Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Spatial variation of zero vitamin A-rich food consumption and associated factors among children aged 6-23 month in Ethiopia

Adugna Mengesha Mulugeta
adu12man@gmail.com
Debre Markos University
Anley Shiferaw Enawgaw
Debre Markos University
Yihenew Getahun Ambaw
Woldia University
Mequanent Dessie Bitewa
Debre Markos University
Smegnew Gichew Wondie
Mizan Tepi University
Tadele Derbew Kassie
Debre Markos University
Zinie Abita Mengie
Mizan Tepi University
Simegnew Adugna Kallu
Haramaya University
Berhanu Ayana Tafere
Debre Markos University
Tesfaye Shumet Mekonnen
Debre Markos University
Mikias Getahun Molla
Injibara University
Daniel Mulat Eshetu
Injibara University
Thomas Kidanemariam Yewodiaw
Amhara Region Emergency Operation Center
Ambachew Motbaynor Wubaye
Debre Tabor University
Birhanu Feleke Shitu

Jhpiego
Amare Mebrat Delie
Injibara University
Aysheshim Belaineh Haimanot
Debre Markos University
Yezbie Wagaw Ayicheh
Debre Markos University

Article

Keywords: zero vitamin A-rich food consumption, spatial regression, Ethiopia

Posted Date: April 9th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9340236/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Spatial variation of zero vitamin A-rich food consumption and associated factors among children aged 6-23 month in Ethiopia

Adugna Mengesha Mulugeta[1*], Anley Shiferaw Enawgaw[1], Yihenew Getahun Ambaw[2], Mequanent Dessie Bitewa[1], Smegnew Gichew Wondie[3], Tadele Derbew Kassie[1], Zinie Abita Mengie[3], Simegnew Adugna Kallu[4], Berhanu Ayana Tafere[1], Tesfaye Shumet Mekonnen[1], Mikias Getahun Molla[5], Daniel Mulat Eshetu[5], Thomas Kidanemariam Yewodiaw[6], Ambachew Motbaynor Wubaye[7], Birhanu Feleke Shitu[8], Amare Mebrat Delie[5], Aysheshim Belaineh Haimanot[1], Yezbie Wagaw Ayicheh[1]

[1]Department of Public Health, College of Medicine and Health Sciences, Debre Markos University, Debre Markos, Ethiopia

[1]Department of Public Health, College of Medicine and Health Sciences, Debre Markos University, Debre Markos, Ethiopia

[2]Department of Veterinary Medicine, College of Agricultural Sciences, Woldia University, Woldia, Ethiopia

[1]Department of Public Health, College of Medicine and Health Sciences, Debre Markos University, Debre Markos, Ethiopia

[3]Department of Public Health College of Medicine and Health Sciences, Mizan-Tepi University, Mizan Aman, Ethiopia.

[1]Department of Public Health, College of Medicine and Health Sciences, Debre Markos University, Debre Markos, Ethiopia

[3]Department of Public Health, College of Medicine and Health Sciences, Mizan-Tepi University, Mizan Aman, Ethiopia

[4]College of Veterinary Medicine, Haramaya University, Dire Dawa, Ethiopia

[1]Department of Midwifery, College of Medicine and Health Sciences, Debre Markos University, Debre Markos, Ethiopia.

[1]Department of Public Health, College of Medicine and Health Sciences, Debre Markos University, Debre Markos, Ethiopia

[5]Department of Public Health, College of Medicine and Health Sciences, Injibara University, Injibara, Ethiopia

[5]Department of Public Health, College of Medicine and Health Sciences, Injibara University, Injibara, Ethiopia.

[6]Medical Officer at International Medical Corps, Amhara Region Emergency Operation Center, Gondar Field Office, Gondar, Ethiopia

[7]Department of Veterinary Science, College of Agriculture and Environmental Sciences, Debre Tabor University, Debre Tabor, Ethiopia

[8]Norther Resilence Cluster office, Jhpiego, Ethiopia

[5]Department of Public Health, College of Medicine and Health Sciences, Injibara University, Injibara, Ethiopia

[1]Department of Public Health, College of Medicine and Health Sciences, Debre Markos University, Debre Markos, Ethiopia

[1]Department of Public Health, College of Medicine and Health Sciences, Debre Markos University, Debre Markos, Ethiopia

*Corresponding author: Adugna Mengesha Mulugeta

Email: adu12man@gmail.com

Abstract

Zero vitamin A-rich food consumption defined as the absence of any vitamin A-rich food intake among children aged 6–23 months within a 24-hour recall period. Substantial regional, socioeconomic, and agro-ecological disparities suggest that zero vitamin A-rich food consumption may exhibit geographic variation across the country. However, evidence on its spatial distribution and context-specific determinants remains limited. Therefore, this study aimed to assess the spatial variation of zero vitamin A-rich food consumption and its associated factors among children aged 6–23 months in Ethiopia using nationally representative data.

Methods: A community-based cross-sectional study was conducted using nationally representative data from the 2019 EMDHS. The study included a weighted sample of 1,543 children aged 6–23 months with complete information on vitamin A-rich food consumption. Stratified two-stage cluster sampling technique was applied in the original survey. Data were analyzed using Stata 16, ArcGIS 10.8, SaTScan 9.6, and MGWR 2.0. Spatial autocorrelation was assessed using Global Moran's I, and hot spot analysis was performed using the Getis-Ord Gi* statistic. Model comparison was conducted using adjusted R^2 and AICc values, and statistical significance was declared at $p < 0.05$ with a 95% confidence interval.

Result: The spatial distribution of zero vitamin A-rich food consumption among children aged 6–23 months was non-random in Ethiopia (Moran's I = 0.874, $p < 0.001$). Hot spot and spatial scan analyses identified 74 significant clusters. Maternal current pregnancy status, marital status, maternal education, number of under-five children, and age of the child were significant predictors of the spatial variation of zero vitamin A-rich food consumption.

Conclusion: Significant geographic variation in zero vitamin A-rich food consumption was observed across Ethiopia. Maternal education, current pregnancy status, number of under-five children, marital status, and child age were significant predictors. These findings highlight the need for geographically targeted, context-specific interventions.

Key word: zero vitamin A-rich food consumption, spatial regression, Ethiopia

Introduction

Optimal nutrition, defined as the adequate intake of energy, macronutrients, and essential micronutrients to meet age-specific physiological needs, which is fundamental for child survival, healthy growth, immune function, and cognitive development(1). The first two years of life represent a critical window of opportunity for establishing optimal nutritional status and long-term health outcomes. In particular, the period from 6 to 23 months is especially sensitive, as children transition from exclusive breastfeeding to complementary feeding while their nutritional requirements substantially increase. Inadequate complementary feeding during this stage exposes children to micronutrient deficiencies, recurrent infections, growth faltering, and an increased risk of morbidity and mortality (2-5).

Within this critical period of complementary feeding, micronutrient adequacy plays a central role in determining child health outcomes, among which vitamin A is of particular public health importance. It is an essential micronutrient required for vision, immune competence, epithelial integrity, and normal growth. Globally, its deficiency remains a major public health problem among infants and young children, particularly in low- and middle-income countries (2, 6, 7). The World Health Organization estimates that vitamin A deficiency affects millions of preschool-aged children worldwide and contributes substantially to preventable childhood morbidity and mortality by increasing susceptibility to infections such as measles and diarrheal diseases (6, 8, 9). Regular consumption of vitamin A-rich food is recognized as a sustainable, food-based strategy for the prevention of vitamin A deficiency (9).

Contrary to this Zero vitamin A-rich food consumption is defined as a child aged 6–23 months not consuming any foods rich in vitamin A during the 24-hour period preceding the survey (based on maternal recall). Despite global initiatives aimed at improving infant and young child feeding (IYCF) practices, zero consumption of vitamin A-rich foods remained widespread in many low-resource settings. Evidence from low and middle income countries shows that a large proportion of children aged 6–23 months fail to consume any vitamin A-rich foods within a 24-hour recall period (10). This problem is particularly pronounced in sub-Saharan Africa, where dietary diversity is constrained by poverty, food insecurity, low maternal education, limited access to health and nutrition services, and cultural feeding practices (2, 11). Seasonal food availability and geographic barriers further exacerbate inequalities in access to micronutrient-rich diets.

In Ethiopia, under-nutrition and micronutrient deficiencies remain persistent public health challenges, despite notable progress in reducing under-five mortality. National surveys indicate that complementary feeding practices among children aged 6–23 months remain suboptimal, with a considerable proportion of children not consuming vitamin A-rich foods (12, 13). Although vitamin A supplementation programs are implemented nationwide, reliance on supplementation alone does not ensure sustained micronutrient adequacy, highlighting the importance of food-based dietary sources. Studies using Ethiopian Demographic and Health Survey (EDHS) data have documented low dietary diversity and inadequate consumption of vitamin A-rich foods, influenced by maternal education, household wealth, child age, and access to health services (2, 14-17).

Ethiopia's marked regional, agro-ecological, socioeconomic, and cultural diversity suggests that zero vitamin A-rich food consumption may not be evenly distributed across the country(18). Variations in agricultural production, market access, health service coverage, and nutrition information dissemination are likely to produce geographic clustering of poor feeding practices(19). However, most existing studies have focused on national-level prevalence and associated factors, with limited attention to spatial heterogeneity. Spatial analytical approaches such as Global Moran's I, spatial scan statistics, and geographically weighted regression can identify geographic clustering and location-specific determinants, providing critical insights for targeted nutrition interventions.

Therefore, this study aims to examine the spatial variation of zero vitamin A-rich food consumption and its associated factors among children aged 6–23 months in Ethiopia using nationally representative data. Identifying geographic hotspots and context-specific determinants

will support evidence-based, geographically targeted strategies to improve complementary feeding practices and reduce micronutrient deficiencies particularly zero vitamin A-rich food consumption among Ethiopian children.

Methods

Study setting and period

This study was conducted in the Federal Democratic Republic of Ethiopia using nationally representative data from the 2019 Ethiopia Mini Demographic and Health Survey (EDHS). Ethiopia is located in the Horn of Africa and is administratively divided into nine regional states and two city administrations by the time of data collection that exhibit substantial geographic, socio-economic, cultural, and health service-related diversity, all of which may influence childhood vitamin A- rich food consumption. The EDHS covers all sampled regions including both urban and rural population allowing for comprehensive assessment of spatial variation at national level. This study was conducted from January to march 2026 to identify geographic clustering and associated factors of zero vitamin A-rich food consumption across regions of Ethiopia.

Study design

A community based cross sectional study design was employed using the 2019 MDHS**.**

Population

Source population

All living children aged 6-23 month and living in all enumeration areas.

Study population

All living children aged 6-23 month and living in selected enumeration areas prior to the survey.

Eligibility criteria

Inclusion criteria

All living children aged 6-23 month, living in selected enumeration areas and selected households prior to the survey.

Sample size determination and sampling procedure

The sampling procedure and sample size determination for this study was based on the 2019 Ethiopia Mini Demographic and Health Survey (EDHS), which employed a nationally representative, stratified two-stage cluster sampling. In the first stage, enumeration areas (EAs) were selected independently within each stratum (urban and rural strata for each region) using probability proportional to size based on the 2019 population census frame. In the second stage, a fixed number of households were systematically selected from each sampled EA. All eligible children aged 6–23 months living in the selected households were included in the survey, and for the present study, weighted sample of 1543 children with complete information on vitamin A-rich food consumption and relevant explanatory variables was included as final sample from KR.

Study variables

Dependent variable

Zero vitamin A-rich food consumption (yes/no). Percentage of children aged 6–23 months who did not consume any vitamin A rich food during previous days.

Independent variables

Explanatory variables included in this study were residence, altitude, age of the child, maternal education, marital status, maternal age, wealth index, sex of household head, pregnancy, breast feeding, age at the first birth, place of delivery, post natal care, ante natal care and number of under five children

Measurement

The variables included in the analysis, along with their calculated proportions, are presented in Table1.

