# Spatial Distribution and factors associated with childhood anemia in Ethiopia

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# Abstract

Introduction

The magnitude of childhood anemia has increased from 44% in 2011 to 56% in 2016. Thus, even if the Ethiopian government tried remarkable solutions, anemia among under-five children still continues as a serious health issue. So, exploring spatial distribution and identifying factors associated with childhood anemia helps to design appropriate strategies for control and prevention.

Methods

For this study data from the recent 2016 Ethiopian Demographic Health Survey were employed. The sample size was 8602 children aged 6–59 months. They were selected by stratified two-stage cluster sampling techniques. Sat Scan version 9.4 was also used to identify childhood anemia by geographic clusters and ArcGIS version10.1 was used to show anemia cases through Regions of Ethiopia. Thus to declare factors that are statistically related with anemia among under-five children a Mixed effect logistic regression model was utilized.

Result

This study showed there is spatial clustering of childhood anemia throughout Ethiopia (Moran's I: 0.65, $p<0.001$). Statistically significant clusters were detected in Somali, Afar, Harari and southern part of Oromia regions ($P<0.001$). Age of child, wealth index, mother's current working status, maternal anemic status, number of living children in the family, history of fever, and stunting were significant factors associated with anemia among under-five children.

Conclusion

In the country childhood anemia showed spatial clustering. Regions high risk of childhood anemia should be emphasized by allocating additional resources and providing appropriate interventions which have public health implications.


# Introduction

Anemia is a disease which is characterized by decreased quantity of red blood cells or hemoglobin level that results in insufficient oxygen-carrying capacity of blood to meet cellular metabolic demand of the body (1). Nutritional deficiencies were the utmost cause of anemia. Among nutritional deficiencies, Iron deficiency was the major contributor of anemia globally. However, folic acid, vitamin B12 and vitamin A were also cause nutritional deficiency anemia. Other causes of anemia can be inflammations, infections due to parasites, and disorders which distress survival or production of red blood cells and hemoglobin synthesis (1, 2).

Anemia is a global community health threat upsetting both high and low income nations (3). The most important effects of anemia were poor socio-economic development and increased mortality and morbidity (3). It occurs in all population groups of human being. But young children and pregnant women had higher risk of developing anemia. In children, besides increasing child mortality, severe anemia resulted in impaired cognitive and physical development (2, 3).

Globally, majority of preschool children and 1.6 billion people in Africa and south East Asia were expected to be anemic (3). The national prevalence of anemia among preschool children was predictable above 40% in developing nations including Ethiopia (4–6).

According to World Health Organization (WHO); anemia considered as a major public threat when prevalence was greater than 40%, as a moderate public threat when prevalence was from 20–40%, and as a mild threat when prevalence was from 5–20%. In our country, the magnitude of childhood anemia increased from 44% in 2011 to 56% in 2016 (4, 5). Even if the Ethiopian government and different stakeholders applied tremendous efforts to control the disease, childhood anemia still continues as threat (7). Therefore, understanding the spatial variation and determinants of anemia among this group of children is important to design effective interventions and to manage program resources fairly.

However, previously there were studies conducted to identify determinant factors of anemia in children. But the majority of studies were based on data collected in specific localized areas of the country where findings were not representative (7–11). Although a study done by using 2011 Ethiopian demographic and health survey (EDHS) data which was representative of the entire country, its analysis for determinants of childhood anemia does not account for clustering and hierarchical nature of the EDHS data (12). Furthermore, spatial distribution of childhood anemia was not studied previously. Thus, by considering the above limitations, this study was designed to explore spatial clustering of childhood anemia in Ethiopia.

# Methods

Study design and period

This study was conducted from January 18 to June 27, 2016 and a community based cross sectional study design was used.

Study setting

The study was done in Ethiopia which is located in the eastern horn of Africa with (3º-14º N and 33º – 48°E). The country is divided into nine regional states and two city administrations. There are 68 zones, 817 districts and 16,253 kebeles (lowest local administrative units of the country) (5). It has an space of 1.1 million $km^2$ (square kilometer) and has abundant topographical variety, extending from 4,550 meter above sea level depressed to 110 m below sea level (Fig. 1).

Population and sample

All children aged 6 to 59 months in Ethiopia in the selected households from January 18 to June 27 in 2016 were study population for this study. A total of 8602 children were included in the study.

As sampling strategy stratified two-stage cluster sampling technique was utilized. The sampling units were Enumeration areas (EA) and households for the first stage and second stage respectively. There were 645 clusters in which 202 from urban and 443 from rural were carefully sampled with a probability proportional allocation to cluster size with independent sampling in each sampling stratum. Among these, 18,008 households and 16,583 eligible women were incorporated. The detailed sampling procedure was found in the full EDHS report (5).

Study variables and data collection procedure

In this study the response variable was anemia status among children age 6–59 months. The predictor variables were grouped as:

(1).socio-demographic factors: sex of child, age of child, residence, educational status of mother, maternal age, husband’s educational status, religion of mother, wealth index, working status of mother, and number of children in the house hold.

(2). Nutritional factors: stunting, wasting, and size of child at birth.

(3). Clinical factors: maternal anemia status, diarrhea, fever and cough two weeks prior to data collection, and

(4). Medical related factors: taking of iron pills or sprinkles or syrup, and drugs for intestinal parasites, and vitamin A in the last six months.

Adjusted concentration of blood hemoglobin less than 11 mg/dl was considered as an anemic (1). Hence anemic status was determined based on blood hemoglobin concentration relative to altitude.

An approval letter for the use of the data was available from the Measure DHS.

The dataset was taken from website www.measuredhs.com(https://dhsprogram.com/data/availabledatasets.cfm).

The dependent and independent variables were obtained from the EDHS 2016 child data set. Both latitude and longitude coordinates was taken from selected clusters.

