Spatial Distribution and Determinant Factors of Anaemia Among Adults Aged 15-59 in Ethiopia; Using Mixed-Effects Ordinal Logistic Regression Model

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Abstract

Background: Anaemia is a global public health problem particularly in developing countries. Assessing the geographical distributions and determinant factors is a key and crucial step in designing targeted prevention and intervention programmes to address anaemia. Thus, the current study aimed to assess the spatial distribution and determinant factors of anaemia among adults aged 15-59 in Ethiopia.

Methods: A secondary data analysis was done based on 2016 Ethiopian Demographic and Health Surveys (EDHS). Total weighted samples of 29,140 adults were included. Data processing and analysis were performed using STATA 14; ArcGIS 10.1 and SaTScan 9.6 software. Spatial autocorrelation was checked using Global Moran's index (Moran's I). Hotspot analysis was made using Gettis-OrdGi*statistics. Additionally, spatial scan statistics were applied to identify significant primary and secondary cluster of anaemia. Mixed effect ordinal logistics were fitted to determine factors associated with the level of anaemia.

Result: The spatial distribution of anaemia among adults age 15-59 was found to be clustered in Ethiopia (Global Moran's I = 0.81, p value < 0.0001). In the multivariable mixed-effect ordinal regression analysis; being females [AOR = 1.53; 95% CI: 1.42, 1.66], never married [AOR = 0.86; 95% CI: 0.77, 0.96], higher educated [AOR = 0.71; 95% CI: 0.60, 0.84], rural residents [AOR = 1.53; 95% CI: 1.23, 1.81], rich wealth status [AOR = 0.77; 95% CI: 0.69, 0.86] and underweight [AOR = 1.15; 1.06, 1.24] were significant predictors of anaemia among adults.

Conclusions: A significant clustering of anaemia among adults aged 15-59 were found in Ethiopia and the significant hotspot areas with high clusters of anaemia were identified in Somalia, Afar, Gambella, Dire Dewa and Harari regions. Besides, gender, marital status, educational level, place of residence, region, wealth index and body mass index (BMI) were significant predictors of anaemia. Therefore, effective public health intervention and nutritional education should be designed in the identified hotspot areas and risk groups to decrease the incidence of anaemia.

Background

Anaemia is a condition characterized by a low blood hemoglobin concentration (below 130 g/L for men, 120 g/L for non-pregnant women and below 110 g/L in pregnant women). In such condition the oxygen-carrying capacity of Red blood cells (RBCs) is insufficient to meet the physiological needs. It is a global public health problem particularly in low- and middle-income countries (1, 2).

Globally, over a quarter of the world population is affected by anaemia. Anaemia can affect the population of all age groups with the highest prevalence is in preschool-age children (47.4%), the lowest prevalence is in men (12.7%) and the greatest number of individuals affected among non-pregnant women (468.4 million) (3, 4). In Africa, prevalence rates of 16.8 to 33.8% among adults was reported from Uganda (5) whereas another study in South Africa (6) indicated anaemia prevalence is 12.5% in males and 13.2% in females. In Ethiopia, prevalence of 13% was reported among adults of both sexes (7).

Micronutrient deficiencies, parasitic infection, infectious diseases like TB, HIV, and maternal blood loss are common causes of anaemia in developing countries. The occurrence of the risk factors of anaemia concomitantly makes the efforts to single out a definitive cause challenging, especially in resource poor settings (8–10). Drug toxicity, deficiencies of iron, certain vitamins, copper, and protein are additional contributing factors for anaemia and Iron deficiency is the most common cause of anaemia responsible for 75% of anaemia cases (11).

Anaemia has large negative consequences on the health and economic wellbeing of nations and communities (12). In Ethiopia, despite the efforts to reduce anemia nationally, it is still an important public health problem and there is geographical variation (13). Assessing the geographic distributions of anemia and determinant factors are key and crucial step in designing targeted prevention and intervention programmes to address anaemia. Moreover, mapping the spatial distribution of anaemia prevalence by regions can help focus resources for prevention and treatment in the hot spot areas. Therefore, this study aimed to assess the spatial distribution and determinant factors of anaemia among adults aged 15–59 in Ethiopia using mixed-effect ordinal logistic regression.

Methods

Data

This study was a secondary data analysis based on 2016 Ethiopian Demographic and Health Surveys (EDHS). The 2016 EDHS was used a stratified two-stage cluster sampling technique using 2007 Population and Housing Census (PHC) as a sampling frame. Stratification was achieved by separating each region into urban and rural areas. Accordingly, a total, 21 sampling strata had been created.

In the first stage, 645 Enumeration Areas (EAs) (202 in urban areas and 443 in rural areas) were selected with probability proportional to the enumeration area size and with independent selection in each sampling stratum. At the second stage, since the time has passed since the PHC, a complete household listing operation was carried out in all selected EAs before the start of fieldwork and on average 28 households were systematically selected.

In the EDHS 2016, blood specimens for anaemia testing were collected from women and men that voluntarily consented to be tested. Blood samples were drawn from a drop of blood taken from a finger prick and collected in a micro cuvette. Hemoglobin analysis was carried out on site using a battery-operated portable HemoCue analyzer. The detailed sampling procedure and the anaemia testing data (14) were presented in the full 2016 EDHS report. In the current study, total weighted samples of 29,140 adults were included. Latitude and longitude coordinates had been also taken from selected EAs (clusters).