172 **Table2. Measurements of explanatory variables**

Variables	**Measurements**
Number of under five- children	Proportion of children living with more than one under-five children
Antenatal care	Proportion of mother who received 3 or less ANC visits during last pregnancy
Residence	Proportion of children residing in rural areas
Altitude	Proportion of children residing in altitude ≥2,400 m above sea level
Age of the child	Proportion of children aged 12–23 months
Maternal education	Proportion of mothers who received at least primary level education
Marital status	Proportion of mothers currently married or living with man
Maternal age	Proportion of mothers aged ≥25
Wealth status	Proportion of children from middle /rich wealth quintile
Sex of household head	Proportion of household with female household head
Pregnancy	Proportion of children whose mother is currently pregnant
Breast feeding	Proportion of children whose mother is currently breast feeding
Age at first birth	Proportion of age mothers who gave birth before the age of 18
Place of delivery	Proportion of children who were delivered at home
Post natal care	Proportion of children who received postnatal care at 2 months

173

Data collection procedure and data quality assurance

The information was collected using standardized and structured questionnaires administered by trained field workers through computer-assisted personal interviewing (CAPI) technology. To maintain high data quality, comprehensive procedures were applied throughout the survey process. These included intensive training of data collectors, pretesting of survey instruments prior to field implementation, and close supervision during data collection.

Data processing and analysis

The data for this study were obtained from online DHS program. Different software packages were employed for data management and analysis, including Microsoft Excel, Stata version 16, ArcGIS version 10.8, Satscan version 9.6 and MGWR version 2.0. These tools were used for data extraction, cleaning, recoding, spatial visualization, and statistical analysis. Descriptive statistical methods were applied, and the results were presented using text, tables, and graphical illustrations.

Spatial autocorrelation analysis

Spatial autocorrelation analysis was conducted to assess whether the distribution of zero vitamin A-rich food consumption among children aged 6–23 months in Ethiopia was spatially random, clustered, or dispersed. Global Moran's I statistic was computed using cluster-level proportions of zero vitamin A-rich food consumption to quantify the overall spatial dependence across the study area.

Hot spot analysis

Assessing how events are distributed at the local level makes it possible to explore spatial interactions within the study area in greater detail. Local measures of spatial autocorrelation, including the Getis-Ord Gi* statistic, help identify significant hot and cold spots by generating a Z-score and corresponding p-value for each spatial unit(20). This method enhances understanding of spatial clustering patterns. In most cases, the statistic reflects the share of values within a particular area compared to the overall total, and its significance is evaluated according to a specified confidence threshold(21).

Spatial interpolation

The hot spot analysis was further refined using empirical Bayesian Kriging interpolation, enabling the estimation of zero vitamin A-rich food consumption in unsampled areas among children aged 6–23 months(21).

Spatial scan analysis

Spatial scan analysis was conducted using Kuldorff's SaTscan version 9.6 software with a Bernoulli-based model to identify significant primary and secondary clusters of zero vitamin A-rich food consumption among children aged 6–23 months. Within a circular scanning window covering the country, children who had not consumed any vitamin A-rich foods in the previous 24 hours were classified as cases, while those who had consumed them were considered controls. The maximum spatial cluster size was restricted to less than 50% of the population. Likelihood ratio tests, along with significance levels determined from 999 Monte Carlo replications, were used to detect the most probable clusters.

Spatial regression analyses

Spatial regression is essential for understanding the relationship between the occurrence of certain events and various environmental, demographic, and socioeconomic factors (22). Accordingly, this study aimed to examine how different explanatory variables are associated with the prevalence of zero vitamin A-rich food consumption among children aged 6–23 months.

Spatial exploratory regression

This regression approach examines all possible combinations of candidate explanatory variables to identify those that best account for the dependent variable based on user-defined criteria(23). Initially, potential combinations that could explain the geographical variation of the outcome were determined. Ordinary Least Squares (OLS) regression was then conducted, and model diagnostics were assessed, including R^2, adjusted R^2, variance inflation factor (VIF), Jarque-Bera statistic, joint F and Wald tests, and the Koenker (BP) statistic. The adjusted R^2 measures the proportion of variation in the outcome explained by the explanatory variables. The joint F and Wald statistics assess the overall significance of the model, with the Wald statistic preferred if the Koenker statistic is significant ($p < 0.01$). The Jarque-Bera statistic indicates the reliability of model predictions, where a high value suggests non-random residuals. The Koenker statistic evaluates the consistency of spatial processes, with significance pointing to non-stationarity. The VIF accounts for potential multicollinearity among variables(24). Residuals were also checked for spatial autocorrelation, and significant autocorrelation indicated that the OLS model was unreliable due to spatial heterogeneity. Therefore, using Geographically Weighted Regression (GWR) was necessary to obtain more accurate and locally sensitive estimates.

Geographically weighted regression analysis

For each cluster, the overall proportion of zero vitamin A-rich food consumption and the associated predictor variables were calculated. The Geographically Weighted Regression (GWR) used the same dependent and explanatory variables as those in the global OLS model. Parameter estimates for the GWR model were calibrated using Multiscale Geographically Weighted Regression (MGWR) version 2.0. Weights were determined through a kernel distance decay function (35), with the choice of kernel type guided by the spatial distribution of the data. Since the observations were clustered, an adaptive bi-square kernel was employed for geographic weighting, as it is well-suited for this type of data (24). A key consideration in GWR is the bandwidth parameter, which defines the number of neighbors or distance band and controls the degree of smoothing in the model (25). To simplify the model while accounting for the number of variables and the bandwidth, the AICc method was used to automatically select the bandwidth that minimizes AICc (24). Five explanatory variables were included, and notable clustering was observed. Therefore, the adaptive kernel identified via the golden section search method based on AICc was chosen to reduce model complexity. The model with the lowest AICc was considered the best fit for estimating local parameters. Model performance was compared between GWR and OLS using adjusted R^2 and AICc, with the optimal model having a high adjusted R^2 and low AICc (26). Finally, after accounting for the spatial dependencies observed in the OLS residuals, the GWR residuals were tested for spatial autocorrelation to confirm whether they were randomly distributed.

Ethical considerations

This study analyzed publicly accessible secondary data from the 2019 Ethiopia Mini Demographic and Health Survey (MDHS). While ethical approval had already been secured by

the original data collectors and no further clearance was required for this research, permission to access the dataset was formally requested and granted through the online DHS program.

Results

Among the total weighted sample of 1,543 included in the analysis slightly more than half of the mothers had received formal education (51.20%), while the remaining 48.80% had no formal schooling. More than half of the households had more than one under-five child (57.10%), and a greater proportion of respondents belonged to the middle or rich wealth index category (53.40%). Concerning maternal and child health service utilization, more than half of the mothers did not attend any antenatal care visit (58.33%), and home delivery was more common than delivery at a health facility (56.57% vs. 43.43%)(Table 3).

Spatial distribution of ZVA rich food consumption

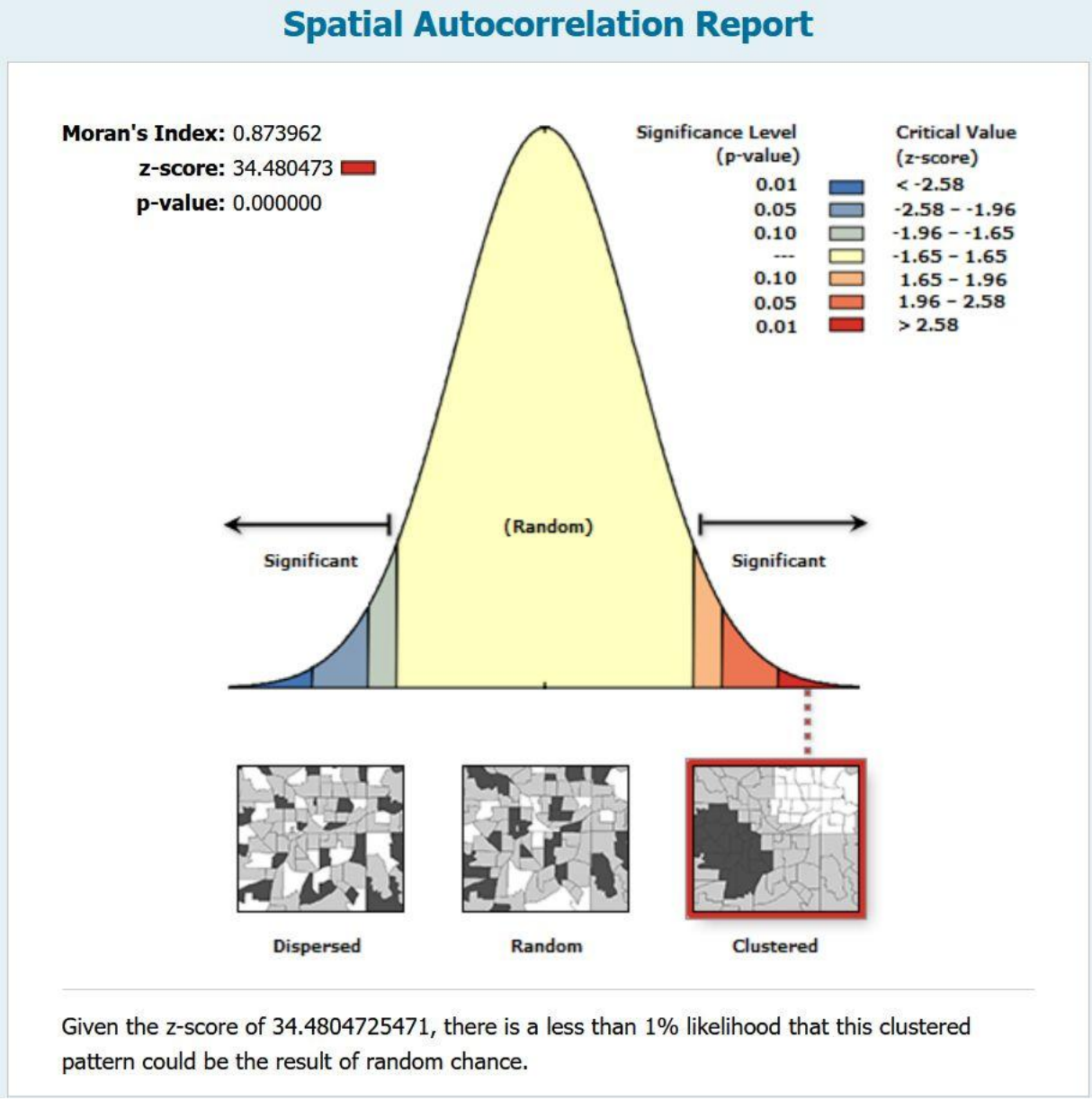


Figure 1. Global spatial autocorrelation analysis

The global Moran's Index of 0.874 indicates a very high degree of positive spatial autocorrelation, meaning that areas with similar levels of ZVA-rich food consumption tend to be located near one another rather than being randomly distributed with z score of 34.48047 and P_value <0.001(Figure 2).

The hot spot analysis using the Getis-Ord Gi* statistics showed significant hot spots spot areas in most part of Amhara, Tigray, some part of Afar, and Somali (Figure 3) .