As a data collection tool a structured and pre-tested questionnaire was utilized. For 2016 EDHS tablet computers were used to record responses during interview. They were armed with Bluetooth device which enable remote electronic transfer of assignment sheets from supervisors to interviewers and transfer of completed copies back from interviewers to supervisors (5).

## Data management and analysis

Interviewers were trained before data collection, and Interviews were performed using local languages (5). Descriptive and summary statistics were done using STATA version 14 after extracting and editing of data from EDHS 2016 child data set. Then Cross tabulations and summary statistics were used to define the study population.

Children found in one cluster are more similar as compared to those children found in other clusters (regions) of Ethiopia in case of EDHS data. This disrupts the assumption of independence of observations and equality of variance across clusters. This leads the use of advanced models to consider the between cluster variability. Thus, a mixed effect logistic regression model was considered. Hence the outcome variable was dichotomous (non-anemic child = no, anemic child = yes), logistic regression and GLMM (generalized linear mixed model) was fitted. Then the GLMM was selected based on result of AIC (Akaikie Information Criteria) and BIC (Bayesian information criteria), and ICC (intra class correlation) values. Thus variables having p- value up to 0.2 in the bi-variable analysis were taken to fit the model in the multi variable analysis. Finally, p-value less than 0.05 in the multivariable model of mixed-effects logistic regression was used to select variables which had statistically significant association with anemia. Goodness of fit was checked by using deviance and ICC.

## Spatial autocorrelation analysis

Spatial autocorrelation (Global Moran's I) statistic was used to measure the patterns of childhood anemia. Anemia is dispersed if Global Moran's I value approaches to -1, anemia clustered if Global Moran's I near to + 1, and randomly distributed if Global Moran's I had zero value. A statistically significant Moran's I ($p < 0.05$) showed the existence of spatial autocorrelation. ArcGIS version 10.1 software was utilized to exploit the Moran's I analysis.

## Spatial scan statistical analysis

Spatial scan statistic used a scanning window which travels through the study area. It was explored to detect the presence of statistically significant spatial clusters of childhood anemia by using Kuldorff's SaTScan version 9.4 software (23). Children with anemia were taken as cases and those without the disease as controls to fit the Bernoulli model was fitted i.e. anemic childhood as cases and non-anemic childhood as controls. To detect both small and large clusters, and overlooked clusters which contained more than the maximum limit with elliptical shaped window the default maximum spatial cluster size of < 50% of the population was used as an upper limit. To decide if the number of observed anemia cases within the cluster was significantly greater than the expected or not a Likelihood ratio test statistic was employed. Likelihood ratio tests based on the 999 Monte Carlo replications and using p-values were indicated Primary and secondary clusters (23).

## Ethical consideration

Ethical clearance was gained from the ethical review board of Institute of Public Health, College of Medicine and Health Sciences, University of Gondar. Written consent was gotten from Measure DHS International Program which approved 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.

# Results

Socio -demographic characteristics of respondents

A total of 8602 under-five children were incorporated in the 2016 EDHS survey. Among these children, 7815 granted the consent statement for hemoglobin. Out of 7815 children who granted the consent form, hemoglobin level was determined for 7794 children. About half, 4010(51.45%) children were males and 6467 (82.97%) rural residency. About two third, 5,084 (65.23%) of mothers had no formal education. Considering age of children, the mean age was found to be 2.64 years (S.D ± 0.18 months). Regarding of wealth index, 2854(36.62%) of respondents belongs to the poorest families (Table 1).

Table 1
Socio demographic characteristics of respondents in Ethiopia from January 18 to June 27, 2016(N = 7,794).

| Variable | Categories | Frequency percent |
| --- | --- | --- |
| Age of the child in months | 6–11<br>12–23<br>24–35 | 914 11.73<br>1765 22.65<br>1702 21.84 |
| | 36–47 | 1656 21.25 |
| | 48–59 | 1757 22.54 |
| Sex of the child | Male | 4010 51.45 |
| | Female | 3784 48.55 |
| Residence | Urban | 1327 17.03 |
| | Rural | 6467 82.97 |
| Religion of mothers | Orthodox | 2,350 30.15 |
| | Protestant | 1,417 18.18 |
| | Muslim | 3,837 49.23 |
| | Others* | 190 2.44 |
| Maternal educational level | No education | 5084 65.23 |
| | Primary | 1,981 25.42 |
| | Secondary | 486 6.24 |
| | Higher | 243 3.12 |
| Maternal age in years | 15–24 | 1,757 22.54 |
| | 25–29 | 2,355 30.22 |
| | 30–34 | 1,778 22.81 |
| | 35–48 | 1,904 24.43 |
| Wealth index of child's family | Poorest | 2854 36.62 |
| | Poorer | 1387 17.80 |
| | Middle | 1156 14.83 |
| | Richer | 983 12.61 |
| | Richest | 1414 18.14 |

*Other religion: catholic and traditional

| Variable | Categories | Frequency percent |
|---|---|---|
| Region | Tigray | 828 10.62 |
| | Afar | 744 9.55 |
| | Amhara | 783 10.05 |
| | Oromia | 1220 15.65 |
| | Somali | 1019 13.07 |
| | Benishangul | 659 8.47 |
| | SNNPR | 995 12.77 |
| | Gambella | 509 6.53 |
| | Harari | 373 4.79 |
| | Addis Ababa<br>Dire-Dawa | 305 3.91<br>359 4.61 |
| *Other religion: catholic and traditional | | |

The highest and the lowest prevalence of anemia among under-five children were identified in Somali (81.94%) and Amara (42.40%) regional states respectively.

Spatial distribution of childhood anemia

In this study the distribution of childhood anemia across the country among children age 6–59 months were clustered with Global Moran's I 0.65 ($p < 0.001$). The clustered patterns (on right sides) depicted that high number of anemia cases in the study setting. A z-score of 9.7 indicated that there was less than 1% likelihood for this clustered pattern due to a random chance. An increased level of significance was demonstrated by the bright red and blue colors in both side ends (Fig. 2).

