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Research Article

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Spatial disparities and associated factors of Under-five diarrhea disease in Ilubabore Zone, Oromia Regional State, Ethiopia

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Abstract

Background

Diarrhea is commonly a sign of an infection in the intestinal tract that is caused by different bacteria, viruses, and parasitic entities. It is one of the leading causes of child mortality worldwide, especially in sub-Saharan African countries including Ethiopia. The main objective of this study was to identify spatial disparities and associated factors of under-five diarrhea disease in Ilubaborazone, Oromia regional state, Ethiopia.

Study Design: *A community based cross sectional study design was used*

Methods

The study was carried out in the Ilu Aba Borazon of entire districts, and the data is essentially both primary and secondary, obtained from each woreda health office in the Ilu Aba Borazon and the corresponding mother or care giver of the sampled child. Spatial disparities in under-five diarrhea were identified using global and local measures of spatial autocorrelation. A Geo-additive regression model was used to identify the spatial disparities and associated factors of under-five diarrheal diseases.

Results

The value of global and local measures of spatial autocorrelation shows that under-five diarrheal disease varies according to geographical location and shows significant positive spatial autocorrelation. The results of the Geo-additive regression model showed a statistically significant relationship between under-five diarrhea disease and independent variables.

Conclusion

There is evidence of significant under-five diarrheal disease clustering in the Ilu Aba Borazon, southwest Ethiopia. Model-based data analysis showed that there is a significant relationship between under-five diarrhea and covariates (mother's age, mother's education, source of drinking water, quality of toilet facility, DPT 3 vaccination, Polio 3 vaccination, and household wealth index).

Keywords: Under-five diarrhea, Spatial Autocorrelation, Bayesian Geo-additive Regression Model.

Introduction

The world health organization defines diarrhea as the passage of three or more loose or liquid stools per day in a period not exceeding 14 days. Diarrhea is one of the leading causes of child mortality, mostly in children less than 5 years of age living in low and middle-income countries 16.Globally, 530,000 children under five years old are dying every year due to diarrheal disease, and diarrhea is the second leading cause of mortality in under-five children, next to pneumonia, which is responsible for one in nine child mortality 17.In 2015, diarrheal disease was responsible for more than 88% of deaths in children under the age of five in Africa, particularly in Sub-Saharan Africa 17. In Ethiopia, childhood morbidity and mortality remain high due to the burden associated with highly prevalent diseases such as diarrhea, fever, cough, malaria, and HIV/AIDS. For instance, diarrhea contributes to more than one in every ten (13%) child deaths in Ethiopia 19.Diarrhea is commonly a sign of an infection in the intestinal tract that is caused by different bacteria, virus and parasitic entities 18 and characterized by abnormally loose or watery stools. Diarrhea remains the leading cause of morbidity and mortality in children under 5 years old worldwide. In particular, diarrhea diseases cause 8% of deaths among children under age five globally 20. The burden is disproportionately high among children in low and middle-income countries. Young children are especially vulnerable to diarrheal disease, and a high proportion of the deaths occur in the first 2 years of life. Worldwide, the majority of deaths related to diarrhea take place in Africa and South Asia. Nearly half of deaths from diarrhea among young children occur in Africa, where diarrhea is the largest cause of death among children under 5 years old and a major cause of childhood illness 5. According to the UNICEF report in 2016, approximately 5.6 million children under the age of five die every year, which is a decrease from over 12 million in 1990. 80% of deaths are from sub-Saharan African countries like Ethiopia. Regardless of the noticeable improvement in the reduction of under-five deaths in Ethiopia, childhood diarrhea is still the leading cause of death in the country. In Ethiopia, few studies have been conducted on diarrhea to find risk factors associated with under-five diarrhea diseases 13, 15. However, they did not include spatial dependence in their work, which results in incorrect parameter estimation results; thus, most health event data are spatially correlated. Finding a spatial disparity is very important to designing and monitoring effective intervention programs to reduce the prevalence of diarrhea. The basic research questions are: Does the spatial distribution of diarrhea in districts of Illubabor zone, which districts are under cold spot and which districts are under hot spot, and among study variables, which predictor variables significantly affect the five diarrhea diseases in this study area? The overall goal of this study was to identify spatial disparities and associated factors of under-five diarrhea diseases in the Illubabor zone of Ethiopia's Oromia regional state.