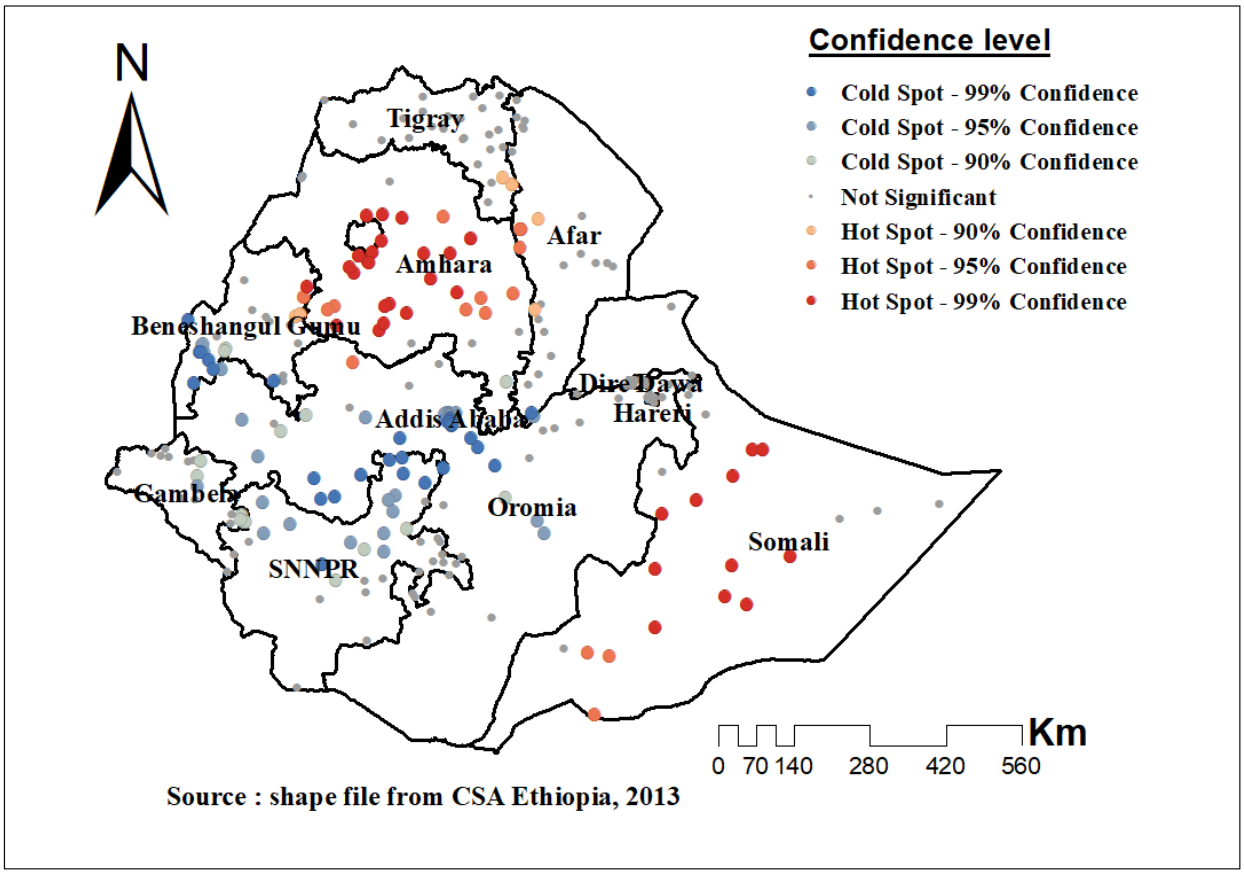


Figure 4. Hot spot analysis

Empirical Bayesian Kriging interpolation

Among Ethiopian children aged 6–23 months, empirical Bayesian Kriging interpolation was used to estimate spatial variations in zero vitamin A-rich food consumption, identifying areas with both high and low predicted prevalence. Accordingly, zero vitamin A-rich food consumption was markedly concentrated in almost all Amhara, most part of Somali, southern Tigray, western afar, and tip of northern, eastern &southern Oromia (Figure 5).

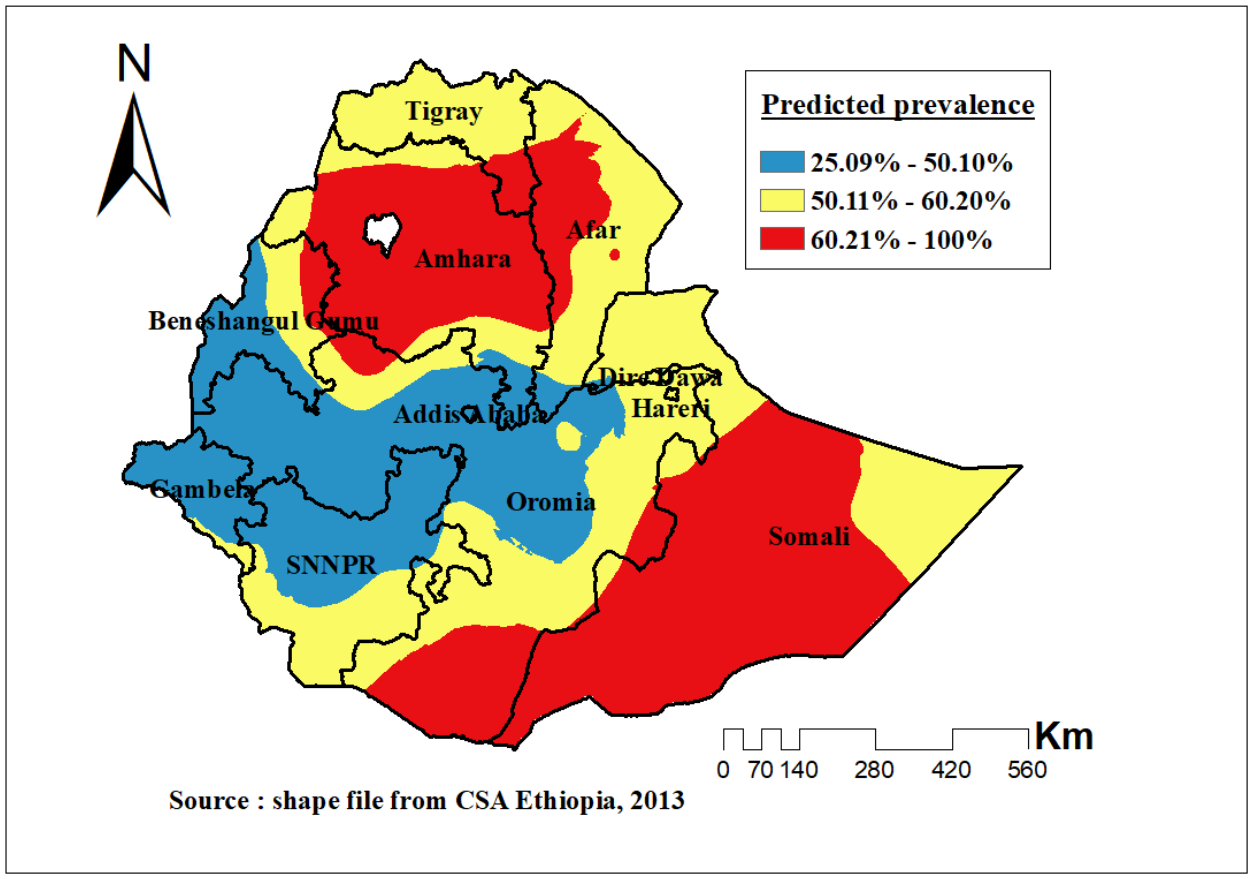


Figure 6. Interpolation of zero vitamin A-rich food consumption

Spatial scan analysis

Spatial scan analysis identified a total of 74 statistically significant clusters of which 26 were primary clusters and the rest 48 were secondary clusters. The primary clusters were located in Somali region, and eastern Oromia at Coordinates / radius of (6.639662 N, 44.465850 E) / 388.01 km (Figure 7). Children living within this cluster were 90.9% more likely to experience zero vitamin A-rich food consumption (RR=1.66, LLR=44.284445, $p< 0.01$) compared with those living outside the scanning window. Secondary significant clusters located in most part of Amhara, western & tip of northern afar, and some part of Addis Ababa at Coordinates / radius of (11.072970 N, 38.884160 E) / 224.25 km (Figure 8). the children residing within this cluster

were 74.0% more likely to have zero vitamin A-rich food consumption (RR=1.34, LLR=15.927202, p <0.01) compared with those living outside the scanning window (Table 4).

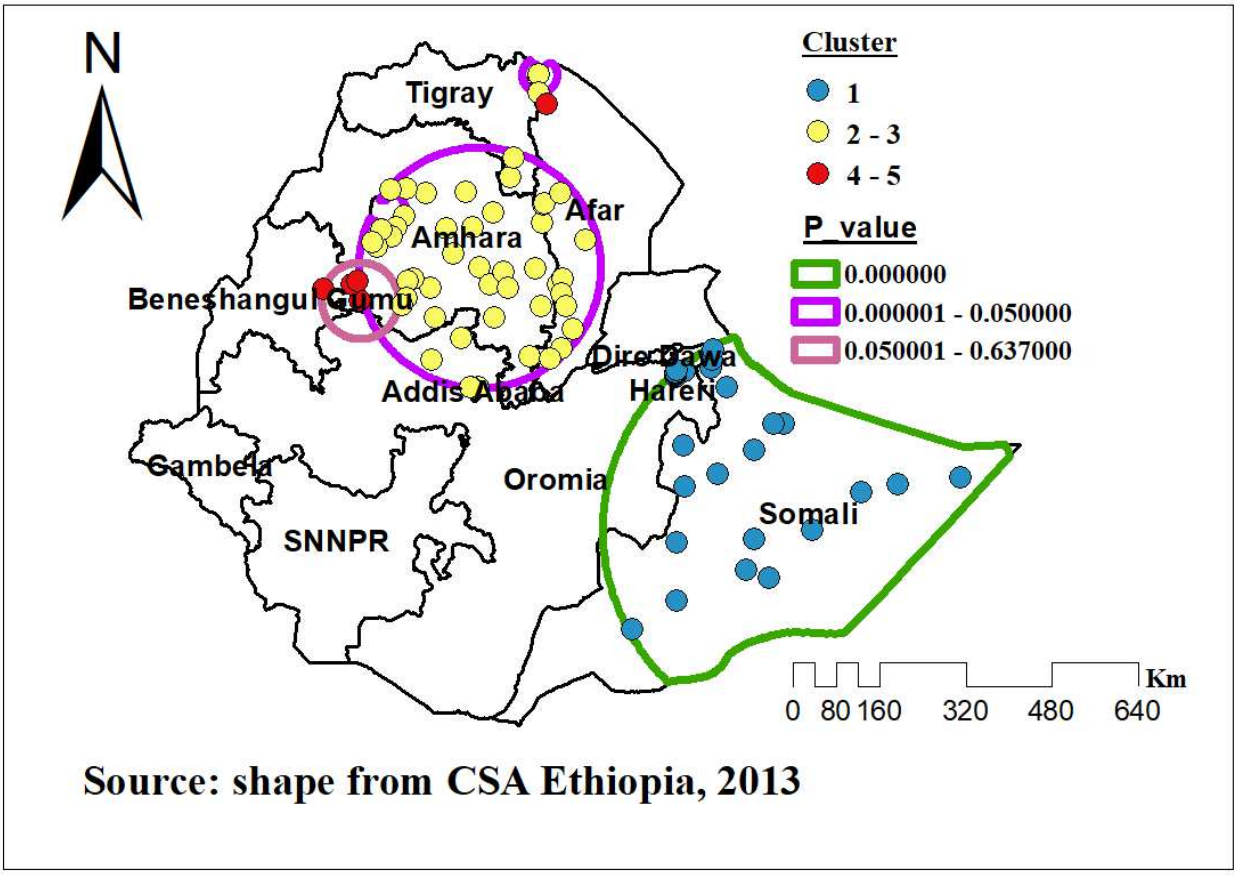


Figure 9. Spatial scan analysis of zero vitamin A-rich food consumption

Table 5. Spatial scan analysis result

	Cluster type	
	Primary cluster	Secondary cluster
Significant clusters detected	135, 123, 140, 137, 138, 124, 131, 145, 132, 122, 134, 136, 142, 133, 139, 129, 121, 130, 107, 250, 141, 128, 248, 249, 255, 254	65, 51, 63, 60, 66, 61, 58, 67, 71, 64, 62, 70, 73, 76, 68, 100, 44, 78, 72, 48, 47, 49, 52, 46, 29, 57, 83, 81, 59, 54, 50, 18, 69, 99, 53, 74, 82, 75, 33, 45, 43, 40, 20, 42, 84, 269, 256, 257
Coordinates / radius	(6.639662 N, 44.465850 E) /	(11.072970 N, 38.884160 E) /

	388.01 km	224.25 km
Population	154	254
Number of cases	140	188
Relative risk	1.66	1.34
Percent cases in area	90.9	74.0
Log likelihood ratio	44.284445	15.927202
P-value	0.00000000000000056	0.000065

Exploratory regression analysis

In this study, fifteen variables were initially considered, identified from prior literature and expert consultation. An exploratory regression analysis was then performed using the following criteria: adjusted $R^2 \geq 0.5$, variance inflation factor (VIF) ≤ 7.5, and p-value ≤ 0.05. Based on these thresholds, three candidate variable combinations were generated, and their Ordinary Least Squares (OLS) regression results were compared with the corresponding Geographically Weighted Regression (GWR) outputs. Among these, one combination was determined to have superior explanatory power. The final model comprised the proportion of children whose mother is currently pregnant, Proportion of mothers who received at least primary level education, Proportion of children living with more than one under-five children, Proportion of mothers currently married or living with man, Proportion of children aged 12–23 months. Consequently, both the OLS and GWR models were fitted using only these selected variables.