Each spot (point data) on the map denotes one census enumeration area which contains a number of anemia cases. In the Map more cases depict anemia risk regions. Consequently, the red color shows areas had high number of anemia cases (Fig. 3).

Spatial scan statistical analysis

In the study about 114 significant clusters (80 primary and 34 secondary) were recognized. The spatial window for primary clusters was positioned in south-eastern part of oromia, Harari, Dire- Dawa and Somali regions. It was centered at 5.589269 N, 44.175032 E with 508.89 km radius, with a relative risk (RR) of 1.47 and Log-Likelihood ratio (LLR) of 14.47, at p-value < 0.001. It demonstrated that children

found inside the window were 1.47 times more risky for anemia as compared with those found outside the window (Table 2, Fig. 4).

Table 2
Significant spatial clusters of childhood anemia in Ethiopia, 2016

| Clusters | Enumeration areas(clusters) detected | Coordinates/radius | Population | Cases | RR | LLR | P-value |
|---|---|---|---|---|---|---|---|
| 1 | 138, 164, 85, 358, 146, 492, 92, 490, 543, 278, 171, 198, 95, 318,77, 187, 497, 556, 520, 629, 521, 588, 553, 458, 480, 208, 214, 251,573, 239, 269, 116, 22, 394, 378, 630, 568, 33, 277, 286, 527, 289, 64, 439, 57, 186, 8, 210, 472, 452, 377, 454, 513, 436, 501, 212, 68, 580, 622, 483, 566, 133, 587, 194, 240, 500, 321, 418, 58, 115, 29, 534, 179, 257, 387, 157, 397, 56,607, 228, 28, 396, 60, 393, 357, 419, 443, 173, 238, 329, 1, 288, 383, 495, 381, 610, 473, 372, 453, 242, 523, 281, 642, 166, 311, 307, 30, 557 | (5.589269N, 44.175032E) /508.89 km | 108 | 89 | 1.47 | 14.47 | <0.001 |
| 2 | 334, 570, 205, 499, 178, 440, 632, 596, 75, 368, 348, 55, 547, 191, 276, 571, 389, 254, 189, 241, 4, 620, 345, 611, 427, 544, 332, 344, 37, 283, 496, 599, 135, 18 | (11.430282N, 40.918452E) /145.46 km | 34 | 30 | 1.50 | 6.84 | < 0.001 |

But the relatively small secondary clusters window was found in afar regional state. It was fixed at 11.430282 N, 40.918452 E with 145.46 km radius, and a RR (Relative Risk) of 1.50 and LLR of 6.84, with p < 0.001. It revealed that children found inside the spatial window were 1.5 times more risky for anemia compared with children found outside the window (Table 2, Fig. 4).

The most statistically significant spatial windows contained primary most likely (primary) clusters of childhood anemia was represented by bright red colors. Childhoods found inside the spatial window (cluster) have a greater risk for anemia compared with those childhoods found outside the spatial window.

Determinants of childhood anemia

Model comparison

The calculated AIC and BIC for Mixed-effects Logistic regression was smallest as compared with Logistic regression (Table 3). In addition to this, the ICC value was 0.13 which implies to use mixed effect logistic regression model over the traditional logistic regression model.

Table 3
Model comparison between logistic regression and Mixed-effect logistic regression

| Proposed models | AIC value | BIC value |
|---|---|---|
| Logistic regression | 8833.456 | 9157.877 |
| Mixed effect logistic regression | 8676.244 | 9007.568 |

Age of child, number of under-five children in the house, age of child, stunting and wasting status, residence, maternal and husbands educational level, educational level, history of diarrhea, fever and cough in the last two weeks, family wealth index, taking of iron pills or sprinkles or syrup, maternal working status, maternal anemic status, size of child at birth, age of mothers, drugs for intestinal parasites in the last six months, and vitamin A supplement in the same period were statistically significant in the bi-variable analysis at p-value < 0.05.

But age of child, religion, wealth index, mother’s current working status, maternal anemic status, number of under five children in the house hold, fever in the last two weeks, and stunting remained significant predictors of childhood anemia in the multivariable mixed effect logistic regression model.

Children age between 12–23 months were 32% less (AOR = 0.68, 95%CI = 0.55–0.85), between 24–35 months were 62% (AOR = 0.38, 95% CI = 0.31–0.47), between 36–47 months were 75% less (AOR = 0.25, 95%CI = 0.2–0.31), and between 48–59 months were 84% less (AOR = 0.16, 95%CI = 0.13–0.20) likely to develop anemia when compared with those children age between 6–11 months.

The likelihood of developing anemia in children with family wealth index of poor, middle, richer and richest is lower by 26% (AOR = 0.74, 95%CI = 0.63–0.88), 40% (AOR = 0.60, 95%CI = 0.50–0.72), 35% (AOR = 0.65, 95%CI = 0.53–0.79) and 43% (AOR = 0.57, 95%CI = 0.43–0.74) respectively as compared with those with family wealth index of poorest.

The likelihood of developing anemia among children who had working mothers were decreased by 13% (AOR = 0.87, 95%CI = 0.76–0.99) as compared with children whose mothers were not working currently. Regarding maternal anemic status, children who had anemic mothers were 53% (AOR = 1.53, 95%CI = 1.35–1.73) more likely to develop anemia as compared with those children who had non anemic mother.

Children from households who had three or more under five children were 19% (AOR = 1.19, 95%CI: 1.03–1.38) more likely to develop anemia as compared with those children whose house hold had one or two under- five children.