Study variables

The outcome variable for this study was hemoglobin level in the blood, a key indicator for anaemia. Hemoglobin levels (after adjusting for cigarette smoking and altitude in enumeration areas that are above 1,000 meters) in which women and men are considered not anaemic, mild, moderate and severe anaemic were presented in Table 1. Gender, age, marital status, educational level, place of residence, region, wealth index, source of drinking water, type of toilet facility, and Body Mass Index (BMI) were included as an independent variable in this study.

Table 1
Description of outcome variable used in the analysis

Anaemia levels	**Respondents (Hemoglobin level in g/dl)**		
	Pregnant women	**Non-pregnant women**	**Men**
Not anaemic	≥ 11.0	≥ 12.0	≥ 13.0
Mild	10.0-10.9	10.0-11.9	10.0-12.9
Moderate	7.0-9.9	7.0-9.9	7.0-9.9
Severe	< 7.0	< 7.0	< 7.0

Data source and extraction

The data for this study was taken from the demography heath survey (DHS) program official database www.measuredhs.com, after authorization was granted through online request by explaining the goal of our study. We used the Personal Record (PR file) data set and extracted the outcome and independent variables.

Data processing and management

Data processing and analysis were performed using STATA 14; ArcGIS 10.1 and SaTScan 9.6 software. The data were weighted using sampling weight, primary sampling unit and strata before any statistical analysis to restore the representativeness of the survey and to tell the STATA to take into account the sampling design when calculating standard errors to get reliable statistical estimates. Cross tabulations and summary statistics were conducted to describe the study population.

Spatial analysis

Spatial autocorrelation analysis

The existence of spatial autocorrelation was checked using Global Moran's index (Moran's I). Global Moran's index (Moran's I) was used to identify the presence of spatial autocorrelation. Moran's I value ranges from-1 to 1 (15). A value close to 1 indicates a strong positive spatial autocorrelation, whereas a value close to -1 indicates a strong negative spatial autocorrelation. If Moran's I close to 0, it indicates that there is no spatial autocorrelation. A statistically significant Moran's I ($p < 0.05$) led to the rejection of

the null hypothesis (anemia is randomly distributed) and showed the presence of spatial autocorrelation. Hotspot analysis was made using Gettis-OrdGi*statistics.

Spatial scan statistical analysis

Spatial scan statistics were applied to identify a significant primary (most likely) and secondary cluster of anemia using Kuldorff's SaTScan software. SaTScan™ works with a moving window and requires fixing of the window size that moves across the study area. The outcome variable (anaemic and not anaemic) has a Bernoulli distribution so; the Bernoulli model was used by applying the Kulldorff method for purely spatial analysis.

Adults who were anaemic (mild, moderate, and severe) were taken as cases and those who were not anaemic were taken as controls to fit the Bernoulli model. 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. Areas with high Log Likelihood Ratio and significant p-value were considered as areas with high anaemic compared to areas outside of the window.

Statistical analysis

Since the EDHS data has a hierarchical nature, adults within a cluster may be more similar to each other than adults in the other cluster. Due to this, the assumption of independence of observations and equal variance across clusters might be violated. Therefore, an advanced statistical model is required to take into account the between cluster variability to get a reliable standard error and unbiased estimate.

Furthermore, by taking into account the ordinal nature of the outcome variable, ordinal logistic regression and mixed effect ordinal logistic were fitted. Model comparison was done based on Information Criteria. Mixed effect model with the lowest Information Criteria was selected **(**Table 2**).** Adjusted Odds Ratio (AOR) with a 95% Confidence Interval (CI) and p-value 0.05 in the multivariable model were used to declare the determinant factors of anaemia. The assumption of proportional odds was checked and the results tell that the assumption of proportional odds is plausible at 5% level of significance for all considered covariates in the model.

Table 2
Model comparison between ordinal logistic regression & mixed effect ordinal logistic regression.

Proposed models	AIC value	BIC value
Ordinal logistic regression	30925.94	31229.31
Mixed effect ordinal logistic	30543.93	30855.5

AIC: Akaike Information Criteria; BIC: Bayesian Information Criteria

Results

Characteristics of study population

In this study, a total of weighted samples of 29,140 adults were included. Among this respondent, more than half (53.04%) of them were females, more than one-third of them were uneducated (38.51%), 34.94% were poor in wealth index and more than three fourth (80.61%) of them were rural residents. Around 5,142 (20.73%) of the study participants were in the age range of 15 to 19 years. Concerning the marital status, around 18,249 (62.62%) respondents were married while 8,889 (30.51%) respondents were never married. Near to one third (35.98%) of the study participants were from Oromia region. Only 6.77% of the respondents had improved toilet facility, whereas near to two third (64.50%) of study participants used improved drinking water. Regarding, the body mass index, more than one quarter (26.44%) of the respondents were underweight (Table 3).

Table 3
Characteristics of respondents in Ethiopia from January 18 to June 27, 2016 (N = 29,140)

Variables	Anaemia level (weighted frequency)				Total	Percent
	Not anemic	Mild	Moderate	Severe		
Gender						
Female	12,674	2,050	626	106	15,456	53.04
Male	11,847	1,413	375	49	13,684	46.96
Age						
15–19	5,142	699	179	20	6,040	20.73
20–24	3,987	508	157	27	4,679	16.06
25–29	4,271	563	200	27	5,061	17.37
30–34	3,308	501	193	37	4,039	13.86
35–39	2,952	429	103	18	3,502	12.02
40–44	2,097	362	73	12	2,544	8.73
45–49	1,746	233	57	14	2,050	7.04
50–54	549	99	20	0	668	2.29
55–59	469	68	20	0	557	1.91
Marital status						
Never married	7,752	892	223	22	8,889	30.51
Married	15,092	2,329	712	116	18,249	62.62
Widowed	424	70	19	6	520	1.78
Divorced	1,253	172	46	11	1,482	5.09
Educational level						
Uneducated	9,124	1,498	490	109	11,221	38.51
Primary	10,426	1,487	399	36	12,348	42.37
Secondary	3,264	360	68	9	3,701	12.70
Higher	1,664	115	44	0	1,823	6.25
Don’t know	44	3	0	0	47	0.16
Place of residence						