The organizations as well as individuals who work in this area get a clue about the spatial disparities of diarrhea in the districts of the Illubabor zone. The other basic significance of this study was to further assist other researchers interested in explanatory spatial data analysis and they may use it as a benchmark for their future work in identifying the spatial distribution of disease. Therefore, researchers would benefit by getting familiar with this method and may further help in advertising explanatory spatial data analysis. Therefore, the result of this study has the following importance:

- It enables the government and other concerned organizations to do strategic planning to reduce the prevalence of under-five diarrhea diseases.
- Provide information to researchers for further studies on explanatory spatial data analysis and use different statistical model.
- Help to identify factors that affect diarrhea prevalence in this study area.
- Help to identify woredas under hot spots and cold spots.

Methods

Location of research

The study was conducted in Illubabor zone, Oromia regional state southwest Ethiopia. There are 14 woredas in this zone. The capital city of the zone, Mettu town is located in south west of Ethiopia at 600 Km far from Addis Ababa. This zone is bordered on the south by the Region, on the southwest by the Gambela Region, on the west by Kelem Wollega Zone, on the north by west Wollega Zone ,on the east by Bunno bedele Zone.

Data collection

For this study both secondary and primary source of data were used. Secondary data (under-five diarrhea cases counts for each woreda) was taken from each woredas of Ilubaborazone for the purpose of spatial pattern analysis and community based data(primary source data) was taken from corresponding mother or care givers of sampled child for the purpose of associated factors of under-five diarrhea analysis. For the data collection the researchers used both questionnaire and face to face interview as data collection tools.

Study Population and variables

The study was focused on children under five years of age whom had diarrhea in the last two weeks prior to data collection time, which was conduct from December to the end of February 2021. The sample size includes a total of 685,583 children under five years of age who were residents in the households during the time of the survey.

Dependent variable: The primary outcome variable was the reported occurrence of diarrhea. i.e. If the child had diarrhea in the last two weeks including the last 24 hours prior to data collection time. Therefore, the response variable was dichotomous in nature i.e. children diarrhea status (0=no, 1=yes (child had diarrhea))

Independent Variables: mother's age, mother's education, mother's work status, source of drinking water, mother's place of residence, quality of toilet facility, DPT 3 vaccination, Polio 3 vaccination, age of the child and household wealth index.

Ethics approval and consent to participate

Ethical clearance was obtained from the ethical review committee of Mettu University. Formal letter of permission was obtained from this office and submitted to Ilu Aba borazone. Written informed consent was obtained from study participants before interview. The right to refuse or discontinue participation at any time they want and the chance to ask any thing about the study was given. All personnel information was kept anonymously and confidentiality was assured throughout the study period.

Study Design

A community based cross sectional study design was used to assess the spatial disparities and associated factors of diarrhea prevalence among under-five children of Illuba borazone and the data were analyzed in Geoda, ArcGIS, R software (version 3.6).

Method of Data Analysis

Spatial data Analysis

Spatial data analysis is defined as an analysis that involves the accurate description of data relating to a process operating in space, the exploration of patterns and relationship in such data, and the search for explanation of such patterns and relationships[3].

Therefore in this study exploratory spatial data analysis like Moran's I and Geary's C was used to detect the presence of spatial dependency (association) in our data and Bayesian Geo-additive regression model is used to identify the determinants of prevalence of diarrhea with spatial disparities. Spatial dependence indicates that near places are more likely to be related than distant ones and usually most geographical patterns of interest involve groupings of similar values in clusters.