Children who had fever were 36% (AOR = 1.36, 95% CI: 1.13–1.65) more likely to develop anemia as compared with their counterparts. Similarly, children who had moderate stunting were 30% more (AOR = 1.30, 95%CI: 1.13–1.50) and severe stunting were 82% more (AOR = 1.82, 95%CI: 1.54–2.16) likely to develop anemia as compared with those children who had no anemia (Table 4).

Table 4

Bi-variable and multi-variable mixed-effect logistic regression analysis of determinants associated with anemia among children age 6 to 59 months in Ethiopia from January 18 to June 27 in 2016 (N = 7794)

| **Variables** | **Anemic status** | | **COR (95%)** | **AOR (95%CI)** | |
|---|---|---|---|---|---|
| | **Non anemic** | **anemic** | | | |
| Residency | | | | | |
| Urban | 608 | 719 | 1 | 1 | |
| Rural | 2496 | 3971 | 1.47(1.20–1.80) | 0.89(0.68–1.17) | |
| Age of child in months | | | | | |
| 6–11 | 200 | 714 | 1 | 1 | |
| 12–23 | 497 | 1268 | 0.71(0.57–0.86) | 0.68(0.55–0.85)** | |
| 24–35 | 646 | 1056 | 0.40(0.33–0.49) | 0.38(0.31–0.47)** | |
| 36–47 | 770 | 886 | 0.26(0.21–0.32) | 0.25(0.20–0.31)** | |
| 48–49 | 991 | 766 | 0.17(0.14–0.21) | 0.16(0.13–1.20)** | |
| Maternal educational level | | | | | |
| No education | 1903 | 3181 | 1 | 1 | |
| Primary | 840 | 1141 | 0.90(0.79–1.02) | 0.95(0.82–1.11) | |
| Secondary | 233 | 253 | 0.75(0.60–0.93) | 0.83(0.63–1.10) | |
| Higher | 128 | 115 | 0.60(0.44–0.82) | 0.76(0.51–1.12) | |
| Religion of mother | | | | | |
| Orthodox | 1243 | 1107 | 1 | 1 | |
| Protestant | | 641 | 776 | 1.24(1.02–1.49) | 1.213(0.99–1.48) |

COR: Crude odds ratio, CI: Confidence interval, AOR: adjusted odds ratio, 1: Reference category, *: significant at $p < 0.05$, **: Significant at $p < 0.001$

| Variables | Anemic status | | COR (95%) | AOR (95%CI) |
|---|---|---|---|---|
| | Non anemic | anemic | | |
| Muslim | 1145 | 2692 | 2.48(2.11–2.91) | 2.07(1.75–2.46) |
| Others | 75 | 115 | 1.71(1.17–2.49) | 1.49(1.01–2.22) |
| Wealth index | | | | |
| Poorest | 849 | 2005 | 1 | 1 |
| Poorer | 568 | 819 | 0.69(0.59–0.81) | 0.74(0.63–0.88)** |
| Middle | 543 | 613 | 0.56(0.47–0.67) | 0.60(0.50–0.72)** |
| Richer | 465 | 518 | 0.56(0.47–0.68) | 0.65(0.53–0.79)** |
| Richest | 679 | 735 | 0.46(0.38–0.55) | 0.57(0.44–0.74)** |
| Husband’s educational level | | | | |
| No education | 1317 | 2305 | 1 | 1 |
| Primary | 1034 | 1420 | 0.89(0.78-1.00) | 1.01(0.88–1.16) |
| Secondary | 304 | 404 | 0.86(0.71–1.05) | 1.02(0.81–1.27) |
| Higher | 220 | 294 | 0.84(0.67–1.06) | 1.26(0.95–1.68) |
| Mother’s current working status | | | | |
| Not working | 1317 | 3501 | 1 | 1 |
| Working | 1022 | 1187 | 0.76(0.68–0.86) | 0.87(0.76–0.99)* |
| Maternal anemic status | | | | |
| Non anemic | 2291 | 2708 | 1 | 1 |
| Anemic | 813 | 1982 | 1.60(1.43–1.80) | 1.53(1.35–1.73)** |

COR: Crude odds ratio, CI: Confidence interval, AOR: adjusted odds ratio, 1: Reference category, *: significant at $p < 0.05$, **: Significant at $p < 0.001$

| Variables | Anemic status | | COR (95%) | AOR (95%CI) |
|---|---|---|---|---|
| | Non anemic | anemic | | |
| Size of child at birth | | | | |
| Average | 1372 | 1943 | 1 | 1 |
| Above average | 997 | 1375 | 0.95(0.84–1.07) | 0.97(0.85–1.10) |
| Below average | 700 | 1338 | 1.21(1.07–1.38) | 1.11(0.96–1.27) |
| Number of under-five children | | | | |
| 1–2 children | 2622 | 3655 | 1 | 1 |
| children | 482 | 1035 | 1.27(1.10–1.46) | 1.19(1.03–1.38)* |
| Maternal age in years | | | | |
| 15–24 | 620 | 1137 | 1 | 1 |
| 25–29 | 912 | 1443 | 0.87(0.75–1.01) | 1.05(0.89–1.23) |
| 30–34 | 714 | 1064 | 0.83(0.71–0.96) | 1.06(0.89–1.26) |
| 35–48 | 858 | 1064 | 0.71(0.61–0.82) | 0.95(0.80–1.13) |
| Had diarrhea in the last two weeks | | | | |
| No | 2762 | 4079 | 1 | 1 |
| Yes | 339 | 604 | 1.35(1.15–1.58) | 0.90(0.75–1.07) |
| Had fever in the last two weeks | | | | |
| No | 2718 | 3924 | 1 | 1 |
| Yes | 382 | 765 | 1.54(1.33–1.79) | 1.36(1.13–1.65)* |
| Had cough in the last two weeks | | | | |

