Correlates of Spatial Differences in under-five mortality in Nairobi's informal Settlements

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Abstract

Child mortality in Kenya is often associated with individual level factors including socio-economic status, nutritional status, and poor access to health services. Geographical factors are less documented as important predictors of child mortality in the country. Using a Bayesian geo-additive survival model, this paper examines the factors associated with child mortality in two Nairobi slums, Korogocho and Viwandani, accounting for spatial random effects. It uses longitudinal data for the period 2006-2011 involving 30339 children aged below five years from the Nairobi Urban Health and Demographic Surveillance System implemented in the two slums. In addition to determinants such as mother's education and age, size of the household and ethnicity, our findings show a certain spatial structure in child mortality risk, with differences between some villages in Viwandani, while no spatial variations were observed in Korogocho. The results call for specific efforts from policymakers to refine child health interventions in Nairobi's urban slums.

Key words: spatial analysis, child, mortality, slums, Nairobi

Résumé

La mortalité infantile au Kenya est souvent associée aux facteurs individuels dont le statut socio-économique, le statut nutritionnel et le faible accès aux services de santé. Les facteurs géographiques sont faiblement documentés comme étant des prédicteurs de la mortalité infantile. Utilisant un model bayésien géo-additif d'analyse de survie, cet article examine les facteurs associés à la mortalité infantile dans deux banlieues précaires de Nairobi, Korogocho et Viwandani, tout en considérant les effets spatiaux aléatoires. Il utilise des données longitudinales collectées entre 2006 et 2011 auprès de 30339 enfants âgés de moins de cinq ans et issus du Système de Surveillance Sanitaire et Démographique en zone Urbaine à Nairobi mis en œuvre dans les deux banlieues. En plus des déterminants tels que le niveau d'éducation de la mère et son âge, la taille du ménage et l'ethnicité, nos résultats montrent une certaine structure spatiale du risque liée à la mortalité infantile, avec des différences notées entre certains villages à Viwandani, tandis qu'à Korogocho aucune différence entre villages n'a été observée. Ces résultats interpellent les autorités locales quant à la mise en œuvre de stratégies spécifiques visant à améliorer les programmes de survie de l'enfant dans les banlieues de Nairobi.

Mots clefs: analyse spatiale, mortalité, infantile, banlieue, Nairobi

Introduction

Child mortality rates in sub-Saharan Africa (SSA) remain the highest in the world with under-five mortality rate (U5MR) estimated at 98 deaths per 1000 live births (UNICEF, 2014). Neonatal deaths account for about a third of under-five deaths in SSA (UNICEF, 2014). Although Western and Central Africa have the highest mortality rates in the region (with U5MR of 118 deaths per 1,000 live births), the rates in Eastern and Southern Africa are equally high at 77 deaths per 1,000 live births (UNICEF, 2014).

Childhood mortality has substantially declined in Kenya although overall levels remain high. However, available evidence indicates that Kenya is one of the countries that did not make sufficient progress towards attaining MDG 4 which aimed to reduce under-five mortality by two-thirds by 2015 (Government of Kenya, 2013). For instance, infant mortality declined from 77 per 1,000 live births during the period 1998-2003 to 52 per 1,000 live births during the period 2003-2008 (Central Bureau of Statistics (CBS) [Kenya] et al., 2004, Kenya National Bureau of Statistics (KNBS) and ICF Macro, 2010). The corresponding figures for under-five mortality were 115 and 74 deaths per 1,000 live births over the same periods (Central Bureau of Statistics (CBS) [Kenya] et al., 2004, Kenya National Bureau of Statistics (KNBS) and ICF Macro, 2010). Under-five mortality rates are higher in rural than urban areas (86 deaths and 74 deaths per 1,000 live births respectively) (Kenya National Bureau of Statistics (KNBS) and ICF Macro, 2010). However, under-five mortality rates in Nairobi's informal settlements are higher than in rural areas of the country. For instance, a 2014 study found that under-five mortality rate in Nairobi's slums was 104 deaths per 1,000 live births for the period 2003-2010 (Kimani-Murage et al., 2014).

Child mortality has often been associated with a number of factors including unfavorable socio-demographic characteristics, retrogressive cultural practices, low socio-economic status, poor child nutritional status, and lack of access to basic health services (O'Neill et al., 2012, Mwalali and Ngui, 2009, Anyamele, 2009, Omariba et al., 2007). Several studies have also documented urban-rural differences in child mortality (Kimani-Murage et al., 2014, Garenne, 2010). In addition, family and community-level factors have been found to influence child mortality (Bolstad and Manda, 2001).

However, geographical and environmental factors are less documented as important predictors of child mortality. A number of environmental and health promotion theories hypothesize that social and community support as well as the physical environment influence health outcomes. For instance, the socio-ecological model posited that health is shaped by many environmental subsystems, including family, community, workplace, economics, and the physical and social environments (Bronfenbrenner, 1977).