Moran's I

Moran's I Global measures summarize spatial association with respect to the whole region. The Moran I values ranged from -1 to +1. A positive spatial autocorrelation (+1) referred to a map pattern where geographical features of similar value tended to cluster together, a negative spatial autocorrelation showed a map pattern in which geographical units of similar values were scattered throughout the map and a statistically insignificant spatial autocorrelation depicted a random distribution. The general formula for computing Moran's I is:

$$I = \frac{N}{\sum_i \sum_j w_{ij}} \frac{\sum_i \sum_j w_{ij}\,(y_i - \bar{y})(y_j - \bar{y})}{\sum_i (y_i - \bar{y})^2}$$

Where N is the number of spatial units indexed by i and j; y is the variable of interest; $\bar{y}$ is the mean of y; and w_{ij} is an element of a matrix of spatial weights.The observed value of I can be compared to its distribution under the null hypothesis of no spatial autocorrelation or no clustering i.e. when the values of yi are independent of the values $yj(i \neq j)$ at neighboring locations. This is equivalent to say that under the reference null distribution, data are randomly distributed over locations. Therefore, inference can be based on the standardized version of I, namely:

$$Z(I) = \frac{I - E(I)}{\sqrt{var(I)}}$$

The expected value of Moran's I under the null hypothesis of no spatial autocorrelation is

$$E(I) = \frac{-1}{N-1}$$

Its variance equals $var(I) = E(I^2) - (E(I))^2$

$$= \frac{N^2(N-1)S_1 - N(N-1)S_2 - 2S_0^2}{(N+1)(N-1)S_0^2}$$

Where $S_0 = \sum_{i \neq j}^{n} wij$, $S_1 = \frac{1}{2}\sum_i \sum_j \left(w_{ij} + w_{ji}\right)^2$,

$$S_2 = \sum_i \left(\sum_j w_{ij} - \sum_j w_{ji}\right)^2$$

In this study, the global Moran's I test statistic is used to test the null hypothesis:

Ho: No significant clustering of diarrhea prevalence (no spatial auto correlation) in the entire study region. The mean found by Moran's I coefficient analysis is used to identify the presence of spatial autocorrelation by comparing Moran's I calculated with the tabulated value.

Geary's C

The Geary C statistic is useful in identifying local patterns of health event distribution (distribution of diarrhea prevalence in case of this study).Geary's C interactions are not the cross product of the deviations from the mean, but the deviations in intensities of each observation location with one another.

Geary's C can be computed as follows:

$$C = \frac{(N-1)\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}\ (y_i - y_j)^2}{2\left(\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}\right)\sum_{i=1}^{N}(y_i - \bar{y})^2}$$

Usually the values of C range between 0 and 2.Values of C between 1 and 2 indicate presence of negative spatial autocorrelation while values between 0 and 1 indicate presence of positive spatial autocorrelation and a value of 1 showing a random pattern. Moran's I gives a more global indicator, whereas the Geary's coefficient is more sensitive to differences in small neighborhoods. Testing the significance is done by using the standardized version of C, namely:

$$Z(C) = \frac{C - E(C)}{\sqrt{var(C)}}$$

With $E(C) = 1$, $var(C) = \frac{((2S1+S2)(n-1)-4SO^2)}{2(n+1)SO}$

Bayesian Geo-additive Regression Model for Binary Spatial data

A common way to build regression models extending the classical linear model for Gaussian responses to more general situations such as binary responses are generalized linear models, originally introduced 14.While being flexible in terms of the supported response distributions, generalized linear models obey rather strong assumptions considering the linearity of the influence of covariates and the independence of the observations. However in most practical situation, we are facing at least one of the following problems in which generalized linear model is not appropriate to fit data:

- For the continuous covariates in the data set, the assumption of a strictly linear effect on the predictor may not be appropriate.
- Observations may be spatially correlated.
- Heterogeneity among individuals or units may not be sufficiently described by covariates because of the hierarchical structure of the data.
- To overcome these difficulties a model with predictors that contain spatial effect and non-linear effect of metrical covariate called Geo-additive regression model is proposed 9.Geo-additive model is one class of structural additive regression (STAR) model which based on the framework of Bayesian generalized linear models11, 4.

