Depot	88	80	North Kaneshie	29
Nungua	87	62	-26	Ministries	49	79	Tesano	27
Tudu	86	75	-11	South Labadi	37	77	Apenkwa	25
Mpoase	84	81	-3	Cantonments	26	76	Adedenkpo_Old Fadama	24
Korle Gonno	81	48	-33	Tudu	86	75	Legon Staff Village	22
Labadi	78	31	-47	Mempeasem	60	75	North Labone	22
Sukura	77	51	-26	Abofu	70	74	Dzorwulu	22
North Odorkor	76	46	-31	Sahara	40	74	Darkuman	21
Pig Farm	75	70	-5	Mataheko	56	73	Mataheko	16
New Fadama	75	47	-28	Military Hospital	14	71	New Mamprobi	16
North Teshie	73	62	-11	James Town	100	70	Dansoman	15
Abeka	73	48	-24	Pig Farm	75	70	Korle Bu	15
Darkuman	72	93	21	Abelenkpe	28	69	Mempeasem	15
Motorway Industrial Area	72	113	41	Korle Dudor_Agbogbloshie	97	68	Flagstaff House	14
Kotobabi	71	80	9	Gbegbeyise	109	68	Accra Central	11
West Abossey Okai	71	48	-23	Tesano	40	67	Kotobabi	9
Larterbiokorshie	71	50	-21	Ussher Town	132	66	Int'l Trade Fair Ctr	9

Achimota	71	51	-20	Kpehe	70	66	Burma Camp_Teshie	9
Abofu	70	74	3	Kokomlemle	70	66	Mamprobi	9
Kpehe	70	66	-4	Accra New Town	97	66	Kaneshie	5
Bawaleshie	70	56	-14	Kanda	68	66	East Legon	5
Kokomlemle	70	66	-4	Ridge_E _ W	34	66	Avenor	5
Nii Boi Town	69	118	49	Flagstaff House	50	64	South Odorkor	3
Mamponse	69	40	-28	Kwashieman	62	64	Abofu	3
Kanda	68	66	-2	North Labone	41	63	Kwashieman	3
Adabraka	64	63	-1	Okponglo	61	63	Old Dansoman	2
Kwashieman	62	64	3	Adabraka	64	63	Okponglo	2
Okponglo	61	63	2	North Teshie	73	62	Zoti	1
Zoti	60	61	1	South Odorkor	59	62	Achimota forest	-1
Mempeasem	60	75	15	Mamprobi	53	62	Adabraka	-1
South Odorkor	59	62	3	Burma Camp_Teshie	53	62	Airport	-2
South Industrial Area	58	48	-10	Nungua	87	62	Kanda	-2
Old Dansoman	58	60	2	Roman Ridge	30	61	Mpoase	-3
Mataheko	56	73	16	Zoti	60	61	Kokomlemle	-4
Apenkwa	56	81	25	East Legon	56	61	Kpehe	-4
Adedenkpo_Old Fadama	56	80	24	Legon	1	60	Pig Farm	-5
East Legon	56	61	5	Old Dansoman	58	60	Osu	-6
Teshie_Nungua Estates	55	40	-14	Dzorwulu	38	60	Police Training Depot	-8
Achimota forest	54	54	-1	New Mamprobi	43	59	South Industrial Area	-10
Mamprobi	53	62	9	North Industrial Area	18	59	North Teshie	-11
Burma Camp_Teshie	53	62	9	Korle Bu	41	56	Tudu	-11
North Kaneshie	52	80	29	Legon Staff Village	33	56	Teshie_Nungua Estates	-14
Hedzoleman_Teshie	52	89	38	Bawaleshie	70	56	Bawaleshie	-14
Osu	51	46	-6	Mamobi	124	56	Alajo	-18
Flagstaff House	50	64	14	Airport Residential	19	55	Achimota	-20
Ministries	49	79	30	Achimota forest	54	54	Larterbiokorshie	-21
Kaneshie	48	54	5	Kaneshie	48	54	West Abossey Okai	-23
East Cantonments	46	108	61	Sabon Zongo	129	53	Abeka	-24
New Mamprobi	43	59	16	Bubuashie	97	52	Nungua	-26
Korle Bu	41	56	15	Russia	101	51	Sukura	-26
North Labone	41	63	22	Sukura	77	51	New Fadama	-28
Tesano	40	67	27	Achimota	71	51	Mamponse	-28
Sahara	40	74	33	Greefe	136	50	Korle Dudor_Agbogbloshie	-29
Asylum Down	40	91	51	Larterbiokorshie	71	50	James Town	-30
Dzorwulu	38	60	22	Abeka	73	48	North Odorkor	-31
South Labadi	37	77	40	West Abossey Okai	71	48	Accra New Town	-31
Int'l Trade Fair Ctr	36	45	9	South Industrial Area	58	48	Korle Gonno	-33
Ridge_E _ W	34	66	32	Chorkor	134	48	Gbegbeyise	-42
Legon Staff Village	33	56	22	Korle Gonno	81	48	Bubuashie	-45
Dansoman	32	47	15	New Fadama	75	47	Labadi	-47
Roman Ridge	30	61	31	Dansoman	32	47	South Teshie	-49

