# Geospatial Inequality of Anemia Among Children in Ethiopia

**bilal Endris** ( bilalshikur10@gmail.com )
Addis Ababa University https://orcid.org/0000-0002-5321-1034
**Geert-Jan Dinant**
Maastricht University
**Seifu Hagos Gebreyesus**
Addis Ababa University
**Mark Spigt**
Universiteit Maastricht Care and Public Health Research Institute

**Research**

**Keywords:** Anemia, hotspot, geospatial, inequality, children

**Posted Date:** August 6th, 2020

**DOI:** https://doi.org/10.21203/rs.3.rs-54237/v1

# Abstract

Background: Anemia remains a severe public health problem among children in Ethiopia. The lack of progress in the trend of anemia infers the failure of national anemia prevention and control programs. If there are considerable geospatial differences in the prevalence of anemia in Ethiopia, targeted approaches, based on the distribution and specific risk factors for that setting are needed to efficiently target health interventions. This study aimed to identify and locate anemia hotspots among children in Ethiopia.

**Methods**: Data analysis was performed using Ethiopia Demographic and Health Survey (EDHS) 2016 Data. Blood specimens for anemia testing were collected from children age 6-59 months. Hemoglobin analyses were placed in a HemoCue photometer and the results were recorded onsite for 9,268 children. The outcome variable anemia was categorized into a dichotomous variable (anemic and not anemic); a child was considered as anemic if the blood-hemoglobin count was less than 11.0 g/dl. We applied Kulldorf's spatial scan statistics and used SaTScanTM to identify locations and estimate cluster sizes. In addition, we ran LISA (local indicator of spatial association) and the Getis-Ord Gi(d) local statistics to detect and locate hotspots of anemia. We ran multilevel multivariable analysis to identify risk factors for anemia clustering.

**Result:** More than half (57%) of children aged 6-59 months were anemic in Ethiopia. Higher prevalence of anemia was found among children who live in Somali region (83%), in rural area (58%), in the lowest wealth quintile (68%), and among children of mothers' with no education (59%). We found significant geospatial inequality of anemia among children in Ethiopia. We identified one anemia cluster (hotspot) in the eastern part of Ethiopia. Women anemia, stunting and high fertility were associated with anemia clustering.

**Conclusion**: Anemia clustering was found in the eastern part of Ethiopia. We recommend that policy makers and programmers should especially target this area for accelerated reduction of anemia.


# Introduction

Anemia is defined as a less than normal red blood cell or hemoglobin (Hb) level that is inadequate to meet the body's physiologic need. For children 6 months to 5 years of age anemia is defined as a Hb level of less than 11 g/dL(1). Globally, close to half of preschool children and pregnant women are anemic (2). More than half of the world's population of preschool children and pregnant women live in countries where anemia is a severe public health problem, Africa and Asia being the most affected (3).The consequences of Anemia include poor pregnancy outcome, poor motor and mental performance in children and low work productivity in adults (4, 5). Furthermore, Anemia causes huge economic loss due to physical productivity loss and cognitive loss (5).

Ethiopia is one of the exemplar countries with remarkable reduction in stunting, from 52% in 2000 to 38% in 2016 (6). However, the prevalence of anemia remains a severe public health problem among preschool children with no improvement for more than ten years; i.e 54% in 2005 and 57% in 2016 (6, 7). Lack of any progress in anemia implies the failure of anemia prevention and control programs in Ethiopia. Although anemia is a severe public health problem in all regions of Ethiopia, there is significant regional disparity (6).

The causes of anemia are multi-factorial and vary across geography. The most important causes of anemia include nutritional deficiencies (Iron, Folate, Vitamin B12, A and C), Infections (malaria, helminthes, other acute and chronic inflammations) and genetic conditions (sickle cell diseases, thalassemia) (3, 8, 9). The causes and environmental drivers of anemia showed a high degree of geographic clustering (10). A growing body of evidence indicated that

Hb concentration (anaemia) is clustered geographically (10–14). A study on spatial heterogeneity of Hb concentration in sub Saharan Africa showed that Hb concentration among preschool children was highly clustered geographically in both western and eastern Africa(10, 12). Similarly, spatial analyses in Hb concentration of the children in Nigeria revealed that Northern Nigeria possess a higher risk of anaemia(11). In a geo-spatial study of anemia among adults in Ethiopia, hotspots of anemia were concentrated in the eastern parts of the country (Somali, Dire Dawa and Harari, Afar regions), while cold spots of anemia were observed in the northern (Tigray and Amhara), central (Addis Ababa and Oromia) and western (Benishangul-Gumuz and Gambella) parts of the country (13, 14).

In anemia control, the use of national prevalence estimates of anemia in the presence of subnational variability is likely to hamper the efficient delivery of control programmes. Targeted approaches based on the geographical distribution of high-risk communities are needed to efficiently allocate health interventions and to attain accelerated reduction of anemia. In Ethiopia, given a high degree of agro ecological and geographic variation, we hypothesize that there is anemia clustering among preschool children. This study aimed to identify and locate anemia clusters (hotspots) among children in Ethiopia using multiple methods of geospatial analysis. To the best of our knowledge, this is the first study to assess geospatial inequality of anemia among pre school children in Ethiopia using multiple methods.

## Methods And Materials

# Study settings

Ethiopia is the second most populous country in Africa and characterized by enormous diversity. The country has extensive altitudinal and geographic variations. The altitude ranges from 116 meters below sea level in the Danakil Depression to the peak of 4,620 meters above sea level on Mount Ras Dashen. The mean annual rainfall ranges from 500 mm to 2800 mm. Similarly, mean annual temperatures range from below 10 to above 30$^{o}$C. In the submoist, moist, and sub humid highland areas, there is opportunity for agricultural growth. However, Agricultural production can be low in lowlands of Ethiopia, which is characterized by warm and a dry climate leading to food insecurity. In addition, Ethiopia is gifted with diverse culture with more than 80 Ethnic groups. Despite being one of the world's poorest countries, Ethiopia's economic growth is one of the fastest globally (15, 16).