This paper examines the spatial variations in the risk factors associated with child mortality in two urban informal settlements in Kenya - Korogocho and Viwandani. Each of the slums has seven geographical entities, called villages, with regular boundaries and administrative units established by the Government of Kenya for purposes of conducting censuses. Households living in a particular village co-reside with those from neighboring villages as a community with the same physical infrastructure such as health facilities and schools. As a possible consequence of that co-residence, health determinants and outcomes in a particular village might be closely related to conditions in neighboring villages according to propositions of the socio-ecological model (Bronfenbrenner, 1977). In particular, child health status in a given village is assumed to be associated with factors within the village as well as random effects of neighboring villages/communities. Neighboring random effects can be defined based on geographical structure, cultural/traditional likenesses and global health status. This paper explores the socio-demographic correlates of child mortality taking into account the specific area of residence (village) and spatial random effects of neighboring villages.

A few studies have included spatial variations among possible predictors of child mortality in sub-Saharan Africa. Exploring child health inequities in Accra, Ghana, Weeks et al. (2006) found notable spatial and ethnic variations in child mortality using a spatial index of dissimilarity as a global measure of residential segregation. In South Africa, spatial random effects of HIV/TB child mortality were modeled using the Stochastic Partial Differential Equations (SPDEs) (Musenge et al., 2013). The study identified child age and birth weight as important factors associated with HIV/TB child mortality risk but did not clarify the influence of the spatial random effects on the outcome.

Studies in the Democratic Republic of Congo also demonstrated provincial disparity in child health and survival because of precarious hygienic, social, and economic conditions, using a Bayesian geo-additive mixed model (Kandala et al., 2014, 2011). Although several studies have documented the determinants of child mortality in Nairobi's informal settlements, most of them used conventional regression models, which did not consider the role of spatial random effects in influencing child mortality in these settings. This paper examines the correlates of child mortality in Nairobi's informal settlements using a Bayesian inference which is based on Markov chain Monte Carlo (MCMC) simulation techniques (Geyer, 2011). This approach enables us to determine the extent to which spatial patterns of child mortality are driven by socioeconomic variations between geographically distinct units.

METHODS

Data

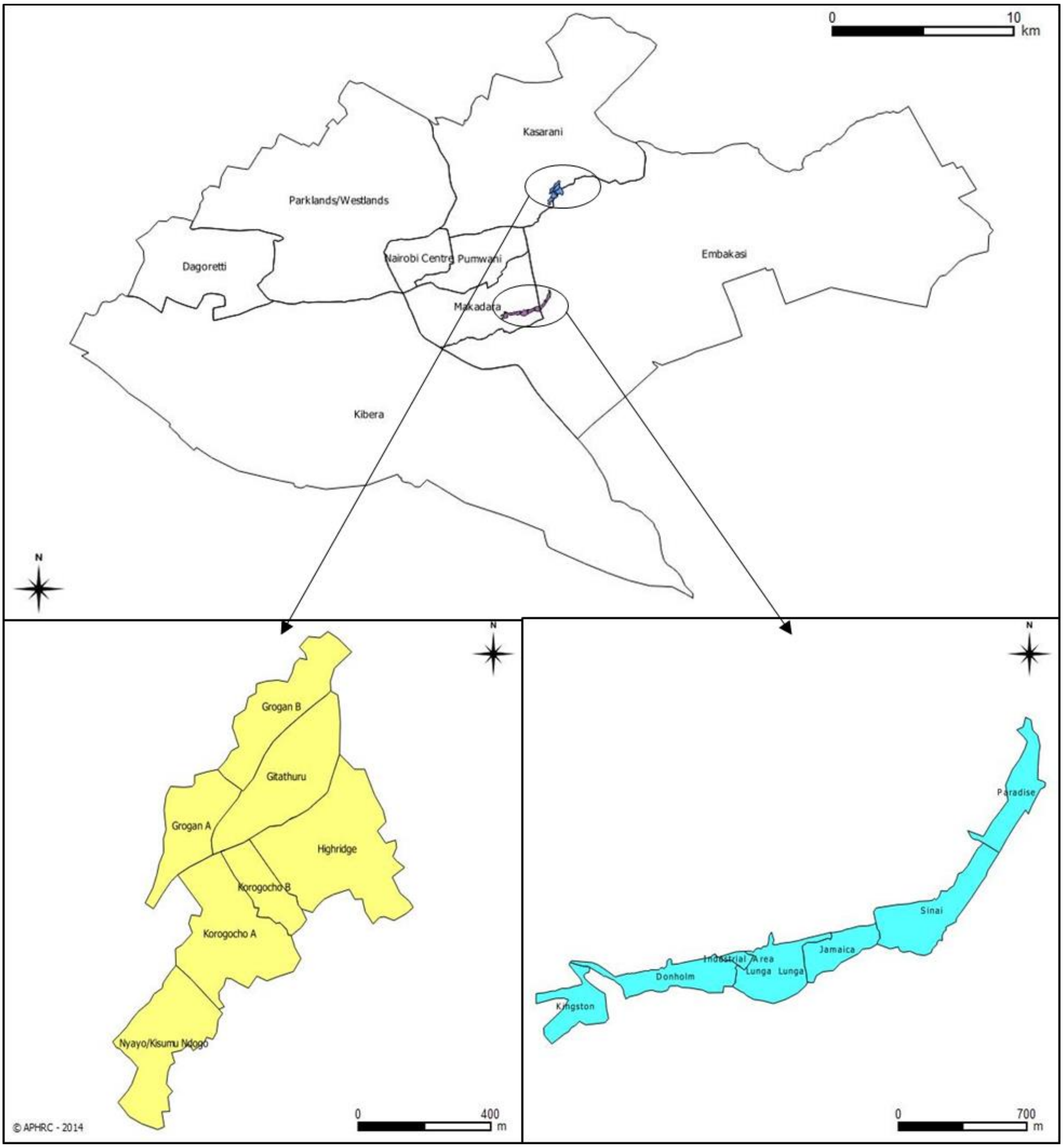
Data for this paper come from the Nairobi Urban Health and Demographic Surveillance System (NUHDSS), implemented by the African Population and Health Research Center to investigate the linkages between migration, urbanization, poverty, and health dynamics. The NUHDSS has been in operation since 2002, and covers two informal settlements in Nairobi - Korogocho and Viwandani. The two study sites are located approximately 10 kilometers from the city center and about 7 km from each other (Emina et al., 2011) (see Figure 1).

