Spatial Distribution and Associated Factors of Neonatal Mortality in Ethiopia: using Ethiopian Demographic and Health Survey 2016

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Abstract

Background: Neonatal mortality is continuing on top of the agenda of public health and international development agencies. In Ethiopia, it is still high accounts 60% infant mortality and 43% of under-five mortality. However, the distribution of the problem across the regions of Ethiopia is not well addressed. Therefore, this analysis aimed to assess spatial distribution of neonatal mortality and identify associated factors in Ethiopia using the 2016 Ethiopian Demographic Health Survey (EDHS). Exploring spatial distribution and identifying associated factors is important to select priority areas and design effective intervention program to reduce neonatal mortality.

Methods: The analysis included 7,193 live births, selected by stratified two-stage cluster sampling techniques. Spatial analysis was done to explore spatial distribution of neonatal death using Geographic information system and Sat scan. Multilevel logistic regression was fitted to identify individual and community level factors associate with neonatal mortality.

Results: The hot-spot areas for neonatal mortality were Amhara, West Tigray, northeast, southwest and central part of Oromia. Mother's with age >35 years (AOR=2.25, 95CI%: 1.47, 3.45), family size of 3-5 (AOR=0.14, 95CI%: 0.06, 0.36) and 6 and above (AOR=0.08, 95%CI: 0.02, 0.20), male neonates (AOR=3.45, 95%CI: 2.27, 5.22), smaller birth size (AOR=1.61, 95%CI: 1.02, 2.54), birth interval less than 2 years (AOR=3.58, 95%CI: 1.66, 7.70) and 2 years and more (AOR=2.54, 95%CI: 1.26-5.11), early initiation of breast feeding (AOR=0.20, 95%CI: 0.09-0.42), had no ANC visit (AOR=1.68, 95%CI: 1.08, 2.60), did not receive PNC services (AOR=3.58, 95%CI: 1.13 -11.33) and C/S delivery (AOR=19.55, 95%CI: 8.07, 47.34) were statistically significant variables for neonatal mortality.

Conclusions: High risk areas for neonatal mortality were identified in northern, central and southwest part of the Ethiopia. Individual level variables were important factors associated with neonatal mortality. Focusing on maternal health care services, increase birth interval and initiation of breast feeding early will be needed to reduce neonatal mortality.

Background

Neonatal mortality is the death of new born up to first 28 days after birth (1). Globally, 2.5 million deaths occurred in the first month of life at rate of 18 deaths per 1,000 live births which accounts 47% of under-five mortality in 2017. The majority, 80% of neonatal deaths, occurred in Sub-Saharan Africa (27 per 1000 live births) and South Asia countries (2). In spite of many efforts taken by Ethiopian government and other stakeholders, neonatal death is still high, 29 per 1000 live births, which accounts 60% of infant mortality and 43% of under-five mortality. The reduction progress was by 41% from 49 to 29 per 1000 live births for the last 16 years from 2000 to 2016 (3).

Neonatal mortality is continuing on top of the agenda of public health and international development agencies because sustainable development goals (SDGs) for child survival cannot be met without substantial reductions in neonatal mortality. Reduction of neonatal death would be important to achieve both the neonatal and under-five mortality targets of the sustainable development goals. The SDGs have two specific targets to reduce the neonatal mortality rate and under-five mortality rate to 12 and 25 per 1000 live-births within 2030 (4).

The majority of neonatal deaths are caused by preventable or treatable diseases worldwide like neonatal sepsis or pneumonia, tetanus, birth asphyxia, low birth weight, preterm birth complications, congenital abnormalities and other causes (2, 5). Previous studies showed that leading causes of new born death are prematurity, low birth weight, asphyxia, infections, congenital abnormalities and other causes (6, 7). Many literatures also indicated that neonatal mortality was influenced by mother's age, educational status of mother and father, income condition, residence, regional differences, neonatal related factors, maternal health care services and obstetric related factors (8-10).

Although there are studies conducted on neonatal mortality and associated factors in Ethiopia, they did not show the spatial distribution of the problem in the country. Neonatal mortality varies in the country in space and time by changing its magnitude. The individual and community level factors were also not addressed previously.

The present study therefore, aimed to examine the spatial patterns and identify determinants of neonatal mortality in Ethiopia using the 2016 EDHS data. First, the study examined whether there was a significant global spatial autocorrelation for the neonatal mortality. If the presence of global spatial dependency was confirmed, local spatial autocorrelation was explored, and map the spatial distribution of neonatal mortality by region.

The spatial exploration of neonatal mortality would have an important implications to select priority areas design targeting policy for effective intervention program to reduce neonatal mortality

Methods

Study setting and period

The data for this study were collected in all nine regions and two city administrations of Ethiopia from January 18 to June 27, 2016. Each region is subdivided into zones, and zones into administrative units called district. Each district is further subdivided into the lowest administrative unit, called kebeles. There are a total of 68 zones, 817 districts and 16,253 kebeles in the country (3).

Population and Sample

All neonates in Ethiopia born within the five years preceding the survey were the source population, whereas all neonates in Ethiopia who were in the selected clusters were considered as the study population. Neonates with incomplete data, and longitude and latitude zero degree for spatial data exploration were excluded from the analysis.

A total of 7,193 live births taken from 645 (202 in urban and 443 in rural areas) Enumeration Areas (EA) were included in the analysis. Stratified two-stage cluster sampling was used to select the estimated sample. Each region was stratified into urban and rural areas, yielding 21 sampling strata. Samples of EAs were selected independently in each stratum in two stages. In the first stage 645 clusters of EAs were selected, 18,008 households were enumerated in the second stage (3). The 7,193 household had neonates during the data collection and all neonates were included in the analysis.

Data collection Procedures

The source of this study was the 2016 EDHS. Permission letter for the use of this data were obtained, and data sets were downloaded from the Measure Demographic web site: www.measuredhs.com.

Data for the original work were collected by using compressive standard questionnaires.The household Questionnaire, the woman's questionnaire and the man's questionnaire were used to collect socio-economic and demographic information, women's birth history and other important information. After all questionnaires were finalized in English, they were translated into Amharic, Tigrigna, and Oromiffa. The collected data was back translated into English to keep consistence.