COR: Crude odds ratio, CI: Confidence interval, AOR: adjusted odds ratio, 1: Reference category, *: significant at p < 0.05, **: Significant at p < 0.001

| Variables | Anemic status | | COR (95%) | AOR (95%CI) |
|---|---|---|---|---|
| | Non anemic | anemic | | |
| No | 2615 | 3853 | 1 | 1 |
| Yes | 489 | 836 | 1.29(1.12–1.48) | 1.02(0.86–1.21) |
| Taking of Vitamin A in the last 6 months | | | | |
| No | 1445 | 2482 | 1 | 1 |
| Yes | 1606 | 2134 | 0.86(0.77–0.95) | 0.92(0.82–1.04) |
| Taking iron pills, sprinkles or syrup | | | | |
| No | 2786 | 4288 | 1 | 1 |
| Yes | 280 | 350 | 0.86(0.71–1.03) | 0.99(0.81–1.22) |
| Drugs for intestinal parasites in the last 6 months | | | | |
| No | 2560 | 4072 | 1 | 1 |
| Yes | 483 | 557 | 0.81(0.69–0.94) | 1.12(0.95–1.33) |
| Stunting status | | | | |
| No stunting | 2101 | 2839 | 1 | 1 |
| Moderate stunting | 588 | 949 | 1.24(1.09–1.41) | 1.31(1.13–1.50)** |
| Severe stunting | 347 | 751 | 1.61(1.38–1.89) | 1.82(1.54–2.16)** |
| wasting status | | | | |
| No wasting | 2793 | 3980 | 1 | 1 |
| Moderate wasting | 237 | 523 | 1.37(1.14–1.64) | 1.09(0.89–1.32) |
| Severe wasting | 32 | 95 | 1.93(1.24-3.00) | 1.44(0.91–2.28) |

COR: Crude odds ratio, CI: Confidence interval, AOR: adjusted odds ratio, 1: Reference category, *: significant at $p < 0.05$, **: Significant at $p < 0.001$

| Variables | Anemic status | | COR (95%) | AOR (95%CI) |
|---|---|---|---|---|
| | Non anemic | anemic | | |
| | | | | |

COR: Crude odds ratio, CI: Confidence interval, AOR: adjusted odds ratio, 1: Reference category, *: significant at p < 0.05, **: Significant at p < 0.001

# Discussion

The Global Moran's I value 0.65 (p value < 0.001) showed that there was a significant clustering of childhood anemia in Ethiopia. Similarly, the spatial scan statistical analysis identified 114 statistically significance clusters.

The eastern and south-eastern parts of the country mainly Somali, Afar, Harari and Dire Dawa were the hotspot regions of childhood anemia. The most probable explanation for geographic variation in the risk of anemia might be related with the dynamics of the soil content of minerals since the identified high risk regions were categorized to eastern and south-eastern part of the country. Meaning high risk regions share similar environmental condition as evidenced by boundary formation to each other. In addition, epidemiological factors such as fever and stunting which were identified as determinants of anemia in different studies including our study were more common in high risk regions. Similarly the finding from Nigeria indicated that Northern parts of the country were at a greater threat of anemia (13). Furthermore, according to a study done in sub-Saharan Africa which reported the distribution of anemia was exacerbated by factors acquired from the environments (6).These all implied that the dynamics of mineral content of the soil was the most probable explanation for observed geographical variation in the risk of anemia.

This study showed that children age between 12–59 months was less affected by anemia. This finding was consistent with majority of studies conducted a cross the world (8, 9, 11, 12, 14–22). This might be because of a wide gap between high iron demand for fast growth (3) and low iron supply because of inappropriate initiation of complimentary feeding (11, 24) and highest depletion of prenatal iron store starting at six months of age(25). However, this finding is different from the study conducted in southern Ethiopia that demonstrated statistically non-significant effect for anemia (7). This can be explained by the difference in sample size. The previous study's sample size (399 children) was very small as compared with current study.

This study also showed wealth index was significant predictors of childhood anemia. Consequently, children from poor, middle, richer and richest family were lowered by 25.8%, 40.4%, 35.2% and 43.3% to develop anemia respectively as compared with those children from the poorest family. The finding was

consistent with studies conducted in brazil(20, 21), Nigeria(13) and Ethiopia(8, 11). The possible explanation for this could be, poorest families had no competence to pay for diversified foods and additionally suffering from health getting medical services which causes leads to anemia (3, 26).

Children who had working mothers were lower compared with children who had mothers not working currently. It is supported by a study done in Ethiopia(12). The possible justification could be related with increased empowerment of working mothers to childcare and other health related actions (27, 28).

Maternal anemic status was also significant predictors of childhood anemia in the study. This finding is concordance with reports from Cuba(18), Burma(20) and Ethiopia(12). This association might be explained by influence of poor maternal iron reserve during pregnancy and breast feeding on iron store of their child (29, 30). Nevertheless, the association might partly reflect the effect of confounding because of unmeasured observation on shared socioeconomic, genetic and biological environment.

Those children from households who had three or more under-five children were higher in anemia. It was concordant with majority of findings done from Brazil(15), Lao People's Democratic Republic(17) and Ethiopia(12). The possible reason for the observed association is that higher number of children imposes high demand on household not only for food but also for clothing and health care services. Again it exacerbates quality to care for children, and thereby worsen anemia. However, this finding was different from studies conducting in Nigeria(13) and southern Ethiopia(7) which showed that; number of children in the household had no impact on anemia (7). The discrepancy might be related with inclusion of all children in the household in the previous studies. This mixed independent family members with dependent family members which pools the real association towards the null. In addition the study conducted in southern Ethiopia had very small sample size (399 children) as compared with current study.

Children who had fever were more affected by anemia in this study when compared with the counterparts. The result was concordant with reports from Burma(20), Nigeria(13) and southern Ethiopia(7). This might be related with the infectious cause of childhood fever mainly malaria, septicemia, tuberculosis and leshimaniasis which causes anemia by infecting and destructing red bloods cells or other mechanisms (31).

