

Review Article

Hematology

Spatial Distribution and Socioeconomic Correlates of Anaemia among Women of Reproductive Age in Ghana: A Hotspot Analysis of the 2022 Demographic and Health Survey

Abubakar Iddrisu Siddiq^{*1}, Theophilus Arthur-Gyimah², Grace De-Graft Aitee³, Nii Annan Jeremiah Oku¹, Emmanuel Vondee¹, Godlove Osei Asumang¹

¹Department of Public Health, Faculty of Medical Sciences, Presbyterian University, Ghana

²Laboratory Service Directorate, Haematology Unit, Komfo Anokye Teaching Hospital

³Central Regional Health Directorate, Ghana Health Service

Abstract

Background: Anaemia in women of reproductive age is a persistent contributor to maternal morbidity and adverse birth outcomes in sub-Saharan Africa. Ghanaian surveys have repeatedly placed national anaemia prevalence in the World Health Organization's severe public health problem range, yet the geographical distribution of this burden, and the socioeconomic factors that may account for it after geographical adjustment, remain insufficiently elucidated.

Methods: This cross-sectional study analysed the women's and cluster GPS files of the 2022 Ghana Demographic and Health Survey. Anaemia was defined as altitude- and smoking-adjusted haemoglobin below World Health Organization thresholds among 7,557 women aged 15–49 years with a valid measurement. Survey-weighted multivariable logistic regression, accounting for clustering, stratification, and sampling weights, was used to elucidate socioeconomic and demographic correlates. Cluster-level prevalence was tested for spatial clustering with global Moran's I and local Getis-Ord Gi* statistics (k-nearest neighbour weights, k = 8). The four-level severity outcome was also modelled with survey-weighted proportional-odds (ordinal) logistic regression. Robustness of the hotspots was examined with k = 4, k = 12 and distance-band weights, empirical Bayes smoothing, Benjamini–Hochberg false discovery rate (FDR) correction and a Bernoulli spatial scan statistic.

Results: Weighted anaemia prevalence was estimated at 41.1% (mild: 22.6%, moderate: 17.3%, and severe: 1.1%). Pregnant women appeared to have higher adjusted odds of anaemia than non-pregnant women (adjusted odds ratio [AOR] 1.71, 95% CI 1.38–2.12), as did women in the Oti (AOR 1.54, 95% CI 1.16–2.06) and Northern (AOR 1.35, 95% CI 1.04–1.76) regions relative to Greater Accra, while the Bono region showed lower odds (AOR 0.64, 95% CI 0.43–0.94). Associations with rural residence, education, and wealth that were significant in crude analysis appeared substantially attenuated after adjustment. In the ordinal model, pregnancy (odds ratio [OR] 1.63, 95% CI 1.35–1.97) and residence in Oti (OR 1.44, 95% CI 1.11–1.87) were associated with more severe anaemia, and wealth showed no gradient (OR per quintile 0.97, 95% CI 0.90–1.04). Moran's I suggested significant positive spatial autocorrelation (I = 0.156, p = 0.001); Getis-Ord Gi* identified 109 hotspot and 117 cold spot clusters among 618 clusters, with hotspots concentrated in the

Correspondence:

Abubakar Iddrisu Siddiq, Department of Public Health, Faculty of Medical Sciences, Presbyterian University, Ghana, ORCID: 0009-0008-4143-4426, Email: ai.siddiq0234@presbyuniversity.edu.gh

Received Dates: Oct 09, 2026;

Accepted Date: Oct 13, 2026;

Published Date: Oct 15, 2026:

north and cold spots in the mid-southern forest belt. Global clustering and the broad pattern were stable across specifications and were confirmed by the scan statistic (northern high-risk window, relative risk 1.25; forest-belt low-risk window, relative risk 0.76), but only 12 hotspots (mainly on the Western region coast and in Volta and Oti) and 10 cold spots (mainly in Bono) remained significant after FDR correction.

Conclusion: Two in five women of reproductive age in Ghana were estimated to have been anaemic in 2022. Risk appeared to be shaped more by region and pregnancy status than by household wealth or education once geography was accounted for. Anaemia-control programming may benefit from prioritising the northern high-risk zone alongside routine antenatal supplementation, with the smaller coastal Western and Volta hotspots investigated further; individual cluster-level hotspots should be treated as exploratory.

Keywords: Anaemia; Women of reproductive age; Socioeconomic factors; Spatial analysis; Getis-Ord G_i^* ; Demographic and Health Survey; Ghana; Cross-sectional study

INTRODUCTION

Anaemia, defined by the World Health Organization as a haemoglobin concentration below an age-, sex-, and physiology-specific threshold, remains among the most widespread nutritional and public health problems affecting women of reproductive age (World Health Organization (WHO), 2011). It is not a single disease but the common endpoint of several overlapping causes, principally iron deficiency, malaria; other parasitic infections, chronic inflammation and haemoglobinopathies, and their relative contributions differ by setting (Hess et al., 2023). Globally, anaemia affects roughly three in ten women of reproductive age, with the burden concentrated disproportionately in low- and middle-income countries; sub-Saharan Africa carries one of the highest regional prevalences worldwide (Stevens et al., 2022; WHO, 2025).

The consequences extend beyond a laboratory value. In pregnancy, anaemia is associated with an increased risk of low birth weight, preterm delivery and maternal mortality from haemorrhage, and in non-pregnant women, it is linked to fatigue, reduced physical work capacity and impaired cognitive performance, with adverse effects on household productivity and child care (Young et al., 2023; Zhang et al., 2021). Because women of reproductive age transition between pregnancy and non-pregnancy across the life course, population-level anaemia control may also constitute a form of preparedness for the physiological demands of pregnancy.

In Ghana, successive Demographic and Health Surveys have shown anaemia prevalence among women persisting in the range the World Health Organization classifies as a severe public health problem (Tetteh et al., 2023). The 2022 Ghana Demographic and Health Survey, whose data this paper analyses, reported anaemia in roughly two in five women overall, with a higher burden among pregnant women than non-pregnant women (Ghana Statistical Service (GSS) & ICF, 2024). This persistence, despite decades of national nutrition and malaria control programming, suggests that national averages alone do not adequately capture the factors sustaining anaemia in the Ghanaian population.

A substantial literature across Ghana and the wider sub-Saharan region has examined individual- and household-level correlates of anaemia in women, generally associating pregnancy status, rural residence; lower household wealth, lower educational attainment, and high parity (Klu et al., 2024; Mare et al., 2023). A smaller but growing body of work has moved beyond individual predictors to ask whether anaemia clusters geographically in ways that a conventional regression, which treats every woman as an independent observation, cannot show. Geographically weighted and hotspot analyses of Demographic and Health Survey data from Ethiopia and elsewhere in the region suggest that both

the prevalence of anaemia and the strength of its socioeconomic correlates vary markedly across space, and that administrative units with the highest anaemia burden are not always the same units that conventional poverty targeting would prioritise (Belay et al., 2022; Nyarko et al., 2023). Within Ghana specifically, the north-south gradient in poverty, food insecurity, and child malnutrition is well documented (Van de Poel et al., 2007).

Two recent analyses are closest to the present study. Agulu et al. (2025) analysed the same 2022 survey round separately for non-pregnant and pregnant women and represented geography with a three-category ecological zone variable (southern, middle and northern) in modified Poisson regression models; they reported higher prevalence in the northern zone but did not use the survey's cluster coordinates. Inusah et al. (2026) described trends and regional inequalities in anaemia among women of reproductive age from 2000 to 2019, with projections to 2030, using modelled estimates for Ghana's former ten administrative regions in an ecological design without formal spatial statistics. A regional or zonal indicator in a regression model estimates one average difference for all women within an administrative boundary. It cannot show whether high prevalence is concentrated in particular parts of a region, whether such concentrations cross regional boundaries, or whether a region whose average odds ratio is close to the reference contains a localised area of high burden. Cluster-level spatial statistics address these questions directly, and they operate closer to the district and sub-district scale at which supplementation, malaria control and nutrition outreach are delivered. To our knowledge, no published study has formally tested for statistically significant spatial clusters, or hotspots, of anaemia among Ghanaian women of reproductive age using the geocoded 2022 survey round, or examined whether such clusters persist under alternative spatial specifications and correction for multiple testing.

This evidence gap consequently warrants further investigation. Ghana's national anaemia prevalence figure, however precisely measured, is a population average that can obscure sub-national concentrations of risk; a district or cluster with an average burden can sit beside one with a substantially higher burden without either being visible in the national statistic. Anaemia control resources, from iron-folic acid supplementation and malaria chemoprevention to nutrition education, are finite and are typically allocated at the regional or district level. Identifying whether Ghana's anaemia burden is randomly scattered or forms statistically significant geographic clusters, and whether those clusters coincide with, or diverge from, conventional socioeconomic risk markers, may have a direct bearing on how such resources might reasonably be targeted.

This study therefore aimed to describe the prevalence and severity of anaemia among women aged 15–49 years in Ghana using the 2022 Demographic and Health Survey, to examine its socioeconomic and demographic correlates using survey-weighted multivariable logistic regression, and to test for and map statistically significant spatial clusters of anaemia prevalence at the survey-cluster level using Getis-Ord G_i^* statistics. Specifically, the study sought to: (1) estimate the weighted prevalence and severity distribution of anaemia among women of reproductive age; (2) identify socioeconomic and demographic factors independently associated with anaemia and with its severity; and (3) determine the spatial distribution of anaemia and identify statistically significant hotspot and cold spot clusters across the country, and assess how sensitive these clusters are to alternative analytical specifications.

METHODS

Study design and setting

The present study comprised a secondary analysis of cross-sectional data from the 2022 Ghana Demographic and Health Survey (GDHS), a nationally representative household survey implemented by the Ghana Statistical Service in partnership with the Ghana Health Service and ICF, with technical and financial support from the DHS Program (GSS & ICF, 2024). Fieldwork covered all 16 administrative regions of Ghana (GSS & ICF, 2024). The survey used a stratified two-stage cluster design: enumeration areas (clusters) were selected as primary sampling units within urban/rural strata in each region, followed by systematic selection of households within each selected cluster. Full details of the sampling frame, questionnaire content, and fieldwork procedures are documented in the official survey report (GSS & ICF, 2024).

This analysis used two publicly available components of the survey: the women's Individual Recode file (GHIR8CFL), which contains interview and biomarker data for women aged 15–49 years, and the geographic (GPS) dataset (GHGE8AFL), which provides displaced global positioning system (GPS) coordinates for each survey cluster.