Korogocho has 7 villages and less mobile population compared to Viwandani, while about a quarter of its residents aged 12 years and above were born in the slum (Emina et al., 2011). By contrast, Viwandani has the same number of villages as Korogocho but a more transient community which attracts a youthful and highly mobile population seeking job opportunities in the nearby industries (Emina et al., 2011).

Households in the NUHDSS are visited 3 times a year to capture information on vital events—births, deaths and migration. In addition, information on household characteristics and socio-economic status is collected from all households in the study sites once every year. All women aged 15-49 years respond to questions related to pregnancy irrespective of whether they are pregnant or not. Any pregnancy that is reported is followed to term and the outcome recorded. Live births are recorded in the system and followed over time. The survival status of all household members is recorded during the quarterly round visits.

In this paper, we draw on data collected for all under-five children living in the two slums between 2006 and 2011. In total, 30339 children were observed until they reached the age of five years, migrated out of the study site or died.

Figure 1: Maps of Nairobi, Korogocho and Viwandani



Techniques of analysis

The paper uses different analytical techniques. First, frequencies and percentages are used to describe the distribution of the study population and the number of deaths by key social and demographic characteristics. Second, we estimate a Cox regression model using STATA 13 to determine the factors associated with under-five mortality, especially those at village level. Cox regression model is suitable since this is a longitudinal study in which under-five children were prospectively followed over time until they died, survived past age five, moved out of study sites or were lost to follow-up. However, one limitation of the conventional regression models like the Cox models is that, they assume the random components at the contextual level (village in our case) are mutually independent. In practice, villages that are close to each other are more similar than villages that are far apart because of socio-cultural, political and contextual factors. In other words, the independence assumption leads to poor estimates as neighboring villages are more likely to have similar characteristics. In order to overcome this challenge, we further estimated a Geo-additive regression model using BayesX (Brezger et al., 2005, Belitz et al., 2012). The Geo-additive regression model estimates the risks of death within a village, taking into consideration the neighboring spatial effects. The assumption underlying this estimation is that spatial units that share a border, in our case villages, are likely to share common risk factors that may be associated with the event being observed (Kandala et al., 2009). Hazard ratios are reported for the Cox model while Odds ratios are reported for the Bayesian geo-additive model.

Measures

For the Cox regression model, time to death is the main dependent variable while for the Bayesian geo-additive model, the outcome was a binary variable with the value "1" when the child died and "0" when the child survived during the five-year period. Each child was observed from birth (if born in the study area) or date of in-migration in the slums (if born outside the slums) between 2006 and 2011 until death or censoring due to loss to follow-up, out-migration or end of follow-up for children who were still alive as at December 31, 2011 or at their fifth birthday. Children could out-migrate and return to the slums, allowing gaps in the observation time.