Ordinary least square regression analysis result

The diagnostic results from the Ordinary Least Squares (OLS) regression offer important information regarding the model's adequacy and underlying assumptions. The Joint F-statistic (25.19, p = 0.000) and the Joint Wald statistic (844.35, p = 0.000) indicated that the explanatory

318 variables collectively made a statistically significant contribution to the model, demonstrating
319 strong overall model performance. However, the Koenker (BP) statistic (14.34, $p \leq 0.001$)
320 revealed the presence of heteroskedasticity and/or spatial non-stationarity, suggesting that the
321 variance of the residuals was not constant across observations. This violation implies that the
322 OLS estimates may be inefficient or biased, thereby reducing the reliability of the results.
323 Consequently, a Geographically Weighted Regression (GWR) model was employed, as it
324 accounts for spatial non-stationarity by allowing relationships to vary across locations. The
325 Jarque–Bera statistic (2.52, $p = 0.28$) showed no significant departure from normality, indicating
326 that the residuals satisfied the normality assumption. In addition, multicollinearity among
327 explanatory variables was assessed using the Variance Inflation Factor (VIF). A threshold of 7.5
328 was applied, above which variables are typically considered problematic. In this analysis, all
329 variables had VIF values below 7.5 confirming that multicollinearity was not a concern and no
330 further corrective measures were necessary (Table 6).

331 **Table 7. OLS regression result output of zero vitamin-rich food consumption**

Variable	Coefficient	Robust Std.error	Robust probability	VIF
Intercept	0.00	0.016	0.955	-----
Proportion of women who were pregnant	0.49	0.12	0.000	0.06
Proportion of women with formal education	-0.38	0.051	0.000	1.25
Proportion of children living with more than one under five children in the house	-0.13	0.057	0.023	1.28
Proportion of mothers currently	0.92	0.062	0.000	1.37

married				
Proportion of children aged 12–23 months	-0.18	0.073	0.015	1.27

OLS diagnostics		
Diagnostic parameters	Value	P_value
Number of observations	305	-----
Joint F statistic	25.19	0.000
Joint Wald statistic	844.35	0.000
Koenker (BP) statistic	14.34	0.000
Jarque Bera statistic	2.52	0.28

Geographical weighted regression (GWR) analysis

Table 8. The GWR regression result of zero vitamin A-rich food consumption

Parameter	**value**
Bandwidth(neighbor)	278
Residual square	19.87
Effective number	18.15
Sigma	0.26
AICc	64.34
R^2	35.07%
Adjusted R^2	31.20%

The Geographically Weighted Regression (GWR) model was fitted using the same set of explanatory variables as the OLS model and showed improved performance. The adjusted R^2 increased from 29.07% (Table 9) in the OLS model to 31.20% (Table 10) in the GWR model, demonstrating that GWR accounted for an additional 2.13% of the regional variation in zero

vitamin A rich food consumption. Moreover, the corrected Akaike Information Criterion (AICc) decreased from 68.96 in the OLS model to 64.34 in the GWR model, reflecting a reduction of 4.62 units. This substantial decline indicates that the GWR model provided a better fit and more effectively captured the underlying geographical heterogeneity (Table 11).

Table 12. The OLS and GWR model comparison

Model comparison		
Model parameter	OLS(Global)	GWR
R^2	30.23%	35.07%
Adjusted R^2	29.07%	31.20%
AICc	68.96	64.34

Before interpreting the GWR findings, residual spatial autocorrelation was assessed. The residuals from the GWR model were randomly distributed, as indicated by a Moran's I value of 0.03 ($p = 0.46$), which showed no statistically significant spatial autocorrelation (Figure 10). This lack of residual clustering implies that the model was well specified and that the selected variables adequately explained the spatial patterns that had remained in the residuals of the global OLS model.

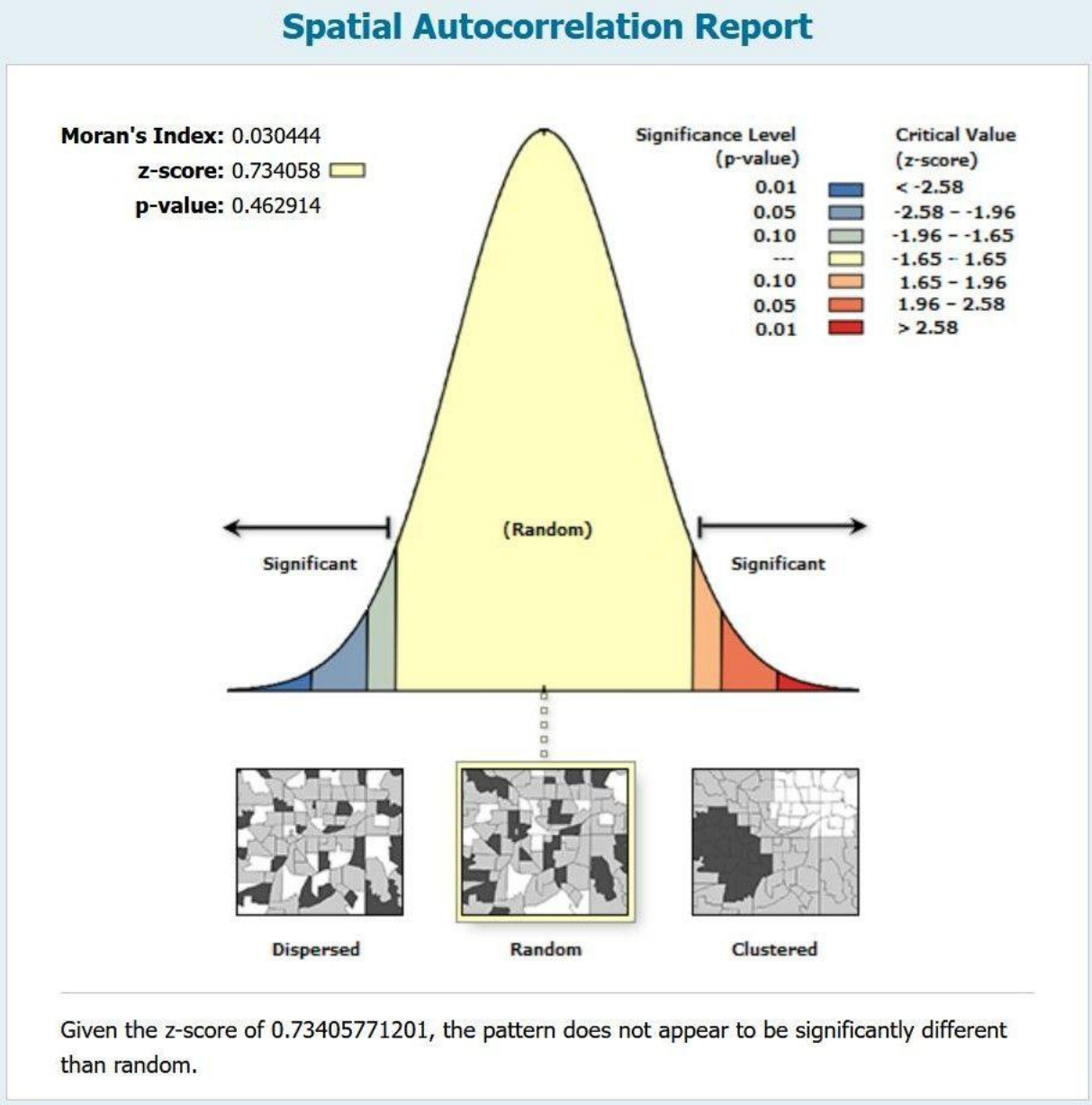


Figure 11. The GWR model residual spatial autocorrelation analysis

Maternal current pregnancy status had positive effect on children's ZVA rich food consumption throughout the country which ranged from 0.138 to 0.203 where 1% increase in proportion of children whose mother is currently pregnant results in 13.8% to 20.3% increase in children's ZVA rich food consumption (Figure 12, Figure 13).