BMI: Body Mass Index; SNNPR: Southern Nation and Nationality and Peoples Regions

Variables	Anaemia level (weighted frequency)				Total	Percent
	Not anemic	Mild	Moderate	Severe		
Urban	5,018	524	103	6	5,651	19.39
Rural	19,503	2,940	897	149	23,489	80.61
Region						
Tigray	1,744	234	60	7	2,045	7.02
Afar	141	44	20	2	207	0.71
Amhara	6,920	779	136	11	7,846	26.92
Oromia	8,593	1,379	432	80	10,484	35.98
Somali	404	150	112	22	688	2.36
Benishangul	243	28	7	0	278	0.95
SNNPR	5,051	695	193	28	5,967	20.48
Gambella	66	10	2	0	78	0.27
Harari	43	7	3	1	54	0.18
Addis Ababa	1,205	116	28	1	1,350	4.63
Dire Dawa	113	21	8	1	143	0.49
Wealth index						
Poor	8,115	1,445	522	101	10,183	34.94
Middle	4,863	689	190	12	5,754	19.74
Rich	11,543	1,330	288	42	13,203	45.31
Source of drinking water						
Improved	16,142	2,071	528	54	18,795	64.50
Not improved	8,379	1,392	473	101	10,345	35.50
Type of toilet facility						
Improved	1,710	209	50	3	1,972	6.77
Not improved	22,811	3,254	951	152	27,168	93.23
BMI						
Underweight	6,390	963	300	52	7,705	26.44

BMI: Body Mass Index; SNNPR: Southern Nation and Nationality and Peoples Regions

Variables	Anaemia level (weighted frequency)				Total	Percent
	Not anemic	Mild	Moderate	Severe		
Normal	16,715	2,324	655	90	19,784	67.89
Overweight	1,124	135	40	13	1,313	4.51
Obese	292	41	5	1	339	1.16
BMI: Body Mass Index; SNNPR: Southern Nation and Nationality and Peoples Regions						

Spatial analysis of anemia

Spatial distribution of anemia

The spatial distribution of anaemia among adults aged 15–59 was identified to be clustered in Ethiopia (Global Moran's I = 0.81, p value < 0.0001) (Fig. 1). The highest proportion of anaemia were found in the Somalia, Afar, and Gambella and regions, whereas low proportion of anemia was located in the Amhara, Tigray, northern part of SNNPR and Benishangul regions (Fig. 2) .

Gettis-OrdGi statistical analysis of anemia

Based on the Gettis-OrdGi statistical analysis, this study identified hotspots and cold spot areas of anaemia among adults aged 15–59 in Ethiopia. Accordingly, the red colors indicate the significant hotspot area (higher cluster of anaemia), which were found in the Somalia, Afar, Gambella, Dire Dewa and Harari regions. In contrast, the blue color indicates significant cold spot areas (low cluster of anaemia), located in the Amhara, central Tigray and northern part of SNNPR and Benishangul regions (Fig. 3).

Spatial SaTScan analysis of anaemia (Bernoulli based model)

A spatial scan statistical analysis recognized a total of 193 significant primary and secondary clusters. Among these, 192 clusters were primary (most likely) clusters which were located in the Somalia, Dire Dewa, Harari and eastern part of Oromia region at 5.589269 N and 44.175032 E, with 647.61 km radius, a Relative Risk (RR) of 1.89, and Log-Likelihood Ratio (LRR) of 237.90, at p-value < 0.01 (Table 4). This told us that adults within the spatial window had 1.89 times higher risk of experiencing anaemia as compared to adults outside the spatial window. The secondary clusters were found in border areas between SNNPRs and Oromia regions (Fig. 4).

Table 4
Significant spatial clusters with high rate of Anaemia among adults age 15–59 in Ethiopia, 2016.

Cluster	Enumeration area (cluster) identified	Coordinate (radius)	Population	Case	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, 44, 534, 179, 257, 387, 157, 397, 56, 607, 228, 28, 614, 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, 202, 441, 594, 613, 352, 74, 519, 380, 535, 273, 471, 631, 151, 5, 185, 444, 111, 514, 282, 27, 390, 606, 493, 385, 224, 467, 644, 43, 363, 190, 546, 101, 140, 25, 93, 7, 476, 412, 529, 245, 123, 333, 506, 319, 422, 122, 491, 562, 213, 34, 71, 82, 518, 49, 26, 619, 51, 405, 524, 230, 564, 468, 576, 313, 365, 316, 589, 39, 438, 601, 149, 398, 336, 12, 125, 391, 522, 600, 445, 578, 484, 135	(5.589269 N, 44.175032 E) / 647.61 km	6265	1638	1.89	237.90	< 0.001
2	180	(6.720108 N, 37.624880 E) / 0 km	113	45	2.56	19.19	< 0.001
LLR: Likelihood ratio; RR: Relative risk							

Determinant factors of anaemia

Based on multivariable mixed-effects ordinal logistic regression model, gender, marital status, educational level, place of residence, region, wealth index and BMI were significantly associated with the level of anaemia among adults in Ethiopia at p-value 0.05 (Table 4).

