Geostatistical analysis and mapping: Social and environmental determinants of under-five child mortality, evidence from the 2014 Ghana Demographic and Health Survey.

Justice Moses K. Aheto (justiceaheto@yahoo.com)
University of Ghana School of Public Health https://orcid.org/0000-0003-1384-2461
Robert Yankson
African Institute For Mathematical Sciences Ghana
Michael Give Chipeta
Malawi-Liverpool Wellcome Trust Clinical Research Programme, Blantyre, Malawi

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Abstract

Background Under-five mortality (U5M) rates are among the health indicators of utmost importance globally. It is the goal 3 target 2.1 of the Sustainable Development Goals that is expected to be reduced to at least 25 per 1000 livebirths by 2030. Despite a considerable reduction in U5M was observed globally, several countries especially those in sub-Saharan Africa (SSA) like Ghana are struggling to meet this target. Evidence-based targeting and utilization of the available limited public health resources are critical for effective design of intervention strategies that will enhance under-five child survival. We aimed to estimate and map U5M risk, with the ultimate goal of identifying communities at high risk where interventions can be targeted.

Methods The 2014 Ghana Demographic and Health Survey data was used in this study. Geostatistical analyses were conducted on 5,801 children residing in 423 geographical clusters. The outcome variable is child survival status (alive or dead). We employed a geostatistical generalised linear mixed model to investigate both measured and unmeasured child specific and spatial risk factors for child survival. We then visualise child mortality by mapping the predictive probability of survival.

Results Of the total sampled under 5 children, 280 (4.83%) experienced the outcome of interest. Children born as multiple births were at increased risk of mortality with AOR (9.28, 95% CI: 6.35 – 13.58) compared to singletons. Maternal education AOR (0.80, 95% CI: 0.68 – 0.93) and number of children under 5 within each household AOR (0.34, 95% CI: 0.28 – 0.41) were shown to have a protective effect. The predicted U5M risk in 2014 was at 8.3%. High altitude areas were highly associated with high U5M.

Conclusion The analysis found that multiple births and high elevation are highly associated with U5M in Ghana. The high-resolution maps show areas and communities where interventions for U5M can be prioritised to have health impact.

Background

Under-five mortality (U5M) remains a critical challenge to public health experts and the world at large because it reflects the public health and macroeconomic situations, priorities and values of every nation and the world. U5M rates are among the health indicators of utmost importance globally. It is the goal 3 target 2.1 of the Sustainable Development Goals (SDG) that is expected to be reduced to at least 25 per 1000 livebirths by 2030 [1]. Despite a considerable reduction in U5M was observed globally over the past two decades, several countries especially those in sub-Saharan Africa (SSA) like Ghana are struggling to meet this target [2, 3].

The global U5M was 93 deaths per 1000 livebirths in 1990 and reduced to 39 deaths per 1000 livebirths in 2017, representing a 58% reduction though differences exist in this reduction across nations and within a given country [4]. The Global Burden of Disease (GBD) 2017 SDG Collaborators reported that several countries are on track for achieving the target of at least 25 deaths per 1000 livebirths by 2030 but noted that about 31 countries/territories would need to achieve annual rates of decline from 2015 to 2030 that are two to ten times higher than what was reported for 1990–2015 in order to achieve this goal [2, 3].

The rates have been persistently higher in sub-Saharan Africa (SSA) compared to other regions from 1990 to 2017 where SSA alone contributed about 50% of the global U5M in 2017 while it was 30% in 1990 and the rate is expected to increase to 60% by 2050. The U5M rate in Sub-Saharan Africa was 79 deaths per 1000 live births compared to the global rate of 41 deaths per 1000 live births in the same 2015 [5]. The U5M rates in SSA was 76 deaths per 1000 live births in 2017 per the 2018 report of the United Nations Inter-agency Group for Child Mortality Estimation (UN IGME) [4, 6].

Despite the considerable reduction in U5M rates in Ghana from 127 deaths per 1000 live births in 1990[4, 7] to 60 deaths per 1000 live births in 2014[8], the country failed to meet the Goal 4 of the Millennium Development Goals (MDGs) targets which aimed at a two-thirds reduction in the under-five mortality rate by 2015. The under-five mortality rate in Ghana was 60 deaths per 1000 live births which fell short of the target set in the Ghana Under-five Child Health Policy 2007–2015 which targeted a reduction in under-five mortality to 40 deaths per 1000 live births by 2015[3, 8, 9].

Despite several national policies and interventions rollout in Ghana to improve and promote health of children with notable ones among them being the Child Health Policy 2007–2015, National Health Insurance and Community-based Health Planning and Services (CHPS) policy [3, 9, 10], the U5M rate remains high. A recent study conducted in 2016 among 46 African countries observed that Ghana is among 8 countries who are making very little progress towards reduction in under-five mortality[11].

In 2017, the U5M rate was estimated at 49 deaths per 1000 live births with marked regional geographic inequalities [4]. Thus, the mortality rates across the country varied [3, 12], demonstrating the need for examining more localised spatial trends in U5M. Unfortunately, information on localised spatial distributions and determinants which are critical for effective design of intervention strategies that will enhance the survival of children aged below 5 years old are not readily available. We aimed to estimate and quantify under-five mortality, its localised spatial distribution, social and environmental determinants, with the ultimate goal of identifying communities at high risk where interventions can be targeted by developing risk maps of U5M. Our findings are expected to help inform health policy and intervention strategies aimed at achieving the United Nations SDG Goal 3 target 2.1.