Model building

Consider regression models, where observations (y_i, x_i, w_i);); i= 1…n on response y_i, a vector $x_{i=}(x_1 \ldots\ldots x_p)$ 'of metrical covariates (continuous covariate), spatial covariates (district or woreda) in case of this study and a vector $w_i=(w_{1,} \ldots\ldots w_r)$'Of further covariate, in which categorical variables are often given. Where, the response Yi is a binary indicator of the response variable

i.e.Yi~Binomial (ni,πi)

The generalized additive modeling framework assumes that, given x_i and w_i, the distribution of the response yi belongs to an exponential family, with mean $\mu_i=(y_i \mid x_i, w_i)$linked to an additive semi-parametric predictor $\mu_i=\underline{h}(\eta_i)$.

Traditionally the effect of the covariates on the response y_i, is modeled by a linear predictor:

$\eta_i = x'_i \ \beta + w'_i \gamma$……………………………………………………………………..……1

Where h is a known response function.

The predictor on equation 1 above is the predictor of generalized linear model. But In this Predictor, spatial variability is not included and as well as non-linearity of metrical covariate is not assumed. Therefore in order to account spatial dependency with non-linearity assumption of metrical covariate, equation (1) is extended to a geo-additive model by accommodating the spatial variability and non-linear effect of metrical covariate as follows:

$\eta_i = f_1(x_{i1})+\cdots+f_p(x_{ip}) + f_{spa}(s_i)+ w'_i \gamma$………………………………………2

Where, $f_{1,} \ldots, f_p$ are nonlinear smooth effects of the metrical (continuous) covariates and f_{spat} is an additional spatially correlated effect of the location s_i an observation pertains to.

In a further step, we may split up the spatial effectf_spatinto a spatially correlated (structured) and an uncorrelated (unstructured) effect.

$f_{spat}(s_i)=f_{str}(s_i)+f_{unstr})(s_i)$……………………………………………….…………….3

Here, spatial variability is usually contained many unobserved influences exist only locally [1]. Therefore, equation (1) is extended as the following on equation 4 and gives the predictor of geo-additive regression model.

$\eta_i^{geo}=f_1(x_{i1})+\cdots+f_p(x_{ip})+f_{str}(s_i)+f_{unstr}(s_i) + w'_i \gamma$……………….…4

Where:

- η_i is a linear predictor of variable of interest(prevalence of diarrhea disease) on socio-demographic, environmental factor, behavioral risk factor and geographic variables in this study.
- γ is unknown parameters(fixed effect parameter) corresponding categorical predictor.
- f_{str}) (s_i)is spatially correlated (structured) effect, $f_{unstr}(s_i)$ spatially uncorrelated (unstructured) effect.

Method of Estimation

The type of inferential concept used for estimation of regression parameters in this study is full Bayesian inference via Markov chain Monte Carlo (MCMC).Bayesian inference is based on posterior distributions and is carried out using MCMC simulation techniques so that samples are drawn from full conditionals of single parameters or block parameters given the rest. Let αdenote the vector of all unknown parameters in the model (i.e. α=(fj ,f_{spa}),γ and τ represent the vector of all variance components. Then, under usual conditional independence assumptions, for the binomial logit model:

$$P(\alpha/y) \propto \prod_{i=1}^{n} L_i(y_i,\eta_i) \prod_{j}^{p} \{p(\beta_j/\tau_j^2)p(\tau_j^2)\}$$

$$p(f_{str}/\tau_j^2)p(f_{unstr}/\tau^2_{unstr}) \prod_{j=1}^{r} p(\gamma_j)\, p(\sigma^2)$$

Where,β_j,j=1……p,are the vectors of regression coefficients corresponding to the functions f_j.

For updating the parameters in an MCMC sampler, we used Metropolis–Hastings algorithm based on iteratively weighted least squares (IWLS) proposals introduced by [6].