# Study Design

The data for the present analysis was obtained from the Ethiopian Demographic and Health Survey (EDHS) 2016. The EDHS is carried out every five years to provide health and health-related indicators at the national and regional levels in Ethiopia. The 2016 EDHS sample was selected using a stratified, two-stage cluster sampling design. In the first stage, 645 clusters of census enumeration areas (EAs), including 202 urban areas and 443 rural areas were selected. In the second stage, 18,008 households were selected. In this study we used data from the 9,268 children who had undergone anemia testing. Due to the non-proportional allocation of the sample to different regions and their urban and rural areas, we applied sampling weight to ensure the actual representative of the survey results at both the national and domain levels. We also applied complex survey design to account for the stratified multi stage sampling methods of EDHS. The detailed sampling procedure is presented in the EDHS report (6). The EDHS 2016 data were downloaded from the DHS website (http://dhsprogram.com) after we secured online permission. Potential predictor variables such as wealth index, educational level, BMI, age, residence (urban vs rural), region and other variables were extracted from the dataset. In addition, ecologic level variables such as temperature, malaria incidence, rainfall, and altitude were extracted from openly available DHS spatially interpolated datasets download from DHS Program Spatial Data Repository (http://spatialdata.dhsprogram.com).

# Measurements

Blood specimens for anemia testing were collected from all children age 6–59 months from whom consent was obtained from their parents or another responsible guardian. Blood samples were drawn from a drop of blood taken from the palm side of the end of a finger and in the case of children age 6–11 months, blood was taken from the heel prick. The blood samples were collected on a HemoCue micro cuvette. Blood samples were placed in a HemoCue photometer and the results were recorded on site. Anemia status was defined as follows: mild anemia (10.0- 10.9 g/dl), moderate anemia (7.0- 9.9 g/dl) and severe anemia ( < = 7.0 g/dl). For the purpose of this study, the outcome variable anemia was recoded into a dichotomous variable where a child was considered to be anemic if the blood-hemoglobin count was less than 11.0 g/dl(6).

# Data analysis

The statistical analysis was performed using the software packages STATA 14 and SaTScanTM. Descriptive statistics were used to analyze baseline characteristics of children and their caregivers including sex, age, residence, mother's and father's education level and wealth index to provide an overall picture of the sample. The prevalence of each risk factor and the 95% confidence interval were also presented.

# Analysis Of Spatial Clustering

We made an attribute table containing information for each EA such as EA number, the number of children less than 5 years of age in each EA (population), proportion of anemia cases and EA coordinates. This file was imported into ArcGIS 10·1 for visualization. The visualization was made based on EA median Hb. Hb concentration of less than 110 mg/dl was considered as anemic and Hb concentration of greater than or equal to 110 mg/dl was considered as non-anemic. The coordinates' projection was defined using the World Geodetic System (WGS) 1984, Universal Transverse Mercator (UTM) Zone 37°N. The shape file created was exported to the software SaTScanTM version 9·1·1 (http://www.satscan.org) for cluster analysis.

We conducted analysis of the spatial clustering of anemia in two steps. The first step aimed at examining the presence and locations of a significant cluster of anemia at national level. For examining the spatial clustering at the national level, we used the data from all regions (eleven) of Ethiopia. The second step aimed at detecting spatial clustering within each regions separately, and if present defined the characteristics of clusters such as size and location. We applied Kulldorf's spatial scan statistics and used SaTScanTM version 9·1·1 to identify locations and estimate cluster sizes. The scan statistics evaluate whether proportion of anemia cases are distributed randomly over a defined space. If the process is not random, the scan statistics help to identify significant spatial clusters (17, 18). A circular window is used by the Kulldorf spatial scan to identify significant clusters with high cases of anemia over the study area. The statistical significance of this largest likelihood ratio was assessed through Monte Carlo simulation (1000 simulation performed). In order to detect both small and large clusters, we set the upper limit of the window size at 50% of the study population. The spatial relationships among EAs were conceptualized by calculating the spatial weights from the input file containing the proportion of anemia for each

EA (the number of anemia cases divided by the total number of tested children in the EA) and the geo-coordinates data for each EA. We assumed that spatial autocorrelation for anemia declined with the distance and therefore a spatial weight matrix conceptualizing the spatial relationship between clusters was generated using an inverse distance approach. In addition to Kulldorf's spatial scan statistics, we ran LISA (local indicator of spatial association) and the Getis-Ord Gi(d) local statistics to detect and locate clusters (hotspots) of anemia. LISA (local indicator of spatial association) indicates spatial autocorrelation for each location (19). The Getis-Ord Gi(d) statistic(20) was performed using ArcGIS 10.2 to identify the locations of clusters for high occurrence of anemia. The Gi(d) statistic performs the spatial analysis by looking at each cluster within the context of neighboring clusters.

## Analysis Of The Determinants Of Anemia Clustering

Although identifying the presence of clustering was our primary objective, we performed further analysis to help identify the underlying process that governs the observed clustering. The observed clustering might be due to the underlying aggregation of known risk factors that are not randomly distributed geographically (or the presence of spatial dependency;'Tobler's first law of geography') (21). We initially ran bivariate analyses to determine the potential risk factors of anemia. We used both individual and ecologic level data such as 1) individual variables: socio-demographic (child age, sex), child disease (fever, diarrhea), Dietary intake (dairy consumption, consumption of vegetables and fruits), child stunting and wasting, Maternal characteristics (women age, women anemia, women education, women BMI, number of ANC visits, iron consumption during pregnancy, number of births), household characteristics (improved water source, improved latrine, wealth status, residence), 2) ecologic level variables: rainfall, temperature, enhanced vegetation index and altitude. We used variables with p-value of less than 0.2 for the analysis of anemia clustering in the multilevel multivariable logistic regression. Regions and households were considered as levels. In the final model, variables such as women anemia, wealth, child stunting, child wasting, women, education, availability of improved toilet, number of births and amount of rainfall were included. We identified risk factors that varied across cases (anemic children) identified within the cluster and cases (anemic children) outside the cluster. A significance level of 0.05 was chosen for all the analyses.

## Results

## Characteristics of study participants

Table 1 describes the background characteristics of study participants. This study involved a total of 9267 children 6–59 month. Most children lived in rural area (90%). Majority of mothers had no formal education (67%). Only thirteen percent (13%) of children lived in the highest wealth quintile.

As shown in Table 1, nearly 57% of children were anemic. In general, prevalence of anemia decreased with increasing age; ranging from 77% among 6–11 month children to 40% among 48–59 month children. A higher prevalence of anemia was found among children who lived in Somali region (83%), in the rural area (58%), among those living in the lowest wealth quintile (68%), and among children who had mothers' with no education (59%).