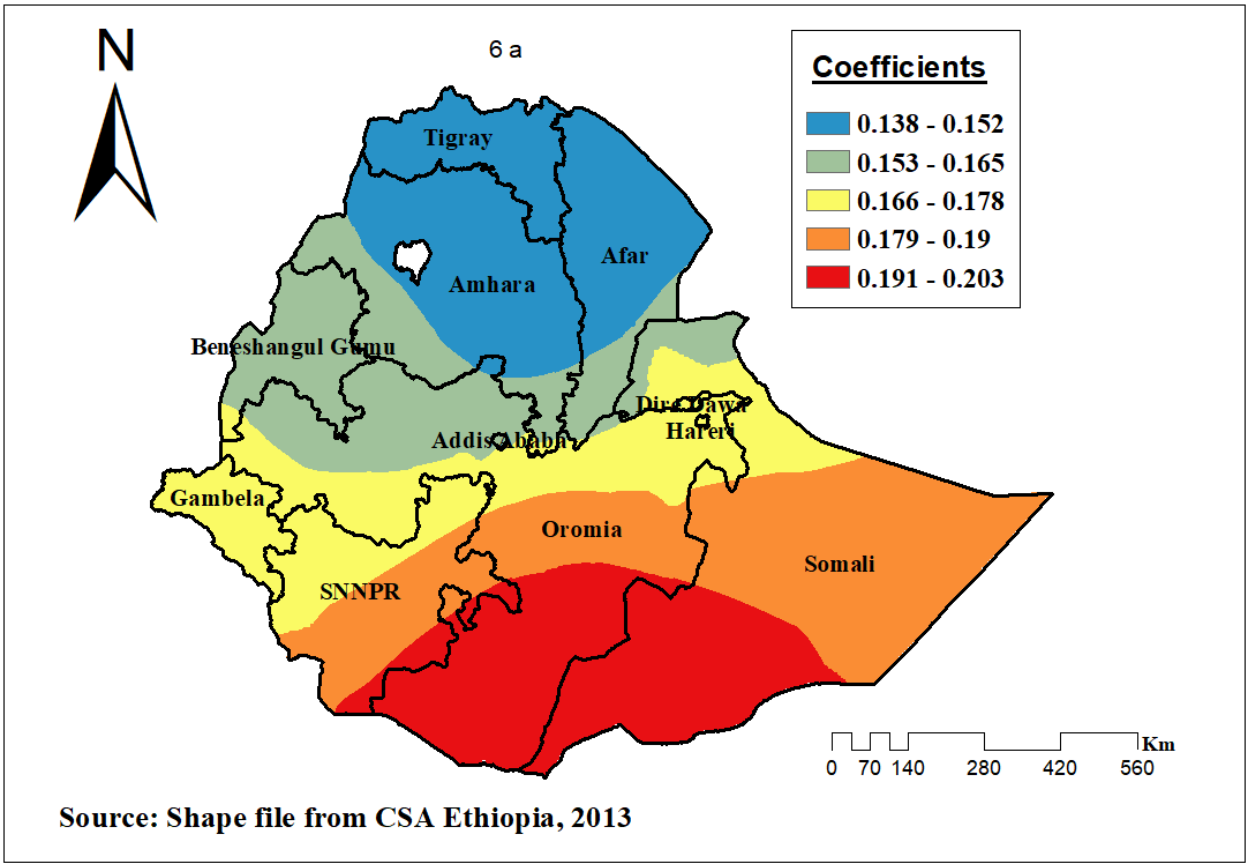


Figure 14. The coefficient of current pregnancy

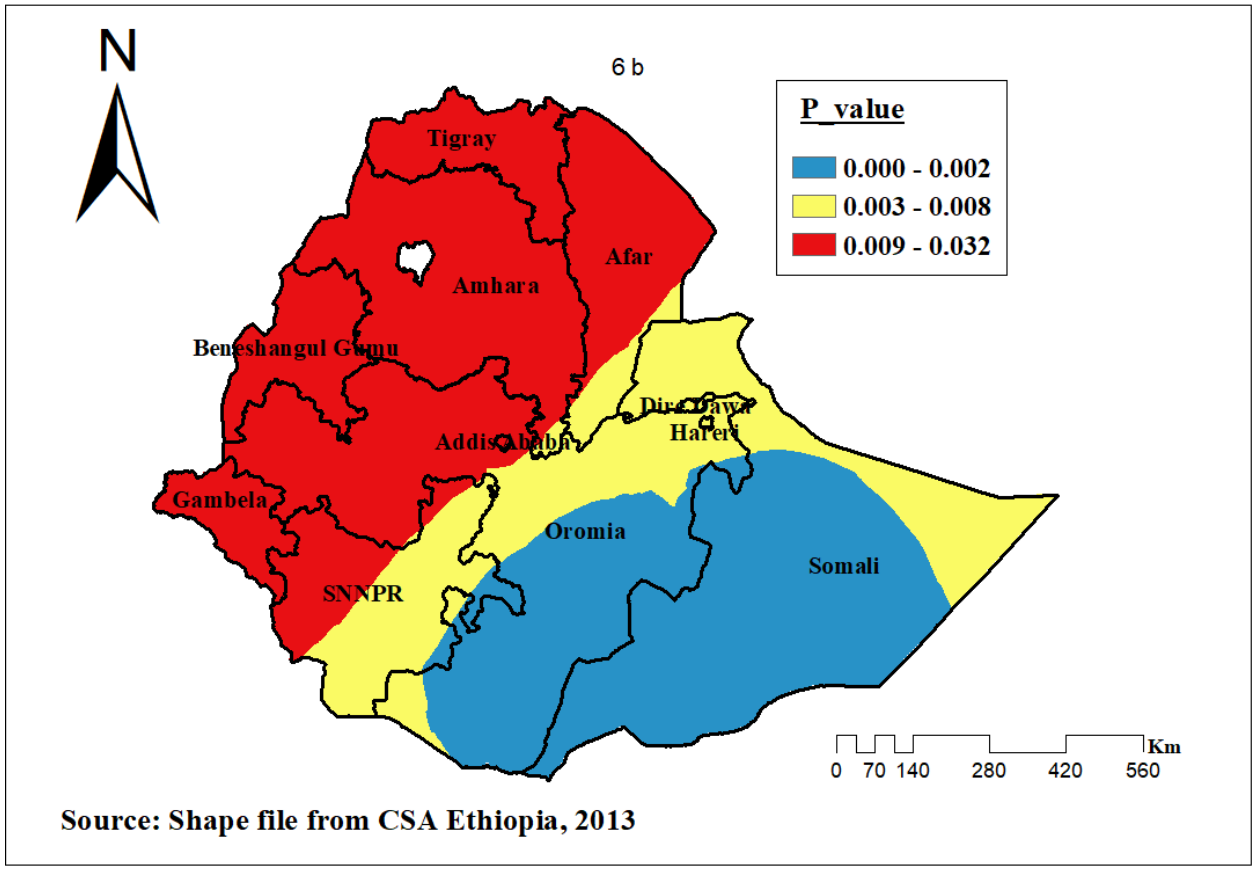


Figure 15. The GWR coefficient (6a) and p_ value (6b) of current pregnancy

Maternal education had negative effect on children's ZVA rich food consumption throughout the country which ranged from -0.497 to -0.323 where 1% increase in Proportion of mothers who received at least primary level education results in 32.3% to 49.7% drop in children's ZVA rich food consumption (Figure 16, Figure 17).

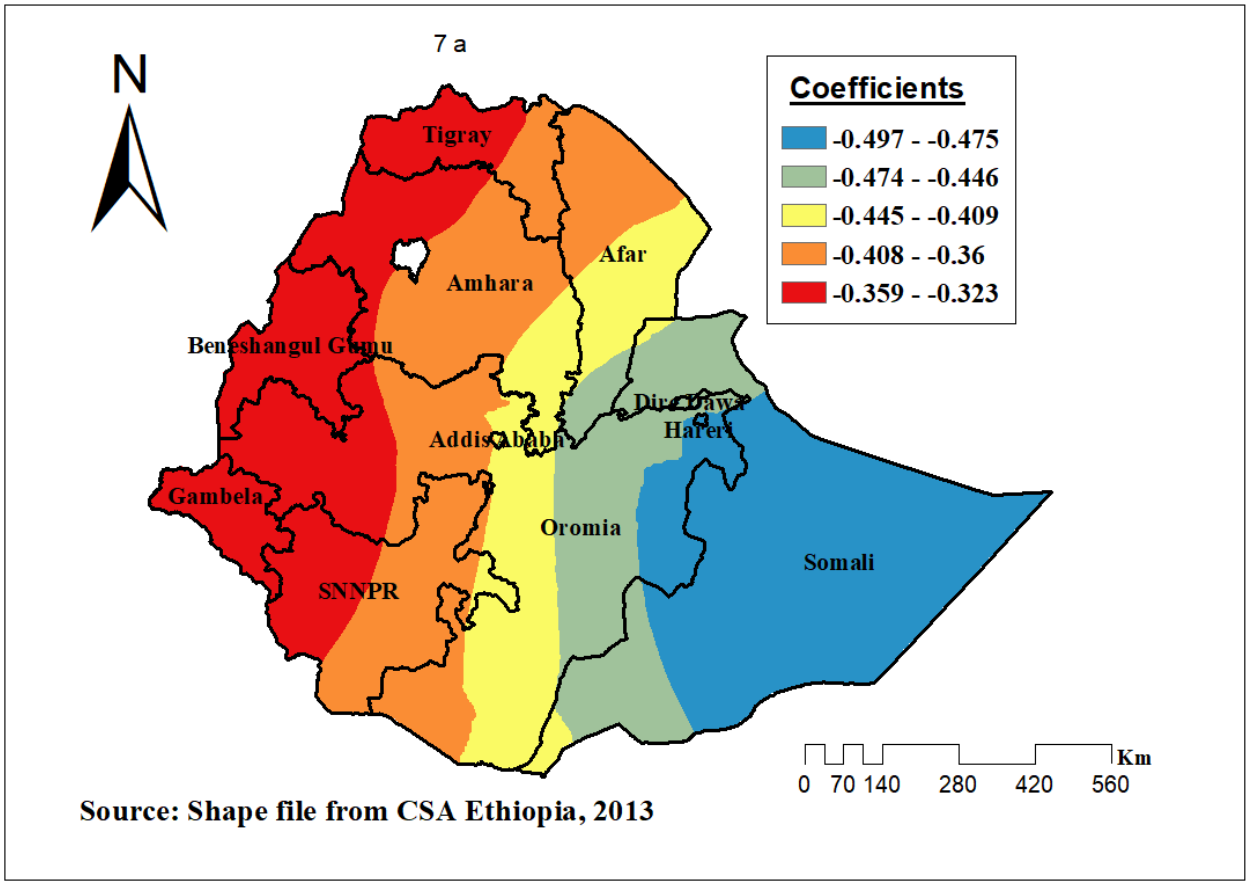


Figure 18. The coefficient of maternal education

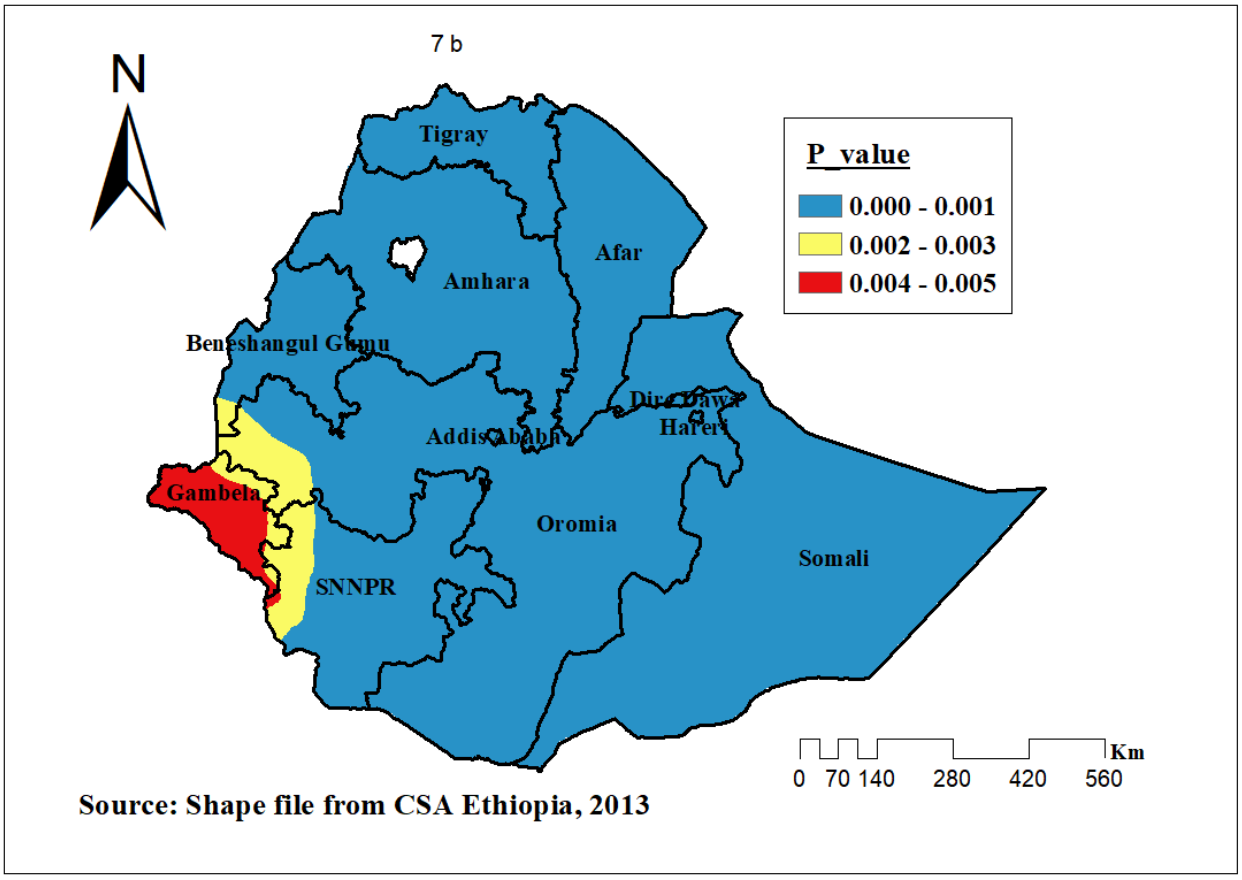
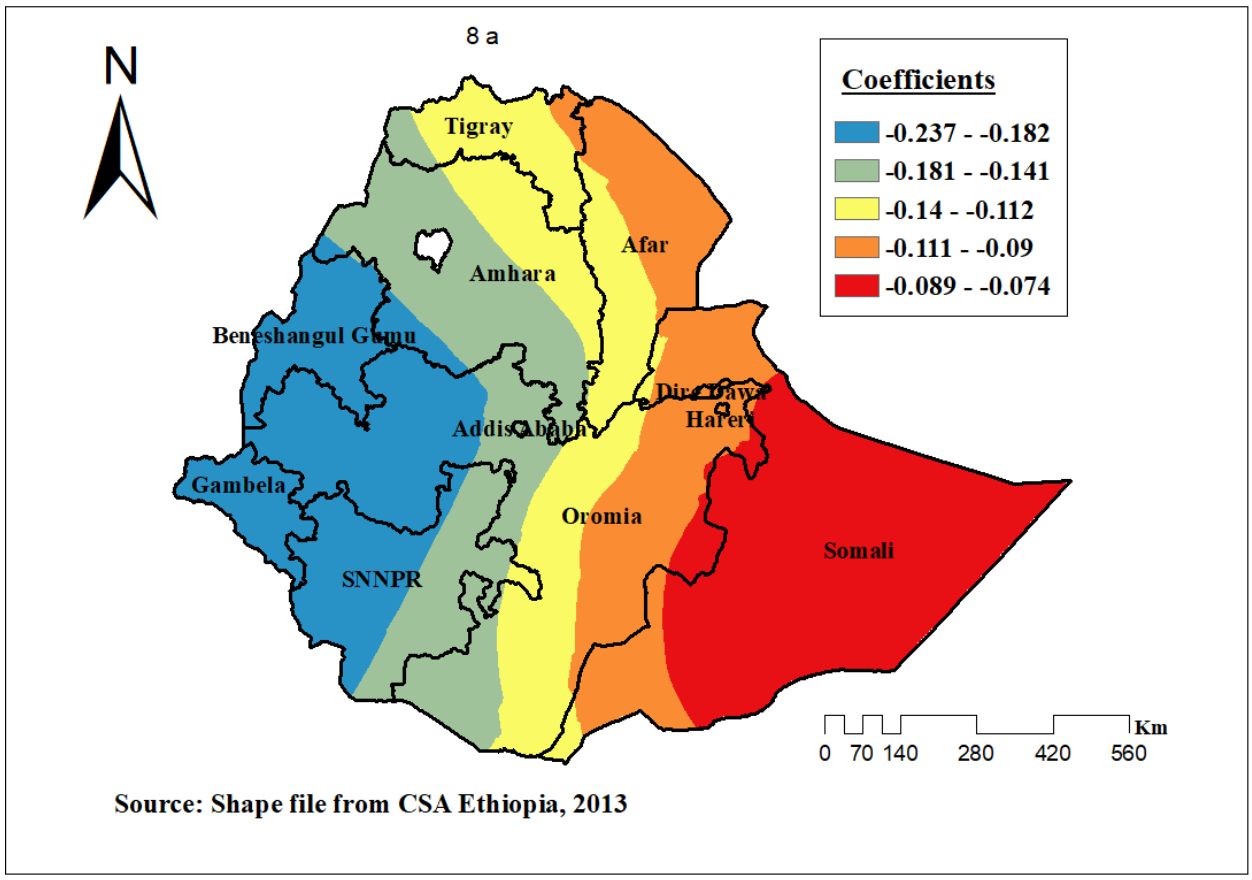