The odds of female adult having severe anaemia (Compared to moderate, mild or non-anaemic) were 1.53 times higher than male adults while keeping other variables constant (OR = 1.53; 95% CI: 1.42, 1.66). Making other variables constant, the likelihoods of never married adult experiencing severe anaemia (relative to moderate, mild or non-anaemic) were 0.86 times lower than married adults (OR = 0.86; 95% CI: 0.77, 0.96).

Educational level was an important variable that showed significant association with level of anaemia among adults in Ethiopia. Holding other variables constant, the chances of uneducated adults developing severe anaemia (versus moderate, mild or non-anaemic) were 0.90, 0.81, 0.71 times lower than primary, secondary and higher educated adults respectively.

The odds of rural adult experiencing severe anaemia (against moderate, mild or non-anaemic) were 1.53 times higher than urban adults while adjusting for other variables (OR = 1.53; 95% CI: 1.23, 1.81). Keeping other variables constant, the likelihoods of underweight adult having severe anaemia (opposed to moderate, mild or non-anaemic) were 1.15 times higher than normal adults (OR = 1.15; 95% CI: 1.06, 1.24).

The likelihoods of rich adult developing severe anaemia (compared to moderate, mild or non-anaemic) were 0.77 times lower than poor adults (OR = 0.77; 95% CI: 0.69, 0.86) while holding other variables constant.

Regarding region, adults residing in Afar, Somali, Harari and Dire Dawa were 1.68, 3.43, 1.48 and 2.04 times more likely to be severe anaemic (relative to moderate, mild or non-anaemic) than adults residing in Oromia respectively whereas the odds of severe anaemic (opposed to moderate, mild or non-anaemic) were decreased by 40%, 37% and 24% among adults residing in Amhara, Benishangul and SNNPR as compared with adult residing in Oromia respectively.

Table 5
Bi-variable and multivariable mixed-effects ordinal logistic regression model of anaemia among adults age 15–59 in Ethiopia, 2016. ((N = 28,450))

Variables	Crude odds ratio		Adjusted odds ratio		
	OR	95% CI	OR	95% CI	P-value
Gender					
Male	Ref	Ref	Ref	Ref	Ref
Female	1.57	[1.47, 1.68]	1.53	**[1.42, 1.66]**	**< 0.001**
Age					
15–19	Ref	Ref	Ref	Ref	Ref
20–24	1.01	[0.90, 1.12]	0.96	[0.85, 1.08]	0.49
25–29	1.12	[1.01, 1.25]	1.04	[0.91, 1.18]	0.59
30–34	1.28	[1.14, 1.43]	1.12	[0.97, 1.29]	0.12
35–39	1.15	[1.02, 1.29]	1.01	[0.86, 1.17]	0.95
40–44	1.16	[1.02, 1.32]	1.03	[0.88, 1.21]	0.70
45–49	1.02	[0.88, 1.18]	0.91	[0.76, 1.08]	0.29
50–54	0.99	[0.78, 1.24]	1.13	[0.87, 1.46]	0.37
55–59	1.06	[0.82, 1.37]	1.18	[0.89, 1.57]	0.26
Marital status					
Married	Ref	Ref	Ref	Ref	Ref
Never married	0.74	[0.69, 0.80]	0.86	**[0.77, 0.96]**	**0.01**
Widowed	1.13	[0.91, 1.40]	0.99	[0.80, 1.24]	0.98
Divorced	1.02	[0.88, 1.17]	0.96	[0.83, 1.11]	0.62
Educational level					
Uneducated	Ref	Ref	Ref	Ref	Ref
Primary	0.72	[0.67, 0.78]	0.90	**[0.83, 0.98]**	**0.02**
Secondary	0.58	[0.51, 0.65]	0.81	**[0.71, 0.92]**	**0.02**
Higher	0.47	[0.40, 0.55]	0.71	**[0.60, 0.84]**	**< 0.001**
Don’t know	0.33	[0.12, 0.95]	0.46	[0.16, 1.32]	0.15

AOR: Adjusted Odd ratio; COR: Crude Odd Ratio; CI: Confidence interval; SNNPR: Southern Nation and Nationality and Peoples Regions

Variables	Crude odds ratio		Adjusted odds ratio		
	OR	95% CI	OR	95% CI	P-value
Place of residence					
Urban	Ref	Ref	Ref	Ref	Ref
Rural	1.93	[1.64, 0.27]	1.53	**[1.23, 1.81]**	**< 0.001**
Region					
Oromia	Ref	Ref	Ref	Ref	Ref
Tigray	0.79	[0.62, 1.02]	0.80	[0.64, 1.02]	0.06
Afar	2.38	[1.84, 3.09]	2.04	**[1.61, 2.59]**	**< 0.001**
Amhara	0.61	[0.47, 0.77]	0.60	**[0.48, 0.76]**	**< 0.001**
Somali	3.76	[2.95, 4.79]	3.43	**[2.75, 4.28]**	**< 0.001**
Benishangul	0.66	[0.50, 0.87]	0.63	**[0.49, 0.81]**	**< 0.001**
SNNPR	0.75	[0.59, 0.96]	0.76	**[0.60, 0.94]**	**0.01**
Gambella	1.02	[0.78, 1.34]	1.10	[0.86, 1.41]	0.44
Harari	1.13	[0.85, 1.51]	1.48	**[1.13, 1.93]**	**0.01**
Addis Ababa	0.53	[0.40, 0.69]	1.01	[0.77, 1.34]	0.92
Dire Dawa	1.18	[0.89, 1.56]	1.68	**[1.28, 2.19]**	**< 0.001**
Wealth index					
Poor	Ref	Ref	Ref	Ref	Ref
Middle	0.811	[0.73, 0.91]	0.92	[0.83, 1.03]	0.17
Rich	0.59	[0.53, 0.66]	0.77	**[0.69, 0.86]**	**< 0.001**
Source of drinking water					
Not improved	Ref	Ref	Ref	Ref	Ref
Improved	0.87	[0.80, 0.96]	1.05	[0.96, 1.14]	0.32
Type of toilet facility					
Not improved	Ref	Ref	Ref	Ref	Ref
Improved	0.94	[0.84, 1.07]	1.01	[0.90, 1.15]	0.81