Study population

The target population consisted of women of reproductive age (15–49 years) who were usually resident in or had stayed the night before the survey in sampled households across Ghana. The source population for this analysis was the 15,014 women who completed the individual woman's questionnaire in the 2022 GDHS. The study population for the primary analysis was defined as the subset of these women who resided in households randomly selected for haemoglobin testing and who had a valid haemoglobin measurement recorded. The unit of analysis for the descriptive and regression analyses was the individual woman; the unit of analysis for the spatial hotspot analysis was the survey cluster (primary sampling unit).

Eligibility criteria

Inclusion criteria: women aged 15–49 years who completed the individual interview in the 2022 GDHS, resided in a household selected for the haemoglobin testing subsample, and consented to and received a capillary blood haemoglobin measurement with a recorded, valid result.

The study excluded women who were not selected for the haemoglobin-testing subsample and women who, although selected, had no haemoglobin measurement because they refused testing ($n = 91$), were absent at testing ($n = 22$), or had an unrecorded result ($n = 6$).

Sample size

This was a secondary analysis; accordingly, no new sample size was calculated, and the analytic sample was determined by the original Ghana Demographic and Health Survey (GDHS) 2022 sampling design and haemoglobin-testing completeness. The Ghana Statistical Service and ICF determined the overall GDHS 2022 sample size using standard DHS Program sample size procedures (GSS & ICF, 2024). Of the 15,014 women interviewed, 7,676 resided in households randomly selected for haemoglobin testing; of these, 7,557 (98.4%) had a valid haemoglobin measurement and formed the analytic sample for the individual-level analyses. All 618 survey clusters had at least four women with a valid haemoglobin result (median 12, interquartile range 10–15) and were retained for the cluster-level spatial analysis.

Sampling and recruitment

The GDHS 2022 used a stratified, two-stage probability sampling design (GSS & ICF, 2024). In the first stage, enumeration areas (clusters) were selected with probability proportional to size within each of the 32 sampling strata, which were formed by crossing the 16 regions with urban and rural residence. In the second stage, households were systematically selected from a household listing conducted in each selected cluster. Every eligible woman aged 15–49 years in selected households was interviewed. A subsample of households was additionally selected for anthropometric and biomarker measurement, including haemoglobin testing by trained fieldworkers using a battery-operated HemoCue photometer on a capillary blood sample, following standard DHS Program biomarker protocols. No independent participant recruitment was undertaken in this study; rather, the GDHS 2022 field teams completed all sampling and recruitment before data release.

Study variables and operational definitions

Primary outcome. The primary outcome was anaemia status, derived from haemoglobin concentration adjusted for altitude and smoking status using the standard Demographic and Health Surveys (DHS) Program adjustment algorithm (Sullivan et al., 2008). Consistent with World Health Organization thresholds (WHO, 2011), women were classified by severity as not anaemic, mildly anaemic, moderately anaemic, or severely anaemic, using survey variable v457. For the regression analyses, anaemia was dichotomised as anaemic (mild, moderate, or severe) versus not anaemic, consistent with the binary primary-outcome specification agreed for this analysis; the four-level severity classification (none, mild, moderate, severe) was retained as a secondary ordinal outcome and analysed with ordinal logistic regression, as described below.

Independent and candidate variables. Candidate socioeconomic and demographic correlates were: place of residence (urban/rural); region (16 categories, Greater Accra as reference); age group in five-year bands; highest educational level attained (no education, primary, secondary, higher); household wealth quintile (the DHS Program's composite wealth index, constructed from household asset ownership and housing characteristics via principal components analysis and grouped into national quintiles); marital status (never in union, currently in union, formerly in union); occupation, grouped from the detailed International Standard Classification of Occupations-based survey codes into not working, agriculture, manual or skilled labour, sales and services, and professional/clerical/managerial categories; parity (number of children ever born, grouped as 0, 1–2, 3–4, 5 or more); and current pregnancy status. Body mass

index was examined descriptively but not entered into the regression models, because it may itself be altered by pregnancy (Versele et al., 2023) and could duplicate, rather than adjust for, the pregnancy-status pathway already modelled directly.

Potential confounders. Age, region, residence, wealth, education, marital status, occupation, parity, and pregnancy status were considered simultaneously in the multivariable model as mutually adjusting covariates rather than as a strict exposure-confounder hierarchy, consistent with the descriptive, correlate-identification aim of this analysis rather than a single a priori causal exposure.

Data collection instrument

Data collection employed the standard DHS Program Women's Questionnaire, administered face-to-face by trained interviewers in the respondent's preferred language, and a Biomarker Questionnaire for anthropometric and haemoglobin measurement. Both instruments appear to be standardised, previously validated DHS Program tools that have been used across numerous countries and survey rounds (GSS & ICF, 2024); country-specific adaptations for the 2022 round (translation, local occupation, and region codes) are documented in the survey's final report. This study used no additional, investigator-designed instrument.

Pre-testing, validity and reliability

The Ghana Statistical Service and ICF conducted questionnaire pre-testing, interviewer training, translation, and content-validity review as part of the standard DHS Program survey implementation protocol prior to this study's involvement. No new validity or reliability testing, including Cronbach's alpha, appears to have been conducted for this secondary analysis, since no new composite scale was constructed; the wealth index used is the DHS Program's existing, previously validated asset-based index (Martel et al., 2021).

Data collection procedure

Trained Ghana Demographic and Health Survey (GDHS) 2022 field teams conducted household listing, interviews, and biomarker measurement under the supervision of the Ghana Statistical Service. The study's involvement commenced after the authors obtained public-release de-identified data from the DHS Program; the authors undertook no original data collection, respondent contact, or field supervision.

Data management and statistical analysis

All analyses were conducted in Python 3 using pandas for data management, the samplics package for design-based (survey-weighted) estimation, and libpysal and esda for spatial statistics. Women's individual sample weights (v005, rescaled by dividing by 1,000,000) were applied throughout the individual-level analyses to restore national representativeness; primary sampling unit (v021) and sample strata (v023) were incorporated into all inferential analyses using Taylor-series linearisation to obtain design-based standard errors, consistent with DHS Program guidance for complex-survey analysis (Croft et al., 2023). The ordinal model, the beta-binomial empirical Bayes smoothing and the spatial scan statistic were programmed in Python with NumPy and SciPy.

Descriptive statistics. Sociodemographic characteristics and anaemia prevalence were summarised as weighted percentages with unweighted sample sizes (Table 1).

Bivariate analysis. The unadjusted (crude) association between each candidate variable and anaemia was estimated using single-variable survey-weighted logistic regression, yielding crude odds

ratios (COR) with 95% confidence intervals and Wald p-values, rather than a design-naïve chi-square test, so that the bivariate and multivariable estimates were derived under an identical, survey-consistent estimation framework (Table 2).

Multivariable analysis. All candidate variables were entered simultaneously into a single survey-weighted multivariable logistic regression model to obtain adjusted odds ratios (AOR) with 95% confidence intervals (Table 3). Reference categories were selected as the largest or conceptually most neutral category of each variable (Tables 2 and 3). Multicollinearity among candidate predictors was assessed using variance inflation factors (VIF) on the corresponding unweighted dummy-coded design matrix; all VIF values were below 6, which may suggest an absence of severe multicollinearity. Statistical significance was set at $\alpha=0.05$ throughout. Because the smallest observed p-values were below the precision of standard reporting, they are presented as $p < 0.001$ rather than $p = 0.000$.

Ordinal analysis. To use the full severity information, the four-level outcome was modelled with a survey-weighted proportional-odds (cumulative logit) model containing the same covariates as the binary model (McCullagh, 1980). Odds ratios from this model express the odds of being in a more severe category. The proportional-odds assumption was examined by fitting survey-weighted binary logistic models at the 'any anaemia' (mild or worse) and 'moderate or severe' thresholds and testing the equality of all coefficients across the two thresholds with an adjusted Wald test based on their joint linearised covariance. The severe threshold was not modelled separately because only 68 women (1.1%) had severe anaemia. A linear trend across wealth quintiles was tested by entering wealth as a score from 1 to 5, and joint adjusted Wald F-tests were used for region and wealth. Standard errors were obtained by Taylor-series linearisation with the same weights, primary sampling units and strata as the binary models.

Spatial analysis. Individual-level anaemia status was aggregated, using survey weights, to a weighted anaemia prevalence for each of the 618 survey clusters. These cluster-level prevalence estimates were merged with the corresponding displaced cluster GPS coordinates from the geospatial covariates file. Global spatial autocorrelation was assessed with Moran's I; local spatial clustering was assessed with the Getis-Ord G_i^* local statistic (Ord & Getis, 1995), using a k-nearest-neighbour spatial weights matrix with $k=8$ neighbours per cluster. Statistical significance of the G_i^* statistic for each cluster was assessed using a conditional permutation approach (999 permutations) and clusters were classified by confidence level (90%, 95%, 99%) as hotspots (significantly high prevalence surrounded by high-prevalence neighbours), cold spots (significantly low prevalence surrounded by low-prevalence neighbours), or not significant, following the standard G_i^* Bin classification convention. Sensitivity to these choices was assessed as described below.

Spatial sensitivity analyses. Because clusters contained a median of 12 tested women (minimum 4), raw cluster prevalences are unstable, and five further analyses were performed. First, cluster prevalences were shrunk towards the national mean by empirical Bayes smoothing (Marshall, 1991), using a beta-binomial model fitted by maximum likelihood to the unweighted numbers of anaemic and tested women in each cluster; Moran's I and G_i^* were then recomputed on the smoothed prevalences. Second, G_i^* was repeated with $k=4$ and $k=12$ nearest neighbours and with a binary distance-band matrix whose threshold (44.0 km, on

Table 1: Sociodemographic characteristics and weighted anaemia prevalence among women aged 15–49 years, Ghana Demographic and Health Survey (DHS) 2022 (n = 7,557).