Figure 19. The GWR coefficient (7a) and P_value (7b) of maternal education

The presence of more than one under five children had negative effect on children's ZVA rich food consumption in significant regions such as western & northern Tigray, most part of Amhara, the whole Beninshangul, Addis Ababa, western, north western & southern half of Oromia, entire gambela and entire SNNPR in which the coefficient ranged from -0.237 to -0.14 where 1% increase in proportion of children living with more than one under five children results in 14% to 23.7% drop in children's ZVA rich food consumption (Figure 20, Figure 21).



377

378 **Figure 22. The coefficient of under- five children**

379

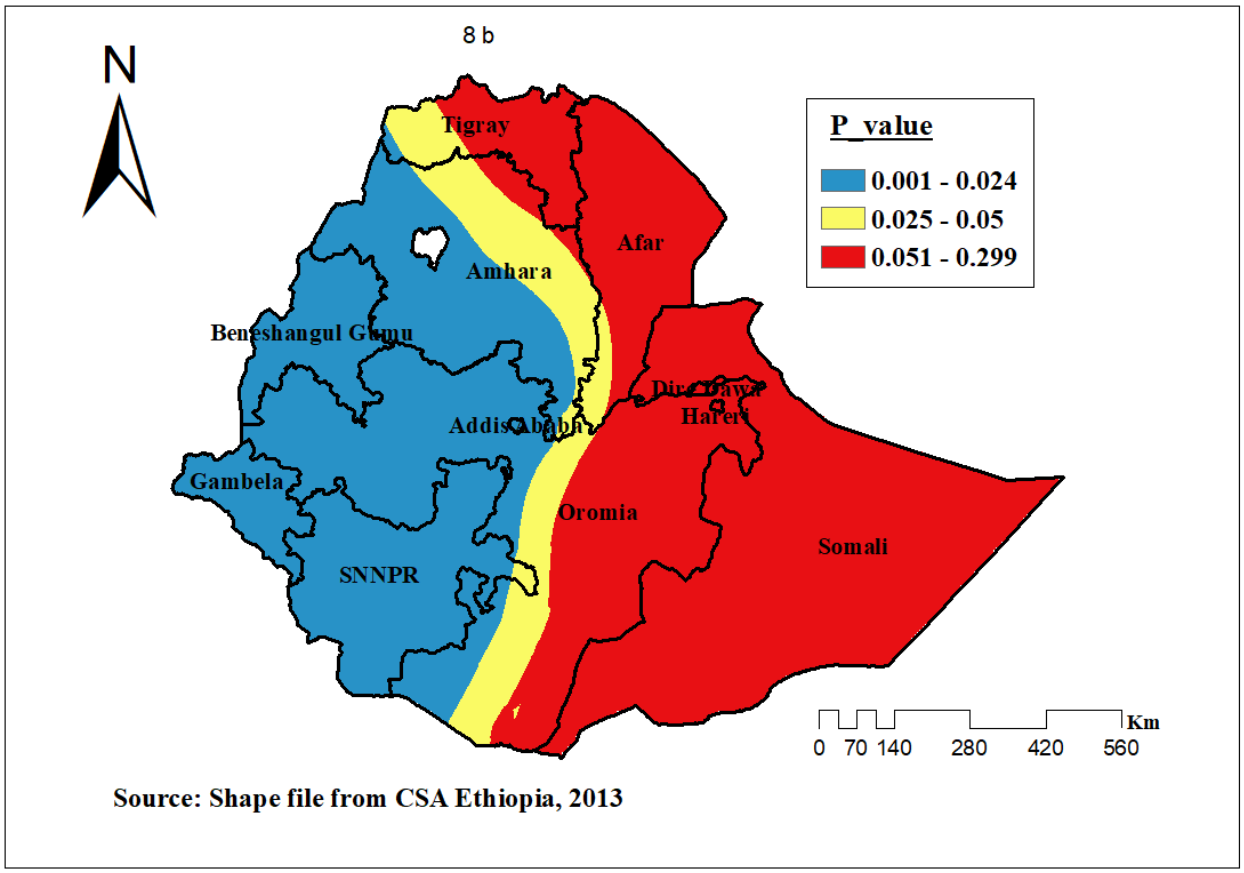
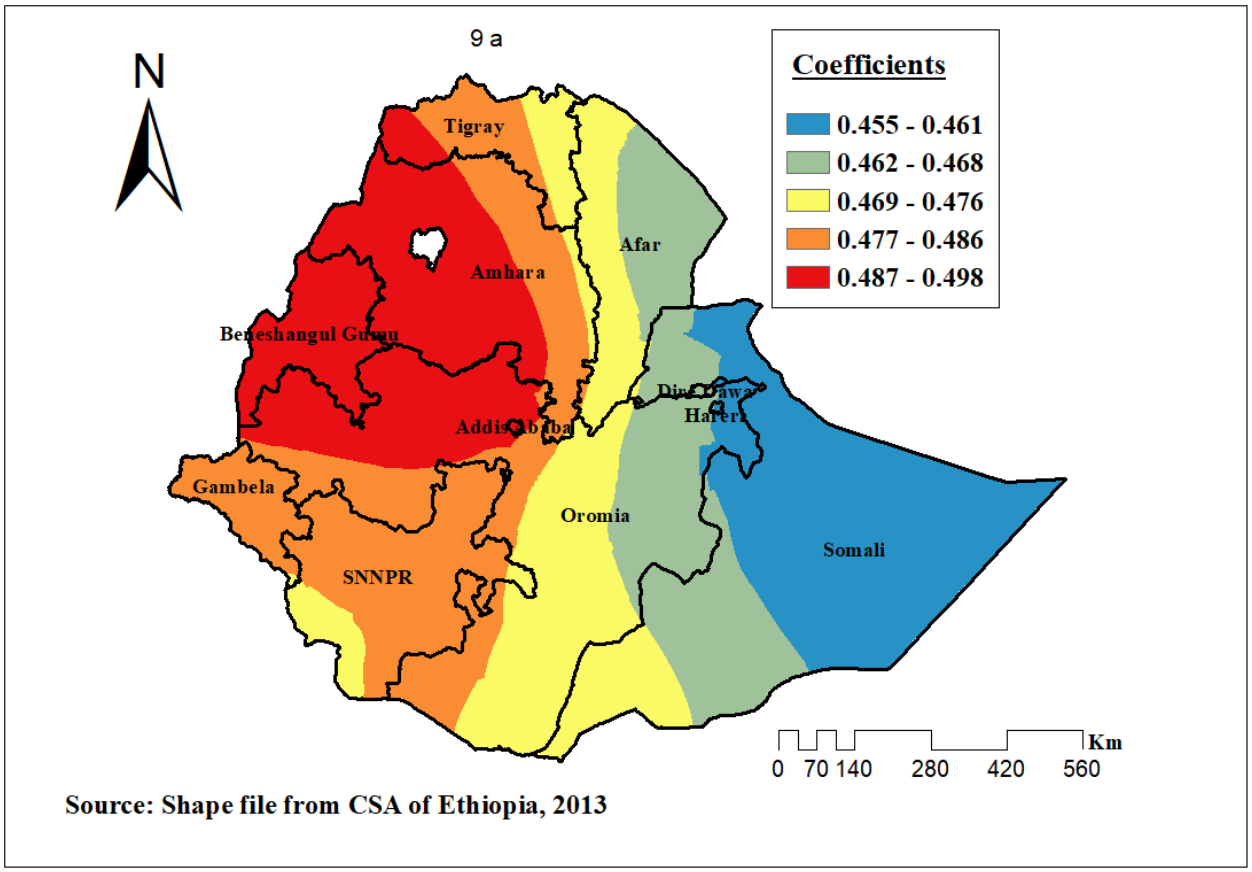