AOR: Adjusted Odd ratio; COR: Crude Odd Ratio; CI: Confidence interval; SNNPR: Southern Nation and Nationality and Peoples Regions

Variables	Crude odds ratio		Adjusted odds ratio		
	OR	95% CI	OR	95% CI	P-value
BMI					
Normal	Ref	Ref	Ref	Ref	Ref
Underweight	1.09	[1.01, 1.17]	1.15	**[1.06, 1.24]**	**< 0.001**
Overweight	0.94	[0.81, 1.09]	0.88	[0.76, 1.02]	0.09
Obese	0.99	[0.77, 1.27]	0.88	[0.68, 1.14]	0.33
Intercepts					
Cut1	-	-	2.05	[1.76, 2.34]	**< 0.001**
Cut2	-	-	3.57	[3.28, 3.86]	**< 0.001**
Cut3	-	-	5.70	[5.39, 6.03]	**< 0.001**
Random intercept					
Var(cons)	-	-	0.28	[0.23, 0.34]	-
AOR: Adjusted Odd ratio; COR: Crude Odd Ratio; CI: Confidence interval; SNNPR: Southern Nation and Nationality and Peoples Regions					

Discussion

This study was aimed to investigate the spatial distribution and determinants of anaemia among adults in Ethiopia. The spatial analysis result showed that the spatial distribution of anaemia among adults was significantly varied across the country. In multivariable mixed-effect ordinal regression analysis; gender, marital status, educational level, place of residence, region, wealth index and body mass index were significant predictors of the level of anaemia among adults in Ethiopia.

The present study documented that the spatial distribution of anaemia among adults was significantly varied across the country, where significant hotspot areas of anaemia were identified in the Somalia, Afar, Gambella, Dire Dewa and Harari regions. This spatial variation might be due to the difference in socioeconomic status, infectious disease risk (such as malaria, hookworm and etc.), dietary diversity and food security (16).

According to the current study, the odds of female adults having severe anaemia (Compared to moderate, mild or non-anaemic) were higher than male adults. This finding is in line with studies conducted in India (17) and United States of America (18). Such similar finding might be due to women experienced more blood loss through menstruation and greater demand on the blood supply for the developing fetus during pregnancy.

In agreement with another study (19), the current study revealed that the chances of uneducated adults developing severe anaemia (versus moderate, mild or non-anaemic) were higher than educated adults. The possible explanations for such results might be due to low socio-economic status, risky lifestyle and low diseases prevention knowledge and skilled among uneducated adults as compared to educated adults.

The present study documented that the odds of rural adults experiencing severe anaemia (against moderate, mild or non-anaemic) were higher than urban adults and this is of course congruent with other reports (19, 20). The possible reasons might be rural adults more likely to have low socioeconomic status, low chance of accessing iron-rich foods and lack of adequate nutrition information as compared to urban adults (19).

In line with other study (20), the present study reported that likelihoods of rich adult developing severe anaemia (compared to moderate, mild or non-anemic) were lower than poor adults. Such result indicates that poor adults have less access to nutritious food and fall sick more frequently as compared to the rich adults. This finding may not be surprising because keeping food security is a big issue among poor families (21).

According to the current study, the likelihoods of underweight adults having severe anaemia (opposed to moderate, mild or non-anaemic) were higher than normal adults. Even though a higher body mass index may not always show proper micronutrient consumption, an underweight (BMI < 18.5 g/m^2) person is more likely to have other concomitant comorbidity illness and scarce some essential micronutrients that may be related with anaemia (20).

The current study has some strengths and limitations that need to be in mind while interpreting the result. The first strength of the current study was using large population-based data with a large sample size, which is representative at national and regional levels, so it can be generalized to adult aged 15 to 59 in Ethiopia. Secondly, the combined use of both ArcGIS and Sat Scan statistical tests facilitated to identify similar and statistically significant areas with a high cluster of anaemia (hot spot area). Furthermore, by considering the ordinal nature of the outcome variable and cluster nature of data, the current study applies an advanced model (mixed effect ordinal logistic regression) to get reliable standard errors and parameter estimates.

The first limitation of the present study were the location of data values was displaced up to 2 kilometers for urban and up to 5 kilometers for rural areas to ensure respondent confidentiality, thus, this was the challenge to know the exact cases of ’ location. Since the current study used secondary data, some important variable like dietary intake and presence of hookworm infection were not included in the analysis.

Conclusion

A significant clustering of anaemia among adults aged 15–59 was found in Ethiopia and the significant hotspot areas with high cluster anaemia were identified in Somalia, Afar, Gambella, Dire Dewa and Harari regions. Besides, gender, marital status, educational level, place of residence, region, wealth index and BMI were significant predictors of anaemia. Therefore, effective public health intervention and nutritional education should be designed in the identified hotspot areas and risk groups to decrease the incidence of anaemia.