Stunting was also found to be significant predictors of childhood anemia in the study. The result was similar with majority of previous findings conducted in Burma(20), Kenya(14) and Ethiopia(7–12). This association could be explained by both pathophysiological mechanism and confounding effect of inadequate dietary intake (both share the common cause). Pathophysiological explanation implied reverse causation between stunting and anemia. In malnourished children, gastrointestinal epithelium disturbance leads to development of anemia by impairing absorption of nutrients(31). To the reverse, anemia during period of rapid growth leads to irreversible growth retardation(3, 29).

As strength findings could be generalized to all under-five children found in the country. In addition the study used advanced spatial techniques which could demonstrate consistent and statistically significant

high burden clusters for childhood anemia. But as a limitation the study didn't show variations of childhood anemia seasonally. Furthermore, for some independent variables like diarrhea, cough, and fever within two weeks there might be misclassification of exposure status because of unable to remember the event (recall bias).

The result would provide valued policy suggestions for targeted interventions and designing related programs. Overall, the study has paramount relevance for the policy makers and stakeholders for appropriately intervening childhood anemia.

# Conclusion

This study showed that the distribution of childhood anemia varied in Ethiopia. More risk areas of childhood anemia were detected in the eastern and south-eastern parts of the country, while low risk areas of childhood anemia were noted in the central, North Western, western and, south-western parts of Ethiopia. Being in the early age category, having poorest family, having mother who is not currently working, having anemic mother, being in the house-hold that had three or more under five children, having fever in the last two weeks, and having moderate or severe stunting were factors increased the odds of developing childhood anemia.

# Abbreviations

AIC: Akaike Information Criteria, AOR: Adjusted Odds Ratio, BIC: Bayesian information criteria, COR: Crude odds ratio, CSA: Central Statics Agency, EA: Enumeration Area, EDHS: Ethiopian Demographic and Health Survey, GIS: Geographic Information System, GLMM: Generalized Linear Mixed Model, ICC: Intra cluster correlation, LLR: Log Likelihood Ratio, SNNPR: Southern Nation Nationality and Peoples Region, and WHO: World Health Organization.

# Declarations

Authors' contribution

ET conceived of the study, coordinate data collection. ET and TA performed statistical analysis and drafted the manuscript. Both authors read and approved the final manuscript.