Methods

Study population

The 2014 Ghana Demographic and Health Survey (GDHS) which is a nationally representative cross sectional study was used in our study [8]. The DHS MEASURE Program[13] provided the data which is freely available online. It contains information on a wide range of population, health and nutrition indicators as well as geographical data. Specifically, the survey collects data on childhood mortality, maternal and child health, use of family planning methods, household socioeconomic variables and nutritional status of women and children. The survey employed a two-stage sample design to select respondents for the study. A nationally representative samples of 12,832 households from 427 clusters (primary sampling unit) were selected and 11,835 eligible households were interviewed. Data were collected on 9,396 women of reproductive age (15–49 years) and 4,388 men aged 15–59 years. Data on 5,884 children aged below 5 years were generated from the interviewed women in the main survey on which the analysis in this study was based. Data on month and year of each biological child's birth and death were extracted from complete birth histories during the survey and served as the source of identifying the number of children born in the last 5 years and child age at death. Retrospective information was obtained about children that died in the last 5 years based on information on all births to a woman within 5 years preceding the survey (i.e. from 2009 to 2014)[8].

Outcome variable

The primary outcome of interest in this study was child survival status categorised as being alive (coded as 0) or dead (coded as 1).

Explanatory variables

The variables used in the analysis are as follows.

Child and household specific variables. Data on a child's age, gender, mother's education, number of under 5 children in the household, whether a child is a twin and family's wealth index were obtained from DHS for all sampled children under 5 years. Wealth indices from DHS data are constructed using principal component analysis on household property ownership. Considered property include television, radio, watch, vehicles, agricultural land, type and number of livestock, bank account, materials used for house construction, access to water and sanitation facilities.

Community-wide and environmental variables. For each sampled cluster, we obtained data on type of residence i.e. rural or urban, altitude (DEM), proximity to major water bodies such as ocean, lakes and big rivers and measure of greenness (EVI).

Statistical analysis

a. Model formulation

The data are obtained from 5,801 children in each of the 423 clusters in Ghana as shown in Figure 1. Let *i* and *j* denote the indices of the ith cluster and jth child within the sampled cluster. At each sampled cluster, the primary interest was survival of the jth child with the outcome dead (1) or alive (0), resulting in the data-format expressed as

[Due to technical limitations, this equation is only available as a download in the supplemental files section.]

where xij is the location of the jthof ni children, nij is the number of children at location xij and yij is the number of under 5 children that died at location xij. In order to deliver valid inferences on the regression coefficients, we need to account for spatial effects. Model based geostatistics, among the many available techniques, provides a mechanism for incorporating both explained and unexplained (residual) spatial variation in the child survival outcome and allows us to predict child mortality throughout the region of interest G.

For the jth child in ith cluster, the response Yijis the binary indicator of survival. The associated covariates vector dij includes whether a child was a twin, number of other under 5 children within the household, mother's education, the family's wealth index, altitude, proximity to water and a measure of wetness, namely the enhanced vegetation index. Note that the first set of three covariates are specific to each child observed and the last set of three covariates are common to all children within a given cluster. We distinguish between two sources of variation in the child survival; between-cluster variation, induced by spatially varying risk factors; and within-cluster variation induced by child specific characteristics. Each of these variations depend on both measured and unmeasured risk factors. To account for unexplained non-spatial variation, we define a generalised linear mixed model as follows. Let S(xi) denote a Gaussian process and Ui denote cluster specific-random effects, which are mutually independent, with mean 0 and common variance υ2. Conditionally on S(xi) and on the Ui, the Yij are then modelled as independent Bernoulli variates with success probabilities pij given by

[Due to technical limitations, this equation is only available as a download in the supplemental files section.]

where d(xij) is a vector of explanatory variables associated with regression coefficients β for xij. The spatially structured residuals Sx are modelled as zero-mean stationary and isotropic Gaussian process with variance σ2 and correlation function

[Due to technical limitations, this equation is only available as a download in the supplemental files section.]

where u is the Euclidean distance between locations x and x'. We assume that ρu is monotone non-increasing in distance u, with scale parameter φ that controls the rate at which the correlation approaches 0 with increasing distance u. Diggle (2007) outlines various parametric families for ρu, in the current analysis, we use the Matérn class of correlation function[14], given by

[Due to technical limitations, this equation is only available as a download in the supplemental files section.]

where φ>0 is the scale parameter and κκ(.) is the modified Bessel function of the second order κ>0. The shape parameter κ determines the smoothness of Sx, in the sense that Sx is κ−1 times mean-square differentiable.

b. Model validation

The model was validated using two methods. First by testing evidence against the residual spatial correlation in the data through the following variogram-based validation procedure (Giorgi et al., 2018). We simulate 1000 empirical variograms under the fitted model and then use these to compute 95% confidence intervals at any given spatial distance of the variogram. If the empirical variogram obtained from the data falls within the 95% tolerance bandwidth, we conclude that the adopted spatial correlation function is compatible with the data. If, instead, that falls outside the 95% tolerance bandwidth, then the data show evidence against the fitted model.

Results

Sample descriptive characteristics

A total of 5,801 children were sampled from 423 unique locations or clusters in the 2014 DHS survey, see Figure 1. The average number of children per cluster varied widely, with lowest number of 1 and highest number of 59 and a median of 13 children. The locations of the sampled clusters are shown in Figure 1. Out of the 5,801 children in the dataset, 280 (4.83%) were reported dead. Of the total, 5,516 (95.1%) were born singletons and 3,018 (52%) were male children. A majority of children (41.3%) belonged to mothers with secondary education while 34.3% belonged to mothers with no education. About 54% of the children came from poor households and 28% of the children came from well-endowed households. A majority of the children (60%) came from rural areas; and 45% of the total number of children were in the 24—35 months age bracket, followed by 22% in the 12—23 months age bracket. Less than 1% of the children came from households with other under 5 children (Table 1).