Study variables

Neonatal mortality was the dependent variable of the study. The independent variables were community level variables (region and residence) and Individual level variables. Individual level variables: demographic and socio-economic variable (mother's age, mother's education level, father's education level, wealth index, father's employment status, mother's employment status, marital status, family size, improved water source, improved toilets), Neonatal related variables(sex, birth interval, birth size and initiation of breast feeding) and maternal health service (ANC visit, PNC visit, Place of delivery, mode of delivery, multiple births, number of tetanus toxoid vaccine).

Data quality control

The quality of this data was maintained by checking its completeness, cleaning the missing values by running frequency tables. In addition to this, the quality of original data were maintained by pretest the questionnaires in all three local languages (Amarigna, Oromiffa and Tigrigna), giving training for interviewers and interviewers used tablet computers to record response.

Statistical Analysis

Data were weighted to account different sampling probabilities and response rates. Descriptive measures were used to summarize the characteristics of the study participants using weighted frequencies and percentages for community level and individual level variables. Neonatal mortality rate across the regions was also estimated and displayed with the graph.

Spatial autocorrelation was examined through global Moran's which is an indicator for spatial autocorrelation and measures whether spatial pattern of neonatal mortality was clustered, dispersed or random. The Moran's I value ranges from −1 to +1. If the test statistics is significance ($P < 0.05$) and Moran's I value approaches -1 indicates dispersion and +1 indicates clustered, while if the test statistics is not significance, the observed pattern of neonatal mortality displays is random.

A Local Moran's I cluster map was used to determine local clustering of the neonatal mortality. It also measures whether there were positively correlated (high-high and low-low) clusters or negatively correlated clusters (high-low and low-high). Moreover, clusters high values (High-High) and clusters of low values (low -low) were identified. The level of clustering of the neonatal mortality within the area were identified using Z-score. High and low level of clustering of neonatal mortality was indicated a positive and negative Z-scores respectively.

High prevalence/low prevalence areas of neonatal mortality were determined using the Getis-Ord Gi. Hot-spot and cold-spot areas identified and indicated by Gi*. The high-risk and low-risk regions for neonatal mortality was predicted by using Spatial kriging interpolation analysis.

Spatial sat scan analysis was conducted using SatScan software version 9.6 to investigate significant primary and secondary clusters of high neonatal mortality. The numbers of cases in each location have Bernoulli distribution and the model requires data cases and control. The default maximum spatial cluster size of <50% of the population was used, as an upper limit, which allowed both small and large clusters to be detected and ignored clusters that contained more than the maximum limit. For each potential cluster, a likelihood ratio test statistic was used to determine if the number of observed mortality within the potential cluster is significantly higher than expected or not. The primary and secondary clusters are identified and reported with log likelihood ratio, relative risk and P-value.

Model Building

Multilevel logistic regression model was fitted to account for the clustering structure of the EDHS data. It was fitted to examine both individual and community level factors that associate with neonatal mortality. Variables having P-value up to 0.2 in the bi-variable analysis were selected to fit the multi-variable multilevel model. Finally, multilevel logistic regression analysis was performed to estimate the adjusted odds ratios and those variables with P-value of <=0.05 was considered as statistically significant.

Four multilevel analysis models were fitted using STATA 14. Model I (null model) was fitted without explanatory variables to test random variability in the intercept and intra-class correlation coefficient (ICC) was determined. Model II was fitted to explore the effect of community level variables, Model III was fitted to examine the effect of individual level variables and Model IV was fitted to indicate the effects of both individual and community level characteristics simultaneously.

The effects of individual-level and community-level factors on neonatal mortality were reported in term of odds ratios with 95% confidence interval. Random effects were expressed in terms of Intra-Cluster

Correlation (ICC) and proportional change Variance (PCV).

The log likelihood and Akaikie Information Criterion (AIC) of the models were estimated to assess the fitness of the model relative to the other models. Variance Inflation Factor were used to identify the presence of multi-collinearity in the model.

Results

Community level characteristics

A total weighted 7,590 live births within five years preceding the EDHS 2016 were included in the analysis. About 6,621 (87.23%) of the study participants were from rural and 3,130 (41.23%) of the neonates were from Oromia (Table 1).

Individual level characteristics

Socioeconomic and Demographic characteristics

About 2,165 (28.53%) neonates were born from mothers aged 25-29 years. The mean age of the mothers was 29.25 (±6.8 SD) years. Of the mothers, 4,791(63.12%) of them have no formal education and 7,165 (94.4%) were married (Table 2).

Neonatal related characteristics

Of the neonates, 3,941(51.92%) were males and 3,081(40.59%) had average birth size according to their mother's perception. About 6,378(84.09) neonates were initiated breast milk within one hour of birth.

Maternal health care services and obstetric characteristics

Among mothers 4,757(62.67%) had antenatal care visits during their last pregnancy, and 2,524 (33.25%) of the mothers were delivered at health facilities. Only 636 (8.36%) of the neonates had postnatal care checkup (Table 3).

Regional neonatal mortality rate

The NMR varies across the regions of the country. The highest and the lowest NMR were observed in Oromia (25 per 1000 life birth) and Adis Abeba (7.5 per 1000 life birth) respectively (Figure 1).

Spatial Analysis of Geographic Information System

The spatial autocorrelation analysis indicated that the spatial distribution of neonatal mortality was non-random. The Global Moran's Index was 0.19 (P-value <0.001) indicates that there was significant clustering of neonatal mortality (Figure 2).

Hot spot (high risk) regions for neonatal mortality were observed in Amhara, west Tigray, northeast, southwest and central part of Oromia. However, Afar, Benshangul-Gumz, Gambela, DireDawa, Harari and, northeast part of Southern Nations, Nationalities and Peoples (SNNP) were identified as cold spot (low risk) regions for neonatal mortality in Ethiopia (Figure 3).

The analysis of cluster and outliers indicated that high outlier clusters and low outlier clusters had nearly equal occurrence. These high outliers were observed on Oromia, border of SNNP and Oromia, border of Benshagul-Gumiz and Oromia, border of Benshagul-Gumiz and Amhara regions. However, low outliers were found in Tigray, Amhara, Oromia, South Afar and SNNP (Figure 4).

The spatial kriging interpolation analysis was used to predicted high risk regions for neonatal mortality. Predication of high risk areas were indicated by red predictions. Southeast and northwest part of Amhara, central and northeast Oromia, Adis Abeba, Tigray and north SNNP were predicted as more risky areas compared to other regions. Whereas, Afar, Benshagul-Gumiz, west Oromia, Somali, SNNP and Gambela were predicated as having less risk for neonatal mortality (Figure 5).