Characteristic	Level	Sample Size (unweighted)	Weighted Percentage	Anaemia Prevalence, Weighted Percentage
Place of Residence				
	Urban	3,708	57.2	39.4
	Rural	3,849	42.8	43.4
Region				
	Greater Accra	508	16.3	38.8
	Ashanti	576	19.4	37.5
	Ahafo	428	2.1	35.6
	Bono	432	3.9	30.1
	Bono East	474	4.3	40.3
	Central	514	11.7	44.4
	Eastern	441	8.2	37.5
	North East	470	1.8	45.0
	Northern	582	7.4	48.4
	Oti	444	2.5	51.8
	Savannah	524	2.2	43.2
	Upper East	501	4.3	47.0
	Upper West	487	2.6	46.3
	Volta	398	4.4	43.0
	Western	409	6.4	45.9
	Western North	369	2.5	36.3
Age Group (years)				
	15–19	1,424	17.8	43.8
	20–24	1,328	17.7	38.6
	25–29	1,194	15.8	40.1
	30–34	1,137	15.1	38.2
	35–39	1,016	13.8	39.7
	40–44	837	11.3	46.2
	45–49	621	8.6	43.4
Highest Educational Attainment				
	No education	1,676	15.9	45.4
	Primary	1,144	14.0	42.6
	Secondary	4,103	60.3	40.3
	Higher	634	9.8	36.8
Wealth Quintile				
	Poorest	1,839	16.0	46.6
	Poorer	1,661	17.8	41.8
	Middle	1,519	20.4	40.8
	Richer	1,391	23.4	39.3
	Richest	1,147	22.4	38.8
Marital Status				
	Never in union	2,441	34.7	40.4
	Currently in union	4,485	55.2	41.3
	Formerly in union	631	10.1	42.8
Occupation				
	Not working	1,677	21.9	42.2
	Agriculture	1,783	17.3	43.7
	Manual/skilled labour	833	10.3	43.4
	Sales and services	2,677	41.7	39.9
	Professional/clerical/managerial	520	7.9	36.7
	Other/not classified	67	1.0	37.1
Parity (children ever born)				
	0	2,311	32.0	41.3
	1–2	2,189	29.7	39.3
	3–4	1,695	22.4	39.9
	5+	1,362	15.8	45.9
Current Pregnancy Status				
	No/unsure	7,004	93.3	40.4
	Yes	553	6.7	51.4
Body Mass Index Category (n = 7,550)^a				
	Underweight	577	7.0	49.3
	Normal	4,151	49.4	44.6
	Overweight	1,729	24.8	37.6
	Obese	1,093	18.8	33.9

BMI category is reported for 7,550 of 7,557 women (7 missing values).

Table 2: Bivariate (crude) analysis of factors associated with anaemia among women aged 15–49 years, Ghana DHS 2022

Characteristic	Level	Anaemia (%)	Crude Odds Ratio (95% Confidence Interval)	p-value
Place of Residence				
	Urban	39.4	1.00 (Reference)	
	Rural	43.4	1.18 (1.04–1.34)	0.009
Region				
	Greater Accra	38.8	1.00 (Reference)	
	Ashanti	37.5	0.94 (0.74–1.21)	0.655
	Ahafo	35.6	0.87 (0.67–1.13)	0.302
	Bono	30.1	0.68 (0.47–0.99)	0.043
	Bono East	40.3	1.07 (0.80–1.42)	0.661
	Central	44.4	1.26 (0.95–1.66)	0.107
	Eastern	37.5	0.95 (0.70–1.28)	0.716
	North East	45.0	1.29 (0.99–1.68)	0.057
	Northern	48.4	1.48 (1.16–1.88)	0.002
	Oti	51.8	1.70 (1.29–2.22)	<0.001
	Savannah	43.2	1.20 (0.92–1.56)	0.186
	Upper East	47.0	1.40 (1.03–1.89)	0.029
	Upper West	46.3	1.36 (1.03–1.80)	0.032
	Volta	43.0	1.19 (0.89–1.59)	0.239
	Western	45.9	1.34 (1.00–1.78)	0.049
	Western North	36.3	0.90 (0.65–1.24)	0.512
Age Group (years)				
	15–19	43.8	1.00 (Reference)	
	20–24	38.6	0.80 (0.66–0.97)	0.026
	25–29	40.1	0.86 (0.70–1.05)	0.129
	30–34	38.2	0.79 (0.64–0.98)	0.028
	35–39	39.7	0.84 (0.68–1.04)	0.115
	40–44	46.2	1.10 (0.88–1.38)	0.407
	45–49	43.4	0.98 (0.75–1.28)	0.887
Highest Educational Attainment				
	No education	45.4	1.00 (Reference)	
	Primary	42.6	0.89 (0.74–1.08)	0.232
	Secondary	40.3	0.81 (0.71–0.93)	0.002
	Higher	36.8	0.70 (0.56–0.88)	0.002
Wealth Quintile				
	Poorest	46.6	1.00 (Reference)	
	Poorer	41.8	0.82 (0.69–0.99)	0.034
	Middle	40.8	0.79 (0.66–0.96)	0.015
	Richer	39.3	0.74 (0.62–0.89)	0.002
	Richest	38.8	0.73 (0.60–0.89)	0.002
Marital Status				
	Never in union	40.4	1.00 (Reference)	
	Currently in union	41.3	1.04 (0.91–1.18)	0.559
	Formerly in union	42.8	1.11 (0.88–1.40)	0.393
Occupation				
	Not working	42.2	1.00 (Reference)	
	Agriculture	43.7	1.06 (0.89–1.27)	0.506
	Manual/skilled labour	43.4	1.05 (0.85–1.30)	0.669
	Sales and services	39.9	0.91 (0.78–1.06)	0.209
	Professional/clerical/managerial	36.7	0.79 (0.64–0.99)	0.040
	Other/not classified	37.1	0.81 (0.43–1.51)	0.504
Parity (children ever born)				
	0	41.3	1.00 (Reference)	
	1–2	39.3	0.92 (0.78–1.09)	0.334
	3–4	39.9	0.95 (0.79–1.14)	0.549
	5+	45.9	1.21 (1.01–1.44)	0.034
Currently Pregnant				
	No/unsure	40.4	1.00 (Reference)	
	Yes	51.4	1.56 (1.27–1.92)	<0.001

COR, crude odds ratio (survey-weighted logistic regression); CI, confidence interval. Bold p-values indicate $p < 0.05$.

Table 3: Multivariable (adjusted) analysis of factors associated with anaemia among women aged 15–49 years, Ghana DHS 2022.

Characteristic	Level	Adjusted Odds Ratio (95% Confidence Interval)	p
Place of Residence	Urban	1.00 (Reference)	
	Rural	1.07 (0.91–1.26)	0.415
Region	Greater Accra	1.00 (Reference)	
	Ashanti	0.90 (0.70–1.16)	0.427
	Ahafo	0.79 (0.59–1.05)	0.100
	Bono	0.64 (0.43–0.94)	0.024
	Bono East	0.98 (0.73–1.32)	0.890
	Central	1.20 (0.90–1.60)	0.225
	Eastern	0.87 (0.64–1.19)	0.399
	North East	1.11 (0.83–1.48)	0.469
	Northern	1.35 (1.04–1.76)	0.024
	Oti	1.54 (1.16–2.06)	0.003
	Savannah	1.02 (0.76–1.37)	0.903
	Upper East	1.25 (0.91–1.70)	0.165
	Upper West	1.19 (0.88–1.61)	0.263
	Volta	1.11 (0.82–1.49)	0.495
	Western	1.27 (0.94–1.70)	0.117
	Western North	0.82 (0.58–1.14)	0.232
Age Group (years)	15–19	1.00 (Reference)	
	20–24	0.81 (0.65–1.00)	0.055
	25–29	0.88 (0.68–1.15)	0.349
	30–34	0.80 (0.59–1.10)	0.166
	35–39	0.86 (0.63–1.18)	0.362
	40–44	1.14 (0.80–1.62)	0.459
	45–49	1.01 (0.69–1.46)	0.966
Highest Education	No education	1.00 (Reference)	
	Primary	0.99 (0.80–1.22)	0.900
	Secondary	0.98 (0.82–1.18)	0.840
	Higher	0.95 (0.67–1.35)	0.779
Wealth Quintile	Poorest	1.00 (Reference)	
	Poorer	0.88 (0.73–1.06)	0.165
	Middle	0.90 (0.71–1.14)	0.376
	Richer	0.86 (0.66–1.12)	0.258
	Richest	0.87 (0.66–1.16)	0.357
Marital Status	Never in union	1.00 (Reference)	
	Currently in union	0.99 (0.79–1.24)	0.920
	Formerly in union	1.14 (0.85–1.53)	0.388
Occupation	Not working	1.00 (Reference)	
	Agriculture	0.88 (0.72–1.09)	0.238
	Manual or skilled labour	1.06 (0.84–1.34)	0.625
	Sales and services	0.93 (0.77–1.11)	0.393
	Professional, clerical, or managerial	0.90 (0.68–1.19)	0.459
	Other/not classified	0.84 (0.44–1.61)	0.605
Parity (children ever born)	0	1.00 (Reference)	
	1–2	0.93 (0.74–1.17)	0.524
	3–4	0.94 (0.70–1.24)	0.646
	5+	1.09 (0.79–1.51)	0.590
Currently Pregnant	No/unsure	1.00 (Reference)	
	Yes	1.71 (1.38–2.12)	<0.001

AOR, adjusted odds ratio, mutually adjusted for all variables shown (survey-weighted logistic regression accounting for clustering, stratification and sampling weights); CI, confidence interval. Bold p-values indicate $p < 0.05$.

coordinates projected to kilometres) was the smallest distance giving every cluster at least one neighbour. Third, because 618 local tests were performed and conditional permutation controls the error rate of each test separately but not across tests, the primary analysis was rerun with 99,999 permutations, to give sufficient p-value resolution, and the Benjamini–Hochberg false discovery rate (FDR) procedure was applied at $q=0.05$ and $q=0.10$ (Benjamini & Hochberg, 1995). Fourth, the primary analysis was repeated with 20 different random seeds for the permutations. Agreement of each alternative classification with the primary one (hotspot, cold spot or not significant at 90% confidence) was summarised as percentage agreement and Cohen’s kappa. Fifth, as a check that does not depend on a spatial weights matrix, a purely spatial Bernoulli scan statistic (Kulldorff, 1997) was applied to the unweighted counts of anaemic and non-anaemic women, using circular windows containing up to 50% of tested women and 999 Monte Carlo replications; high- and low-risk windows with $p < 0.05$ are reported.

Bias and quality assurance

Several sources of potential bias were considered. Selection bias could arise if women selected for haemoglobin testing differed systematically from those excluded, or if non-response to testing (1.6% of the eligible sub-sample) was non-random; the GDHS 2022 biomarker sub-sample was itself randomly selected within the probability sampling design (GSS & ICF, 2024), and non-response was low, which may limit the scope for material selection bias. Measurement bias in haemoglobin readings was minimised through the use of a standardised, calibrated HemoCue device and trained fieldworkers following a uniform protocol across all clusters (GSS & ICF, 2024), though field conditions (temperature, device calibration drift) cannot be fully verified retrospectively from a secondary data source. Recall bias may affect self-reported variables such as parity and occupation, though these are relatively low-recall items compared with, for example, dietary intake. Social desirability bias is unlikely to materially affect the objective, device-measured primary outcome. Residual confounding from unmeasured factors, including malaria parasitaemia, dietary

iron intake, helminth infection, and inflammatory markers, may nevertheless remain because these variables were unavailable in the files used for this analysis; this issue is addressed further under limitations.