[INSERT FIGURE 1 AROUND HERE]

[INSERT TABLE 1 AROUND HERE]

For children who died, majority were those born singleton (82.9%) as compared to those born multiple (17.1%). Children from uneducated women experienced the highest proportion of child-mortality at 40%, followed by children from mothers with secondary level education (37.5%). Mothers with higher education experienced the least child-mortality at 4.3%. Poor households were observed to have the most deaths experienced at 56.1%, followed by well-endowed households (26.1%). More child deaths were observed in rural settings (59.3%) as compared to urban settings. A high proportion of child deaths were observed in Northern region (21.4%), Ashanti (13.6%) followed by Central and Eastern both at 11.1%. The least proportion of child deaths were observed in Greater Accra region at 4.3%. Children aged 24—35 months were observed to experience the highest child-mortality proportion at 70% whereas both those aged below 12 months and children aged 48—59 months did not experience any deaths at the time of observation (Table 1).

Non-spatial analysis

Risk factors associated with under-five mortality

For each child, the variable of interest was the binary indicator of survival (dead or alive). Selected determinants of child-mortality were estimated, and with associated 95% confidence intervals of both crude and adjusted odds ratios (OR). The results in Table 2 indicate that, being born a twin increased the risk of child mortality adjusted OR (9.28, 95% CI: 6.35—13.58). The number of children under the age of 5 within the household showed to have a protective effect on child mortality, adjusted OR (0.34, 95% CI: 0.28—0.41). Household wealth was also shown to have a protective effect on child mortality with adjusted OR (0.86, 95% CI: 0.72—1.02) albeit not significant. All environmental covariates considered, namely digital elevation model (DEM), enhanced vegetation index (EVI) and proximity to water did showed marginal associations with child mortality (Table 2).

[INSERT TABLE 2 AROUND HERE]

Geostatistical analysis

In order to understand the spatial distribution of U5M and identify communities at high risk where interventions can be targeted, we implemented a Generalised Linear Geostatistical Model (GLGM) defined in equation (2) by Monte Carlo maximum likelihood and developed a risk map of U5M. The results of testing the validity of the adopted spatial structure, showed that the empirical semi-variogram was within the 95% tolerance intervals (Figure 2). Thus, the child-mortality data does not show evidence against the fitted geostatistical model. The outcome of the GLGM are presented in Table 3. The parameters $\sigma 2$ and φ are the variance of the gaussian process Sx and the scale of the spatial correlation ρu respectively. Results from GLGM revealed that being a product of multiple births and residing in high altitudes was positively associated with U5M. Maternal education, number of children aged below 5 years in households, and proximity to water were found to be negatively associated with U5M.

[INSERT FIGURE 2 AROUND HERE]

[INSERT TABLE 3 AROUND HERE]

The assembled data were used in the GLGM Equation 2 to generate the 5 x 5 km grids of mean predictions of U5M in 2014 (Figure 3). Overall, the national predicted U5M in 2014 is low with an average of 8.3% and a median rate of 8.7%. However, this is characterised by areas with above average predicted U5M risk. These areas are mainly localised in localised areas of south-central and eastern parts of Ghana. The southern-most end of Ghana, part of which is the Greater Accra region, (urban areas) are showing the lowest predicted U5M risk across the entire country (Figure 3).

[INSERT FIGURE 3 AROUND HERE]

In Figure 4, we show the low and upper quantiles maps, with a low quantile of less than 3 % and a high quantile of approximately 40%. Figure 5 presents the model estimates uncertainty.

[INSERT FIGURE 4 AROUND HERE]

[INSERT FIGURE 5 AROUND HERE]

Discussion

In our study, we set out to develop and apply Generalised Linear Geostatistical Model (GLGM) to spatially analyse under-five child mortality (U5M) in Ghana while adjusting for child, household, community and environmental factors that might influence U5M. Our goal is to produce spatial predictive risk maps of U5M continuously over Ghana that could help identify communities at high risk for targeted public health interventions, given the limited public health resources in the country.

Among the covariates adjusted for in the model, the study found that maternal educational level, number of children U5 in household, type of birth, altitude and proximity to water were predictive of U5M in the spatial model (i.e. GLGM) while only maternal educational level, number of children U5 in household and type of birth were predictive of U5M in the non-spatial model. However, our discussion will be centred on the results from the spatial model because that is the focus of this study.

Broadly, our study is consistent with previous studies that examined factors influencing U5M. For example, U5M is significantly lower among children from mothers with higher levels of education [3, 15, 16]. This is in the expected direction because higher level of maternal education is likely to result in improved health seeking behaviour and utilization of health services for their offspring and themselves, and this is expected to improve the health outcomes of both the children and their mothers. It is also expected to result in optimal childcare and feeding practices with its resultant improved health outcomes for the child [3, 17–19]. U5M is significantly higher among children born multiple compared to those born singleton which could be due to competition for nutrients and health complications that usually occur more among children who are products of multiple births [3, 17, 19, 20]. The unexpected finding that the number of children under-five in household is protective of U5M warrants further investigation as reported in a previous study [3].

Improved vegetation is protective of U5M which is expected because improved vegetation was observed to be protective against adverse health outcomes like child malnutrition in previous studies [21, 22].