Consent for publication

Not applicable

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# Figures

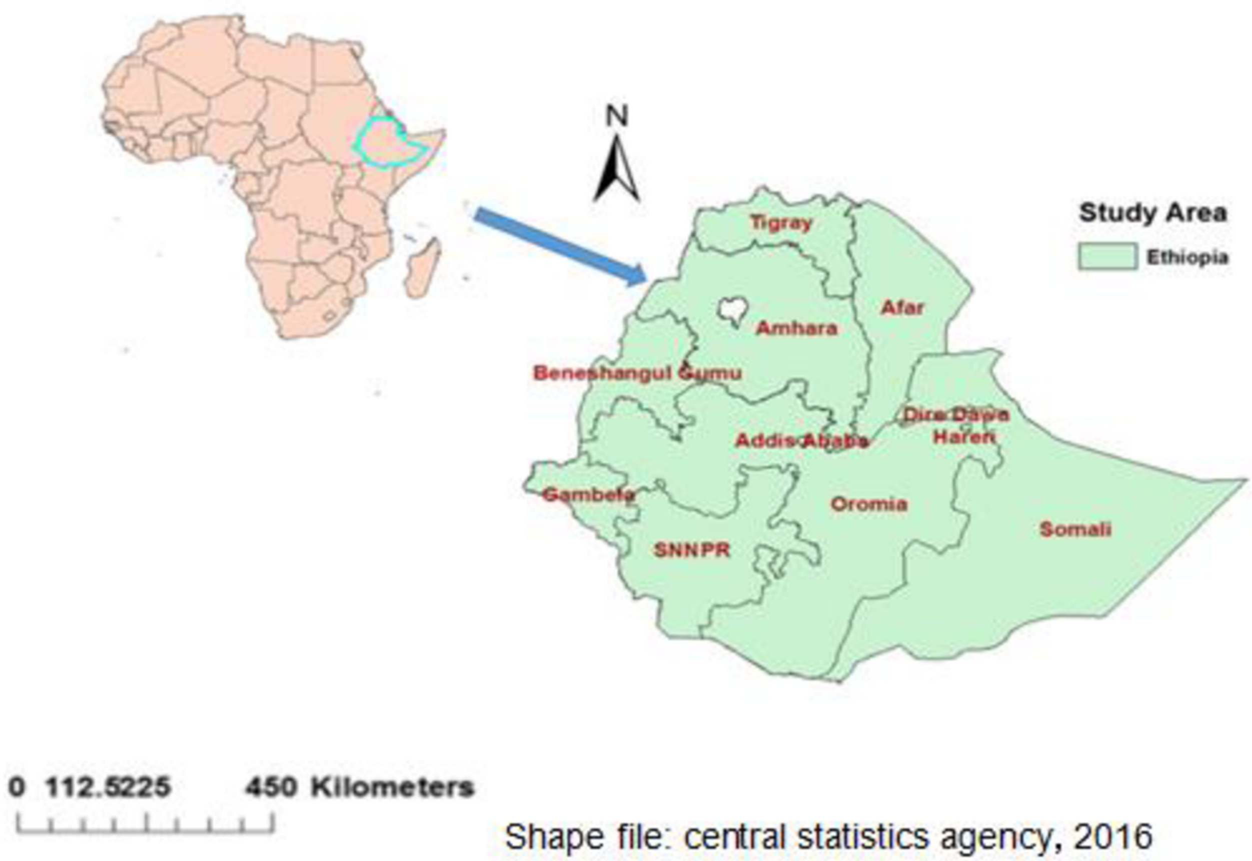


Figure 1: Map of Study Area

**Figure 1**

Map of Ethiopia

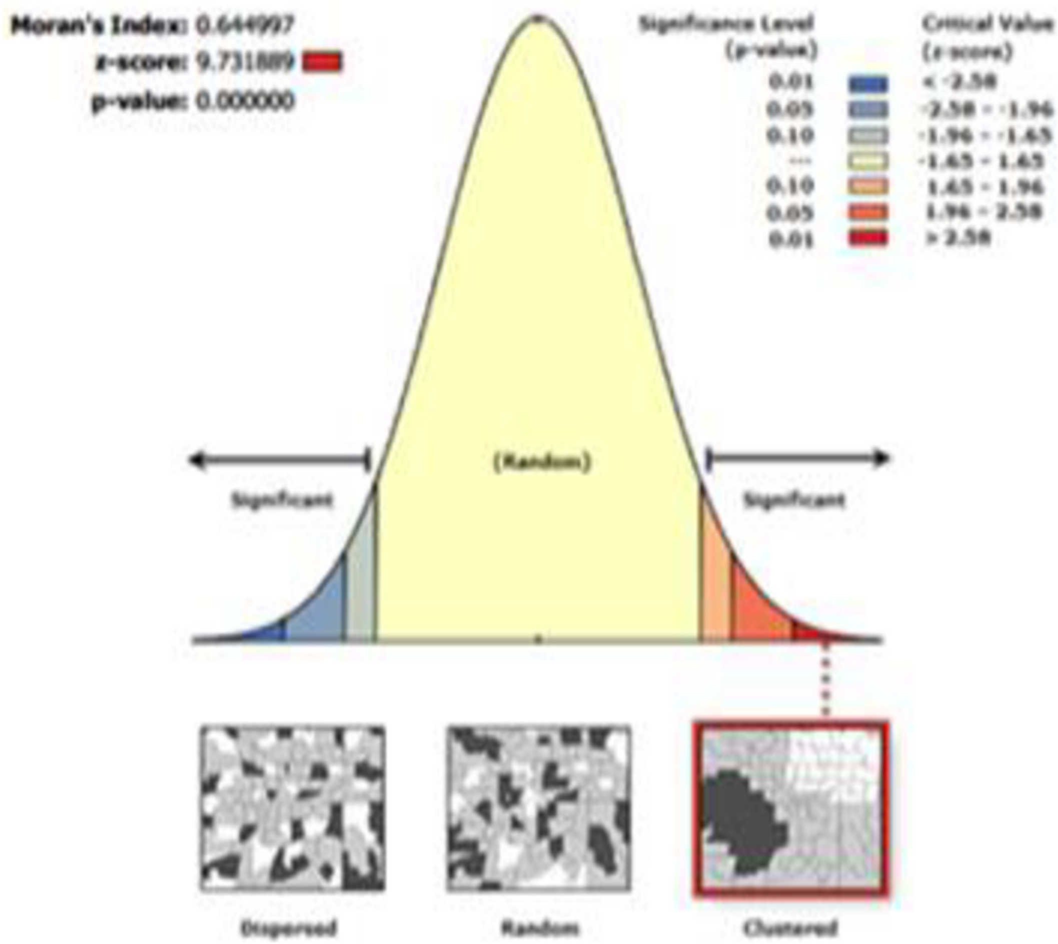


Figure 2| Spatial autocorrelation analysis of childhood anemia in Ethiopia, 2016

**Figure 2**

Spatial auto- correlation analysis of childhood anemia in Ethiopia, 2016.