Spatial sat scan analysis

Nine most likely (primary) clusters were identified and all of them were significant. The primary clusters spatial window was located in central Oromia. It was centered at 7.634301 N, 39.484474 E with 80.38 km radius, with RR of 4.61 and LLR of 21.05, at P-value < 0.001. The RR of 4.61 for clusters of spatial window means neonates within the spatial window had 4.61 times higher risk for death than neonates outside the window. In addition to this, 52 significant secondary clusters were located in Benshagul-Gumiz, west Amhara and western Oromia. It was centered at 11.340042 N, 35.12673 E with 212.45 km radius, with RR of 3.69 and LLR of 11.65, at P-value = 0.003. The RR of 3.69 for clusters spatial window means neonates within the spatial window had 3.69 times higher risk for death than neonates outside the window (Figure 6).

Multilevel logistic regression analysis

The value ICC for Null model was 0.38 which indicates 38% of the total variance in neonatal mortality in Ethiopia can be attributed to the communities in which the mothers were residing Four multi-level models (null model, model fitted with community level variables, model fitted with individual level variables and model fitted with community and individual level variables) were fitted in this study. Then, models were compared by their log likelihood and AIC. Model fitted with community and individual level variables had highest log likeli hood and lowest AIC. This model was selected for analysis.

The fixed effects (measure of association) and the random intercepts for the use of neonatal mortality are presented in Table 4. In the multi-variable multilevel logistic regression mother's age, family size, smaller than average birth size, birth interval, sex of the neonate, breastfeeding initiation time, ANC visit, PNC visit and mode of delivery were statically significant variables for neonatal mortality.

Discussion

The aim of this study was to assess spatial distribution and associated factors of neonatal mortality in Ethiopia using 2016 EDHS data. The spatial analysis indicated that high risk regions for neonatal mortality were observed in northern (Amhara, west Tigray), southwest and central (northeast, southwest and central part of Oromia). In contrast, Afar, Benshangul-Gumz, Gambela, Dire Dawa, Harari and northeast part of SNNP were identified as low risk regions for neonatal mortality. The Sat scan statistical analysis showed that primary clusters were located in central Oromia and secondary clusters were existed in Benshagul-Gumiz, west Amhara and western Oromia. The probable explanation for geographic variation in the risk of neonatal mortality is the distribution of causes of neonatal mortality in the country. A common cause of neonatal mortality in Ethiopia is low birth weight, preterm birth, neonatal sepsis, congenital and other causes. A systematic review and meta-analysis done in Ethiopia on prevalence of low birth weight and associated factor indicated that high prevalence of low birth weight existed in the Tigray, Amhara and Oromia region(11). In addition to this, these regions had high prevalence of preterm birth (12, 13) and neonatal sepsis (14).

The odds of neonatal death among neonates born from mothers' age 35–49 was 2.25 times more than that of neonates born from mothers' age 20–34 years. This finding is consistent with studies done in Ethiopia (15, 16) and Sudan (17). The possible explanation could be due to older mothers have increased risk of over birth weight, gestational diabetes mellitus, gestational hypertension, postpartum hemorrhage which are risk factors for bad birth outcome (18–20).

This study revealed that neonates born from mothers with 3–5, and 6 and above family members were 86% and 92% less likely to have neonatal mortality as compared with neonates born from mothers with 1–2 family size respectively. The result supported by the study done in West Gojam (10). The possible reasons might be due most mothers having large family members assumed to be multi-parity. These multi-parity mothers had low risk of low birth weight, pregnancy and delivery complications that decreases neonatal death (21).

The sex of the new born significantly influenced the occurrence of neonatal mortality.

This study indicated that male neonates were 3.45 times more likely to die within neonatal period than female neonates. This finding is similar studies done in Butajira (22), Zambia (23), Pakistan (24) and India (25). The possible justification might be due to male neonates have increased risk for congenital malformation (26, 27) and more susceptible to infections disease due to immune deficiencies (28).

Neonates born with preceding birth interval of less than 2 years and 2 years and more were 3.58 times and 2.33 times more likely to die within neonatal period as compared with neonates born in first order respectively. This finding is in line with previous studies done in West Gojam (10), Ethiopia (29),Nigeria (30) and Bangladesh (31). The possible reason might be due to mother who have short birth interval increased the risk of maternal nutritional depletion, folic acid depletion, transmission of infection and sibling competition for breastfeeding and parental resources leads to adverse neonatal outcome (32).

The birth size of the neonates had associations with neonatal mortality. This study showed that the odds of neonatal death among neonates with birth size perceived by their mothers as smaller than average was 1.61 times more than neonates with birth size perceived by their mother as average. This finding is similar with studies done Ethiopia (33) and Afghanistan (34). The possible justification might be due to smaller than average birth size neonates indicate low birth weight babies and may result from premature births that increased the risk immune immaturity that predispose for infections, mental retardation, hypothermia and other complication (35).

Neonates initiated breast feeding early were lower the odds of neonatal death by 80% as compared to neonates initiated breast feeding lately. This finding is consistent with studies done in Felege Hiwot hospital (36) and India (37). The possible justification might be due to the first liquid come out from the breast that is called Colostrum is very important for the new-born babies to protect them from infections as it is rich in antibodies that leads to decrease neonatal mortality (38).

The odds of neonatal death among neonates born from mothers had no antenatal care visit was increased by 68% as compared to neonates born from mothers had antenatal care visit. The result is in line with studies conducted in Jimma (7), Gazi- strep (39) and India (37). This is because of attending ANC provide opportunity for screening danger signs of pregnancy complication and health workers give good information about safe delivery, delivery complication, breast feeding and neonatal care (21, 40).

Utilization of postnatal services was related with neonatal mortality. This study revealed neonates who did not received postnatal care were 3.58 times more likely to die within neonatal period than neonates who received postnatal care. This finding is supported by previous studies done in Ghana (9) and India (37). The possible justification might be due to receiving postnatal care services used to identify early danger signs, treat neonatal disease and prevent complication that improves neonatal health (41, 42).