Results

Moran's I and Geary's C Test Statistics for Global Spatial Autocorrelation

The test results of global Moran's I and Geary's C indicate the presence of significant global spatial autocorrelation of Under-five diarrhea disease in the Ilu Aba Bor zone (Table 1). The test results are also shown in Moran's I scatter plot (Figure 1).These global results in the distribution of under-five diarrhea disease need to be further explored using local spatial statistics.

Table 1: Results of Global Moran's I and Geary's C Statistics under randomization and Normality assumption

Assumption	Coefficient	Observed	Expected	Std Dev	Z	P
Normality	Moran's I	0.33	-0.08	0.17	2.47	0.00
Normality	Geary's C	0.60	1.00	0.11	-1.98	0.02
Randomization	Moran's I	0.33	-0.08	0.17	2.44	0.00
Randomization	Geary's C	0.60	1.00	0.19	-2.03	0.02
Source: Illubabor zone health office , Oromia regional state southwest Ethiopia.						

Significant at 0.05 levels

The hypothesis test under the global measure of spatial autocorrelation is: no spatial autocorrelation (:) versus under the alternative hypothesis: (There is spatial autocorrelation (spatial dependence). The variance of Moran's I and Geary's C varies under the assumptions of normality and randomization.

Interpretation: Based on the P-values of Moran's *I* and Geary's *C* coefficients, we reject the null hypothesis of no spatial autocorrelation. Furthermore, the computed Z-statistic for Moran's I is positive under both normality and randomization assumptions, and Geary's C is negative under both normality and randomization assumptions, indicating the existence of significant positive spatial autocorrelation (under-five diarrhea disease clustering of similar value).

In order to visualize global spatial autocorrelation, we use Moran's scatter plot under the assumptions of normality (Figure 1). It shows under-five diarrhea disease can be assumed to occur with unequal distribution in all clusters (woreda).

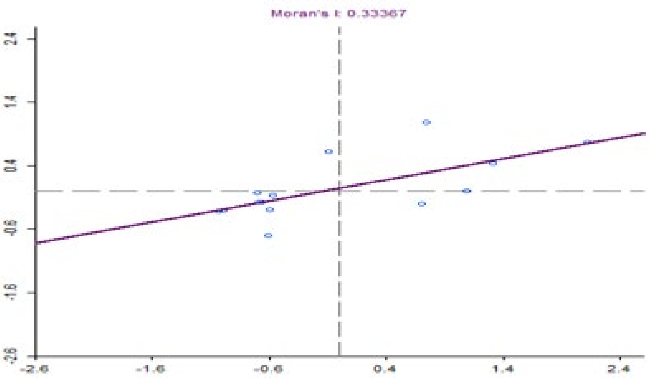

Figure 1: Moran Scatter Plot for Under-five diarrhea disease in Ilu Aba borazon

From above figure 4.1, we conclude that under-five diarrhea disease in the Ilu Aba borazon of each woreda is spatially correlated with neighboring values. From the first quadrant (upper right) of the Moran scatter plot, we understand that in three woredas the distribution of under-five diarrhea diseases was highly clustered. This result indicates that in these three woredas, there are high under-five diarrhea disease clusters of similar values (hot spots). From the 3rd quadrant (lower left), we see that the distribution of under-five diarrhea disease in eight woredas is less clustered. This indicates that the distribution of under-five diarrhea disease is cold spots (low low) in these eight woredas. On the other hand, as it is seen from the second and fourth quadrants (lower right and upper left) of the Moran scatter plot, there is under-five diarrhea disease clustering of dissimilar values in three woreda (either high low or low high value).