Abbreviations

AOR: Adjusted Odds Ratio; BMI: Body mass index; CI: Confidence Interval; CSA: Central Statistics Agency; DHS: Demography heath survey; EAs: Enumeration Areas; EDHS: Ethiopian Demographic and Health Survey; SNNPR: Southern Nation and Nationality and Peoples Regions

Declarations

Acknowledgments

We would like to thank the measure DHS for providing us the data and shape files for the study area.

Ethics approval and consent to participate

The study does not contain the collection of information from subjects. We sent a one-page proposal abstract of the study to the DHS program office. They gave permission to access the data with a reference number of 144749.

Consent for publication

Not applicable.

Availability of data and materials

All necessary information's and supplementary materials were included with the manuscript.

Competing interest

All authors declare no conflicts of interest.

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Authors’ contributions

Conception of the work, design of the work, acquisition of data, analysis, and interpretation of data were done by BS. Data curation, drafting the article, revising it critically for intellectual content, validation, and final approval of the version to be published were done by BS, SA and AB. All authors read and approved the final manuscript.

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Figures

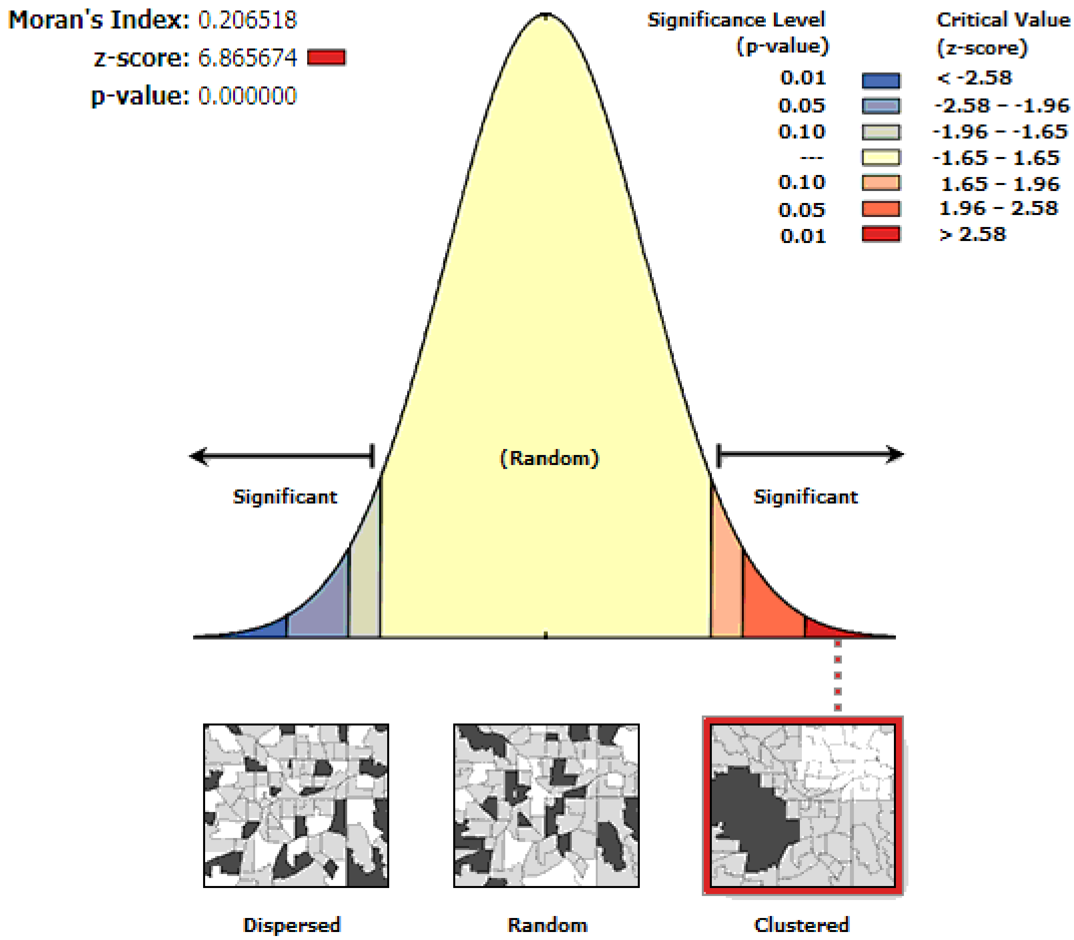

Figure 1

Spatial autocorrelation analysis of anaemia among adults aged 15-59 in Ethiopia, 2016