Table 1
Anemia among children age 6–59 months, by background characteristics

| Background characteristics | Prevalence of anemia | | | |
|---|---|---|---|---|
| | Proportion of Anemia (Hb < 11.0 g/dl) | 95% CI | Number | Percent |
| **Age in months** | | | | |
| 6–11 | 77.1 | (72.5,81.2) | 1043 | 11.3 |
| 12–23 | 69.2 | (65.7,72.5) | 2022 | 21.8 |
| 24–35 | 59.0 | (54.5,63.2) | 1948 | 21.0 |
| 36–47 | 50.9 | (46.9,54.9) | 2019 | 21.8 |
| 48–59 | 40.0 | (36.2,43.9) | 2235 | 24.1 |
| **Sex** | | | | |
| Female | 56.6 | (53.8,59.3) | 4455 | 48.0 |
| Male | 57.2 | (54.1,60.3) | 4812 | 52.0 |
| **Region** | | | | |
| Tigray | 53.6 | (49.0,58.1) | 612 | 6.6 |
| Afar | 74.8 | (70.4,78.6) | 91 | 1.0 |
| Amhara | 42.2 | (37.9,46.5) | 1861 | 20.1 |
| Oromiya | 65.5 | (61.0,69.6) | 4008 | 43.2 |
| Somali | 82.9 | (79.6,85.8) | 371 | 4.0 |
| Benishangul-Gumuz | 42.5 | (37.6,47.6) | 96 | 1.0 |
| SNNPR | 50.0 | (45.0,54.9) | 1992 | 21.5 |
| Gambela | 56.2 | (47.8,64.2) | 21 | 0.22 |
| Harari | 67.9 | (63.1,72.3) | 16 | 0.17 |
| Addis Ababa | 49.2 | (43.4,55.0) | 165 | 1.78 |
| Dire Dawa | 71.5 | (66.0,76.5) | 35 | 0.37 |
| **Wealth quintile** | | | | |
| Lowest | 67.8 | (62.9,72.2) | 2164 | 23.3 |
| Second | 57.6 | (53.5,61.7) | 2166 | 23.4 |
| Middle | 52.6 | (48.3,56.8) | 1963 | 21.2 |
| Fourth | 54.0 | (49.9,58.0) | 1723 | 18.6 |
| Highest | 47.9 | (43.6,52.3) | 1250 | 13.5 |
| **Mothers' education** | | | | |

| Background characteristics | Prevalence of anemia | | | |
|---|---|---|---|---|
| No education | 58.5 | (55.5,61.5) | 5746 | 67.1 |
| Primary education | 56.8 | (53.3,60.3) | 2307 | 26.9 |
| Secondary education | 48.6 | (41.7,55.6) | 345 | 4.0 |
| Higher education | 49.1 | (40.2,58.1) | 170 | 2.0 |
| **Place of residence** | | | | |
| Rural | 57.8 | **(55.1,60.5)** | **8330** | **90%** |
| Urban | 49.3 | **(43.5,53.1)** | **937** | **10%** |
| Total | 56.9 | (54.4,59.4) | 9267 | 100% |

# Spatial Distribution Of Anemia

Figure 1 shows the distribution of hemoglobin concentration across enumeration areas (clusters). Low median hemoglobin concentration (High anemia case) was aggregated in the Eastern part of Ethiopia. The geographic distribution of median hemoglobin concentration varies over the country. The median hemoglobin concentration was significantly lower in North Eastern and South Eastern, South central and south western part of the country. High concentration of anemia was found spanning the country’s border to the East and South West.

The geographic distribution of anemia is shown in Fig. 2. Using both LISA and Gi(d) local statistics, we identified a significant geospatial inequality in the distribution of anemia in Ethiopia. We identified statistically significant hotspots (high anemia cluster) in the eastern part of Ethiopia and cold spots (low anemia cluster) in the western part of Ethiopia. We also identified hotspots in the southwest corner of Ethiopia (Gambela region).

Figure 3 spatial SaTScan statistics result of anemia clustering among preschool children, Ethiopia

Table 2
Distribution of EAs found in cluster (SaTScan) by regions, 2016.

| Region | Frequency | Percent |
|---|---|---|
| Afar | 36 | 16.7 |
| Amhara | 10 | 4.6 |
| Oromia | 33 | 15.3 |
| Somali | 50 | 23.3 |
| SNNPR | 2 | 1.0 |
| Harari | 42 | 19.5 |
| Addis Ababa | 2 | 1.0 |
| Dire Dawa | 40 | 18.6 |
| Total | 215 | 100% |

We further applied spatial scan statistics separately for the 11 regions of Ethiopia to find out whether there was a distinct spatial cluster in the distribution of anemia at a regional level. We found most likely significant clusters in four regions (Table 3). In Oromia region, a cluster of 106 cases (72.94 expected) was detected (blue color) and the odds of anemia among children within this cluster were 1.5 more than the odds of anemia among children outside the cluster (RR = 1.52, $P < 0{\cdot}021$). In Southern Nations Nationalities and People Region (SNNPR), a cluster of 317 cases (269.52expected) was identified and the odds of anemia among children within this cluster were 1.4 more than the odds of anemia among children outside the cluster (RR = 1.42, $P = 0{\cdot}013$). In Benishangul-Gumuz, a cluster of 170 cases (140.35 expected) was detected and the odds of anemia among children within this cluster were 1.5 more than the odds of anemia among children outside the cluster (RR = 1.52, $P = 0.046$). In Gambela, a cluster of 196 cases (160.05 expected) was detected and the odds of anemia among children within this cluster were 1.6 more than the odds of anemia among children outside the cluster (RR = 1.55, $P = 0.011$).

# Risk Factors For Spatial Clustering

This analysis was run to identify the risk factors for the clustering of anemia and further to evaluate whether the observed clustering of anemia is due to the distribution of various risk factors that are not randomly distributed geographically. For this we fitted a regression model and we found no significant differences with respect to household socio-economic status, latrine availability, wasting, and maternal education between anemic cases (children) identified within the spatial cluster and anemic children outside the cluster. However, we found a statistically significant difference in women anemia, stunting and number of births between anemic cases (children) identified within the spatial cluster and anemic children outside the cluster. The odds of stunting was 1.3 times higher among children within the identified cluster compared to the odds among children outside the cluster ($p = 0.041$). The odds of having anemic mothers was 1.4 times higher among children within the identified cluster compared to the odds among children outside the cluster ($p < 0.01$). The odds of having mothers who had two births in the last five years was 1.4 times higher among children within the identified cluster compared to the odds among children outside the cluster ($p < 0.01$).