Ethical considerations

The present analysis was based on de-identified, publicly available secondary data. The original 2022 GDHS received ethical clearance from the Ghana Health Service Ethics Review Committee and from ICF’s Institutional Review Board in the United States, and all participants provided informed consent for interview and biomarker measurement at the time of the original survey (GSS & ICF, 2024). The DHS Program’s public-use data files contain no names, household addresses, or other direct identifiers; geographic identifiers are limited to the regional level in the survey record, and cluster GPS coordinates are randomly displaced (up to 2 km for urban clusters and up to 5 km, with 1% displaced up to 10 km, for rural clusters) so that individual enumeration areas cannot be re-identified (Burgert et al., 2013). Access to the datasets used in this analysis was formally authorised by the DHS Program for the registered research project “Spatial distribution and socioeconomic correlates of anaemia among women of reproductive age in Ghana: a hotspot analysis using DHS 2022 geospatial data” (authorisation letter dated 3 September 2022, issued to Abubakar Iddrisu Siddiq, Presbyterian University, Ghana). No separate institutional ethical clearance appears to have been sought for this secondary analysis beyond DHS Program data-use authorisation.

RESULTS

Participant flow

Of the 15,014 women aged 15–49 years interviewed in the 2022 GDHS, 7,676 resided in households selected for the haemoglobin testing sub-sample. Haemoglobin was not obtained for 119 of these women (91 refused, 22 were not present, and 6 for other reasons), leaving 7,557 women (98.4% of the eligible sub-sample) with a valid haemoglobin measurement, thereby constituting the analytic sample for the present study (Figure 1). All 618 survey

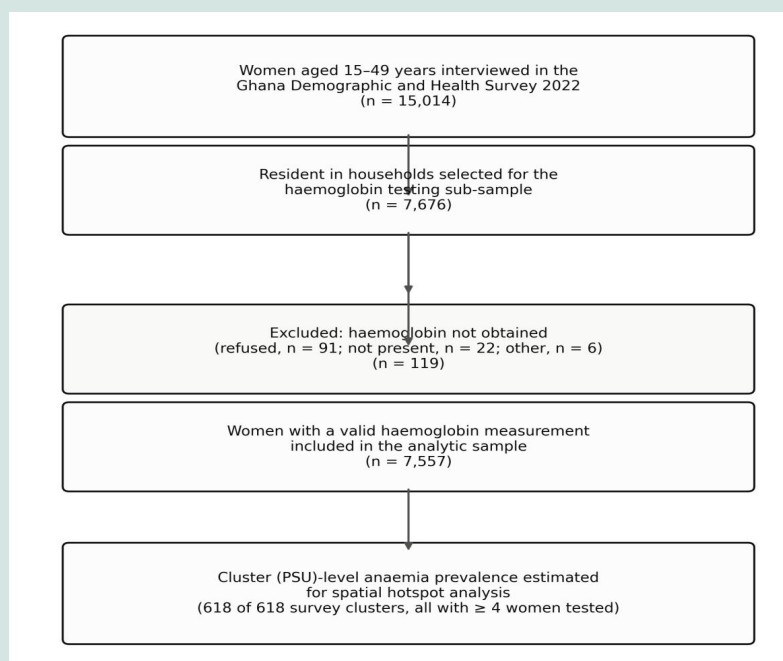


Figure 1: Flow diagram of participant inclusion in the analytic sample

clusters retained at least 4 tested women (median 12 women per cluster) and were used in the cluster-level spatial analysis.

Sociodemographic characteristics of study participants

Table 1 summarises the weighted sociodemographic characteristics of the analytic sample. Slightly more than half of women resided in urban areas (57.2%). The largest regional shares were from Ashanti (19.4%) and Greater Accra (16.3%); the smallest were from Ahafo (2.1%) and North East (1.8%), reflecting the underlying regional population distribution captured by the survey's sampling weights. Most women attained at least secondary education (60.3% secondary, 9.8% higher), while 15.9% had no formal education. Wealth quintiles were relatively evenly distributed, with a slightly larger share in the richer (23.4%) than the poorest (16.0%) quintile. Just over half of women (55.2%) were currently in a union, and 6.7% were pregnant at the time of interview.

Prevalence and severity of anaemia

The weighted prevalence of anaemia among women aged 15–49 years was estimated at 41.1% (3,181 of 7,557 women, unweighted; based on the DHS-standard altitude- and smoking-adjusted classification). The severity distribution suggests that 58.9% of women were not anaemic, 22.6% had mild anaemia, 17.3% had moderate anaemia, and 1.1% had severe anaemia (Figure 2). This computed prevalence appears closely consistent with the figure of approximately 41% reported in the official GDHS 2022 survey report (GSS & ICF, 2024) and with an independent secondary analysis of the same dataset (Agulu et al., 2025), which similarly reported 40.4% among non-pregnant women and 51.4% among pregnant women; the corresponding figures in the present analysis were 40.4% and 51.4%, respectively, thereby providing a close internal consistency check on the survey-weighted computation used here.

Bivariate analysis of factors associated with anaemia

Table 2 delineates the weighted prevalence of anaemia and the crude (unadjusted) odds ratios for each candidate variable. In bivariate analysis, anaemia prevalence was significantly higher among rural women than among urban women (43.4% vs 39.4%;

crude odds ratio [COR] 1.18, 95% confidence interval [CI] 1.04–1.34), among women with no education compared with those with higher education (45.4% vs 36.8%; COR for higher education 0.70, 95% CI 0.56–0.88), and among the poorest compared with the richest wealth quintile (46.6% vs 38.8%; COR for richest 0.73, 95% CI 0.60–0.89). Anaemia prevalence appeared to vary substantially by region, from 30.1% in Bono to 51.8% in Oti. Pregnant women appeared to have higher unadjusted odds of anaemia than non-pregnant women (COR 1.56, 95% CI 1.27–1.92). Women with five or more children had higher odds than nulliparous women (COR 1.21, 95% CI 1.01–1.44).

Multivariable analysis of factors associated with anaemia

In the multivariable model, adjusting simultaneously for residence, region, age, education, wealth, marital status, occupation, parity and pregnancy status, several associations observed in bivariate analysis appeared to be substantially attenuated (Table 3, Figure 3). Rural residence was no longer significantly associated with anaemia after adjustment (adjusted odds ratio [AOR] 1.07, 95% CI 0.91–1.26), nor were education (AOR for higher vs no education 0.95, 95% CI 0.67–1.35) or wealth quintile (AOR for richest vs poorest 0.87, 95% CI 0.66–1.16).

Region appeared to remain independently associated with anaemia after adjustment. Relative to Greater Accra, women in the Oti region were estimated to have significantly higher adjusted odds of anaemia (AOR 1.54, 95% CI 1.16–2.06, $p = 0.003$), as did women in the Northern region (AOR 1.35, 95% CI 1.04–1.76, $p = 0.024$). Conversely, women in the Bono region were estimated to have significantly lower adjusted odds than those in Greater Accra (AOR 0.64, 95% CI 0.43–0.94, $p = 0.024$). No other region differed significantly from Greater Accra after adjustment.

Pregnancy status appeared to exhibit the strongest independent association with anaemia in the multivariable model: pregnant women were estimated to have 71% higher adjusted odds of anaemia than non-pregnant women (AOR 1.71, 95% CI 1.38–2.12, $p < 0.001$). Age group, marital status, occupation and parity were not significantly associated with anaemia after adjustment for the other covariates (all $p > 0.05$; Table 3).

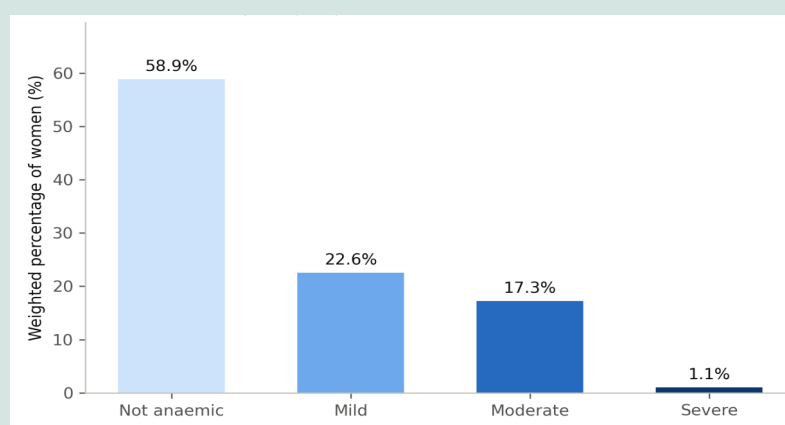


Figure 2: Severity distribution of anaemia among women aged 15–49 years, Ghana DHS 2022 (n = 7,557).