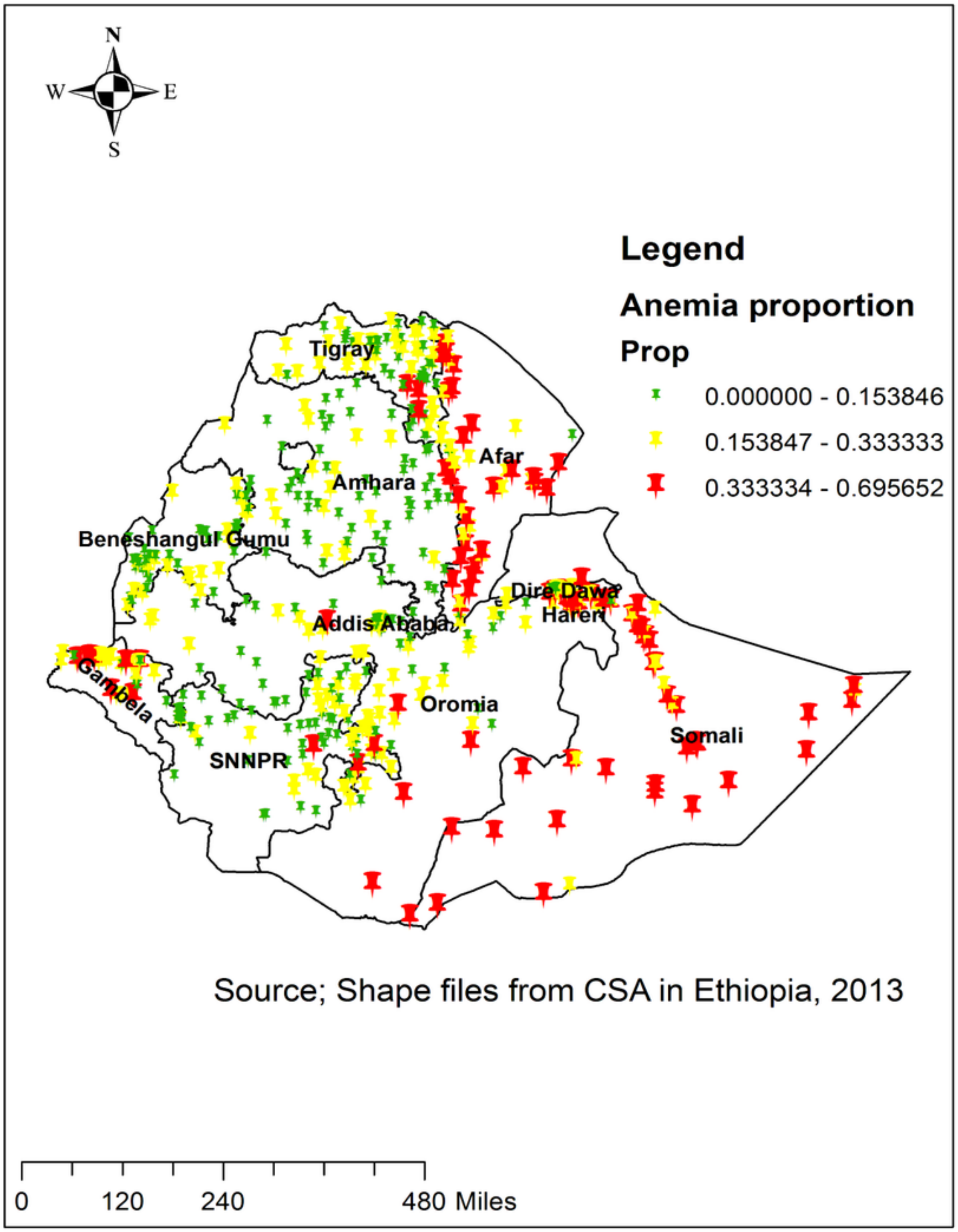

Figure 2

Spatial distribution of anaemia across regions among adults age 15-59 in Ethiopia, 2016