Table 3
Purely spatial scan statistics of the most likely significant clusters for anemia at national and regional level

| | **National (Ethiopia)** | **Oromiya Region** | **SNNP Region** | **Benishangul Gumz Region** | **Gambella Region** |
|---|---|---|---|---|---|
| Number of clusters | 622 | 72 | 71 | 49 | 49 |
| Coordinates | (47.007,7.6506) | (42.438,9.5054) | (38.693,7.0033) | (34.503,9.9730) | (34.196,7.6374) |
| Radius | 8.29 | 0.68 | 1.11 | | 0.73 |
| Population (children) | 2891 | 114 | 542 | 331 | 273 |
| Observed cases | 2135 | 106 | 317 | 171 | 196 |
| Expected cases | 1708.77 | 72.94 | 269.52 | 140.35 | 160.05 |
| Cases/100,000 | 73697.0 | 92790.0 | 58366.0 | 51554.7 | 71646.3 |
| Observed / Expected | 1.25 | 1.45 | 1.18 | 1.22 | 1.22 |
| Relative risk (RR) | 1.45 | 1.52 | 1.42 | 1.52 | 1.55 |
| Log likelihood ratio | 80.160755 | 7.311074 | 8.254107 | 6.432496 | 7.790748 |
| P-value | < 0.001 | 0.021 | 0.013 | 0.046 | 0.011 |

Table 4
Risk factors for clustering of anemia among under five children, Ethiopia 2019

| Explanatory variable | Cases within an Identified spatial cluster | | COR (95% CI) | AOB (95% CI) |
|---|---|---|---|---|
| | Yes (n, %) | No (n, %) | | |
| Women anemia | | | | |
| No | 994(32.1) | 2106 (67.9) | 1.00 | 1.00 |
| Yes | 773 (44.1) | 979(55.9) | 1.31 (1.11,1.56)** | 1.41 (1.11,1.79)*** |
| Stunting | | | | |
| Not stunted | 1116(39.1) | 1739 (60.9) | 1.00 | 1.00 |
| Stunted | 421 (36.4) | 736 (63.6) | 1.15 (0.93,1.41) | 1.26(0.95,1.69)** |
| Severely stunted | 376 (32.9) | 766 (67.1) | 1.02 (0.83,1.26) | 1.36 (1.01,1.82)* |
| Wasting | | | | |
| Not wasted | 1710 (37) | 2914 (64) | 1.00 | |
| Wasted | 155 (37.2) | 261 (62.8) | 0.91 | 1.17 (0.79,1.73) |
| Severely wasted | 69(40.3) | 102 (59.7) | 0.89(0.72,1.74) | 1.14 (0.63,2.08) |
| Household characteristics | | | | |
| SES (quintiles) | | | | |
| Poorest | 668(45.5) | 799 (54.5) | 0.75 (0.56,1.01)* | 1.36 (0.83,2.22) |
| Poor | 509 (40.8) | 739 (59.2) | 0.86 (0.61,1.21) | 1.20(0.70,2.05) |
| Middle | 342 (33.1) | 690 (66.9) | 0.59 (0.41,0.85) | 1.12 (0.65,1.94) |
| Rich | 295 (31.7) | 636 (68.3) | 0.61 (0.43,0.88)*** | 1.40 (0.82,2.41) |
| Richest | 147(24.6) | 452(75.4) | 1.00 | 1.00 |
| Education | | | | |
| No education | 1316 (38.3) | 2124 (61.7) | 0.62 (0.30,1.28) | 0.54 (0.18,1.61) |
| Primary education | 484 (36.4) | 846 (63.6) | 0.72 (0.34,1.50) | 0.91(0.31,2.69) |
| Secondary education | 37 (21.3) | 135 (78.7) | 1.06 (0.44,2.52) | 1.98 (0.59,6.57) |
| Higher education | 24 (27.6%) | 64 (72.4%) | 1.00 | 1.00 |
| Improved toilet | | | | |
| No | 1771 (36.9) | 3023 (63.1) | 1.00 | 1.00 |
| Yes | 190 (39.3 | 293 (60.7) | 0.83 (0.65,1.07)* | 1.00 (0.64,1.57)* |

| Explanatory variable | Cases within an Identified spatial cluster | | COR (95% CI) | AOB (95% CI) |
|---|---|---|---|---|
| | Yes (n, %) | No (n, %) | | |
| Births | | | | |
| 1 | 537(27.3) | 1232 (72.7) | 1.00 | 1.00 |
| 2 | 947(39.8) | 1432 (60.2) | 1.28 (1.06,1.55)** | 1.52 (1.17,1.99)** |
| 3 | 270 (53.9) | 231 (46.1) | 1.19 (0.91,1.55) | 1.05(0.72,1.54) |
| 4 | 69 (88.1) | 9 (11.9) | 2.26 (1.19,4.30)** | 1.51(0.52,4.40)* |
| Rainfall_2015 | m = 764 SD(239.7) | | 1.00 | 1.00 |

**Note**

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; COR: crude odds ratio AOR: Adjusted odds ratio

# Discussion

We assessed geospatial inequality of anemia among preschool children. We used multiple methods to detect spatial clustering of anemia and further locate hotspots of anemia. We found considerable geographical variation; hotspots (clusters) of anemia were concentrated in the eastern part of Ethiopia. Anemic children identified within the cluster had higher odds of being stunted, living with anemic women, and living with women with higher fertility.

Our finding of geospatial inequality of anemia affecting unduly the eastern part of Ethiopia is consistent with other similar studies (13, 14). The high anemia cluster found in Somali, Afar and eastern Oromia regions can be partly explained by the low economic and human development in these regions. These areas are characterized as lowlands, pastoralist or agro pastoralist societies with chronic food insecurity, frequent droughts, poor infrastructure, poor access to health care and education. The human development index (HDI) for Ethiopia's regions indicated that these three regions indeed had the lowest development score in Ethiopia (22). Similarly, Afar and Somali regions had poor maternal and child health service coverage and utilization (such as folic acid supplementation, Institutional delivery, family planning) and vaccination (18). Furthermore, The highest proportions of women with no education and poorest households were concentrated in the same regions(6). A growing body of literature reported that anemia highly affect socioeconomically disadvantaged groups (6, 23, 24). These imply that ensuring equitable socioeconomic and human development of societies could play significant role in the prevention of anemia.