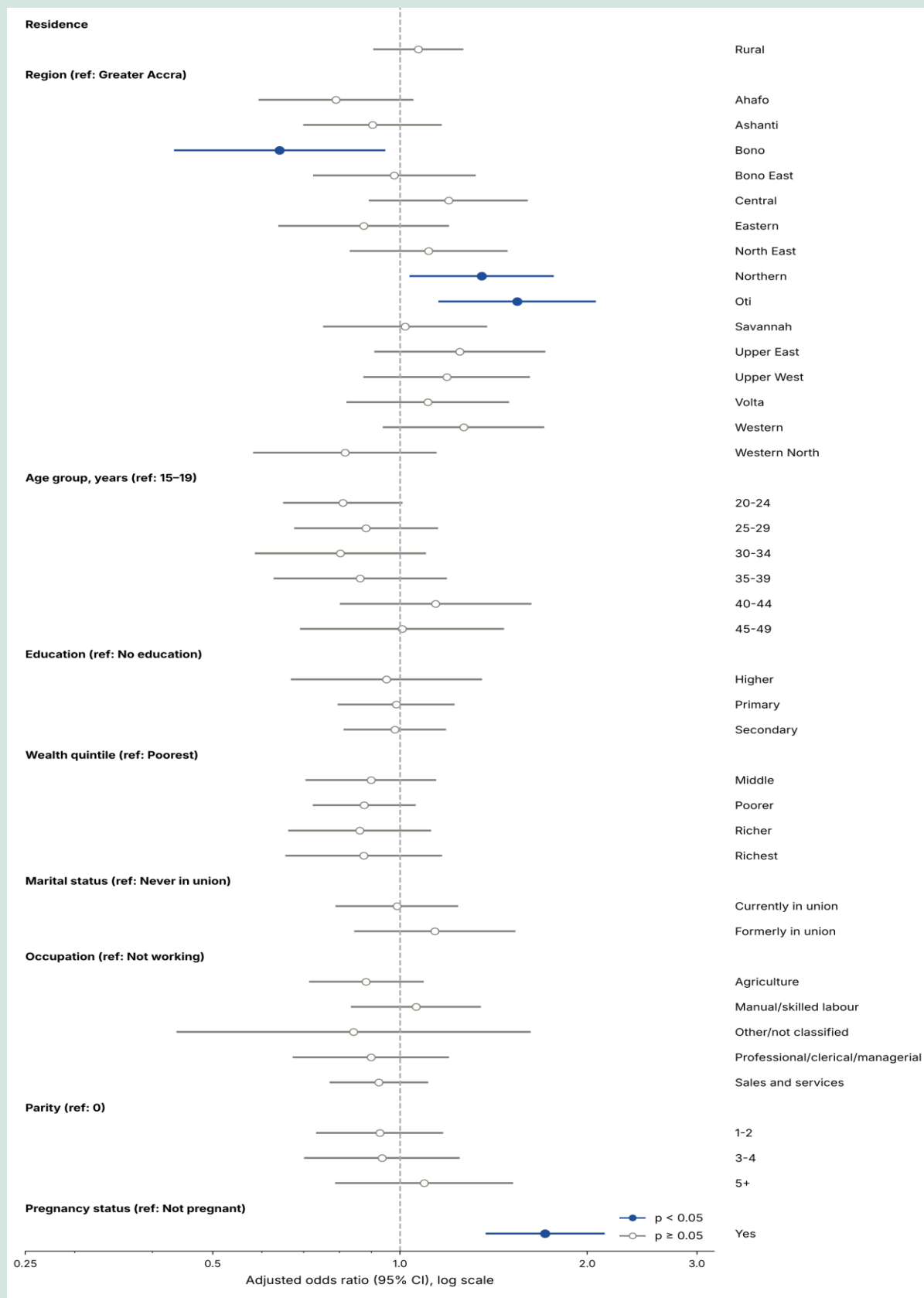


Figure 3: Adjusted odds ratios for socioeconomic and demographic correlates of anaemia among women aged 15–49 years, Ghana DHS 2022 (multivariable survey-weighted logistic regression).

Ordinal analysis of anaemia severity

The severity distribution differed by pregnancy status and region. Among pregnant women, 28.6% had mild, 22.6% moderate and 0.2% severe anaemia, compared with 22.2%, 17.0% and 1.2% among non-pregnant women. Moderate anaemia ranged from 11.9% in Bono to 24.0% in Oti and was 22.5% in the poorest and 14.2% in the richest wealth quintile. Severe anaemia was uncommon (68 women; 1.1%), occurred in only one pregnant woman and was not concentrated in the northern regions: its weighted prevalence was highest in Greater Accra (2.4%), and no severe case was recorded in Upper West.

Table 4 presents the survey-weighted proportional-odds model. Pregnant women had 63% higher odds of being in a more severe anaemia category than non-pregnant women (OR 1.63, 95% CI 1.35–1.97, $p < 0.001$). Relative to Greater Accra, women in Oti had higher odds of more severe anaemia (OR 1.44, 95% CI 1.11–1.87, $p = 0.007$); the estimate for the Northern region had the same direction but was of borderline significance (OR 1.27, 95% CI 0.99–1.64, $p = 0.057$), and women in Bono (OR 0.63, 95% CI 0.43–0.91, $p = 0.015$) and Ahafo (OR 0.75, 95% CI 0.57–0.98, $p = 0.035$) had lower odds. Region was jointly associated with severity (adjusted Wald $F(15, 572) = 3.84$, $p < 0.001$), whereas wealth was not ($F(4, 583) = 0.72$, $p = 0.582$), and there was no linear trend across wealth quintiles (OR per quintile 0.97, 95% CI 0.90–1.04, $p = 0.342$). Rural residence and education were not

associated with severity.

The proportional-odds assumption was supported: coefficients from the 'any anaemia' and 'moderate or severe' threshold models did not differ jointly (adjusted Wald $F(40, 547) = 0.89$, $p = 0.672$), nor for pregnancy ($p = 0.554$), region ($p = 0.742$) or wealth ($p = 0.607$). At the moderate-or-severe threshold, the association with pregnancy persisted (OR 1.59, 95% CI 1.24–2.05), whereas the odds ratios for Oti (1.27, 95% CI 0.89–1.81) and the Northern region (1.16, 95% CI 0.82–1.62) were smaller and not statistically significant. The pregnancy and regional associations therefore reflect a shift from no anaemia towards mild and moderate anaemia. Severe anaemia was too rare to be modelled separately, and its distribution did not follow the regional pattern.

Spatial distribution and hotspot analysis of anaemia

Cluster-level weighted anaemia prevalence ranged from 0% to 100% across the 618 survey clusters (median 41.7%). Global Moran's I indicated statistically significant positive spatial autocorrelation in cluster-level anaemia prevalence (Moran's $I = 0.156$, $p = 0.001$), suggesting that anaemia prevalence is not randomly distributed across Ghana but tends to cluster among geographically proximate survey locations.

The Getis-Ord G_i^* local statistic identified 109 clusters (17.6% of all clusters) as statistically significant hotspots of high anaemia prevalence (23 at 99% confidence, 60 at 95% confidence, 26

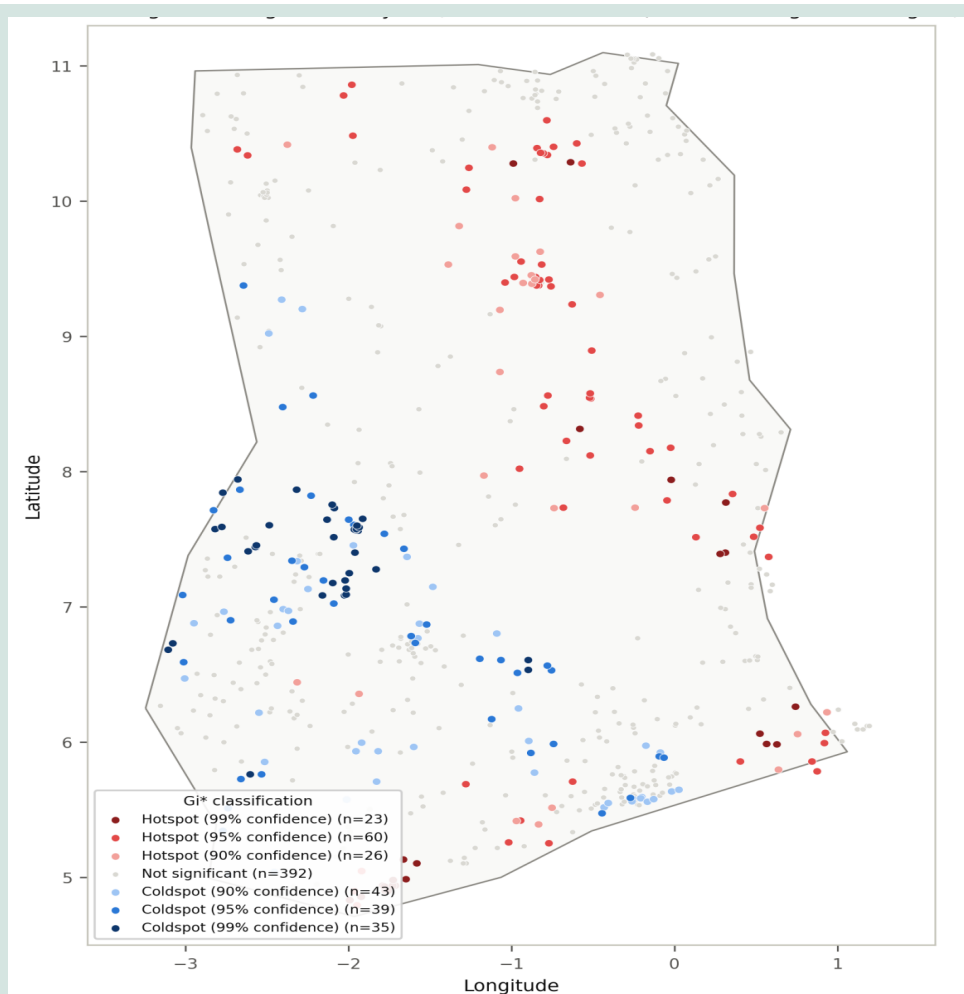


Figure 4: Getis-Ord G_i^* hotspot analysis of cluster-level anaemia prevalence among women aged 15–49 years, Ghana DHS 2022 (k-nearest-neighbour spatial weights, $k = 8$).

at 90% confidence) and 117 clusters (18.9%) as statistically significant cold spots of low anaemia prevalence (35 at 99% confidence, 39 at 95% confidence, 43 at 90% confidence); the remaining 392 clusters (63.4%) showed no statistically significant local clustering (Figure 4). Hotspot clusters appeared to be concentrated in the northern half of the country, principally in the Northern (20 hotspot clusters), North East (14), Oti (13) and Savannah (12) regions (65 of the 109 hotspots lay in Oti and the five northern regions), and in Volta (10), broadly consistent with the elevated regional adjusted odds ratios described above. A second concentration of 15 hotspots, the second largest number for any region, lay along the Western region coast in and around the Sekondi-Takoradi metropolitan area. Cold spot clusters appeared to be concentrated in the mid-southern forest belt, principally Bono (22 cold spot clusters), Ahafo (16), Ashanti (14), Bono East (14) and Eastern (13) regions, together with Greater Accra (12). Hotspot clusters were split roughly evenly between rural (58) and urban (51) classifications, suggesting that the spatial clustering identified here reflects broader regional geography rather than the urban-rural distinction captured in the regression model.

Of the 15 Western region hotspot clusters, 11 were urban. Women in these clusters ($n = 169$) had a weighted anaemia prevalence of 55.8%, compared with 37.8% among women in the region's other clusters ($n = 240$), although they were less often rural (24.3% vs 61.7%), less often in the two poorest wealth quintiles (7.5% vs 37.4%) and less often without formal education (2.7% vs 15.9%). Nationally, women in hotspot clusters ($n = 1,421$) were more often rural (49.8% vs 41.6%), in the two poorest quintiles (45.0% vs 31.9%) and without formal education (26.2% vs 14.1%) than women in other clusters ($n = 6,136$), and their weighted anaemia prevalence was 50.3%, compared with 39.5%.