The odds of neonatal death among neonates born by cesarean section were 19.55 times more than neonates born by normal. The result is consistent with studies conducted in Sudan (17) and Pakistan (43). This might be due most C/S deliveries done by emergency after labor complication and fetal distress that increased the risk of neonatal morbidity and mortality (44).

Conclusions

High risk areas for neonatal mortality were found in northern, central and southwest part of the country. In contrast, low risk areas were identified in western, northwest, eastern and northeast part of the country.

Community level variables were found to be less important factors to design strategies for reducing neonatal mortality. Individual level variables like being male, having smaller than average birth size, born from mothers did not attend ANC visit, had no postnatal care check-up, delivered by caesarean section and born from mothers age 35–49 years were factors that increase the risk of death in neonatal period. Whereas, having large birth interval, born from mothers with large family size and initiating breast feeding early were factors that decrease the risk of neonatal death.

Federal ministry of health needs give priority for northern, central and southwest part of the country that has high risk for neonatal mortality and Improve maternal health care services coverage. Health professionals give emphasis to increase ANC for pregnant mothers and giving PNC for new born, advice mothers to increase birth interval and advice mothers to initiate breasts feeding within early. Researchers can use study as baseline to conduct a study for the reasons why northern, central and southwest part of the country have high neonatal mortality

List Of Abbreviations

AIC: Akaikie Information Criteria, ANC: Antenatal Care, C/S: Cesarean Section, DHS: Demographic Health Surveys, EA: Enumeration Area, EDHS: Ethiopian Demographic and Health Survey, GIS: Geographic Information System, ICC: Intra Class Correlation, LLR: Loglikelihood Ratio, NMR: Neonatal Mortality Rate, PNC: Postnatal Care, proportional change Variance (PCV), RR: Relative Risk, SDG: Sustainable Development Goals, SNNP: Southern Nations, Nationalities and Peoples, TT: Tetanus Toxoid.

Declaration

Ethics approval

Ethical clearance was obtained from the Ethical Review Board of Institute of Public Health, College of Medicine and Health Sciences, University of Gondar. Permission letter was gotten from Measure DHS International Program which authorized the data-sets. All the data used in this study are publicly available, aggregated secondary data with not having any personal identifying information that can be linked to particular individuals, communities, or study participants. Confidentiality of data was maintained anonymously in this study.

Consent to publish

Not applicable

Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

All relevant information is within the manuscript. The data upon which the results based could be accessed on a reasonable request.

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Authors’ contributions

GBD conceived the study, performed data extraction and management carried out the statistical analysis and interpretation and wrote the draft manuscript. DFT and AML participated in the design of the study, revising design and analysis of the research, performed statistical analysis. All authors approved the final version of the manuscript.t

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Tables

Table 1: Community level characteristics of study participants in Ethiopia, 2016

Variables	Categories	Weighted frequency(n)	Weighed percent (%)
Residence	Urban	969	12.77
	Rural	6,621	87.23
Region	Tigray	537	8.01
	Afar	71	0.94
	Amhara	1,632	21.50
	Oromia	3,130	41.23
	Somali	269	3.57
	Benshangul-Gumz	81	1.06
	SNNP	1,601	21.09
	Gambela	21	0.27
	Harari	17	0.23
	Addis Ababa	198	2.61
	Dire Dawa	33	0.44

Table 2: Socio-economic and demographic characteristics of the study participants in Ethiopia, 2016.

Variables	Categories	Weighted frequency(n)	Weighted percent (%)
Mothers age	15-19	339	4.47
	20-24	1,465	19.30
	25-29	2,165	28.53
	30-34	1,661	21.89
	35-39	1,206	15.89
	40-44	547	7.20
	45-49	207	2.73
Mothers employment	Employed	3,512	46.27
	Not employed	4,078	53.73
Maternal educational level	No education	4,791	63.12
	Primary	2,150	28.32
	Secondary& above	649	8.55
Wealth index	Poorest	1,269	16.72
	Poorer	1,427	18.80
	Middle	1,588	20.93
	Richer	1,654	21.79
	Richest	1,652	21.76
Marital Status	Currently married	7,165	94.40
	Not currently married	425	5.60
Father's education level	No education	3,870	50.99
	Primary	2,731	35.99
	Secondary &above	989	13.03
Father's employment	Employed	6,581	86.71
	Not employed	1,009	13.29
Family size	1-3	133	1.75
	3-5	3,503	46.16
	6 and above	3,594	52.09

Table 3: Obstetric and maternal health characteristics of the study participants in Ethiopia, 2016

Variables	Categories	Weighted frequency(n)	Weighted percent (%)
ANC visit	No	2,833	37.33
	Yes	4,757	62.67
Place of delivery	Health facility	2,524	33.25
	Home	5,066	66.75
Number of Tetanus Toxoid vaccine	None or one	3,310	43.6
	Two or more	4,280	56.4
Postnatal care visit	Yes	636	8.38
	No	6,954	91.62
Mode of delivery	Non C/S	7,407	97.59
	C/S	183	2.41
Multiple births	No	7,470	98.42
	Yes	120	1.58

Table 4: Multi-variable multilevel logistic regression analysis of individual and community level factors associated with neonatal mortality in Ethiopia, 2016

Characteristics	Model I	Model II	Model III	Model IV
Fixed effects		**AOR (95% CI)**	**AOR (95%)**	**AOR (95% CI)**
Residence				
Urban			1.00	1.00
Rural			1.78 (0.67-3.48)	2.12 (0.73-6.17)
Region				
Afar			1.00	1.00
Tigray			1.40 (0.57-3.48)	1.68 (0.16-17.29)
Amhara			1.28 (0.52-3.14)	1.23 (0.13-11.74)
Oromia			1.30 (0.55-3.04)	1.16 (0.12-10.87)
Somali			3.06 (1.40-6.69)	2.64 (0.28-27.05)
Benshagul-Gumiz			0.84 (0.32-2.25)	0.94 (0.05-19.53)
SNNP			0.61 (0.24-1.58)	0.56 (0.06-5.61)
Gambela			1.21 (0.44-3.36)	1.52 (0.02-109.26)
Harari			1.78 (0.69-4.59)	1.25 (0.22-72.71)
Adis Abeba			0.77 (0.15-3.80)	0.77 (0.39-15.24)
Dire Dewa			1.40 (0.43-4.60)	1.62 (0.04-60.61)
Mothers age				
20-34		1.00		1.00
15-20		1.69 (0.63-4.51)		1.59 (0.60-4.27)
35-49		2.20 (1.44-3.35)		**2.25 (1.47-3.45)****
Family size				
1-2		1.00		1.00
3-5		0.14 (0.06-0.36)		**0.14 (0.06-0.36)****
6 &above		0.08 (0.03-0.20)		**0.08 (0.02-0.20)****
Father's educational level				
No education		1.00		1.00
Primary		1.20 (0.78-1.84)		1.34 (0.86-2.09)
Secondary &above		0.30 (0.11-0.82)		0.40 (0.14-1.11)
Marital status				
Currently married		1.00		1.00
Not currently married		1.53 (0.78-3.02)		1.61 (0.81-3.20)
Sex				
Female		1.00		1.00
Male		3.44 (2.27-5.20)		**3.45 (2.27-5.22)****
Size of child at birth				
Average		1.00		1.00