Bayesian Geo-additive Regression Model result

Table 2 below shows the result of the Bayesian geo-additive regression model, which represents the fixed effect of categorical covariate plus non-linear effect of metrical covariate plus spatial effect (both structured and un-structured spatial effects). The result showed that most of the covariates have a significant effect on the under-five child's diarrheal disease. The fixed effect results of this model indicate that a mother's educational level, source of drinking water, quality of toilet facility, DPT 3 vaccination, Polio 3 vaccination, and household wealth index significantly affect the occurrence of diarrhea disease in under-five children since their corresponding credible interval has not included zero. In contrast to this mother's occupation, residence location, and child age had no effect on the occurrence of diarrhea disease in children under the age of five because their corresponding credible interval included zero. For convenience and easy understanding of the interpretation, the researchers have interpreted the exponentiation value of the coefficients of the significant variables as follows:

The coefficient value of the source of drinkable water categories of protection was OR= exp (-0.19) = 0.82 with a 95% CI (0.51, 0.89). This is interpreted as children who use protected water had 82% lower odds of being caused by diarrhea than those who use water from an unprotected source. Concerning the quality of toilet category of not good, OR = exp (0.25) = 1.27 with 95% CI (1.12, 1.94), which means that children who use not good toilet facilities had 27% higher odds of being caused by diarrhea than those who use good toilet facilities.

Regarding DPT 3 vaccination, the coefficient value for received categories was OR= exp (-0.256) =0.77 with 95% CI (0.63, 0.85), which means that children who took DPT 3 vaccination had 77% lower odds of being caused by diarrhea than those who did not take it. Another finding of this study was that the mother's educational level has a significant impact on the occurrence of diarrheal diseases in children under the age of five. The odds of children who have diarrheal diseases whose mother's educational level was 0.55 times (OR = 0.55, 95%CI: 0.22, 0.78) less likely than the odds of children whose mother has no education. Concerning the coefficient value for the rich category of house hold wealth index (OR = 0.25, 95%CI: (0.11, 0.62)), which means that the odds of children who have diarrhea disease from a rich family were 0.25 times those from a poor family.

In the same way, the coefficient value for Polio3 vaccination for received categories was OR= exp (-0.41) =0.66 with a 95% CI (0.43, 0.97), which means that children who took Polio3 vaccination had 66% lower odds of being caused by diarrhea than those who did not take it. In this study, both metrical covariate (mother's age) and spatial effect (structural and un-structural) significantly affected the occurrence of under-five diarrhea disease, resulting in 95% credible intervals of [0.73, 6.59], [0.02, 3.74], [0.01, 1.50], which do not include zero. Furthermore, the spatial and metrical covariate effects on under-five diarrhea disease were briefly explained in the section below by its visualization using map effect and graph.

Table 2: Posterior mean estimate of Bayesian Geo-additive Regression model

Variable	Category	Mean	Std error	2.5% quantile	97.5% quantile
Intercept Mothers occupation	No work(ref)	-2.16	0.86	-4.00	-0.63
	Have work	-0.44	0.21	0.87	-0.05
Source of drinkable water	Not protected(ref)				
	Protected	-0.19	0.26	-0.67	-0.31
Quality of toilet	Good (ref)				
	Not good	0.25	0.21	0.18	0.66
DPT3 vaccination	not received (ref)				
	Received	-0.26	0.22	-0.47	-0.16
Educational level of mother	No education(ref)				
	Primary	0.02	0.24	-0.42	0.48
	Secondary	--0.32	0.47	-1.26	0.53
	Higher	-0.59	0.44	-1.41	-0.25
House hold wealth index	Poor(ref)				
	Medium	0.56	0.51	0.51	1.46
	Rich	-1.40	0.47	-2.28	-0.48
Polio3 vaccination					
	Not received (ref)				
	Received	- 0.41	0.22	-0.84	-0.03
Residence place	Urban(ref)				
	Rural	-0.27	0.28	-0.71	0.26
	Smooth terms variances				
Age of mother sx(woreda):mrf sx(woreda):re	Continuous	2.72	1.57	0.73	6.59
		0.92	1.07	0.02	3.74
		0.29	0.41	0.01	1.50
Source: Illubabor zone health office, Oromia regional state southwest Ethiopia.					

Visualization of the effect of Metrical Covariate and Spatial effect

Figure 2, below, displays the posterior mean of the nonlinear effect of the age of the mother on under-five diarrhea disease. From the pattern of this graph, we have seen that the effect of the mother's age is comparably higher in the age interval (20), then somewhat decreases at the age interval (20-29), and again increases at the age interval (30-39). In short, from this graph, we understand that children of young mothers (20) and children of mothers aged > 30 were at higher risk of diarrhea disease as compared to mothers with an age range of 20–29.