We used model-based geostatistics methods to map U5M risk at a fine-scale resolution of 5 x 5 km. The spatial predictive map shows that U5M risk in Ghana is at an average of 8.3% predicted U5M risk with a median of 8.7%. This is similar to the downward trend shown by both Ghana Statistical Service and the World Bank, which shows a rate of 60 and 58 deaths per 1,000 live births in 2014[7, 8], respectively. The world average at the same period shows a rate of 43.5 deaths per 1000 live births. U5M rate has continued a downward trend up to 49 deaths per 1000 live births in 2017, compared to the world rate of 39.1 per 1000 live births in the same year[7]. Thus, U5M is still a critical public health issue in Ghana.

Despite the low U5M rates, there is evidence of localised high predicted U5M risk (Figures 3 and 4). From Figure 3, pockets of high U5M risk are evident especially in the northern and central parts of Volta region. Furthermore, the predicted high U5M risk can be seen across the entire Eastern region as well as west of Ashanti region. It is worth noting that these areas with high predicted U5M risk are all at moderate to high elevated altitudes, suggesting that U5M is driven by altitude.

Our findings therefore show that increase in elevation is associated with increased risk of U5M. These findings are in line with previous studies[23–26]. It has been shown that infant mortality rates and post-natal mortality rates were high in highland zones as compare to lowland zones in the Northwest region of Argentina[27]. A number of factors associated with altitude have been pointed out to influence mortality rates at high altitude. Ecology in high elevation areas influences ecosystems in multiple ways, including reduction of oxygen, reduced temperatures, increased solar radiation, and infertile soils leading to poor agricultural output hence reduced nutrition[27]. Physiological factors induced by high elevation have also been shown to be related to low birthweight [28–30], hence U5M.

Additionally, a possible explanation of the predicted U5M risk patterns could be that these areas are generally resource-constrained settings where access to under 5 child healthcare facilities are limited due to steep terrains. Poor treatment seeking behaviour often results in poor health outcomes[31–33] including increased child mortality. As such, new interventions for curbing U5M could include improved access to health facilities.

The current results also show that children born as multiple births are at a greater risk of U5M. This is in line with findings from previous studies[3, 34, 35]. Monden and Smits (2017) show that mortality among twins in under 5 children is 3 times the mortality among singletons in sub-Saharan Africa[36]. What is not clear in the current study is whether multiple births are also prevalent in areas where high U5M was observed. This question warrants further investigation.

The results presented here should be considered within the context of some limitations. First, we analyzed data for a single year from a cross sectional prevalence study. In order to get a complete picture, a trend of U5M in Ghana should be analyzed. The available data cannot permit this type of analysis. This therefore requires collection and collation of more data to allow U5M trend analysis. Secondly, secondary data from Measure DHS survey database were used and analyzed. The database had limited variables that could have been included in the analysis to improve the understanding of U5M in Ghana.

Conclusion

The current analysis of the 2014 GDHS data set has shown that multiple births and elevation have a negative effect on under 5 children survival in Ghana. The analysis has also shown that maternal education, proximity to water, and number of children under 5 are associated with reduction in U5M risk.

Areas at higher altitudes have been shown to have high U5M risk. The presented map, at 5 x 5 km resolution offers an opportunity to investigate further, especially in the highlighted regions and areas and prioritise interventions to eradicate U5M amidst available limited public health resources in developing countries like Ghana. These findings have important implications for the design of new interventions against U5M in Ghana and other developing countries and present new avenues for further research.

Abbreviations

DEM; Digital Elevation Model

EVI; Enhanced Vegetation Index

GDHS: Ghana Demographic and Health Survey

GLGM; Generalised Linear Geostatistical Model

MDGs: Millennium Development Goals

SDG: Sustainable Development Goal

U5M; Under 5 Mortality

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable.

Availability of data and material

Data supporting the conclusions of this article are freely available at URL: https://dhsprogram.com/data/available-datasets.cfm upon making request to the DHS Program.

Competing interests

The author declared no conflicts of interest with regard to this article.

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Author’s contributions

JMKA conceived and designed the study and collected the data. JMKA, MGC and RY assembled and prepared the data for analysis. MGC, JMKA and RY analysed, interpreted the data and drafted the first manuscript. JMKA, MGC and RY critically reviewed and revised the manuscript and approved the final version of the manuscript.

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Tables

Table 1 Proportions of Mortality among children under-five with respect to covariates under consideration.

	Child Survival		
	Total	*Alive*	*Dead*
	n = 5801	**n = 5521**	**n = 280**
Child is twin			
Single birth	5516 (95.1%)	5284 (95.7%)	232 (82.9%)
Multiple births	285 (4.9%)	237 (4.3%)	48 (17.1%)
Gender			
Male	3018 (52%)	2865 (51.9%)	153 (54.6%)
Female	2783 (48%)	2656 (48.1%)	127 (45.4%)
Education			
No education	1991 (34.3%)	1879 (34%)	112 (40%)
Primary	1193 (20.6%)	1142 (20.7%)	51 (18.2%)
Secondary	2393 (41.3%)	2288 (41.4%)	105 (37.5%)
Higher	224 (3.9%)	212 (3.8%)	12 (4.3%)
Wealth quintile			
Poor	3117 (53.7%)	2960 (53.6%)	157 (56.1%)
Average	1073 (18.5%)	1023 (18.5%)	50 (17.9%)
Rich	1611 (27.8%)	1538 (27.9%)	73 (26.1%)
Region			
Ashanti	584 (10.1%)	546 (9.9%)	38 (13.6%)
Brong Ahafo	653 (11.3%)	628 (11.4%)	25 (8.9%)
Central	603 (10.4%)	572 (10.4%)	31 (11.1%)
Eastern	545 (9.4%)	514 (9.3%)	31 (11.1%)
Greater Accra	445 (7.7%)	433 (7.8%)	12 (4.3%)
Northern	902 (15.5%)	842 (15.3%)	60 (21.4%)
Upper East	551 (9.5%)	534 (9.7%)	17 (6.1%)
Upper West	455 (7.8%)	429 (7.8%)	26 (9.3%)
Volta	481 (8.3%)	459 (8.3%)	22 (7.9%)
Western	582 (10%)	564 (10.2%)	18 (6.4%)
Residence			
Urban	2344 (40.4%)	2230 (40.4%)	114 (40.7%)