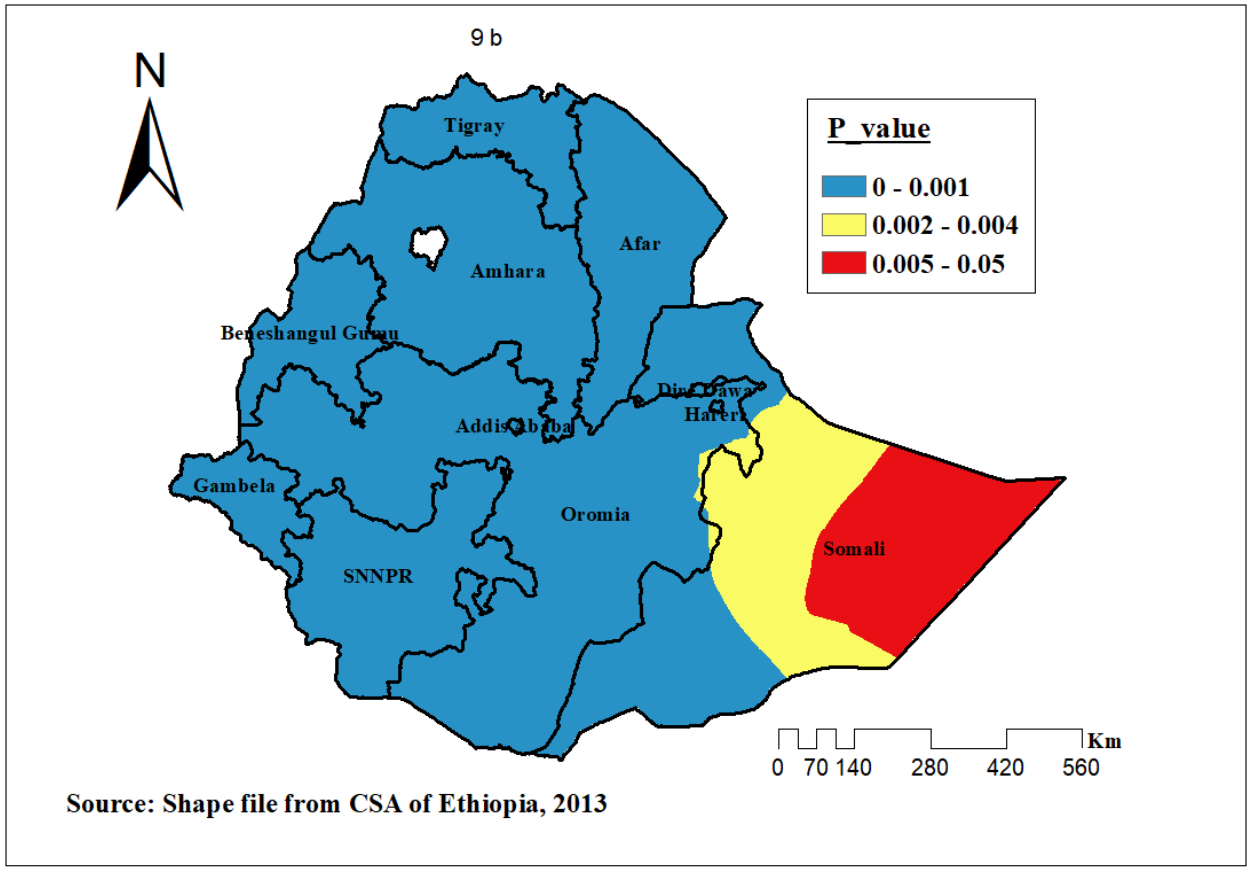
Figure 23. The GWR coefficient (8a) and P_value (8b) of under-five children

Marital status had positive effect on children's ZVA rich food consumption which ranged from 0.455 to 0.498 and was significant in entire part of the country where 1% increase in proportion of mothers currently married results in 45.5% to 49.8% increase in children's ZVA rich food consumption (Figure 24, Figure 25).



386

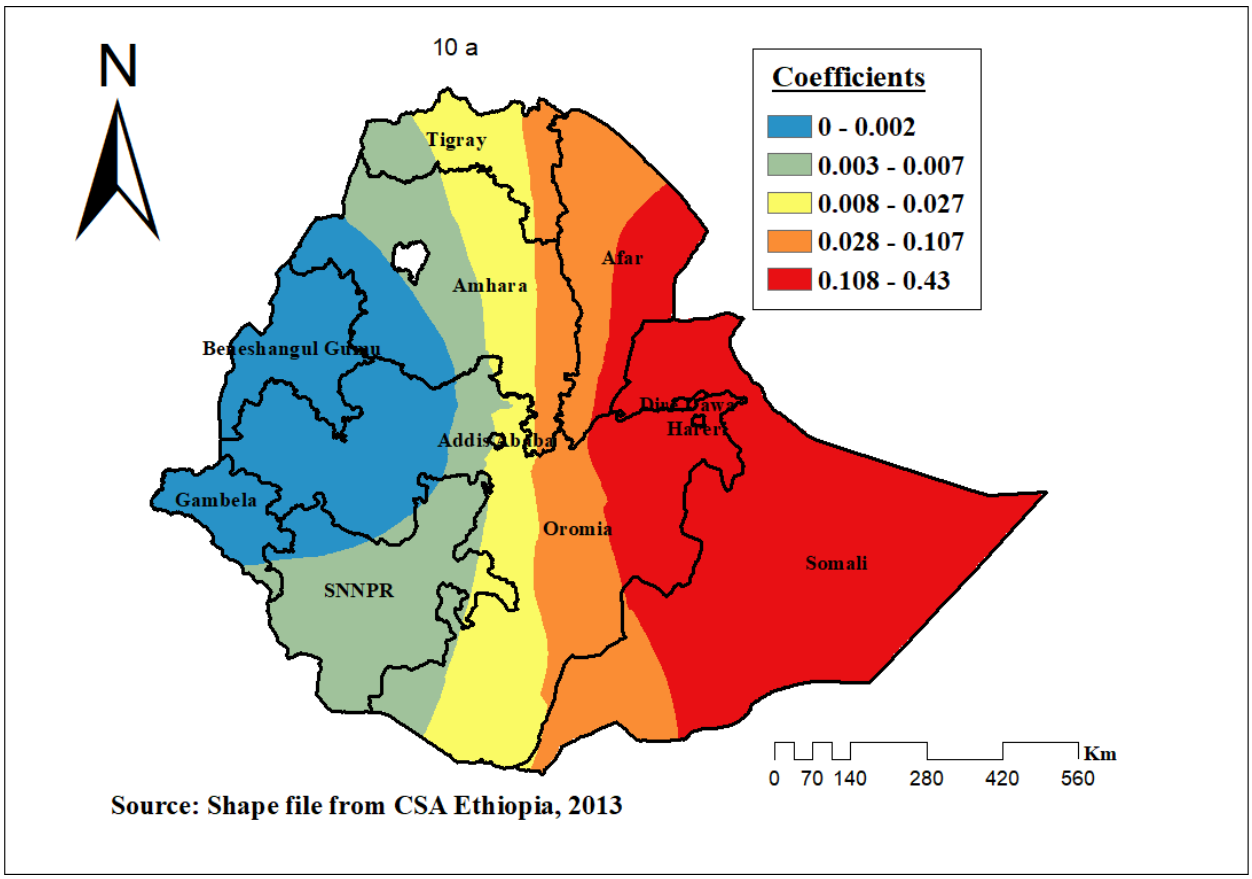
387 **Figure 26. The coefficient of marital status**



388

389 **Figure 27. The GWR coefficient (9a) and P_value (9b) of marital status**

390 The coefficient of the child age on ZVA rich food consumption across Ethiopia ranged from 0 to
391 0.43, indicating positive association between age of the child and ZVA rich food consumption.
392 In significant regions such as entire Tigray, entire Amhara, some part of north Afar, the whole
393 Benishangul, Addis Ababa, entire Gambela, the whole SNNPR and most part of Oromia the
394 coefficient ranged between 0.002 to 0.028. This means 1% increase in proportion of children
395 aged 12-23 month increases the prevalence of ZVA rich food consumption by 0.2% to 2.8%
396 (Figure 28, Figure 29).



397

398 **Figure 30. The coefficient of child age**

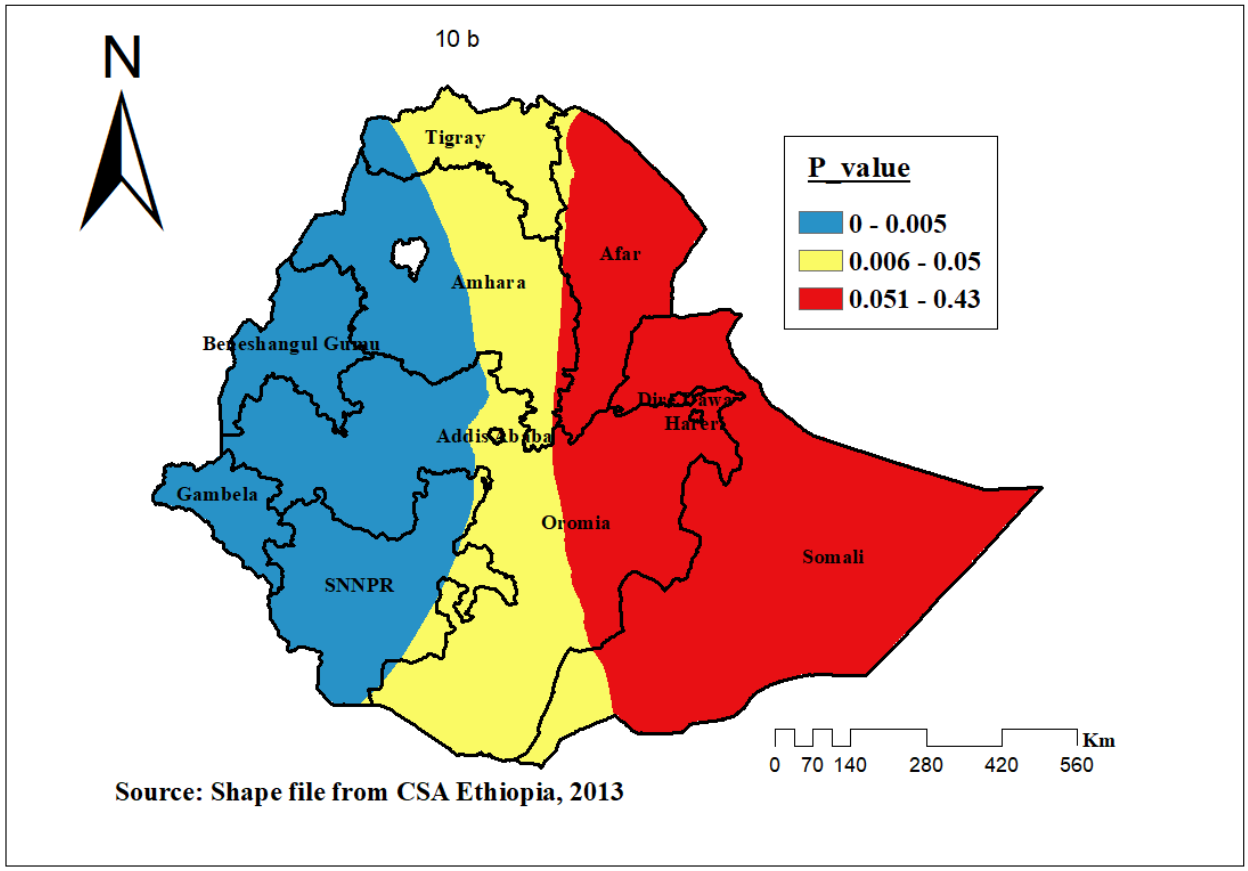


Figure 31. The GWR coefficient (10a) and P_value (10b) of child age

Discussion

This study examined the spatial variation of zero vitamin A-rich food consumption and associated factors among children aged 6–23 months in Ethiopia. Accordingly, the findings revealed that zero vitamin A-rich food consumption distributed non- randomly across Ethiopia including most part of Amhara, southern Tigray, western Afar, eastern & north eastern Benishangul, tip of northern, southern &eastern Oromia and most part of Somali. Former study conducted in Ethiopia also showed regional variation(27, 28). In addition to geographic disparities, current pregnancy status, maternal education, number of under-five children, marital

status, and age of the child were significantly associated with zero vitamin A-rich food consumption (19).

Current pregnancy status was significantly associated with zero vitamin A-rich food consumption, where an increase in proportion of women currently pregnant results in increase of zero vitamin A rich food consumption. This finding is in line with study conducted in Ethiopia (24). This might be possibly explained by when a woman becomes pregnant, she may shift household attention and resources toward the pregnancy. This may negatively affect complementary feeding practices, including the provision of vitamin A-rich foods (2, 29).

Maternal education was another significant predictor and negatively associated with zero vitamin A-rich food consumption, where increase in proportion of mothers who received at least primary level education, decreases children's zero vitamin A rich food consumption. This study is in line with study conducted in Bangladesh (19, 28, 30, 31). The possible explanation for this might be mothers with formal education are more likely to understand the importance of dietary diversity (29, 32-34).