A variable capturing village of residence is the main independent variable. This variable has seven categories for each slum. We also included demographic and socio-economic factors known to affect under-five mortality as control variables: some are directly related to the child (e.g. sex); others are mother-specific (age, ethnicity, and education level), or related to the household (age and sex of household head, education of household head, household size, and wealth index). Household socio-economic status was estimated using tertiles derived from an asset index constructed using Principal Component Analysis (PCA) method based on the presence or absence of certain household assets and amenities. The assets included motor vehicle, motorcycle, cooking stove, television, refrigerator, and phone while amenities included material of household structures, source of water, type of toilet, and type of fuel used for cooking. The generated wealth score was grouped into tertiles with first tertile representing the poorest group and last tertile representing the least poor group (Filmer and Pritchett, 2001). Analyses were done separately for each of the two slums.

RESULTS

Characteristics of children

Table 1 shows the distribution of children who were included in the study and those who died by background characteristics and study site. There were more children from Viwandani than from Korogocho (16,232 and 14,107 respectively). The proportion of boys was similar to that of girls in Korogocho (50% each) while the proportion of girls was slightly higher than that of boys in Viwandani (51% and 49% respectively). The proportion of children from female-headed households was higher in Korogocho than Viwandani (25% and 14% respectively). By contrast, the proportion of children whose mothers had secondary level education was higher in Viwandani than Korogocho (32% and 15% respectively). A similar pattern was noted for the proportion of children from households whose heads had secondary level education (51% in Viwandani and 24% in Korogocho). In addition, nearly two-thirds (61%) of children in Viwandani had young mothers (aged below 30 years) compared to about half (52%) of those in Korogocho. Distribution of children by slum village showed that most of the children in Korogocho (27%) were from Highridge village while most of the children from Viwandani (20%) were from Sinai village (Table 1).

The results further showed that the highest proportion of children in Viwandani (38%) were from the poorest households while the highest proportion of children in Korogocho (42%) were from the least poor households (Table 1). More than one-third (38%) of children from Viwandani came from average sized households (between 1 and 3 household members), while those in Korogocho generally came from larger households (56% from households having between 4 and 6 household members). The highest proportions of children from Korogocho (30%) and Viwandani (35%) belonged to Luo and Kamba ethnic groups respectively.

Distribution of under-five deaths in the two slums during the period 2006-2011 showed that a higher number of deaths occurred in Korogocho than Viwandani. The proportion of under-five deaths also varied by villages and other household characteristics. For instance, in Korogocho, the highest proportion of child deaths were observed in Nyayo and Gitathuru C villages (4.3 and 4.1% respectively), while Grogan A had the lowest proportion at 2.1%. In Viwandani, the highest proportion of deaths was observed in Paradise and Sinai villages at 3.4% and 2.8% respectively and was lowest in Jamaica (1.8%). There were small variations in the proportion of deaths by gender of head household in the two slums (3.7% for female-headed households vs.3.6% for male -headed households in Korogocho; 2.8% vs. 2.5% respectively in Viwandani). Similar pattern was observed in the proportion of deaths by education level of the head of household. Besides, the highest proportion of child deaths in both slums was observed where household heads were aged between 40 and 49 years (4.3% in Korogocho and 3.0% in Viwandani). Considering the mothers' age, child deaths were mostly observed among mothers aged between 30 and 39 years in Korogocho (4.8%) and among the oldest mothers (40 years and above) in Viwandani (5.6%). In addition, the proportion of under-five deaths was higher among mothers with low levels of education (primary or lower) than among those with secondary and above levels of education. Finally, the Luo ethnic group had the highest proportion of recorded deaths (5.3%) followed by the Kikuyu (3.2%) in Korogocho, while in Viwandani the highest proportion of deaths was noted among the Kikuyu (3.1%) followed by the Kamba and Luo ethnic groups (2.6% and 2.5% respectively).

Table 1: Background characteristics (NUHDSS, Kenya 2006 – 2011)

	Korogocho (n=14,107)				**Viwandani (n=16,232)**			
	Under-five children		Deaths		Under-five children		Deaths	
	N	%	N	%	N	%	N	% dead
Villages (Korogocho / Viwandani)								
Grogan A / Paradise	1,070	7.6	22	2.1	2,688	16.6	91	3.4
Grogan B / Sinai	757	5.4	23	3.0	3,063	18.9	85	2.8
Gitathuru C / Jamaica	1,740	12.3	71	4.1	1,847	11.4	34	1.8
Nyayo / Lunga Lunga	3,360	23.8	144	4.3	2,488	15.3	56	2.3
Korogocho A / Industrial area	2,389	16.9	87	3.6	300	1.8	8	2.7
Korogocho B / Donholm	961	6.8	21	2.2	2,949	18.2	77	2.6
Highridge / Kingstone	3,830	27.1	143	3.7	2,897	17.8	67	2.3
Sex of child								
Girl	6,995	49.6	250	3.6	7,919	48.8	204	2.6
Boy	7,112	50.4	261	3.7	8,313	51.2	214	2.6
Sex of Household Head								
Female	3,454	24.5	127	3.7	2,295	14.1	64	2.8
Male	10,653	75.5	384	3.6	13,937	85.9	354	2.5
Education level of Household Head								
No school or Primary	4,726	74.9	185	3.9	3,081	47.2	79	2.6
Secondary or higher	1,537	24.4	59	3.8	3,315	50.8	84	2.5
Don't Know	44	0.7	1	2.3	133	2.0	6	4.5
Age of Household Head								
Below 20	880	6.2	20	2.3	645	4.0	9	1.4
20 to 29	6,514	46.2	216	3.3	9,298	57.3	238	2.6
30 to 39	4,099	29.1	168	4.1	4,976	30.7	132	2.7
40 to 49	1,734	12.3	74	4.3	1,097	6.8	33	3.0
50 and above	880	6.2	33	3.8	216	1.3	6	2.8