Rural	3457 (59.6%)	3291 (59.6%)	166 (59.3%)
Age group			
<12	619 (10.7%)	619 (11.2%)	0 (0%)
12-23	1284 (22.1%)	1236 (22.4%)	48 (17.1%)
24-35	2608 (45%)	2412 (43.7%)	196 (70%)
36-47	805 (13.9%)	769 (13.9%)	36 (12.9%)
48-59	485 (8.4%)	485 (8.8%)	0 (0%)
U5 child in HH [Mean]	1.74 (0.94)	1.76 (0.92)	1.22 (1.11)

Table 2 Logistic regression and 95% confidence intervals adjusted OR estimates for under-five child mortality risk factors.

Variable	**Adjusted OR**	**Lower 95 % CI**	**Upper 95% CI**	**P-value**
Twin	9.28219	6.34500	13.57907	< 0.001
Education	0.79925	0.68422	0.93361	0.005
U5child	0.33854	0.28274	0.40535	< 0.001
Wealth	0.86128	0.72427	1.02419	0.091
DEM*	1.00251	1.00105	1.00397	< 0.001
Water proximity	0.99997	0.99995	0.99999	0.005
EVI**	0.99987	0.99973	1.00001	0.07

*Digital Elevation Model; **Enhanced Vegetation Index

Table 3 Monte Carlo maximum likelihood estimates and 95% confidence intervals for the GLGM fitted to 2014 DHS under-five mortality data.

Term	Estimate	Standard Error	95% Confidence Interval
Intercept	-3.56467	0.40305	(-4.35464, -2.77470)***
Twin	2.30893	0.19824	(1.92038, 2.69748)***
Education	-0.22437	0.08007	(-0.38129, -0.06743)***
U5child	-1.09361	0.09232	(-1.27454, -0.91267)***
Wealth	-0.07995	0.089055	(-0.25449, 0.09459)
DEM	0.00258	0.00074	(0.00113, 0.00404)***
Proximity to water	-0.0000027	0.0000011	(-0.0000048, -0.0000005)*
EVI	-0.0000938	0.0000725	(-0.0002359, 0.0000483)
	0.21164	0.55752	(0.18193, 0.24619)
	1.44661	0.11138	(1.17318, 1.78375)