Abelenkpe	28	69	41	North Odorkor	76	46	Russia	-50
Cantonments	26	76	49	Osu	51	46	Abossey Okai	-54
Borstal Institute	20	91	71	Nima	135	45	Ussher Town	-66
Airport Residential	19	55	35	Int'l Trade Fair Ctr	36	45	Mamobi	-68
Ringway Estates	19	80	61	Mamponse	69	40	Sabon Zongo	-76
North Industrial Area	18	59	41	Teshie_Nungua Estates	55	40	Greefe	-85
Military Hospital	14	71	57	Abossey Okai	89	34	Chorkor	-86
Legon	1	60	59	Labadi	78	31	Nima	-89

Figure 4. Observed Levels of Child Mortality by Vernacular Neighborhood, Accra, Ghana, 2000

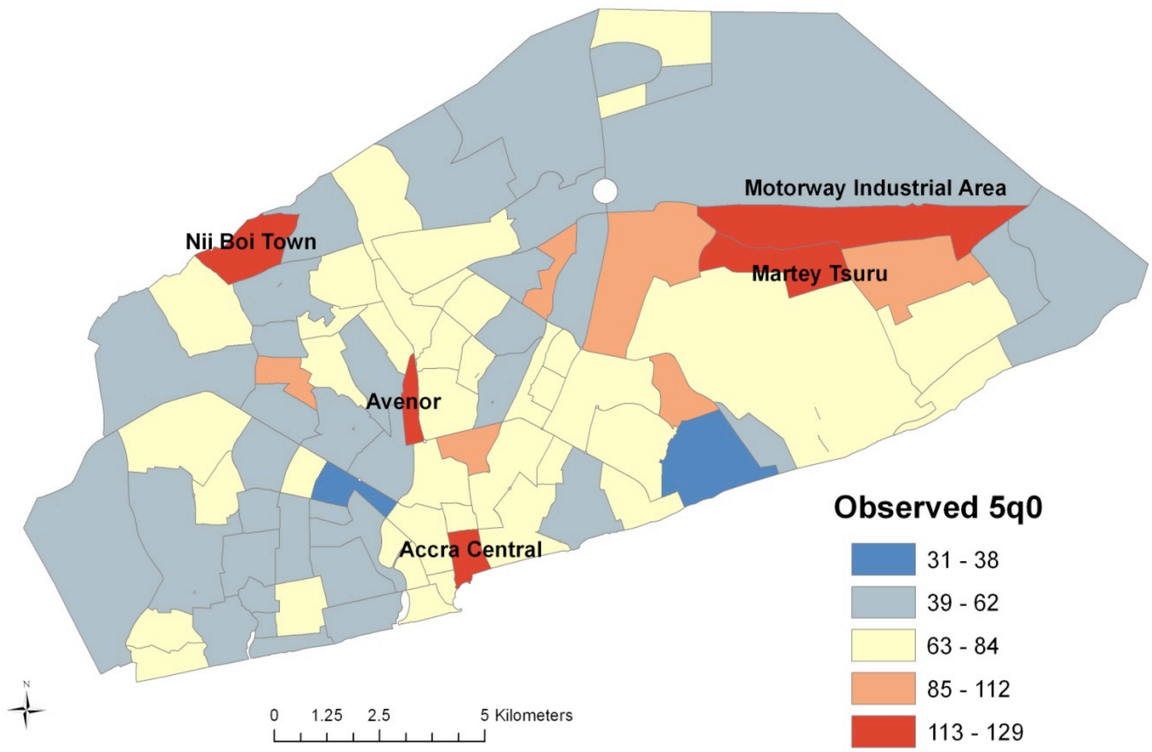

Figure 5. Clusters of High and Low Child Mortality Based on Enumeration Areas, Accra, Ghana, 2000