Sensitivity analyses for the spatial results

Table 5 and Figure 5 summarise the spatial sensitivity analyses. Global spatial autocorrelation was positive and significant under every specification (Moran's I 0.145 to 0.167, all $p = 0.001$). The beta-binomial model indicated modest between-cluster heterogeneity (intracluster correlation 0.035; likelihood-ratio statistic 42.5 against a binomial model), and empirical Bayes smoothing narrowed the range of cluster prevalences from 0–100% to 26.6–56.9%. Gi^* on the smoothed prevalences classified 114 hotspots and 103 cold spots and agreed with the primary classification for 93.0% of clusters ($kappa$ 0.87), retaining 104 of the 109 primary hotspots and 96 of the 117 primary cold spots. Repeating the primary analysis with 20 different permutation seeds gave 119 to 128 hotspots and 104 to 128 cold spots, with 95.2% to 97.4% agreement ($kappa$ 0.91 to 0.95).

Classification was more sensitive to the neighbourhood definition. Agreement with the primary analysis was 76.9% for $k = 4$ ($kappa$ 0.53), 81.9% for $k = 12$ ($kappa$ 0.68) and 74.6% for the 44.0 km distance band ($kappa$ 0.57), and larger neighbourhoods produced more and broader clusters (147 and 140 hotspots for $k = 12$ and the distance band, compared with 88 for $k = 4$). Under every specification the hotspots lay mainly in the northern half of the country, in Volta and on the Western coast, and the cold spots in the Bono, Bono East, Ahafo and Ashanti forest belt and, in most specifications, parts of Greater Accra (Figure 5).

After Benjamini–Hochberg correction with 99,999 permutations, 12 hotspots and 10 cold spots remained significant at $q = 0.05$, and 31 hotspots and 37 cold spots at $q = 0.10$; all were among the primary hotspots and cold spots. These hotspots lay on the Western coast (6 at $q = 0.05$; 13 at $q = 0.10$), in Volta (4; 4) and Oti

(2; 5), with a further 4 in North East, 2 in Upper West and single clusters in the Northern, Savannah and Greater Accra regions at $q = 0.10$. The corresponding cold spots lay mostly in Bono (6; 15), Bono East (2; 8) and Ahafo (0; 7).

The Bernoulli scan statistic identified one large high-risk window covering most of northern Ghana (216 clusters in the Northern, Upper East, North East, Oti, Savannah and Upper West regions and parts of Bono East; 2,946 women; prevalence 47.9%; relative risk 1.25; $p = 0.001$) and a small secondary high-risk window in southern Volta (8 clusters; 75 women; prevalence 66.7%; relative risk 1.59; $p = 0.042$). One low-risk window covered the western forest belt (203 clusters in Ashanti, Western North, Ahafo, Bono, Bono East and inland parts of the Western region; 2,349 women; prevalence 34.6%; relative risk 0.76; $p = 0.001$). The scan statistic did not identify the Western coastal concentration as a significant window.

DISCUSSION

This study found that two in five women of reproductive age in Ghana were anaemic in 2022, that this burden was shaped independently by pregnancy status and region rather than by individual household wealth or education after controlling for geography, and that anaemia appears to form statistically significant geographic hotspots concentrated in the country's northern regions, with corresponding cold spots in the mid-southern forest belt; the broad pattern held under alternative specifications, although only a smaller core of local hotspots survived correction for multiple testing.

The overall prevalence of 41.1% is consistent with the figure reported in the official GDHS 2022 report and an independent secondary analysis of the same survey round (Agulu et al., 2025; GSS & ICF, 2024), which is unsurprising given that all three draw on the same underlying data, but it is a useful internal validity check on the survey-weighted estimation approach used here. This prevalence appears to remain within the World Health Organization's severe public health problem category ($\geq 40\%$ prevalence) for the female population overall (WHO, 2011), and is considerably higher among pregnant women (51.4% in this analysis; see also Agulu et al., 2025). The persistence of this burden across successive DHS rounds, documented by Inusah et al. (2026) for Ghana specifically, suggests that national-level nutrition and malaria control programming, while likely beneficial, may not have been sufficient on its own to bring the national average below the severe threshold.

The finding that pregnancy status carried the strongest independent association with anaemia (AOR 1.71) is consistent with the physiological expectation that pregnancy increases iron and folate requirements while haemodilution lowers measured haemoglobin, and matches the pattern reported by Agulu et al. (2025) in their pregnancy-stratified analysis of the same survey. It supports the rationale for iron-folic acid supplementation throughout antenatal care as a first-line intervention, while also suggesting that a sizeable minority of non-pregnant women, four in ten in this sample, are anaemic outside of pregnancy and would not be reached by antenatal-only programming. The ordinal analysis adds that pregnancy was associated with a shift towards more severe categories (OR 1.63), with proportional odds across the mild and moderate thresholds. Tirore et al. (2024) reported a similar association in pooled data from 21 sub-Saharan African countries (AOR 1.72). Severe anaemia, however, affected only one pregnant woman in this sample, consistent with the 0.2% reported by Agulu et al. (2025); this may reflect detection and

Table 4: Survey-weighted ordinal (proportional-odds) logistic regression of anaemia severity among women aged 15–49 years, Ghana DHS 2022 (n = 7,557).

Characteristic	Level	OR (95% CI), ordinal model	p	OR (95% CI), moderate or severe vs none or mild	p
Place of Residence					
	Urban	1.00 (Reference)		1.00 (Reference)	
	Rural	1.07 (0.91–1.26)	0.421	1.11 (0.90–1.36)	0.324
Region					
	Greater Accra	1.00 (Reference)		1.00 (Reference)	
	Ashanti	0.88 (0.69–1.12)	0.298	0.82 (0.58–1.15)	0.252
	Ahafo	0.75 (0.57–0.98)	0.035	0.63 (0.43–0.92)	0.017
	Bono	0.63 (0.43–0.91)	0.015	0.61 (0.39–0.95)	0.028
	Bono East	0.97 (0.73–1.30)	0.853	1.01 (0.71–1.43)	0.947
	Central	1.18 (0.89–1.58)	0.245	1.16 (0.80–1.69)	0.441
	Eastern	0.84 (0.62–1.13)	0.247	0.72 (0.48–1.10)	0.131
	North East	1.07 (0.80–1.42)	0.657	0.99 (0.67–1.46)	0.960
	Northern	1.27 (0.99–1.64)	0.057	1.16 (0.82–1.62)	0.399
	Oti	1.44 (1.11–1.87)	0.007	1.27 (0.89–1.81)	0.194
	Savannah	0.96 (0.72–1.27)	0.767	0.82 (0.56–1.19)	0.286
	Upper East	1.24 (0.91–1.68)	0.167	1.23 (0.84–1.80)	0.280
	Upper West	1.12 (0.83–1.51)	0.469	1.00 (0.66–1.50)	0.995
	Volta	1.13 (0.83–1.53)	0.429	1.21 (0.82–1.78)	0.343
	Western	1.26 (0.96–1.66)	0.095	1.27 (0.91–1.77)	0.153
	Western North	0.81 (0.58–1.12)	0.194	0.80 (0.53–1.22)	0.301
Highest Education					
	No education	1.00 (Reference)		1.00 (Reference)	
	Primary	0.95 (0.77–1.16)	0.602	0.90 (0.69–1.16)	0.412
	Secondary	0.93 (0.78–1.11)	0.429	0.83 (0.66–1.05)	0.122
	Higher	0.92 (0.66–1.29)	0.631	0.88 (0.58–1.34)	0.547
Wealth Quintile					
	Poorest	1.00 (Reference)		1.00 (Reference)	
	Poorer	0.86 (0.72–1.03)	0.110	0.82 (0.66–1.03)	0.088
	Middle	0.89 (0.70–1.13)	0.349	0.91 (0.68–1.24)	0.559
	Richer	0.85 (0.65–1.11)	0.235	0.83 (0.59–1.17)	0.289
	Richest	0.84 (0.62–1.12)	0.225	0.74 (0.51–1.07)	0.111
Currently Pregnant					
	No/unsure	1.00 (Reference)		1.00 (Reference)	
	Yes	1.63 (1.35–1.97)	<0.001	1.59 (1.24–2.05)	<0.001

OR, odds ratio; CI, confidence interval. Ordinal model: survey-weighted proportional-odds model for the four-level outcome (none, mild, moderate, severe); an OR above 1 indicates higher odds of a more severe category. Moderate or severe: survey-weighted binary logistic model at that threshold. Both models were mutually adjusted for all variables in Table 3, including age group, marital status, occupation and parity (not shown; all $p > 0.05$ in the ordinal model). Test of proportional odds across the two thresholds: adjusted Wald $F(40, 547) = 0.89$, $p = 0.672$. Linear trend across wealth quintiles (ordinal model): OR 0.97 per quintile (95% CI 0.90–1.04), $p = 0.342$. Severe anaemia (68 women) was too rare for a separate model.

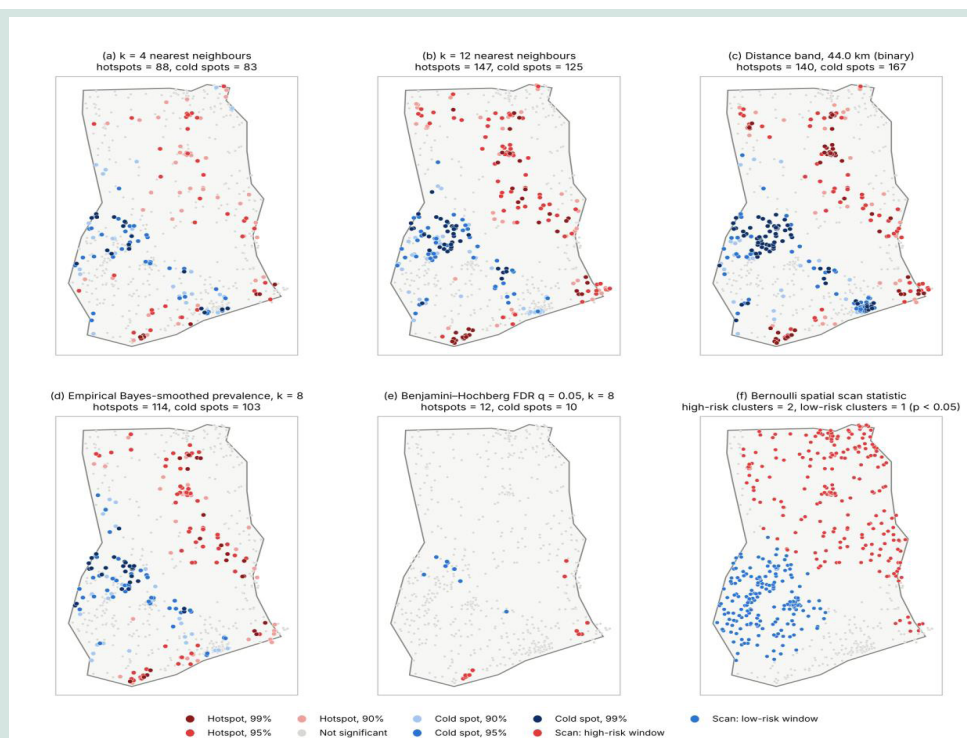


Figure 5: Sensitivity of the Getis-Ord Gi* hotspot classification of cluster-level anaemia prevalence among women aged 15–49 years to (a) $k = 4$, (b) $k = 12$ and (c) 44.0 km distance-band weights, (d) empirical Bayes smoothing and (e) Benjamini–Hochberg FDR correction ($q = 0.05$), with (f) the Bernoulli spatial scan statistic, Ghana DHS 2022.