***Significant at 0.1% level or less; *significant at 5% level or less;

The scale parameter φ has units in kilometres

Figures

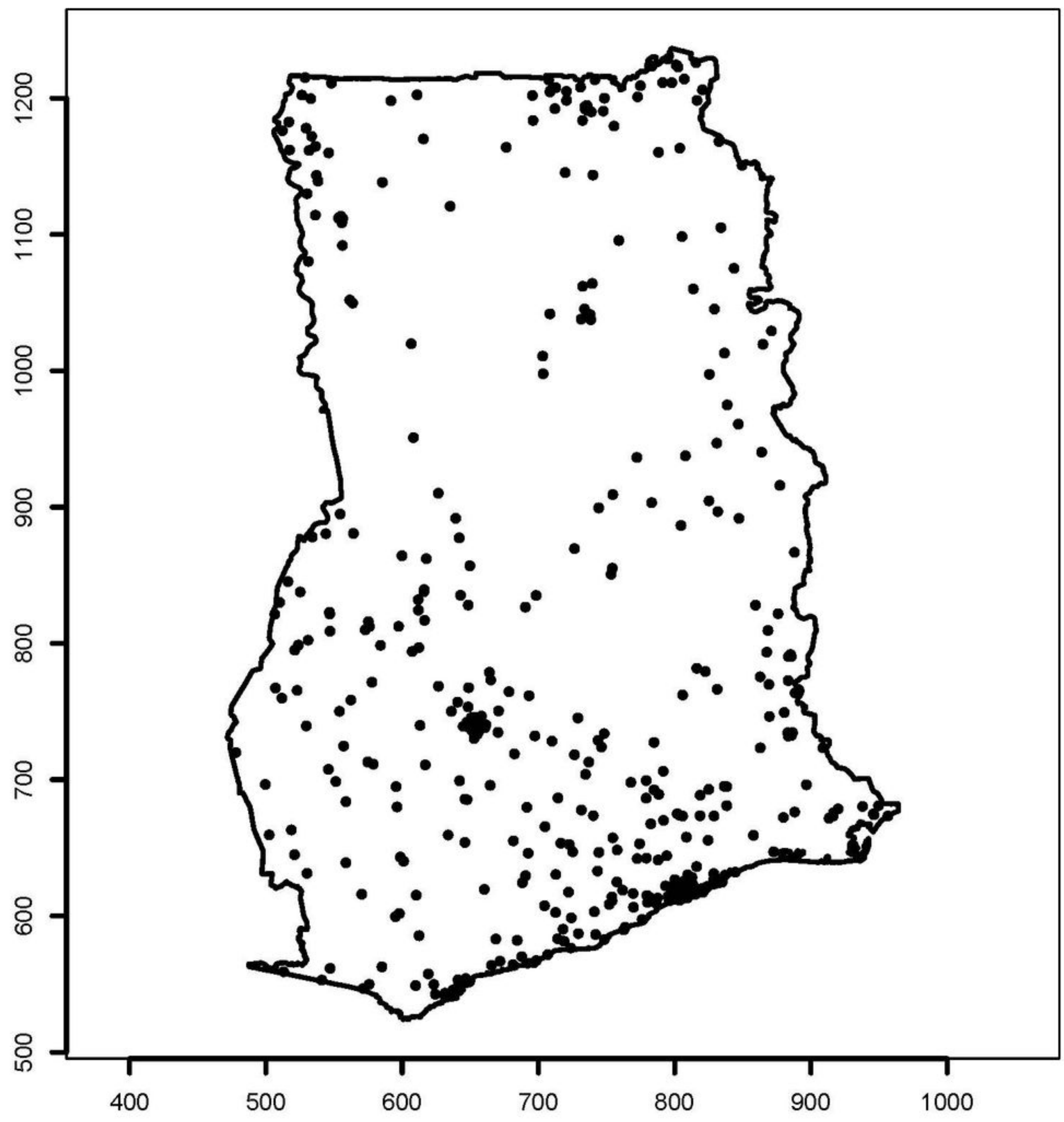

Figure 1

Child mortality in Ghana. The locations for clusters where DHS surveys were conducted in Ghana in 2014.

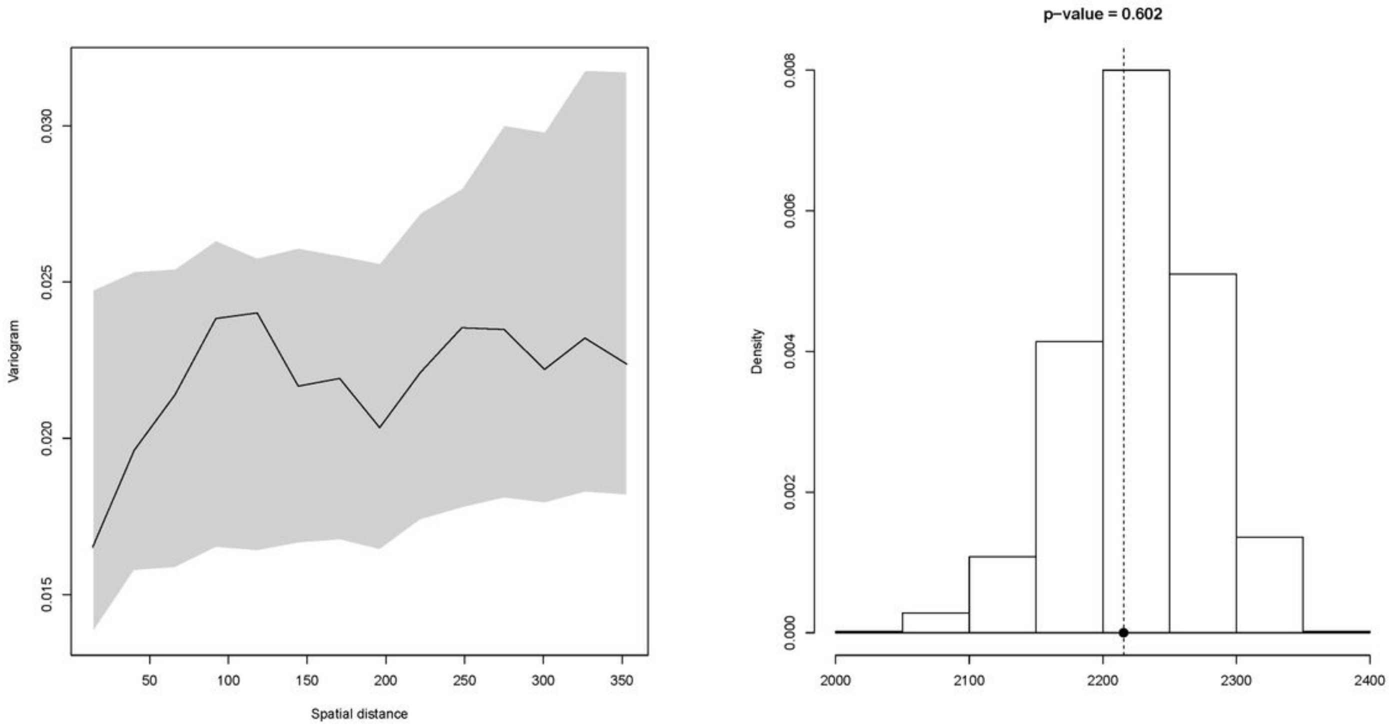

Figure 2

Child mortality in Ghana. Results from variogram diagnostic check for compatibility of data with the fitted geostatistical model (left panel). The solid line is the empirical variogram of the data. The shaded areas are the 95% confidence bands under the hypothesis of spatial dependence. The right panel is the corresponding p-value of the test.