Below average		1.61 (1.02-2.53)		**1.61 (1.02-2.54)***
Above average		1.45 (0.94-2.25)		1.50 (0.97-2.34)
Birth interval				
Frist birth		1.00		1.00
Less than 2 years		3.75 (1.74-8.05)		**3.58 (1.66-7.70)***
Greater than 2years		2.55 (1.27-5.12)		**2.54 (1.26-5.11)***
Ante natal care				
Yes		1.00		1.00
No		1.73(1.13-2.65)		**1.68 (1.08-2.60)***
Postnatal care				
Yes		1.00		1.00
No		3.90 (1.22-12.45)		**3.58 (1.13-11.33)***
Number of Tetanus toxoid vaccine				
Two or more TT		1.00		1.00
None or one		1.23 (0.80-1.88)		1.18 (0.77-1.80)
Delivery mode				
Non cesarean		1.00		1.00
Cesarean		16.09(6.91-37.45)		**19.55(8.07-47.34)****
Breast feeding initiation time				
Late		1.00		1.00
Early		0.20(0.10-0.44)		**0.20 (0.09-0.42)****
Random effects				
ICC (%)	38%			
PCV (%)	reference	4%	5%	25%
Model fitness	**Model I**	**Model II**	**Model III**	**Model IV**
Log likelihood	-712.00	-706.10	-624.67	-619.35
AIC	1428.016	1438.214	1301.332	1298.720