Table 5: Sensitivity of the spatial cluster analysis of anaemia prevalence to alternative specifications, Ghana DHS 2022 (618 clusters).

Specification	Moran's I	Hotspots	Cold spots	Agreement with primary (%)	Kappa	Primary hotspots retained	Primary cold spots retained
Primary: k = 8, raw prevalence, 999 permutations	0.156	109	117	100.0	1.00	109	117
k = 4 nearest neighbours	0.167	88	83	76.9	0.53	61	66
k = 12 nearest neighbours	0.146	147	125	81.9	0.68	99	94
Distance band, 44.0 km (binary)	0.145	140	167	74.6	0.57	93	95
Empirical Bayes-smoothed prevalence, k = 8	0.166	114	103	93.0	0.87	104	96
FDR q = 0.05, k = 8, 99,999 permutations	0.156	12	10	67.0	0.14	12	10
FDR q = 0.10, k = 8, 99,999 permutations	0.156	31	37	74.4	0.38	31	37
Primary, 20 alternative permutation seeds (range)	0.156	119–128	104–128	95.2–97.4	0.91–0.95	109	104–117

All Moran's I values had permutation $p = 0.001$. Hotspots and cold spots are counted at 90% confidence or higher (permutation $p < 0.10$), except in the FDR rows, which count clusters significant after Benjamini–Hochberg adjustment. Agreement and Cohen's kappa compare the three-category classification (hotspot, cold spot, not significant) with the primary analysis. The empirical Bayes row uses beta-binomial posterior mean prevalences. The distance-band threshold was the smallest distance giving every cluster at least one neighbour (mean 21.0 neighbours, range 1–70). FDR, false discovery rate.

treatment of severe anaemia within antenatal care, although the data cannot test this.

The attenuation of rural residence, education and wealth after adjusting for region is the most conceptually important finding of the multivariable analysis. In bivariate analysis, these variables showed the socioeconomic gradient reported in most of the sub-Saharan African literature (Mare et al., 2023), but each association weakened and lost statistical significance once region entered the model alongside the other covariates. Several strands of prior evidence help explain this pattern rather than treating it as anomalous. Multilevel analyses of pooled sub-Saharan African DHS data have found that a substantial share of the variance in anaemia risk sits at the community or cluster level, independent of individually measured household characteristics (Tirore et al., 2024), which is consistent with region absorbing explanatory power that a model without a geographic term would otherwise attribute to wealth or education. Geographically weighted regression analyses in Ethiopia appear to indicate that the strength, and occasionally the direction, of the wealth-anaemia association is not constant across the country but varies by location (Tesema et al., 2021), and a rural-urban stratified Ethiopian analysis similarly found that the wealth-anaemia relationship differs by residence stratum rather than operating as a single fixed effect (Abate et al., 2021). A coverage-equity analysis in Ethiopia likewise found that the areas of highest anaemia burden did not always coincide with the areas of highest conventional poverty targeting would prioritise (Hailu et al., 2021). Read together, this literature suggests that in agrarian, food-insecurity-driven settings such as northern Ghana, regional exposures operating largely independently of individual household wealth—plausibly seasonal food availability, malaria endemicity, dietary iron bioavailability, and distance to health facilities—may play a more significant role in determining anaemia risk than a household's position in the national wealth distribution. This is a plausible interpretation rather than a demonstrated causal mechanism; distinguishing compositional effects (who lives where) from genuinely place-based effects

would require the decomposition or multilevel modelling approaches used elsewhere in the literature (Negussie & Nigatu, 2023), which were beyond the scope of this analysis.

The ordinal analysis points the same way. Wealth showed no gradient in severity (OR per quintile 0.97, 95% CI 0.90–1.04), whereas region did. In the pooled sub-Saharan African data, women in the poorest households had higher odds of more severe anaemia and education was associated with lower severity (Tirore et al., 2024). The absence of these gradients in Ghana after regional adjustment is consistent with the interpretation above, although it may also reflect the overlap between region and wealth in Ghana and the limited precision for individual wealth categories.

The elevated adjusted odds of anaemia in the Oti and Northern Regions, and the hotspot clusters detected in these and neighbouring northern regions by the Getis-Ord G_i^* analysis and the scan statistic, echo a longstanding pattern in Ghana's health and nutrition statistics. The north-south gradient in child malnutrition and poverty documented by Van de Poel et al. (2007) nearly two decades ago, and the persistent regional disparity in anaemia burden reported across multiple DHS rounds by Inusah et al. (2026), both point to a structural, rather than transient, feature of northern Ghana's health landscape. The lower adjusted odds observed in the Bono Region, one of Ghana's more recently created regions situated in the middle forest belt, appear consistent with the cold spot concentration detected there and in neighbouring Ahafo, Bono East, and Ashanti Regions, an area generally associated with more diversified agriculture and food availability than the savannah north. Bono also contained the largest number of cold spots that remained significant after FDR correction.

These explanations for the northern excess draw on evidence from other studies, because the files analysed here contain no malaria, inflammation, micronutrient or dietary measures. The present data support three narrower points. First, women in

hotspot clusters were more often rural, poorer and without formal education than other women, yet Oti and the Northern region retained higher adjusted odds after these characteristics were accounted for, so the northern excess is not fully explained by the measured composition of the population. Second, the excess was concentrated in mild and moderate anaemia; severe anaemia was rare and was not more common in the north. Long-term exposures of moderate intensity, such as low dietary iron bioavailability and repeated malaria episodes, would be expected to produce this pattern, but this remains an inference. Third, the 2017 Ghana Micronutrient Survey found that anaemia and micronutrient deficiencies among non-pregnant women were more common in rural areas, poorer households and the northern belt (Wegmüller et al., 2020), and the factors associated with anaemia differed by ecological zone, with iron deficiency associated with anaemia in children in the northern and middle belts and inflammation in the southern and middle belts (Petry et al., 2021). Linking the survey clusters to malaria and micronutrient biomarker data would be needed to test these explanations directly.

The Western region hotspot requires separate explanation. It contained the second largest number of hotspot clusters (15) and the largest number that survived FDR correction, but the region's adjusted odds ratio was not significant (AOR 1.27, 95% CI 0.94–1.70). The two findings are compatible. The hotspot clusters lay along the coast in and around the Sekondi-Takoradi metropolitan area, where anaemia prevalence was 55.8%, whereas the region's other clusters had a prevalence of 37.8%, close to the national average; a single regional coefficient averages the two. The coastal hotspot also differs from the northern pattern. Its women were mostly urban, relatively wealthy and educated, so household poverty is unlikely to explain it, which agrees with the absence of a socioeconomic gradient in the adjusted model. The available data cannot identify the cause. Possible explanations include local differences in malaria transmission, helminth infection, haemoglobinopathy prevalence or diet, and a measurement effect cannot be excluded, because haemoglobin was measured by field teams assigned to geographically contiguous groups of clusters. The scan statistic, which uses circular windows and unweighted counts, did not detect this narrow coastal strip, so the finding should be confirmed with district health data or a later survey round before it is used for targeting. The same caution applies to the small southern Volta cluster detected by the scan statistic, although Volta has had the highest modelled anaemia prevalence among women of any region in recent years (Inusah et al., 2026).

To our knowledge, this is among the first studies to formally test for, and map, statistically significant Getis-Ord G_i^* hotspots of anaemia among women of reproductive age using the geocoded 2022 GDHS round specifically. Compared with Agulu et al. (2025), who analysed the same survey round with a three-category ecological zone variable, and Inusah et al. (2026), who examined regional trends to 2030 using aggregated estimates for the former ten regions, the present analysis adds three kinds of evidence. It shows that anaemia clusters at a sub-regional scale and that clusters cross current regional boundaries, as with the scan-statistic window spanning Oti, the five northern regions and part of Bono East. It identifies local concentrations that a regional term misses, most clearly the Western coastal hotspot in a region whose adjusted odds ratio was not significant. It also shows which local clusters persist across choices of neighbourhood, smoothing and multiple-testing correction, which is the information needed before sub-regional targeting is considered. The significant

global Moran's I (0.156, $p = 0.001$), which was stable across all specifications (0.145 to 0.167), suggests that this clustering is unlikely to be attributable to chance, and is directionally consistent with hotspot analyses of anaemia and related outcomes conducted elsewhere in the region using comparable DHS geospatial data (Nyarko et al., 2023). The roughly even urban-rural split among hotspot clusters (58 rural, 51 urban) is a notable finding in its own right: it suggests that the spatial clustering detected here reflects a broader regional geography of risk rather than simply redescribing the urban-rural divide already captured by the regression model, where it was found to be non-significant after adjustment. The sensitivity analyses also show that the classification of individual clusters is less certain than the overall pattern. With a median of 12 tested women per cluster, between a fifth and a quarter of clusters changed category when the neighbourhood definition changed, and most nominal hotspots did not survive FDR correction. Cluster-level hotspot maps from a single DHS round are therefore best treated as exploratory, with most weight placed on the stable core: the northern high-risk zone, the Western coastal and southern Volta hotspots, and the Bono and Ahafo cold spots.