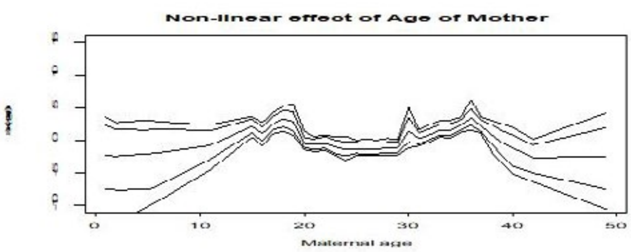

Figure 2: Non-linear effect of mother age on Under-five diarrhea disease in Ilu Aba Bor Zone

With regard to spatial effects, Figure 3 below depicts the estimated posterior mean of the spatial effect by using a map effect on the under-five diarrhea disease in the Ilubabor zone. Therefore, from the pattern of this map, it is clearly seen that there was spatial (geographical) variation between the woredas of the Ilubabor zone. The red color indicates the presence of hot spots (high-high under-five diarrhea case counts clustering) in three woredas, while the light blue color indicates the presence of cold spots (low-low under-five diarrhea case counts clustering) in the eight woredas. The pink and dark magenta colors indicate clustering of dissimilar values. The map shows that there is a high concentration of under-five diarrhea cases (hotspots) in Darimu, Metu town, and Alge sachi woredas. In Nono, Didu, Ale, Halu, Becho, Yayu, Doreni, and Hurumu, there are under-five diarrhea case counts. Clustering of low-low values (cold spots) is observed. In Bilonopha, however, under-five diarrhea case counts cluster in dissimilar values (low-high values), whereas in Bure and Mettu woredas, under-five diarrhea case counts cluster in high-low values. In general, a higher under-five diarrhea case count was observed in the northern and western parts of the Ilubabor zone, while the southern and eastern parts had low under-five diarrhea case counts.

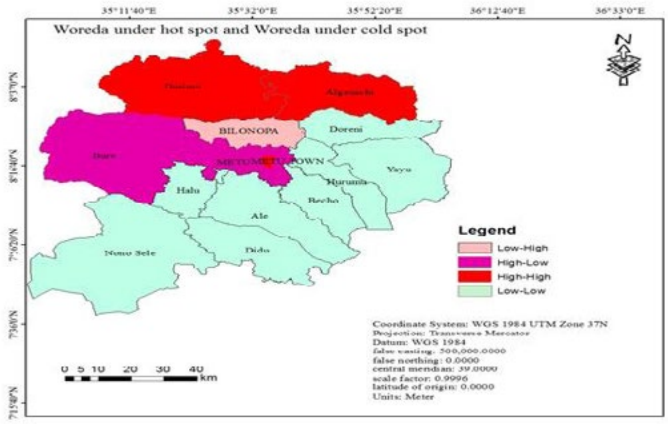

Figure 3: Spatial distribution of Under-five diarrhea disease in Ilu Aba Bor Zone

Discussions

From explanatory spatial data analysis, both global and local measures of spatial autocorrelation are used, and a spatial weight matrix is constructed depending on queen methods. The global tests are performed under the assumption of normality and randomization. The null hypothesis tested states spatial independence (uncorrelated of error terms) and the alternative hypothesis tested states spatial dependence (correlated of error terms) for the data under consideration. Based on the P-values of Moran's I and Geary's C coefficients, we reject the null hypothesis of no spatial autocorrelation and accept the alternative hypothesis that there is spatial autocorrelation. Furthermore, the computed Z-statistic for Moran's I is positive under both normality and randomization assumptions, and Geary's C is negative under both normality and randomization assumptions, indicating the existence of significant positive spatial autocorrelation (under-five diarrhea case counts clustering of similar values). The result of local measures of spatial autocorrelation showed that under-five diarrhea case counts in the Ilu Ababor zone of each woreda are spatially correlated with neighboring woreda (cluster). Generally, measures of spatial autocorrelation show that under-five diarrhea case counts in the Ilu Aba bor zone of each woreda (cluster) are spatially correlated with neighboring woreda (cluster) where high-high (hot spot) value groupings occurred and another one at the opposite extreme where low-low (cold spot) values occurred. Previous studies are also consistent with this result that under-five diarrhea disease is spatially correlated with neighboring regions (clusters), where high (hot spot) value grouping occurred and another one at the opposite extreme, where low (cold spot) value grouping occurred 2.