CI: Confidence interval, AOR: adjusted odds ratio, 1: Reference category,

*: 0.001<p< 0.05, **: p0.001

Figures

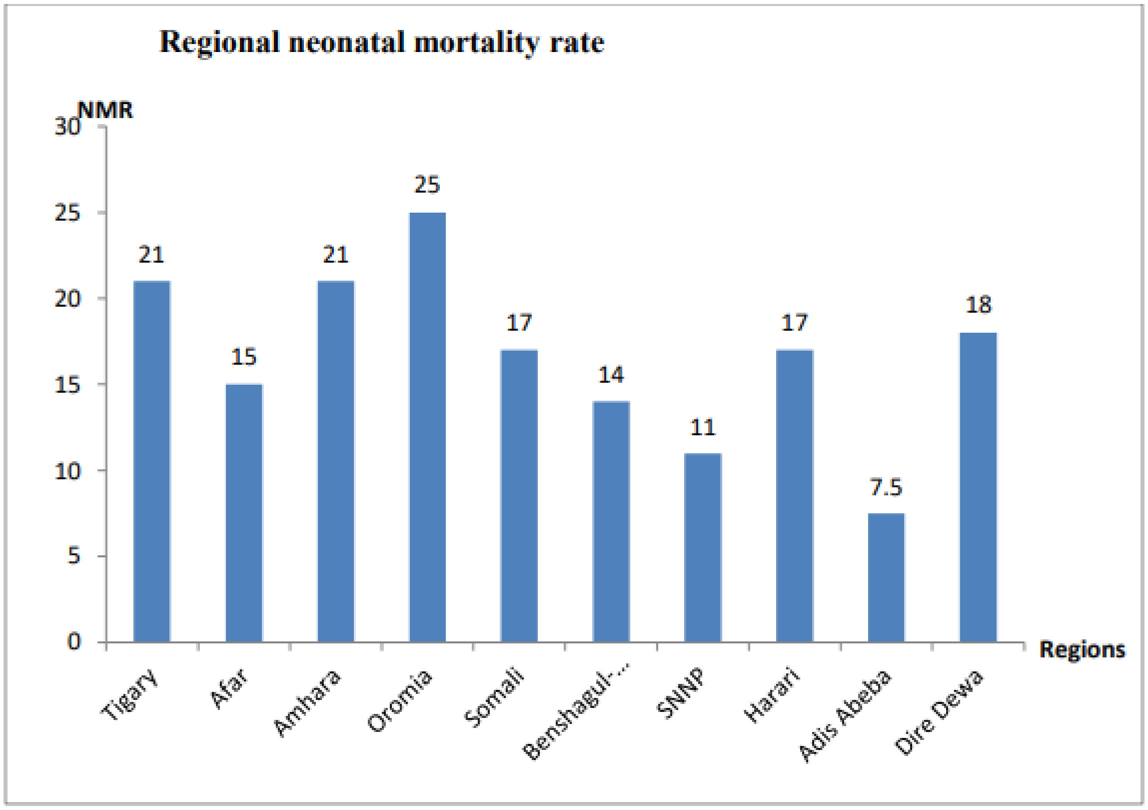

Figure 1

Regional neonatal mortality rate in Ethiopia, 2016

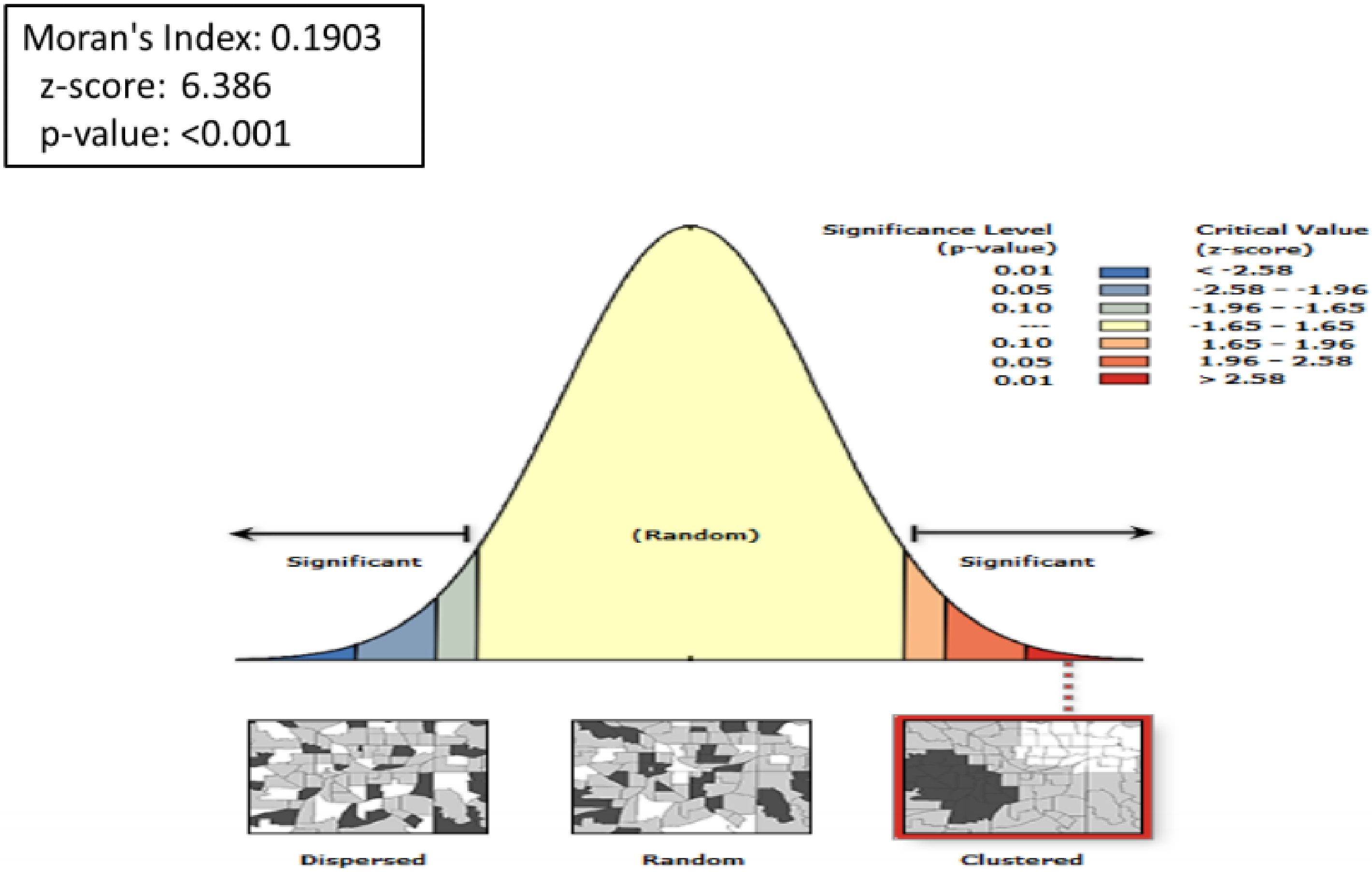

Figure 2