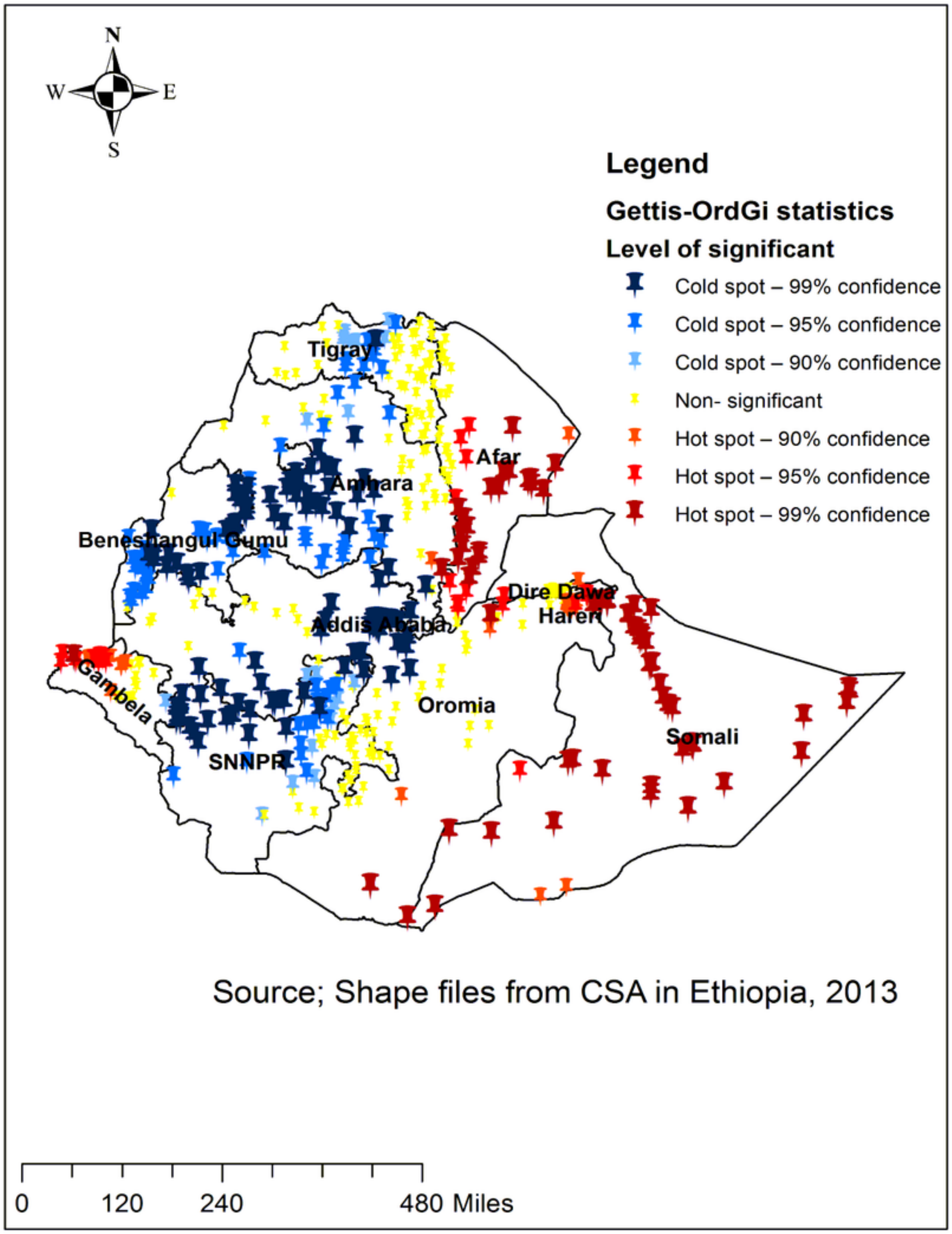

Figure 3

Hotspot and Cold areas anaemia across regions among adults age 15-59 in Ethiopia, 2016

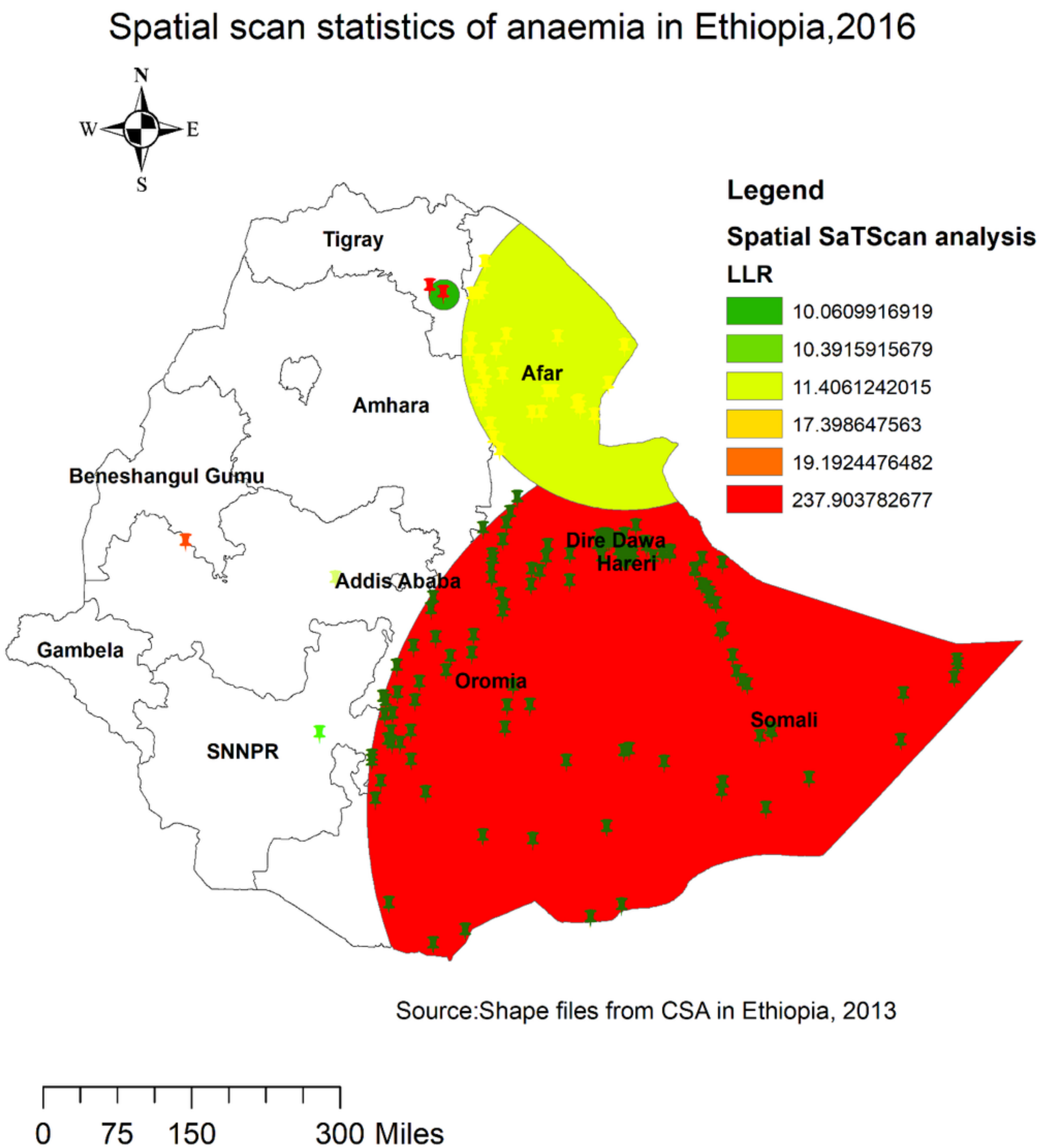

Figure 4

Primary and secondary clusters of Anaemia among adults age 15-59 in Ethiopia, 2016