Mother's age								
Below 20	3,338	23.7	114	3.4	2,925	18.0	65	2.2
20 to 29	8,293	58.8	282	3.4	11,302	69.6	293	2.6
30 to 39	2,203	15.6	105	4.8	1,862	11.5	52	2.8
40 and above	273	1.9	10	3.7	143	0.9	8	5.6
Mother's education								
No school or Primary	10,732	76.1	441	4.1	9,597	59.1	286	3.0
Secondary or higher	2,059	14.6	52	2.5	5,190	32.0	120	2.3
Don't Know	1,316	9.3	18	1.4	1,445	8.9	12	0.8
Wealth Index								
Poor	3,822	27.7	139	3.6	6,096	38.2	166	2.7
Middle	4,195	30.4	172	4.1	5,722	35.9	138	2.4
Least poor	5,796	42.0	193	3.3	4,121	25.9	110	2.7
Household size								
1 to 3	3,601	25.5	109	3.0	6,198	38.2	182	2.9
4 to 6	7,934	56.2	293	3.7	9,062	55.8	209	2.3
7 and above	2,572	18.2	109	4.2	972	6.0	27	2.8
Ethnicity								
Kikuyu	4,158	29.5	135	3.2	3,838	23.6	118	3.1
Luhya	3,046	21.6	88	2.9	2,448	15.1	57	2.3
Luo	4,274	30.3	225	5.3	1,326	8.2	33	2.5
Kamba	862	6.1	22	2.6	5,636	34.7	148	2.6
Others	1767	12.5	41	2.3	2,984	18.4	62	2.1

Results of Cox regression analysis

Table 2 presents adjusted hazard ratios and 95% confidence intervals from the Cox regression model by study site. All variables described in Table 1 were included in the model as covariates. The results show no difference in the risk of under-five mortality by villages in Korogocho. In Viwandani, under-five mortality risks are significantly lower for Lunga-Lunga (HR=0.4) and Jamaica (HR=0.5) villages compared to Paradise village.

Table 2: Hazard ratios from Cox regression model predicting the risk of under-five mortality by study site (NUHDSS; Kenya 2006 - 2011)

	Korogocho		Viwandani	
Variable	HR	95% CI	HR	95% CI
Villages (Korogocho / Viwandani)				
Grogan A / Paradise (ref.)	1.0	-	1.0	-
Grogan B / Sinai	1.1	[0.5;2.5]	0.7	[0.4;1.2]
Gitathuru C / Jamaica	1.4	[0.7;2.8]	0.5*	[0.2;0.9]
Nyayo / Lunga Lunga	1.2	[0.7;2.4]	0.4**	[0.2;0.7]
Korogocho A / Industrial area	1.4	[0.7;2.7]	0.8	[0.3;2.2]
Korogocho B / Donholm	1.1	[0.5;2.6]	0.7	[0.4;1.2]
Highridge / Kingstone	1.7	[0.9;3.3]	0.8	[0.5;1.3]
Sex of child				
Girl (ref.)	1.0	-	1.0	-
Boy	1.1	[0.9;1.4]	1.1	[0.8;1.5]
Sex of Household Head				