Spatial autocorrelation for distribution of neonatal mortality in Ethiopia, 2016

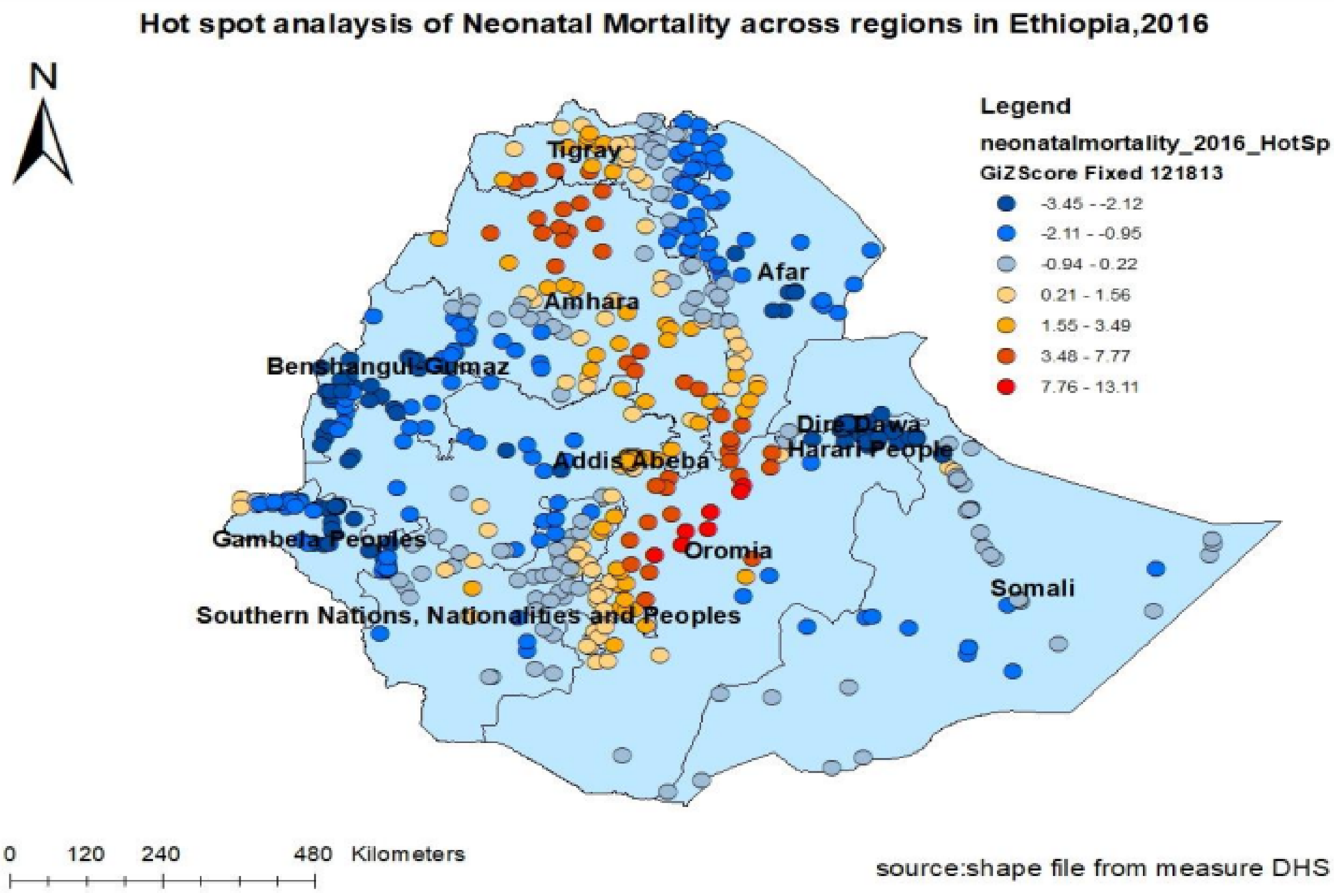

Figure 3

Hot spot and cold spot areas of neonatal mortality in Ethiopia, 2016

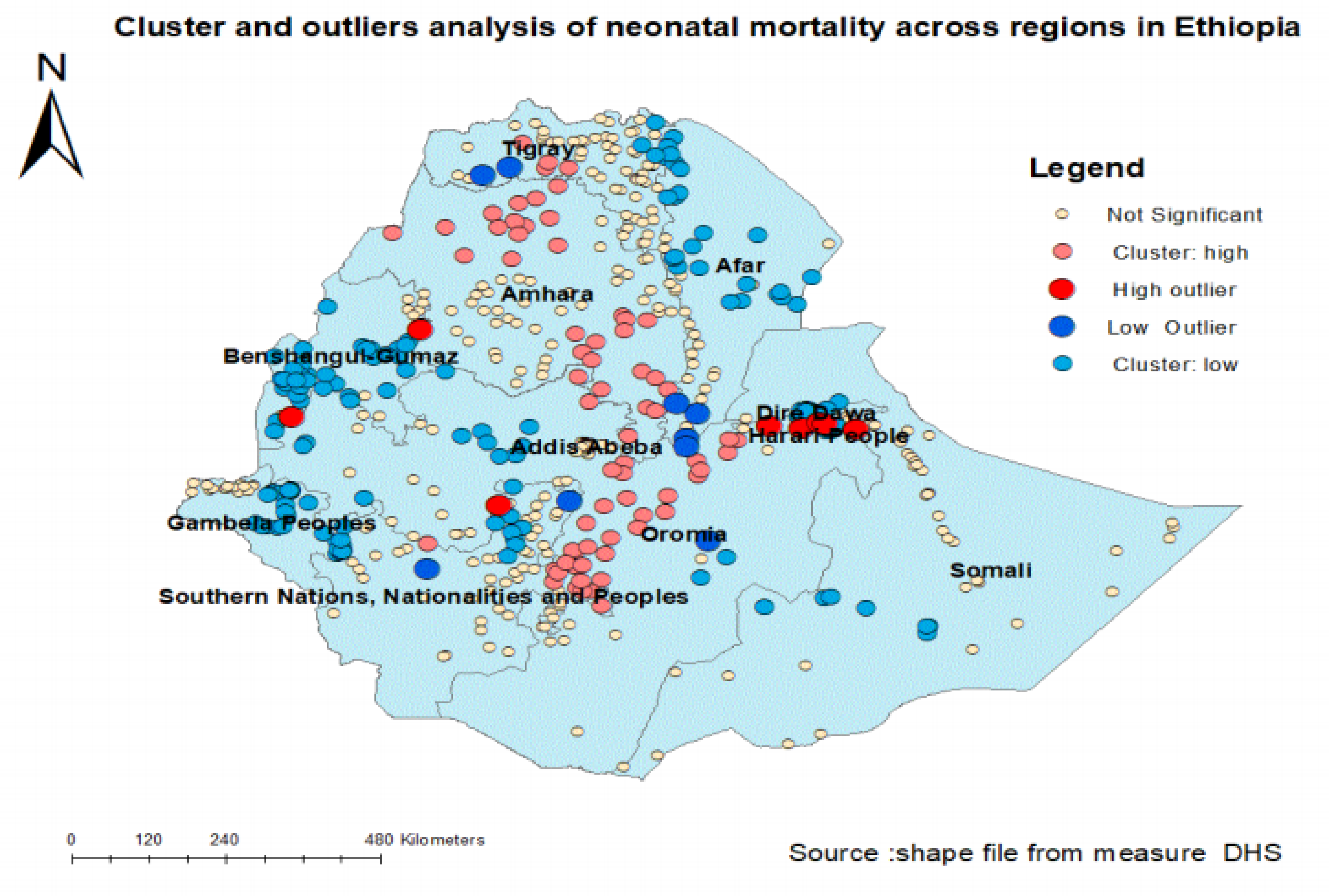

Figure 4

clusters and outlier identification of neonatal mortality in Ethiopia, 2016