Regarding the model-based data analysis part, influential factors for the under-five diarrhea disease were identified by using a Bayesian Geo-additive regression model. From the fixed-effects of the model, the mother's educational level, source of drinking water, place of residence, quality of toilet facility, DPT 3 vaccination, Polio 3 vaccination, and household wealth index significantly affected the occurrence of diarrhea disease in under-five children. Concerning the source of drinkable water, children who used protected water had 82% (OR = 0.82) lower odds of being caused by diarrhea than those who used water from an unprotected source. This result was consistent with previous studies 12. Another important factor in under-five diarrhea disease was toilet quality [OR = = 1.27], which means that children who did not use a good toilet facility had a 27% higher risk of diarrhea disease than those who did, which is supported by previous research 7. Regarding DPT 3 vaccination, the coefficient value for received categories was (OR = 0.77), which means that children who took DPT 3 vaccination had about a 77% lower risk of diarrhea than those who did not take it. So this result was supported by a previous study 8.

We also found that the odds of children who have diarrheal diseases if their mother's educational level was higher was 0.55 times (OR = 0.55) less likely than the odds of children whose mother has no education, which has the same idea as the previous study 13. Concerning the coefficient value for the rich category of house hold wealth index (OR = 0.25), which means that the odds of children who have diarrhea disease from a rich family were 0.25 times those from a poor family. This result has the same idea as the previous study 15.

In the same way, the coefficient value for Polio3 vaccination for received categories was (OR =0.66), which means that children who received the vaccination had 66% lower odds of being caused by diarrhea than those who did not receive it. So this result was supported by the previous study 8.

Regarding both metrical covariates (mother's age), there was a continuous worsening of the risk of under-five diarrhea disease during the mother's age less than 20 years old and between the age intervals (30-39), indicating that children with a mother younger than 20 years old and between the age intervals (30-39) experienced a high risk of diarrhea in comparison to the mother's age interval (20-29). This result has almost the same idea as the previous study 10.

Limitations of the Study

This study is only limited to the zonal level of Ilu Aba Bor due to limited resources.

Conclusions

The results of this study showed that under-five diarrhea case counts in Ilu Aba Bor Zone exhibit a spatial pattern which is dependent on socioeconomic, environmental, and health factors. Under-five diarrhea case counts in the study area are significantly clustered, indicating high levels in the northern part of the zone and low levels in the southern and eastern parts of the zone, with clustering of dissimilar values in the western part of this zone.

Geographical clusters of under-five diarrhea case counts were identified through exploratory spatial data analysis, using Global Moran's I, Geary's C, and also local indicators. The results obtained reveal that the distribution of under-five diarrhea case counts in the Ilu Aba Bor Zone is clustered. Our findings support the notion that under-five diarrhea disease is a basic public health issue in the Ilubabor zone with spatial variation across different woredas. The spatial pattern of under-five diarrhea diseases in the Ilubabor zone was explored and the hot spot woredas were identified. This pattern suggests that the northern and western parts of the zone were highly experienced with the diarrhea disease.

According to the Bayesian Geo-additive regression model, mother's educational level, source of drinking water, quality of toilet facility, DPT 3 vaccination, Polio 3 vaccination, and household wealth index significantly affected the occurrence of diarrhea disease on under-five children, whereas mother's occupation, residence place, and child's age had insignificant effects.

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Conflict of interest

The authors declare that there was no conflict of interest in this study.

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