Female (ref.)	1.0	-	1.0	-
Male	0.9	[0.6;1.2]	0.9	[0.6;1.4]
Education level of Household Head				
No school or Primary (ref.)	1.0	-	1.0	-
Secondary or higher	1.0	[0.7;1.4]	1.0	[0.7;1.4]
Don't Know	0.8	[0.1;5.6]	2.2	[0.9;5.2]
Age of Household Head				
Below 25 (ref.)	1.0	-	1.0	-
25 to 34	1.0	[0.7;1.5]	1.3	[0.8;2.1]
35 and above	1.1	[0.7;1.7]	1.4	[0.8;2.5]
Mother's age				
Below 20 (ref.)	1.0	-	1.0	-
20 to 29	0.9	[0.6;1.3]	1.6	[0.9;2.9]
30 to 39	0.8	[0.5;1.3]	1.5	[0.7;2.9]
40 and above	0.6	[0.3;1.5]	1.7	[0.5;6.1]
Mother's education				
No school or Primary (ref.)	1.0	-	1.0	-
Secondary or higher	0.8	[0.5;1.1]	0.8	[0.5;1.1]
Don't Know	0.5*	[0.2;0.9]	0.4	[0.2;1.0]
Wealth Index				
Poor (ref.)	1.0	-	1.0	-
Middle	1.5*	[1.1;2.1]	0.9	[0.6;1.3]
Least poor	1.3	[0.9;1.9]	1.4	[0.9;2.1]
Household size				
1 to 3 (ref.)	1.0	-	1.0	-
4 to 6	0.8	[0.6;1.2]	0.7*	[0.5;1.0]
7 and above	0.9	[0.6;1.4]	0.7	[0.4;1.3]
Ethnicity				
Kikuyu (ref.)	1.0	-	1.0	-
Luhya	0.9	[0.6;1.3]	0.7	[0.4;1.2]
Luo	1.5*	[1.1;2.2]	0.3*	[0.1;0.8]
Kamba	0.7	[0.4;1.4]	0.7	[0.5;1.0]
Others	0.6	[0.4;1.0]	0.7	[0.4;1.1]

**p<0.05; **p<0.01*

Moreover, there was a statistically significant association between household size and the risk of mortality among children from Viwandani. In particular, children from large families (4 to 6 members) had 30% lower chance of dying compared to those from smaller families (less than 4 members).

Other factors that were significantly associated with increased risk of child mortality based on the Cox model included ethnicity and household wealth status. For instance in Korogocho, the risk of child mortality was significantly higher among Luo than among Kikuyu ethnic group (HR-1.5). Similarly, the risk of child mortality was significantly higher among households of average socio-economic status than among poorest households. However, variations by these indicators were not statistically significant in Viwandani.

Results of geo-spatial analysis

Table 3 presents the adjusted odds ratios and 95% confidence intervals from the Bayesian geo-additive regression model. In both slums, the spatial random effects were not significantly associated with under-five mortality. However, in Viwandani, Paradise village showed slightly higher risk while Jamaica had lower risk of under-five mortality. In Korogocho, Grogan B and Korogocho A villages had a 10% non-significant increased risk of under-five mortality. The risk of under-five mortality was lower in Korogocho B and Gitathuru C. Other findings showed that the risk of under-five mortality significantly increased in both study sites with increased age of the household head. In particular, children from households whose heads were over 30 years were at least two times more likely to die before their fifth birth day compared to those from households headed by individuals. In addition, in Viwandani, children of mothers aged 40 years and above were about two times more likely to die than those of younger mothers aged below 20 years were. Mother's education was significantly associated with under-five mortality, with children born to mothers with at least secondary level education having lower risk of dying before their fifth birthday in Korogocho (OR=0.6) and Viwandani (OR=0.8) compared to those of mothers with lower levels of education. Another result from the Bayesian model was that the size of the household was significantly associated with increased risk of under-five mortality but only in Viwandani. Children from households with at least four members had a 30% lower chance of dying compared with those from households with three or less members. Moreover, in Korogocho, children from Luo ethnic group had 70% higher chance of dying compared to those from Kikuyu ethnic group.

An added advantage of the Bayesian geo-additive model is that it gives a graphical presentation of the spatial effect of under-five mortality as shown in Figures 2 to 5. Figures 2 and 4 show the spatial residual effects of child survival in Korogocho and Viwandani respectively. The red colors indicate increased risk of child mortality, while green shows reduced risk. There were variations in the risk of under-five mortality between villages in both sites.

Table 3: Odds ratios from BayesX geo-additive model predicting spatial variations in under-five mortality (NUHDSS, Kenya 2006 - 2011)

	Korogocho		Viwandani	
I - Fixed Effect Variables	**OR**	**95% CI**	**OR**	**95% CI**
Sex of child				
Girl (ref.)	1.0	-	1.0	-
Boy	1.0	[0.9 ; 1.2]	1.0	[0.8 ; 1.2]
Sex of Household Head				
Female (Ref.)	1.0		1.0	
Male	0.9	[0.7 ; 1.1]	1.1	[0.9 ; 1.5]
Age of Household Head				
Below 20 (Ref.)	1.0	-	1.0	-
20 to 29	1.7	[1.2 ; 2.5]	2.2	[1.2 ; 5.1]
30 to 39	2.0	[1.4 ; 3.2]	2.4	[1.3 ; 5.9]
40 to 49	2.1	[1.4 ; 3.4]	2.7	[1.3 ; 6.0]
50 and above	2.1	[1.3 ; 3.5]	2.6	[1.1 ; 7.7]
Mother's age				
Below 20 (Ref.)	1.0	-	1.0	-
20 to 29	1.0	[0.8 ; 1.3]	1.3	[0.9 ; 1.7]
30 to 39	1.3	[1.0 ; 1.8]	1.2	[0.8 ; 1.9]
40 and above	0.9	[0.4 ; 1.7]	1.9	[0.8 ; 4.2]
Mother's education				
None/Primary (Ref.)	1.0	-	1.0	-
Secondary / Higher	0.6	[0.4 ; 0.7]	0.8	[0.6 ; 0.9]
Unknown	0.3	[0.2 ; 0.5]	0.3	[0.1 ; 0.4]
Wealth Index				
Poor (Ref.)	1.0	-	1.0	-
Middle	1.3	[1.0 ; 1.7]	1.1	[0.8 ; 1.3]
Least poor	1.0	[0.8 ; 1.2]	1.1	[0.9 ; 1.4]
Household size				
1 to 3 (Ref.)	1.0	-	1.0	-
4 to 6	0.9	[0.7 ; 1.2]	0.6	[0.5 ; 0.7]
7 and above	0.9	[0.7 ; 1.2]	0.7	[0.5 ; 1.1]