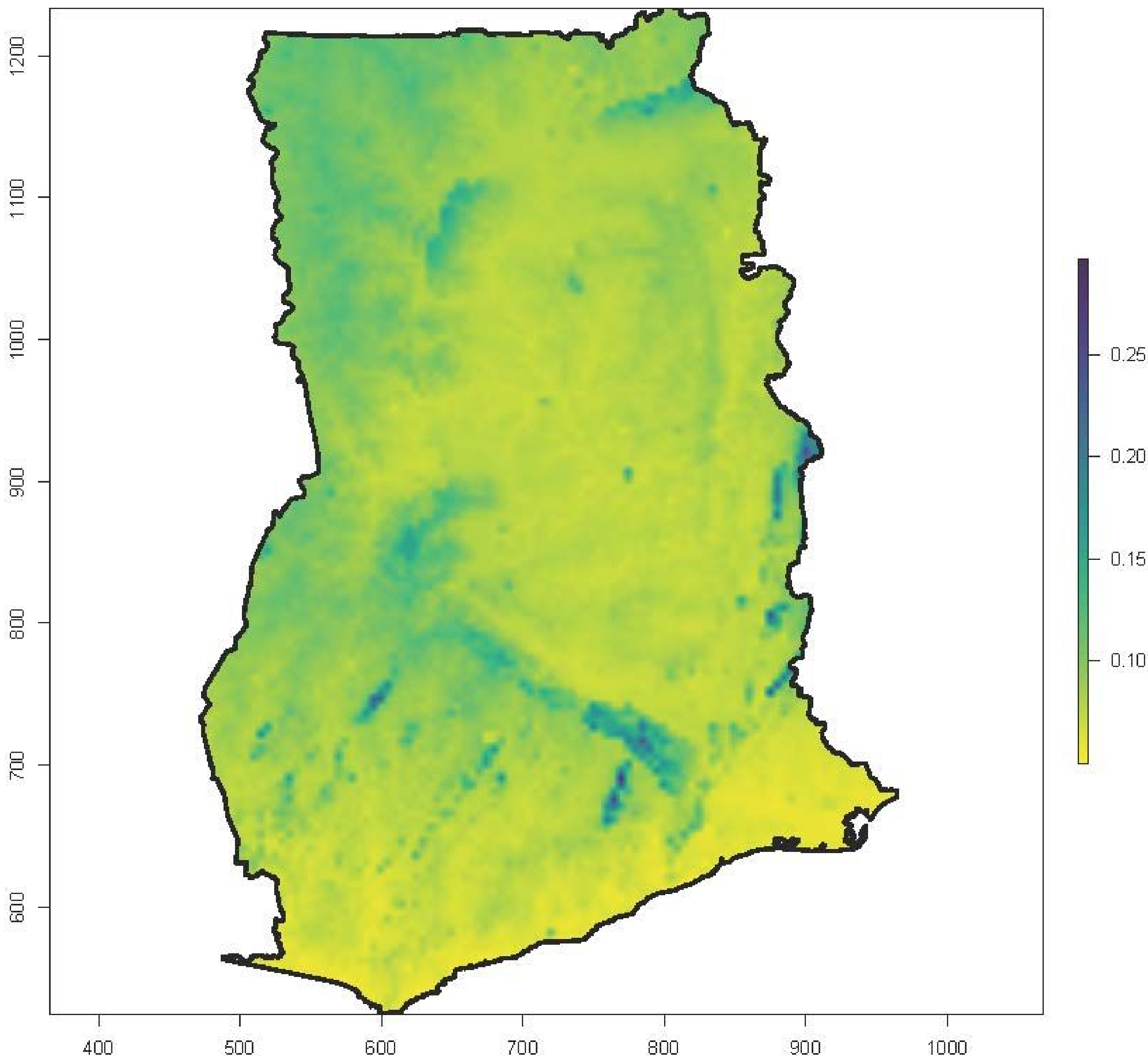

Figure 3

Child mortality in Ghana. Child mortality risk map in Ghana showing relatively low mortality on average with pockets of high mortality in the southern and eastern parts of the country.