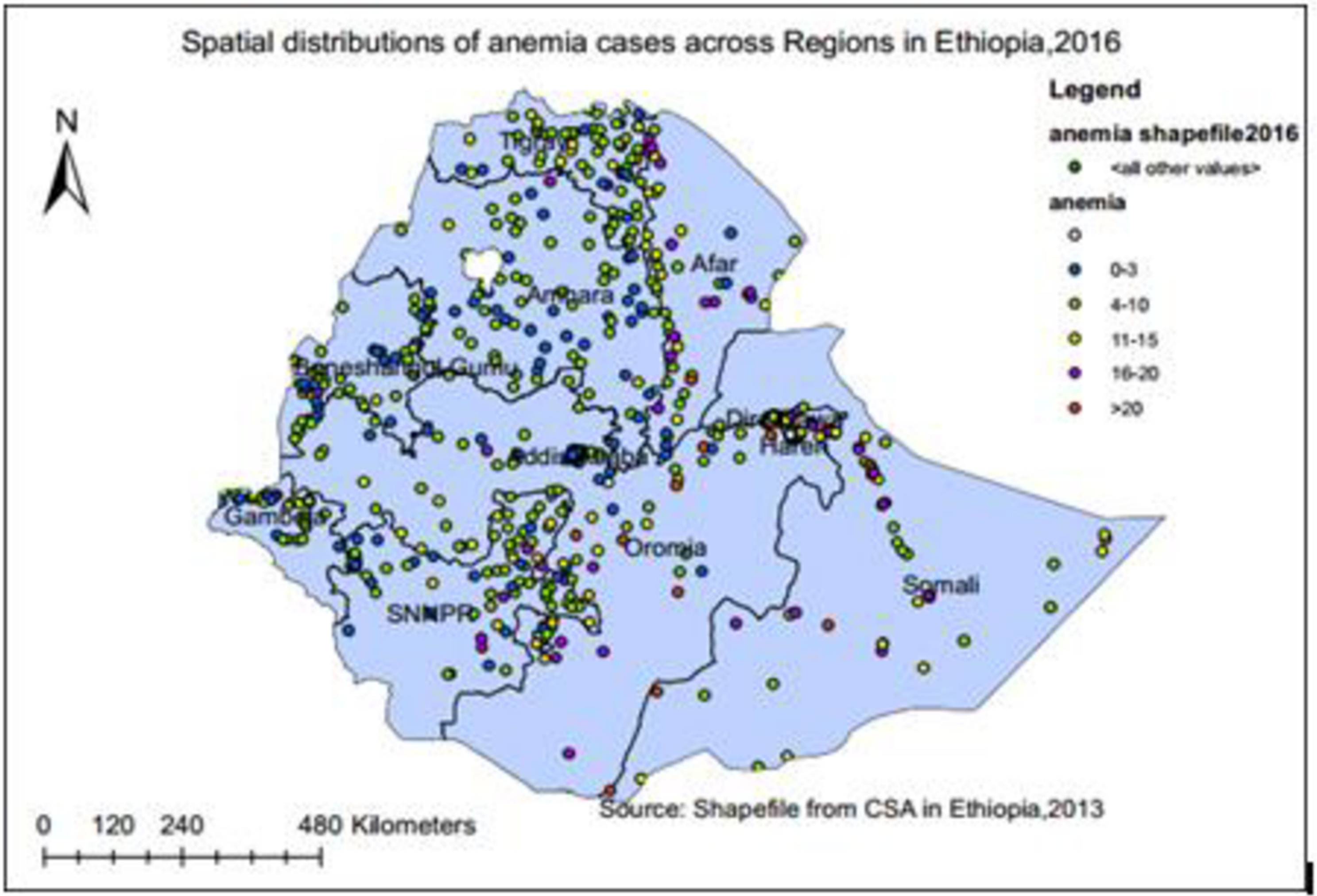


Figure 3: Spatial distribution of Childhood anemia across Regions in Ethiopia, 2016.

### Figure 3

Spatial distribution of childhood anemia across regions in Ethiopia, 2016

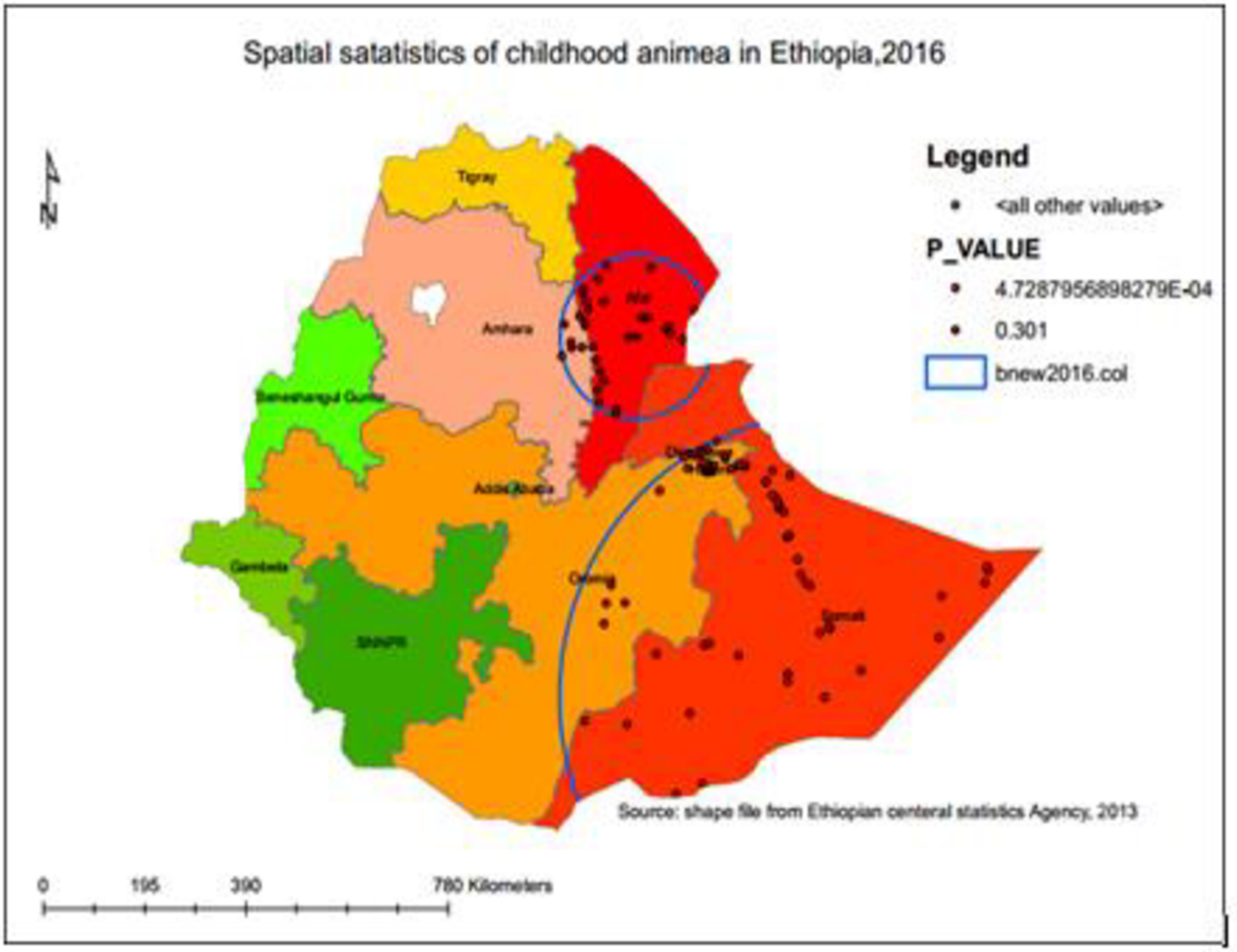


Figure 4: The primary and secondary clusters of childhood anemia in Ethiopia, 2016.

**Figure 4**

Most likely (primary) and secondary clusters of under-five pneumonia across regions in Ethiopia, 2016.