Ethnicity				
Kikuyu (Ref.)	1.0	-	1.0	-
Luhya	0.9	[0.7 ; 1.2]	0.7	[0.5 ; 1.0]
Luo	1.7	[1.3 ; 2.0]	0.8	[0.5 ; 1.2]
Kamba	0.8	[0.5 ; 1.2]	0.8	[0.6 ; 1.0]
Others	0.7	[0.5 ; 1.0]	0.7	[0.5 ; 0.9]
2 - Village Random Effect: (Korogocho / Viwandani)				
Vill 1: Gitahuru C / Paradise	0.9	[0.9 ; 1.7]	1.1	[0.9 ; 1.7]
Vill 2: Grogan A / Sinaï	1.0	[0.8 ; 1.4]	1.0	[0.8 ; 1.4]
Vill 3: Grogan B / Jamaïca	1.1	[0.7 ; 1.1]	0.9	[0.6 ; 1.1]
Vill 4: Highridge / Lunga-Lunga	1.0	[0.7 ; 1.2]	1.0	[0.7 ; 1.2]
Vill 5: Korogocho A / Industrial Area	1.1	[0.7 ; 1.4]	1.0	[0.7 ; 1.4]
Vill 6: Korogocho B / Donholm	0.9	[0.9 ; 1.3]	1.0	[0.9 ; 1.3]
Vill 7: Nyayo / Kingston	1.0	[0.8 ; 1.3]	1.0	[0.8 ; 1.3]
Number of observations		14,108		15,813
Number of deaths		511		418

Figures 3 and 5 show the posterior probabilities on whether the risks are significantly different for the different villages. A black segment depicts significant increased mortality risk while grey shading shows non-significant difference between villages. In Korogocho, the risk did not vary significantly from village to village, while in Viwandani, Paradise village experienced significantly higher risk of under-five mortality compared to other villages.

Figure 2: Total residual spatial effects of child survival in Korogocho

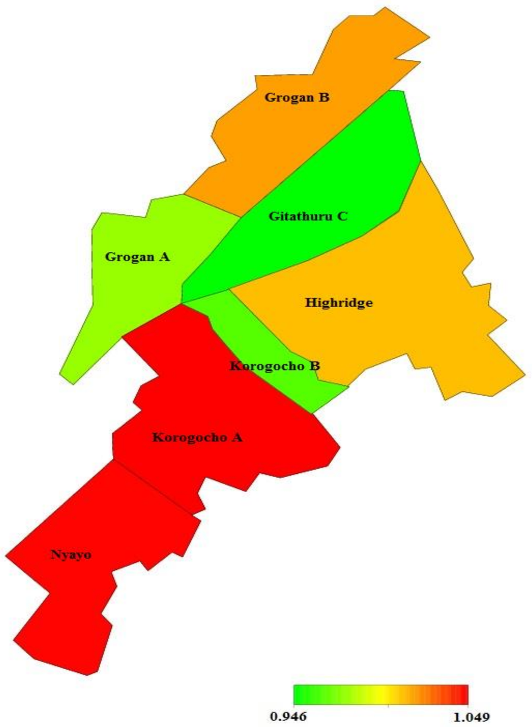


Figure 3: Corresponding posterior probabilities at 95% nominal level in Korogocho