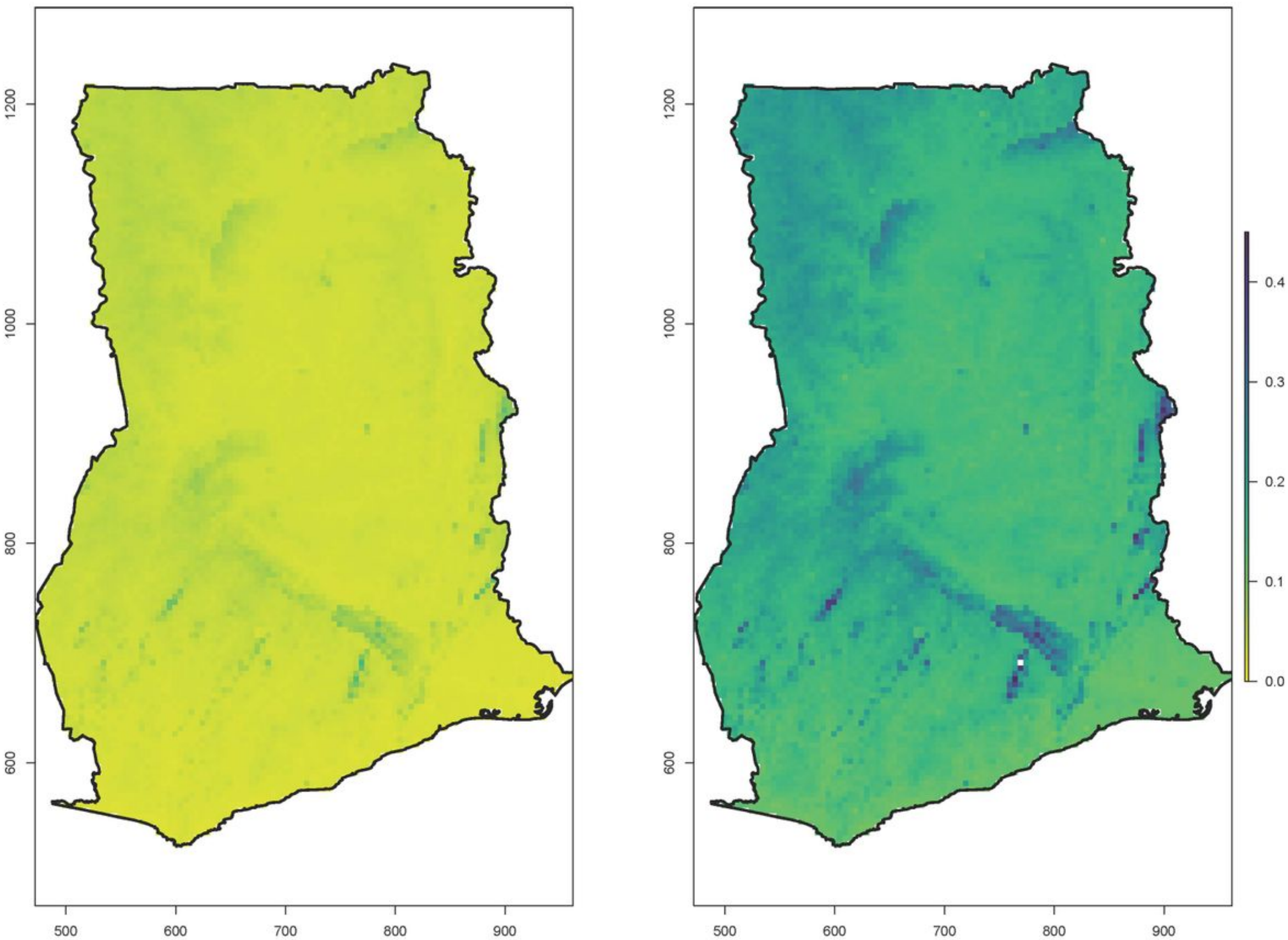

Figure 4

Child mortality in Ghana. Lower and upper 95% confidence maps of child mortality.

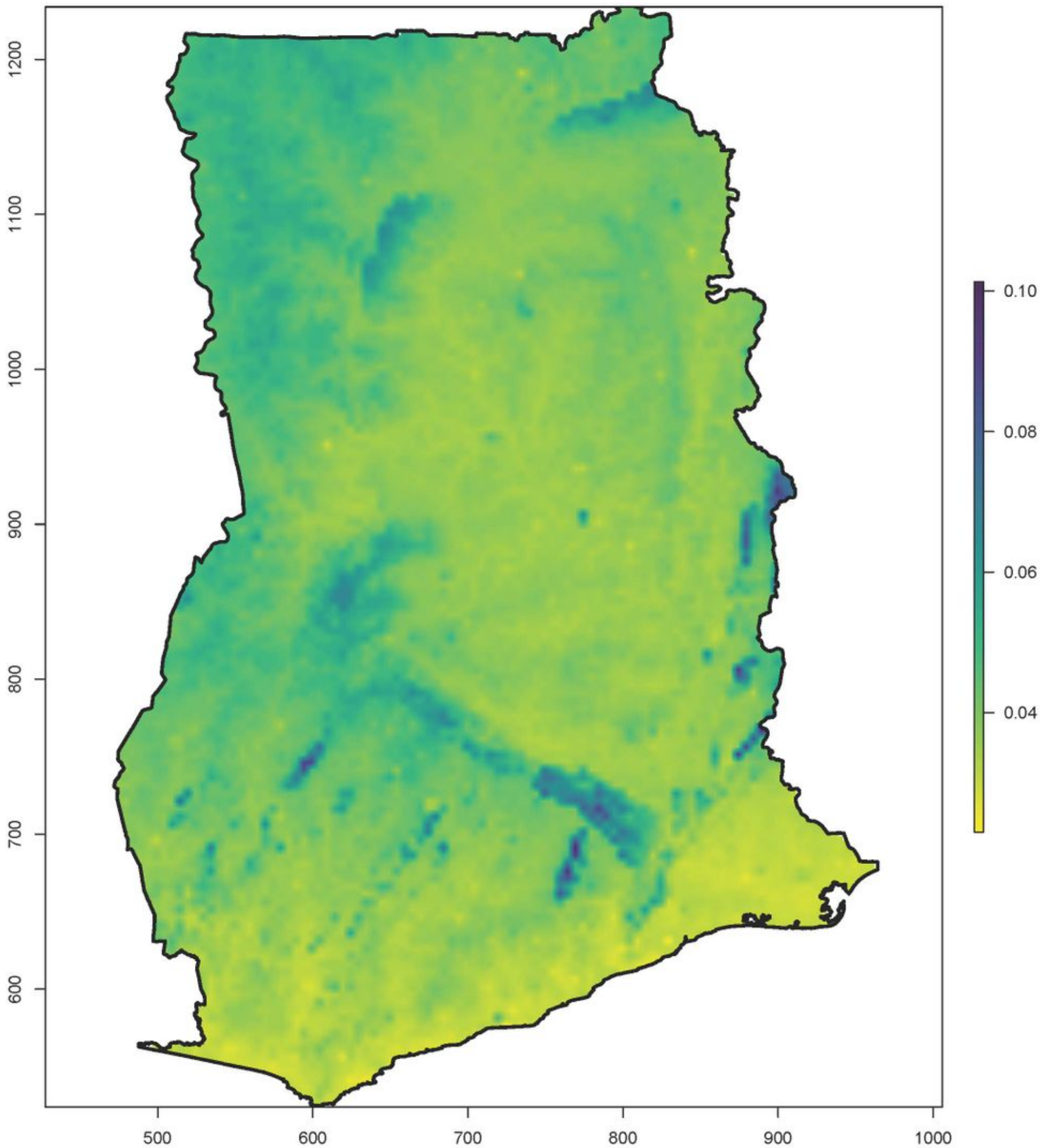

Figure 5

Child mortality in Ghana. Uncertainty measure

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- eq1.jpg
- eq4.jpg
- eq3.jpg
- eq2.jpg