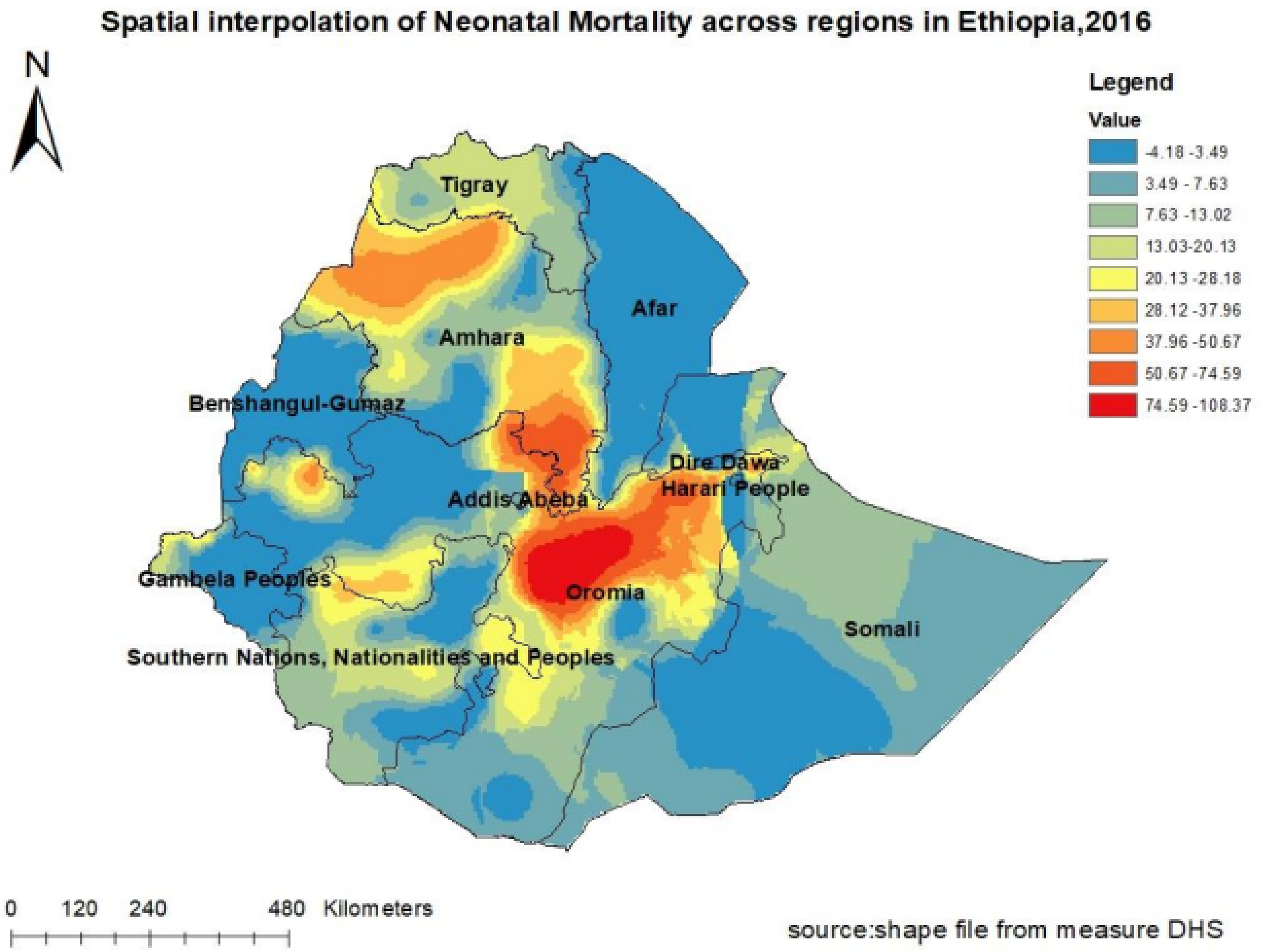

Figure 5

Spatial interpolation of neonatal mortality across regions in Ethiopia, 2016

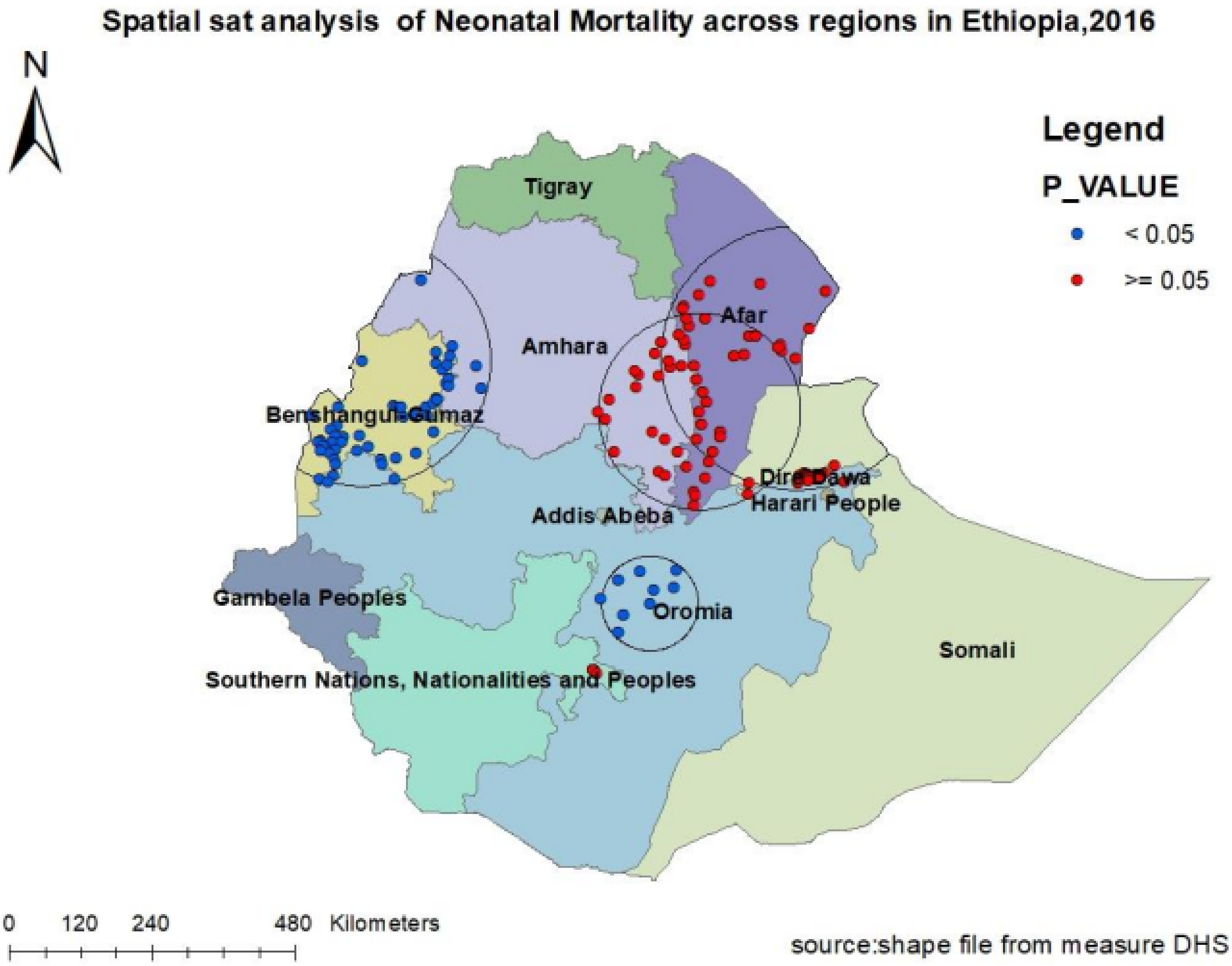

Figure 6

The primary and secondary clusters of neonatal mortality in Ethiopia, 2016