The geospatial inequality of anemia might also be due to variations in food consumption patterns. For example, the highest consumption of Teff (Eragrostis tef), a good source of iron (25), was reported from urban areas and highlands of Ethiopia (for example Amhara region) while the lowest consumption was reported from the lowlands of eastern part of Ethiopia (for example Somali region) (26–28). Similarly, the Ethiopian food consumption survey showed that the highest prevalence of inadequate dietary intake of iron (83%) was reported from Somali region and the lowest from Amhara region (6%) (29). On the other hand, the proportion of the diet contributed by dairy products (iron absorption inhibitor) is higher among women in Somali, Afar and Gambella regions. This implies the need to improve dietary diversification through improving access and utilization of iron rich food.

The prevalence of malaria, using Rapid diagnostic test, was 0.6% among children 6–59 months. Somali, Dire Dawa, Afar and Oromia reported lower prevalence (< 0.2%) of malaria among children 6–59 month (30). Using multiplex serology assays, high malaria burden was observed in the northwest compared to the eastern part of Ethiopia. Proportion of seropositive for P. falciparum by region ranged from 11.0% in Somali to 65.0% (95% CI: 58.0–71.4) in Gambela Region (31). Given the lower prevalence of malaria in the anemia hotspot areas (eastern Ethiopia), it is less likely that malaria is the cause for the geospatial inequality of anemia in Ethiopia. Furthermore, many studies In Ethiopia revealed that infections such as acute respiratory tract infection, diarrhea and soil-transmitted infection are important contributors in the etiology of anemia (32–36). However, these infections are not highly concentrated in the eastern part of compared to other parts of Ethiopia(6). According to a study conducted in different areas of Ethiopia, the prevalence of hookworm among school age children was 22% in Northwestern Ethiopia, 28.4% in southern Ethiopia, 6.7% in eastern Ethiopia and 4.9% in northern Ethiopia) (37). These finding on the prevalence of malaria and other infections indicate that the geospatial inequality of anemia is less likely to be due to acute infections such as malaria, ARI or diarrhea (6).

The current study found that there is a higher odds of anemia among women in the anemia cluster (identified by SaTScan) than outside of the cluster. This in line was the findings of other studies (38, 39). The possible explanation is that women with anemia and anemic children live in a similar socioeconomic, cultural and health related environment (37, 40). There is also high chance of a intergenerational cycle of anemia from the mother to the infant. Additionally, low levels of essential minerals such as iron in the breast milk of the anemic mother, could also affect the Hb level of the breastfeeding child(41). This implies that anemia prevention and control strategies should be integrated targeting both mothers and their children concurrently.

The current study should be interpreted in the context of the following strengths and limitations. The fact that we found similar area of high anemia clustering using multiple methods of geospatial analysis makes our finding robust. In addition, use of nationally and regionally representative DHS data on hemoglobin concentration and GPS coordinates, makes our approach to be reproduced in other countries. However, measurement error and misclassification might have occurred because the locations of DHS clusters are randomly displaced to protect the confidentiality of survey respondents (42). The DHS data lacks comprehensive information on the risk factors of anemia such as malaria, intestinal parasite and nutrition for under-five children. This has limited our analysis to determine the risk factors of anemia clustering. Though we have used the latest EDHS survey (EDHS 2016), changes might happen after the survey and our finding may not reflect the current situation.

# Conclusions

In conclusion, we found significant geospatial inequality of anemia highly affecting the eastern part of Ethiopia. We recommend that policy makers and programmers should especially target this area for accelerated reduction of anemia. Programs should target both women and children since we found strong association between maternal anemia and childhood anemia. Further research is needed to understand the risk factors and etiologies of anemia across the different setting of Ethiopia.

### Ethical approval and consent to participate

Ethical clearance was obtained from Research Ethics Committee at Addis Ababa University. Permission to use the data was obtained from DHS Program manager. Anemia testing was performed after getting Informed consent from parents or another responsible guardian.

**Consent for publication:**

Not applicable

# Availability of data and materials

The datasets used and/or analyzed during the current study are available at DHS website (http://dhsprogram.com)

# Declarations

**Ethical approval and consent to participate**

Ethical clearance was obtained from Research Ethics Committee at Addis Ababa University. Permission to use the data was obtained from DHS Program manager. Anemia testing was performed after getting Informed consent from parents or another responsible guardian.

**Consent for publication**: Not applicable

## Availability of data and materials

## The datasets used and/or analyzed during the current study are available at DHS website (http://dhsprogram.com)

**Competing interest**

The Authors declare that they have no competing interests

**Funding**

This research received no funding

**Authorship**

B.S.E., G.J.D S.H.G., and M.S. study conception and design; B.S.E., G.J.D S.H.G., and M.S analysis and interpretation of data; B.S.E., G.J.D S.H.G., and M.S. critical revision of the article; I B.S.E., drafting of the manuscript.