The presence of more than one under five children was also significant predictor which was negatively associated with zero vitamin A-rich food consumption. This finding is in line with the study conducted in Ethiopia(24, 35). Possible explanation might be maternal exposure to previous child feeding practices(34) and repeated health service (29).

Marital status was positively associated with children's ZVA rich food consumption where an increase in proportion of mothers currently married increases children's ZVA rich food consumption. This finding is in line with study conducted in Ethiopia(36). Likely explanation for this might be married women often bear burden of household responsibilities, which may

reduce the time and attention available for preparing diversified complementary foods (37). In addition to this, cultural feeding norms may favor adult consumption patterns (29).

The age of the child was significantly associated with zero vitamin A-rich food consumption, where an increase proportion of age 12–23 months, results in increase of zero vitamin A-rich foods consumption. This finding is in line with the former study conducted in Ethiopia(19). Possible explanation for this might be as children grow older, feeding may become less structured(37). In addition to this, in many Ethiopian and sub-Saharan African households, family diets are predominantly staple-based with limited regular inclusion of vitamin A-rich foods (38).

Strengths and Limitations

The finding is highly generalizable at national level. However, the assessment of vitamin A-rich food consumption was based on 24-hour maternal recall, which may be prone to bias.

Conclusion

Spatial variation of zero vitamin A-rich food consumption and associated factors among children aged 6–23 months in Ethiopia demonstrates significant spatial variation and is influenced significant factors like Current pregnancy, Maternal education, number of under-five children, marital status, and age of the child. To mitigate the problem context-specific interventions should be applied to varying factors that would enhance the effectiveness and cost-efficiency of regional nutrition and education programs.

Additional files

Declaration

Ethical approval and consent to participate

The study was carried out after obtaining permission from the DHS Program through an online request submitted via their official website. Access to the Ethiopian DHS data was granted following a review of the brief project description provided to the DHS Program. The datasets were handled with strict confidentiality. This research utilized secondary data from the Ethiopian DHS. Ethical considerations such as informed consent, confidentiality, anonymity, and participants' privacy had already been addressed by the DHS Program. The researchers did not alter or use the data beyond the scope of this study.

Consent for publication

Not applicable

Availability of data and materials

All data related to this study are included and presented within this document. The complete dataset is available and can be freely accessed from the DHS Program website (www.dhsprogram.com).

Competing interests

The authors declared that they have no competing interests

Funding

No funding source available

Authors' contributions

Adugna Mengesha Mulugeta, Anley Shiferaw Enawgaw, Yihenew Getahun Ambaw, Mequanent Dessie Bitewa, Smegnew Gichew Wondie, Tadele Derbew Kassie, Zinie Abita Mengie, Simegnew Adugna Kallu, Berhanu Ayana Tafere, Tesfaye Shumet Mekonnen, Mikias Getahun Molla, Daniel Mulat Eshetu, Thomas Kidanemariam Yewodiaw, Ambachew Motbaynor Wubaye, Birhanu Feleke Shitu, Amare Mebrat Delie, Aysheshim Belaineh Haimanot, Yezbie Wagaw Ayicheh

All these authors made a significant contribution to the work reported above including design, data interpretation and critical revision of the manuscript.

Acknowledgment

We would like to express our sincere gratitude to the Demographic and Health Surveys (DHS) Program for granting access to the dataset used in this study. Their commitment to providing high-quality, nationally representative data has made this research possible.

Reference

1. Donkor WE, Adu-Afarwuah S, Wegmüller R, Bentil H, Petry N, Rohner F, et al. Complementary feeding indicators in relation to micronutrient status of Ghanaian children aged 6–23 months: Results from a national survey. 2021;11(9):969.
2. Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, De Onis M, et al. Maternal and child undernutrition and overweight in low-income and middle-income countries. 2013;382(9890):427-51.
3. Organization WH. Indicators for assessing infant and young child feeding practices: definitions and measurement methods. 2021.
4. Ruel MT, editor Measuring infant and young child complementary feeding practices: indicators, current practice, and research gaps. Nestle Nutr Inst Workshop Ser; 2017.

5. Ongprasert K, Chawachat J, Wungrath J, Kiratipaisarl WJBPH. Prevalence and determinants of inappropriate complementary feeding practices among children aged 6–23 months in Chiang Mai, Northern Thailand: a cross-sectional study. 2025;25(1):2043.
6. Organization WH. Global prevalence of vitamin A deficiency in populations at risk 1995-2005: WHO global database on vitamin A deficiency. 2009.
7. Stevens GA, Bennett JE, Hennocq Q, Lu Y, De-Regil LM, Rogers L, et al. Trends and mortality effects of vitamin A deficiency in children in 138 low-income and middle-income countries between 1991 and 2013: a pooled analysis of population-based surveys. 2015;3(9):e528-e36.
8. Baye K, Laillou A, Seyoum Y, Zvandaziva C, Chimanya K, Nyawo MJTAJoCN. Estimates of child mortality reductions attributed to vitamin A supplementation in sub-Saharan Africa: scale up, scale back, or refocus? 2022;116(2):426-34.
9. WHO F. Vitamin and mineral requirements in human nutrition Second edition. Geneva; 2004.
10. Moloney G, Berbari LS, Bucher H. A global perspective on improving the diets of infants and young children. 2022.
11. Ruel MT, Alderman HJTl. Nutrition-sensitive interventions and programmes: how can they help to accelerate progress in improving maternal and child nutrition? 2013;382(9891):536-51.
12. Csace IJAA, Ethiopia,, Rockville M, USA: CSA, ICF. Ethiopia demographic and health survey 2016. 2016:1-551.
13. Demographic EJE, Calverton M, USA: central statistics agency, macro O. Health survey: Addis Ababa. 2011;2011.
14. Organization WH. Guideline: Vitamin A supplementation in infants 1-5 months of age: World Health Organization; 2011.
15. Csa IJEd, health survey AA, Ethiopia, Calverton M, USA. Central statistical agency (CSA)[Ethiopia] and ICF. 2016;1(1).
16. Aemro M, Mesele M, Birhanu Z, Atenafu AJJon, metabolism. Dietary diversity and meal frequency practices among infant and young children aged 6–23 months in Ethiopia: a secondary analysis of Ethiopian demographic and health survey 2011. 2013;2013(1):782931.

17. Tessema M, Belachew T, Ersino GJTPAMJ. Feeding patterns and stunting during early childhood in rural communities of Sidama, South Ethiopia. 2013;14:75.
18. Jateno W, Alemu BA, Shete MJPO. Household dietary diversity across regions in Ethiopia: evidence from Ethiopian socio-economic survey data. 2023;18(4):e0283496.
19. Demsash AW, Chereka AA, Kassie SY, Donacho DO, Ngusie HS, Tegegne MD, et al. Spatial distribution of vitamin A rich foods intake and associated factors among children aged 6–23 months in Ethiopia: spatial and multilevel analysis of 2019 Ethiopian mini demographic and health survey. 2022;8(1):77.
20. Anselin LJGa. Local indicators of spatial association—LISA. 1995;27(2):93-115.
21. Cheng W, Washington SPJAA, Prevention. Experimental evaluation of hotspot identification methods. 2005;37(5):870-81.
22. Srinivasan SJEoG. Spatial regression models. 2008:1102-5.
23. Rosenshein L, Scott L, Pratt MJER. Exploratory Regression: A tool for modeling complex phenomena. 2011;1.
24. Tilahun WM, Simegn MB, Geremew H, Gebreegziabher ZA, Abay LY, Tesfie TKJFiN. Spatial variation of zero fruits/vegetables consumption and associated factors among children aged 6–23 months in Ethiopia: geographical weighted regression analysis. 2024;11:1374845.
25. Arbenina M. Spatial data mining and machine learning techniques to understand cross-border relocations of headquarters in Europe. 2021.
26. Burnham KPJ. Model selection and multimodel inference. 2004:488.
27. Tiruneh SA, Fentie DT, Yigizaw ST, Abebe AA, Gelaye KAJPo. Spatial distribution and geographical heterogeneity factors associated with poor consumption of foods rich in vitamin A among children age 6–23 months in Ethiopia: Geographical weighted regression analysis. 2021;16(6):e0252639.
28. Muhye AB, Assimamaw N, Tamir TT, Alemu TG, Techane MA, Wubneh CA, et al. Spatial distribution and Determinates of poor consumption of foods rich in vitamin A among children aged 6–23 months in Ethiopia using data from Ethiopia Demographic and Health Survey 2019: spatial and multilevel analysis. 2022.
29. European Society for Paediatric Gastroenterology H, Nutrition, Fewtrell M, Baumann U, Bronsky J, Haiden N, et al. World Health Organization (WHO) guideline on the complementary

feeding of infants and young children aged 6− 23 months 2023: A multisociety response. 2024;79(1):181-8.
30. Rima FS, Kundu S, Tarannum S, Jannatul T, Sharif ABJSR. Spatial variations and determinants of vitamin A and iron rich food consumption among Bangladeshi children aged 6–23 months. 2025;15(1):17881.
31. Beressa GJSR. Vitamin A rich food consumption and its predictors among children aged 6 up to 23 months old in Ethiopia. 2025;15(1):22731.
32. Solomon D, Aderaw Z, Tegegne TKJIjfeih. Minimum dietary diversity and associated factors among children aged 6–23 months in Addis Ababa, Ethiopia. 2017;16(1):181.
33. Unicef. The state of the world's children 2019: children, food and nutrition. 2019.
34. Nguyen PH, Avula R, Ruel MT, Saha KK, Ali D, Tran LM, et al. Maternal and child dietary diversity are associated in Bangladesh, Vietnam, and Ethiopia1, 2. 2013;143(7):1176-83.
35. Kassie GW, Workie DLJBPH. Determinants of under-nutrition among children under five years of age in Ethiopia. 2020;20(1):399.
36. Semagn BE, Abubakari AJPo. Zero fruits/vegetables consumption and associated factors among Children aged 6–23 months in Ethiopia: Mixed effect logistic regression analysis. 2023;18(7):e0288732.
37. Jones AD, Ickes SB, Smith LE, Mduduzi MN, Chasekwa B, Heidkamp RA, et al. World Health Organization infant and young child feeding indicators and their associations with child growth: a synthesis of recent findings. Wiley Online Library; 2013.
38. Keeley B, Little C, Zuehlke EJF, UNICEF N--GWiaCW. The state of the World's children 2019: children. 2019;3.

Table 13. Socio-demographic characteristics of the participants and participant's mothers

Variables	Category	Weighted frequancy(1543)	Percentage (%)
Maternal age	<25	485	31.43
	≥25	1,058	68.57
Altitude	<2400	1,361	88.20
	≥2400	182	11.80
Maternal education	No formal education	753	48.80

	Educated	790	51.20
Number of under five children	One	662	42.90
	More than one	881	57.10
Wealth index	poor	719	46.60
	Middle/rich	824	53.40
Age at first birth	<18 years	606	39.27
	≥18 years	937	60.73
Current marital status	Not married	9	0.58
	Married	1,534	99.42
Age of the childe(in month)	6-11	530	34.35
	12-23	1,013	65.65
ANC vist	No	900	58.33
	yes	643	41.67
Place of delivery	Home	672	56.57
	Health facility	516	43.43
Post natal check	No	1,338	86.88
	Yes	202	13.12
Residence	Urban	401	25.99
	Rural	1,142	74.01
Sex of household head	Male	1,208	78.29
	Female	335	21.71
Current pregnancy	No	1,411	91.45
	Yes	132	8.55
Current breast feeding status	No	338	21.91
	Yes	1,205	78.09
Region	Tigray	125	8.10
	Afar	160	10.37
	Amhara	162	10.50
	Oromia	185	11.99
	Somali	142	9.20

	Beniahangul	137	8.88
	SNNPR	173	11.21
	Gambela	122	7.91
	Harari	118	7.65
	Addis Ababa	95	6.16
	Dire dawa	124	8.04

577