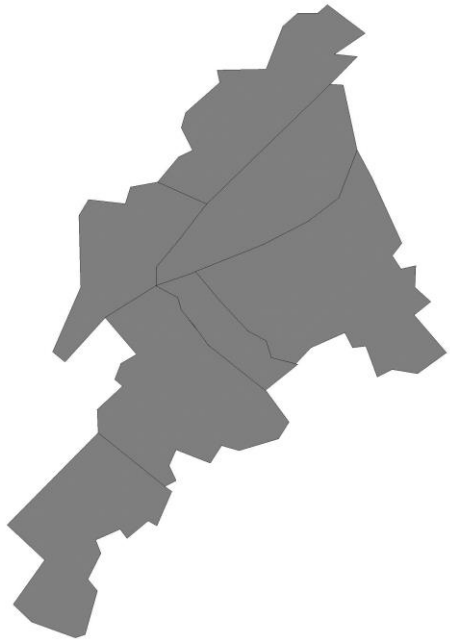


Figure 4: Total residual spatial effects of child survival in Viwandani

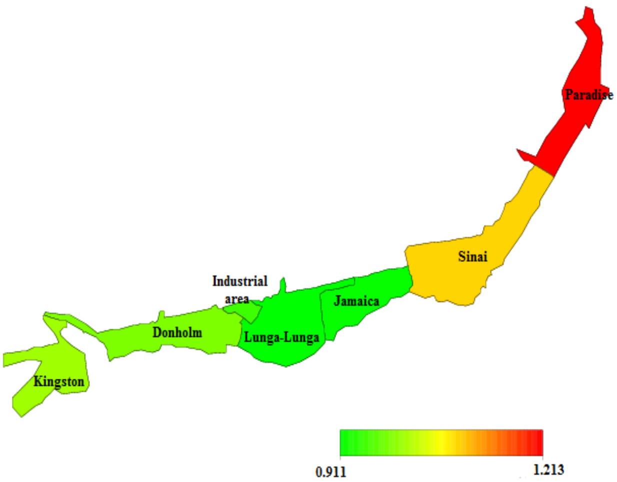


Figure 5: Corresponding posterior probabilities at 95% nominal level in Viwandani

Discussion and Conclusions

The findings of this paper show that besides the individual and household-level factors that have been found to influence under-five mortality in poor urban settings of Kenya (Omariba et al., 2007, Njiri, 2012, Muttunga, 2007, Mustafa and Odimegwu, 2008, Bocquier et al., 2011), there were spatial variations in the risk of death among children in the two informal settlements of Korogocho and Viwandani in Nairobi. Higher child mortality risk is strongly evidenced in Paradise village of Viwandani but spatial variations were not observed within villages in Korogocho. However, child mortality rates remained higher in Korogocho even if the risk did not vary significantly between villages.

The results on the spatial relationship between village of residence and mortality corroborates the important contribution of this study to the literature on child mortality. While the informal settlements appear to be homogeneous, there are notable spatial differentials in child mortality and possibly other health outcomes especially in Viwandani. The finding that Paradise village in Viwandani had significantly higher risk of under-five mortality compared to other villages in the slum could partly be due to unauthorized dumping of garbage in an empty space created between it and a nearby railway line, thereby exposing children to worse health hazards than those in other villages. We did not find any spatial variations in the risk of under-five mortality between villages in Korogocho. Korogocho differs from Viwandani in certain respects. For instance, while Korogocho is characterized by households that had stayed in the slums for long durations, Viwandani is inhabited by labor migrants with short durations of stay. It could be that the 'pseudo-permanency' of Korogocho households has over the years created homogeneity, hence less spatial differences.

Results from geo-spatial analysis further showed that in both slums, children born to mothers with at least secondary level education had significantly lower risk of dying before their fifth birthday compared to those whose mothers had lower levels of education. In addition, among children from Korogocho, the risk of dying before age five was significantly higher among those from households headed by persons aged 40 years and above than among those from households headed by younger persons. Similarly, children from the Luo community had significantly higher risk of dying by age five compared to those from other ethnic groups. These findings are consistent with those of existing studies. For example, available evidence indicates that the Luo community is characterized by poor health outcomes such as early age at first birth, short birth intervals, high HIV prevalence and harmful cultural practices that elevate the risk of child mortality (Gräb, 2009, Emina et al., 2011, Mustafa and Odimegwu, 2008, Daglas and Antoniou, 2012). Other studies have also shown reduced risk of child mortality with increased levels of mothers' education (Mutua et al., 2011, Kimani-Murage et al., 2014, Amendah et al., 2013, Fotso et al., 2013, African Population and Health Research Center (APHRC), 2014, 2008).

The findings of this paper could be influenced by certain limitations. Some covariates that could influence child survival such as mother's marital status, birth interval and the child's birth order were not included in the analysis because the information was not available for the study period. In addition, the study did not collect qualitative information which could provide explanations for some of the quantitative findings, especially the environmental risk factors and the reasons why there is an increased child mortality risk in Paradise village of Viwandani and among the Luo community. In spite of the limitations, the findings show that spatial differences in under-five mortality exist even in settings that might appear homogeneous like informal settlements of urban areas of sub-Saharan Africa.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

CMF conceptualized the study, wrote the initial draft and performed the spatial analyses. MM contributed to the initial draft and performed the descriptive analyses. PE performed the event-history analyses and drafted the methods section. DB provided technical guidance at all steps. All authors reviewed and approved the final draft of the paper.

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