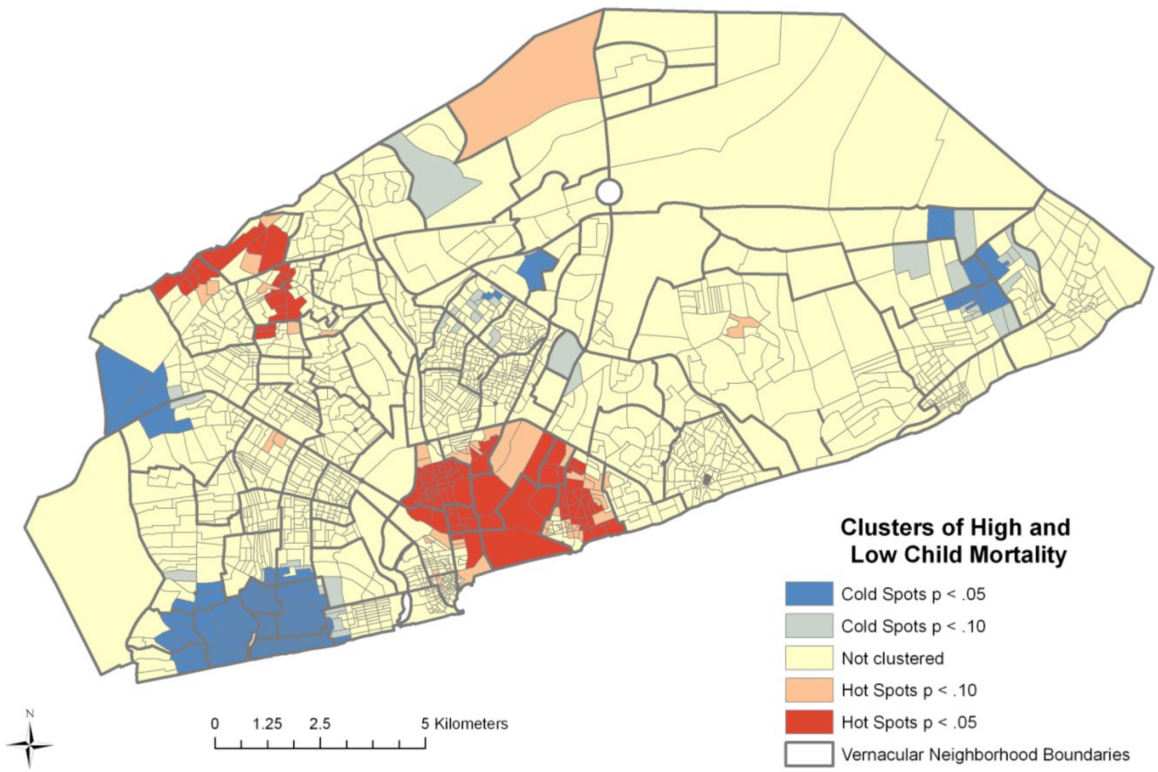

Table 5. Logistic Regression to Predict Whether a Mother Has Lost at Least One Child, Accra, Ghana, 2000

	Model 1			Model 2			Model 3			Model 4			Model 5		
Variable	**B**	**Sig.**	**Exp(B)**	**B**	**Sig.**	**Exp(B)**	**B**	**Sig.**	**Exp(B)**	**B**	**Sig.**	**Exp(B)**	**B**	**Sig.**	**Exp(B)**
AGE	-0.027	0.000	0.973	-0.022	0.000	0.978	-0.022	0.000	0.978	-0.022	0.000	0.978	-0.023	0.000	0.978
CEB	0.368	0.000	1.446	0.376	0.000	1.456	0.378	0.000	1.459	0.378	0.000	1.459	0.378	0.000	1.460
never_married(1)				0.524	0.000	1.689	0.523	0.000	1.688	0.526	0.000	1.693	0.522	0.000	1.686
No education					0.000			0.000			0.000			0.000	
Primary education				-0.017	0.137	0.983	-0.018	0.116	0.982	-0.015	0.218	0.985	-0.016	0.182	0.984
Secondary education				0.009	0.518	1.009	0.001	0.936	1.001	0.006	0.706	1.006	0.005	0.720	1.005
Beyond secondary				0.066	0.000	1.068	0.059	0.001	1.061	0.062	0.001	1.064	0.062	0.001	1.063
Works in private informal sector				-0.032	0.001	0.968	-0.031	0.002	0.970	-0.032	0.001	0.968	-0.031	0.002	0.969
No piped water in house							0.026	0.008	1.027	0.026	0.010	1.027	0.025	0.013	1.026
No toilet in house							0.050	0.003	1.051	0.045	0.011	1.046	0.051	0.004	1.052
3+ persons per room							-0.115	0.000	0.891	-0.115	0.000	0.892	-0.115	0.000	0.891
Insecure tenure							0.062	0.000	1.064	0.061	0.000	1.063	0.058	0.000	1.060
Less than good roof							-0.041	0.306	0.960	-0.039	0.332	0.962	-0.029	0.472	0.972
Akan											0.004			0.000	
Ga										0.040	0.002	1.041	0.045	0.001	1.046
Ewe										0.004	0.809	1.004	0.004	0.811	1.004
All other										-0.004	0.797	0.996	-0.009	0.538	0.991
Not born in Accra										0.041	0.000	1.041	0.038	0.000	1.039
Non-Christian										0.030	0.032	1.030	0.025	0.070	1.026
Cooks with charcoal										-0.018	0.110	0.983	-0.017	0.120	0.983
Lives in compound housing										0.024	0.016	1.024	0.021	0.036	1.021
Cold spot neighborhood														0.000	
Not in a clustered neighborhood													0.149	0.000	1.161
Hot spot neighborhood													0.183	0.000	1.201
Constant	-1.304			-1.279			-1.306			-1.287			-1.310		

-2 Log likelihood	278765.848	277500.910	277328.501	277297.072	277211.600
Nagelkerke R Square	0.131	0.138	0.138	0.139	0.139