**Acknowledgments:** We are grateful to DHS survey team, Addis Ababa University, and Maastricht University

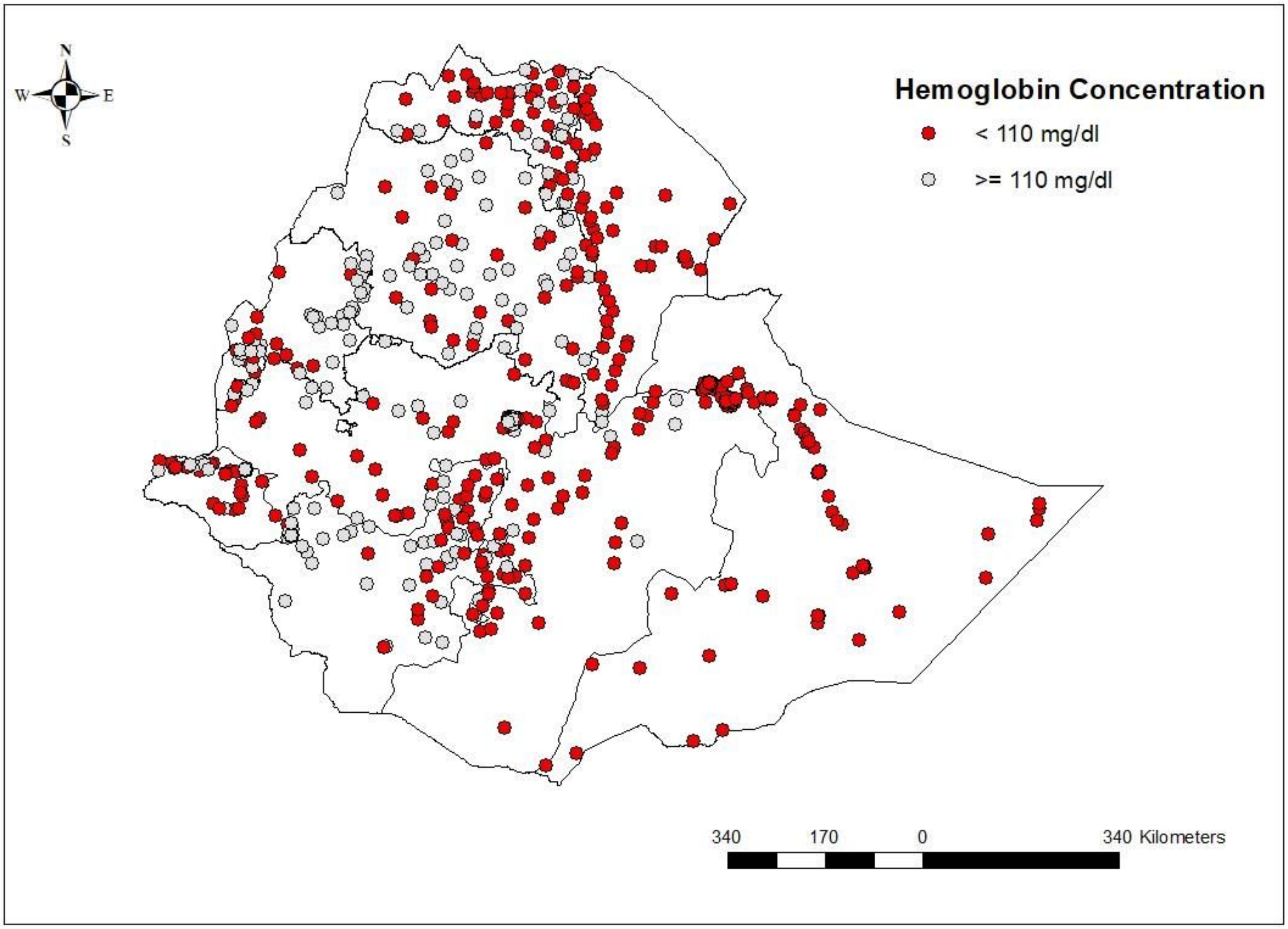
# References

1. WHO. Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity. 2011. Download from: http://www who int/vmnis/indicators/haemoglobin pdf. 2015.
2. Stevens GA, Finucane MM, De-Regil LM, Paciorek CJ, Flaxman SR, Branca F, et al. Global, regional, and national trends in haemoglobin concentration and prevalence of total and severe anaemia in children and pregnant and non-pregnant women for 1995–2011: a systematic analysis of population-representative data. The Lancet Global Health. 2013;1(1):e16–25.
3. Thurnham DI, Northrop-Clewes CA. Infection and the etiology of anemia. Nutritional anemia. 2007:231.

4. Noronha JA, Al Khasawneh E, Seshan V, Ramasubramaniam S, Raman S. Anemia in pregnancy-consequences and challenges: a review of literature. Journal of South Asian Federation of Obstetrics Gynecology. 2012;4(1):64–70.
5. Horton S, Ross J. The economics of iron deficiency. Food policy. 2003;28(1):51–75.
6. CSA I. Central statistical agency (CSA)[Ethiopia] and ICF. Ethiopia demographic and health survey, Addis Ababa, Ethiopia and Calverton, Maryland, USA. 2016.
7. Macro O. Central Statistical Agency: Ethiopia demographic and health survey 2005. Maryland: ORC Macro, Calverton; 2006.
8. De la Cruz-Góngora V, Villalpando S, Rebollar R, Shamah-Levy T, Humarán IM-G. Nutritional causes of anemia in Mexican children under 5 years. Results from the 2006 National Health and Nutrition Survey. Salud pública de México. 2012;54(2):108–15.
9. Yip R, Dallman P. The roles of inflammation and iron deficiency as causes of anemia. Am J Clin Nutr. 1988;48(5):1295–300.
10. Magalhães RJS, Clements AC. Spatial heterogeneity of haemoglobin concentration in preschool-age children in sub-Saharan Africa. Bull World Health Organ. 2011;89:459–68.
11. Gayawan E, Arogundade ED, Adebayo SB. Possible determinants and spatial patterns of anaemia among young children in Nigeria: a Bayesian semi-parametric modelling. International health. 2014;6(1):35–45.
12. Habyarimana F, Zewotir T, Ramroop S. Spatial Distribution and Analysis of Risk Factors Associated with Anemia Among Women of Reproductive Age: Case of 2014 Rwanda Demographic and Health Survey Data. The Open Public Health Journal. 2018;11(1).
13. Kibret KT, Chojenta C, D’Arcy E, Loxton D. Spatial distribution and determinant factors of anaemia among women of reproductive age in Ethiopia: a multilevel and spatial analysis. BMJ open. 2019;9(4):e027276.
14. Ejigu BA, Wencheko E, Berhane K. Spatial pattern and determinants of anaemia in Ethiopia. PLoS One. 2018;13(5):e0197171.
15. Hurni H. Soil Conservation Research Programme Ethiopia. Research report on agro-ecological belts. Ethiopia: Addis Ababa; 1998. 43 pp.
16. Adamu AY. Diversity in Ethiopia: A historical overview of political challenges. International Journal of Community Diversity. 2013;12(1).
17. Kulldorff M. A spatial scan statistic. Communications in Statistics-Theory methods. 1997;26(6):1481–96.
18. Kulldorff M, Nagarwalla N. Spatial disease clusters: detection and inference. Statistics in medicine. 1995;14(8):799–810.
19. Anselin L. Local indicators of spatial association—LISA. Geographical analysis. 1995;27(2):93–115.
20. Getis A, Ord JK. The analysis of spatial association by use of distance statistics. Perspectives on Spatial Data Analysis: Springer; 2010. p. 127 – 45.
21. Waters N. T obler's First Law of Geography. International Encyclopedia of Geography: People, the Earth, Environment and Technology. 2016:1–15.
22. Ethiopia U. Ethiopia National Human Development Report 2018. 2018.
23. Yang F, Liu X, Zha P. Trends in Socioeconomic Inequalities and Prevalence of Anemia Among Children and Nonpregnant Women in Low-and Middle-Income Countries. JAMA network open. 2018;1(5):e182899-e.

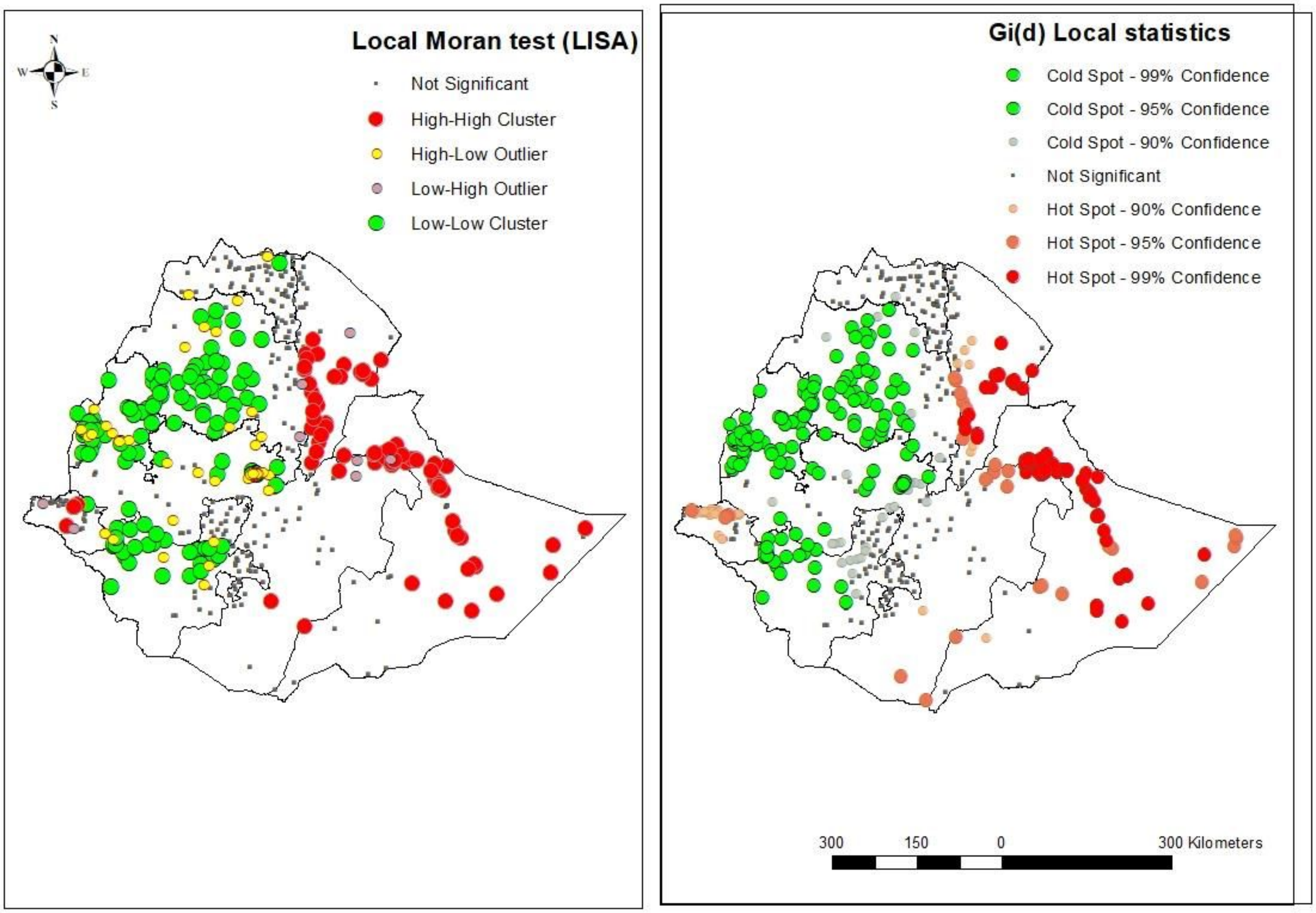
24. Kim J, Shin S, Han K, Lee KC, Kim J, Choi YS, et al. Relationship between socioeconomic status and anemia prevalence in adolescent girls based on the fourth and fifth Korea National Health and Nutrition Examination Surveys. Eur J Clin Nutr. 2014;68(2):253.
25. Baye K. Teff: nutrient composition and health benefits: Intl Food Policy Res Inst; 2014.
26. Hurni H. Agroecological belts of Ethiopia. Explanatory notes on three maps at a scale of. 1998;1(1,000,000).
27. Berhane G, McBride L, Hirfrfot KT, Tamiru S. Patterns in foodgrain consumption and calorie intake. Food and Agriculture in Ethiopia: Progress and Policy Challenges. 2012:190–216.
28. Se AST, Dorosh P, Gemessa SA. Crop production in Ethiopia: Regional patterns and trends. Food and agriculture in Ethiopia: Progress and policy challenges.74:53.
29. Institute EPH. Ethiopia national food consumption survey. Ethiopian Public Health Institute (EPHI) Addis Ababa (Ethiopia); 2013.
30. MoH F. Ethiopia National Malaria Indicator Survey 2015. 2017.
31. Assefa A, Ahmed AA, Deressa W, Sime H, Mohammed H, Kebede A, et al. Multiplex serology demonstrate cumulative prevalence and spatial distribution of malaria in Ethiopia. Malar J. 2019;18(1):246.
32. Deribew K, Tekeste Z, Petros B. Urinary schistosomiasis and malaria associated anemia in Ethiopia. Asian Pacific journal of tropical biomedicine. 2013;3(4):307.
33. Degarege A, Animut A, Medhin G, Legesse M, Erko B. The association between multiple intestinal helminth infections and blood group, anaemia and nutritional status in human populations from Dore Bafeno, southern Ethiopia. Journal of helminthology. 2014;88(2):152–9.
34. Mahmud MA, Spigt M, Bezabih AM, Pavon IL, Dinant G-J, Velasco RB. Efficacy of handwashing with soap and nail clipping on intestinal parasitic infections in school-aged children: a factorial cluster randomized controlled trial. PLoS medicine. 2015;12(6).
35. Alemu A, Shiferaw Y, Ambachew A, Hamid H. Malaria helminth co–infections and their contribution for aneamia in febrile patients attending Azzezo health center, Gondar, Northwest Ethiopia: a cross sectional study. Asian Pacific Journal of Tropical Medicine. 2012;5(10):803–9.
36. Reithinger R, Ngondi J, Graves P, Hwang J, Getachew A, Jima D, et al. Risk factors for anemia in children under 6 years of age in Ethiopia: analysis of the data from the cross-sectional Malaria Indicator Survey, 2007. Trans R Soc Trop Med Hyg. 2013;107(12):769–76.
37. Samuel F. Status of soil-transmitted helminths infection in Ethiopia. Am J Health Res. 2015;3(3):170–6.
38. Ntenda PA, Nkoka O, Bass P, Senghore T. Maternal anemia is a potential risk factor for anemia in children aged 6–59 months in Southern Africa: a multilevel analysis. BMC Public Health. 2018;18(1):650.
39. Pasricha S-R, Black J, Muthayya S, Shet A, Bhat V, Nagaraj S, et al. Determinants of anemia among young children in rural India. Pediatrics. 2010;126(1):e140-e9.
40. Brooker S, Akhwale W, Pullan R, Estambale B, Clarke SE, Snow RW, et al. Epidemiology of plasmodium-helminth co-infection in Africa: populations at risk, potential impact on anemia, and prospects for combining control. Am J Trop Med Hyg. 2007;77(6_Suppl):88–98.
41. Wang J, Wang H, Chang S, Zhao L, Fu P, Yu W, et al. The influence of malnutrition and micronutrient status on anemic risk in children under 3 years old in poor areas in China. PLoS One. 2015;10(10):e0140840.
42. Perez-Heydrich C, Warren JL, Burgert CR, Emch M. Guidelines on the use of DHS GPS data: ICF International; 2013.

# Figures



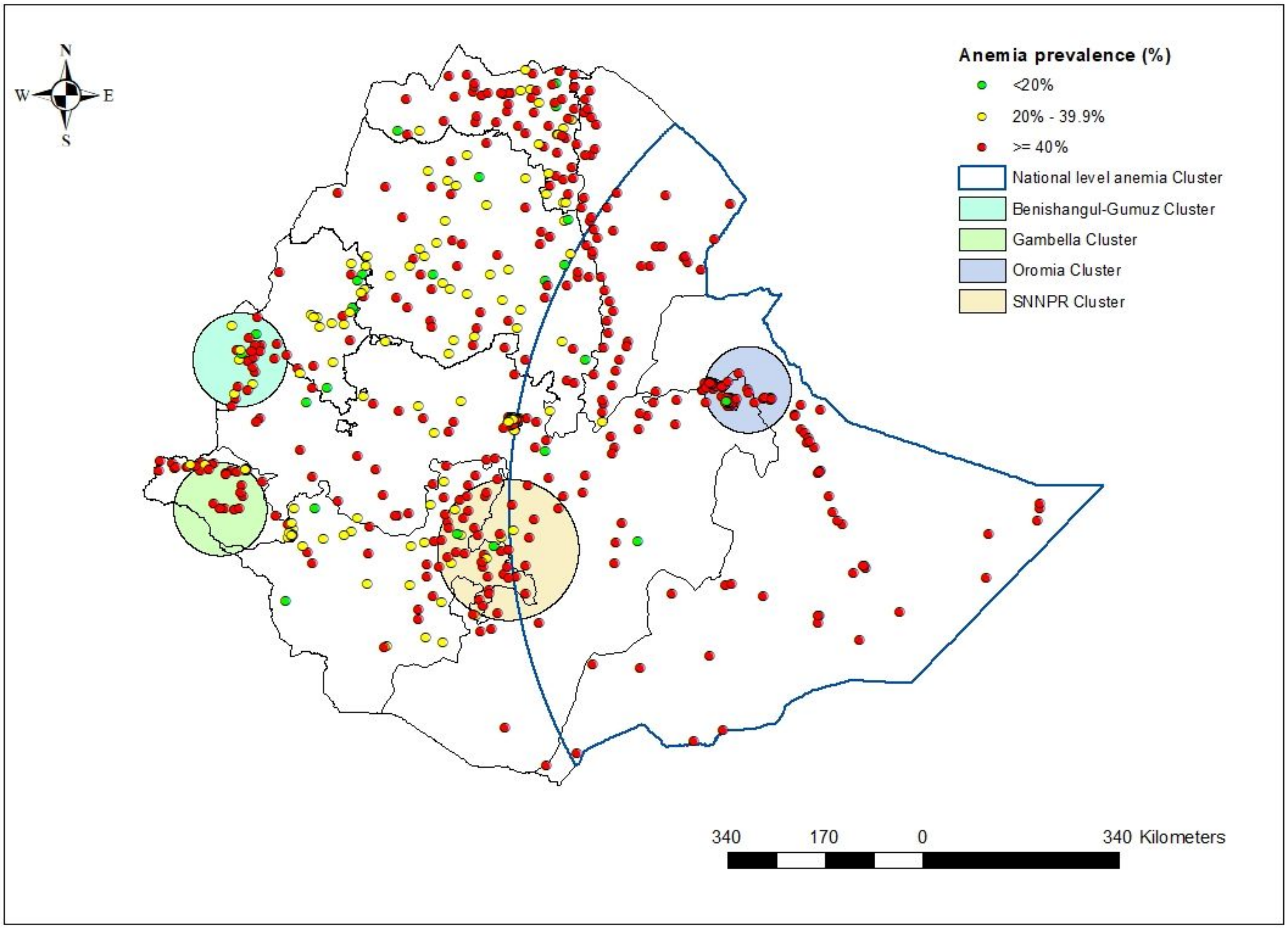

## Figure 1

visualization of hemoglobin concentration across EDHS 2016 Enumeration areas.




## Figure 2

Geospatial distribution of anemia in Ethiopia using LISA and Gi(d) local statistics, EDHS 2016.




## Figure 3

spatial SaTScan statistics result of anemia clustering among preschool children, Ethiopia