STRENGTHS AND LIMITATIONS

This study has several strengths. It used a large, nationally representative sample with objectively measured haemoglobin rather than self-reported symptoms, applied a design-consistent survey-weighted estimation framework throughout both the regression and descriptive analyses, and combined individual-level regression with cluster-level spatial statistics to characterise the anaemia burden from two complementary angles. Using the GDHS 2022 geospatial file enabled the addition of a previously absent Ghana-specific spatial hotspot perspective on anaemia to an already substantial literature on individual-level correlates. The spatial conclusions were also checked against alternative weights matrices, empirical Bayes smoothing, FDR correction and an independent scan statistic, and the severity outcome was analysed with an ordinal model.

Several limitations should be considered when interpreting these findings. First, this is a cross-sectional study; all associations, including the regional and pregnancy-status associations, describe statistical relationships at a single point in time and cannot establish temporal sequence or causation. Second, several biologically plausible confounders and mediators of anaemia, including malaria parasitaemia, helminth infection, inflammatory markers, dietary iron and folate intake, and haemoglobinopathy status, were unavailable in the analytic dataset and could not be adjusted for; residual confounding from these factors, several of which plausibly vary by region, cannot be ruled out and may itself partly explain the regional associations observed. Third, cluster GPS coordinates in DHS Program data are randomly displaced by up to 2 km in urban clusters and up to 5 km (with 1% displaced up to 10 km) in rural clusters, to protect respondent confidentiality (Burgert et al., 2013); this displacement may introduce a small amount of positional noise into the hotspot analysis, which is unlikely to materially affect regional-scale patterns but could attenuate very fine-grained local clustering. Fourth, haemoglobin was measured in a subsample of households rather than the full sample, and while non-response within this subsample was low (1.6%), any systematic difference between tested and untested women that is not captured by the survey weights could introduce a small selection bias. Fifth, although global clustering and the broad hotspot pattern were stable, the classification of individual

clusters changed for between a fifth and a quarter of clusters under alternative neighbourhood definitions, and only 22 of the 226 nominal hotspots and cold spots remained significant after FDR correction at $q = 0.05$; cluster-level classifications should therefore be read as exploratory. Sixth, anaemia was dichotomised for the primary regression, which discards information on severity and treats mild and severe anaemia as equivalent, although they differ in clinical and programme significance. The supplementary ordinal model recovered part of this information, but severe anaemia (68 women) was too rare for a separate multivariable model or for a formal test of proportional odds at the severe threshold. Finally, occupation and parity categories with very small cell sizes (for example, the 67 women classified as having an unclassifiable occupation) yield wide confidence intervals for those specific categories, and results for such categories should be interpreted with caution.

IMPLICATIONS FOR PRACTICE AND POLICY

For antenatal care, the association between pregnancy and anaemia, including moderate anaemia, supports universal iron-folic acid supplementation and early haemoglobin screening. Because four in ten non-pregnant women were also anaemic, preconception and general reproductive health services are needed alongside antenatal programmes.

For regional and district planning, the stable spatial findings support two levels of action: sustained, region-wide anaemia control across the northern high-risk zone, and investigation of the smaller hotspots on the Western coast and in southern Volta, whose causes are unknown and should be established before resources are redirected. Cluster-level hotspots that did not survive correction for multiple testing should not be used for targeting on their own.

Because household wealth and education were not associated with anaemia or its severity once region was included, targeting based on household wealth alone is likely to miss much of the geographically concentrated burden. These implications rest on a single cross-sectional survey round and should be weighed alongside local programme and budget information.

RECOMMENDATIONS FOR FUTURE RESEARCH

The limitations above suggest four directions for future research: First, linking haemoglobin and geospatial DHS data with concurrent malaria parasitaemia, inflammation and micronutrient biomarker data, where available in a given survey round, would allow the relative contribution of infectious and nutritional pathways to the observed regional clustering to be disentangled, rather than inferred indirectly as in this analysis. Second, a multilevel or spatial decomposition analysis, explicitly partitioning anaemia risk into individual-, cluster- and region-level components, would formally test whether the attenuation of socioeconomic associations observed here reflects genuine place-based effects or the compositional sorting of poorer, less-educated women into higher-risk regions, a distinction this cross-sectional regression could not make. Third, repeating this hotspot analysis using earlier GDHS rounds with geospatial data available would establish whether the identified hotspot and cold spot locations are stable over time, which would strengthen the case for using them to guide medium-term programme planning rather than reacting to what could otherwise be a single survey round's sampling variability. Fourth, linking the survey clusters to routine district health and malaria surveillance data would allow the Western coastal and southern Volta hotspots, which the regional

regression did not capture, to be checked before they are used for planning.

CONCLUSION

Anaemia affected two in five women of reproductive age in Ghana in 2022, with pregnant women and women resident in the Oti and Northern regions bearing a disproportionate share of that burden. Pregnancy and residence in Oti were also associated with more severe anaemia, whereas household wealth showed no gradient in severity. Household socioeconomic markers that were associated with anaemia in unadjusted comparisons were not independently significant once region was accounted for, indicating that geography, rather than household wealth or education alone, may constitute a more consistent population-level marker of risk in this dataset. Statistically significant hotspots of high anaemia prevalence, concentrated in the country's northern regions, and cold spots concentrated in the mid-southern forest belt, were identified using Getis-Ord G_i^* analysis of the 2022 survey's geocoded clusters. The broad pattern was stable under alternative specifications and was confirmed by a spatial scan statistic, while a smaller core of hotspots on the Western coast and in Volta and Oti, and cold spots in Bono, survived correction for multiple testing. These findings may support continued prioritisation of antenatal iron-folic acid supplementation for pregnant women, and suggest that anaemia-control programming in Ghana may benefit from incorporating small-area spatial evidence alongside conventional household-wealth-based targeting, particularly in the northern high-risk zone, with the coastal Western and southern Volta hotspots investigated further. Based on a single cross-sectional survey round, this study describes an association pattern rather than a causal one, and its findings should be read as one input among several into programme and policy decisions.

DECLARATIONS

Ethics approval and consent to participate: See Ethical considerations in the Methods section. This study used de-identified, publicly available secondary data released under DHS Program data-use authorisation; the original survey received ethical clearance from the Ghana Health Service Ethics Review Committee and ICF's Institutional Review Board, and all original participants provided informed consent.

CONSENT FOR PUBLICATION: Not applicable (no data, images, or case details concerning identifiable individuals are presented).

AVAILABILITY OF DATA AND MATERIALS: The datasets analysed in this study are publicly available from the Demographic and Health Surveys (DHS) Program (<https://www.dhsprogram.com>) upon registration and approval of a research project, subject to the DHS Program's data use terms (<https://dhsprogram.com/Data/terms-of-use.cfm>). The specific files used were the Ghana 2022 Individual Recode (GHIR8CDT) and geographic (GPS) (GHGE8AFL) datasets. The redistribution of DHS microdata is restricted; interested researchers should apply directly to the DHS Program. Derived, non-identifying analysis code and aggregated cluster-level results are available from the corresponding author on reasonable request.

CONFLICTS OF INTEREST: The authors declare no competing interests.

FUNDING: The authors received no funding for this work.

Authors' contributions: Abubakar Iddrisu Siddiq led the conceptualization, methodology, statistical analysis, and preparation of the original draft; Theophilus Arthur-Gyimah

contributed to data curation and validation; Grace De-Graft Aitee contributed to the literature review and interpretation of findings; Nii Annan Jeremiah Oku contributed to data visualization and results interpretation; Emmanuel Vondee contributed to methodological review and critical revision of the manuscript; and Godlove Osei Asumang contributed to supervision, project administration, and final manuscript review, with all six authors approving the final version.

ABBREVIATIONS

AOR: Adjusted Odds Ratio

CI: Confidence Interval

COR: Crude Odds Ratio

DHS: Demographic and Health Survey

EB: Empirical Bayes

FDR: False Discovery Rate

GDHS: Ghana Demographic and Health Survey

Gi*: Getis-Ord Gi* local spatial statistic

GPS: Global Positioning System

GSS: Ghana Statistical Service

ICF: ICF International (implementing partner of the DHS Program)

OR: Odds Ratio

PSU: Primary Sampling Unit

STROBE: Strengthening the Reporting of Observational Studies in Epidemiology

VIF: Variance Inflation Factor

WHO: World Health Organization

REFERENCES

- Abate, T. W., Getahun, B., Birhan, M. M., Aknaw, G. M., Belay, S. A., Demeke, D., Abie, D. D., Alemu, A. M., & Mengiste, Y. (2021). The urban-rural differential in the association between household wealth index and anemia among women in reproductive age in Ethiopia, 2016. *BMC Women's Health*, 21(1), Article 311. <https://doi.org/10.1186/s12905-021-01461-8>
- Agulu, G. G., Ahissou, N. C. A., Kamiya, Y., Baiden, F., & Matsui, M. (2025). Anaemia prevalence and risk factors among nonpregnant and pregnant women of reproductive age in Ghana: An analysis of the Ghana demographic and health survey data. *Tropical Medicine and Health*, 53(1), Article 118. <https://doi.org/10.1186/s41182-025-00792-8>
- Belay, D. G., Adane, S. M., Ferede, O. L., & Lakew, A. M. (2022). Geographically weighted regression analysis of anemia and its associated factors among reproductive age women in Ethiopia using 2016 demographic and health survey. *PLoS ONE*, 17(9), Article e0274995. <https://doi.org/10.1371/journal.pone.0274995>
- Benjamini, Y., & Hochberg, Y. (1995). Controlling the false discovery rate: A practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society: Series B (Methodological)*, 57(1), 289–300. <https://doi.org/10.1111/j.2517-6161.1995.tb02031.x>
- Burgert, C. R., Colston, J., Roy, T., & Zachary, B. (2013). *Geographic displacement procedure and georeferenced data release policy for the Demographic and Health Surveys* (DHS Spatial Analysis Reports No. 7). ICF International. <https://dhsprogram.com/pubs/pdf/SAR7/SAR7.pdf>
- Croft, T. N., Allen, C. K., Zachary, B. W., et al. (2023). *Guide to DHS statistics*. ICF. <https://dhsprogram.com/Data/Guide-to-DHS-Statistics/>
- Ghana Statistical Service & ICF. (2024). *Ghana Demographic and Health Survey 2022*. <https://dhsprogram.com/pubs/pdf/FR387/FR387.pdf>
- Hailu, B. A., Laillou, A., Chitekwe, S., Beyene, J., & Baye, K. (2021). Subnational mapping for targeting anaemia prevention in women of reproductive age in Ethiopia: A coverage-equity paradox. *Maternal & Child Nutrition*, 20, Article e13277. <https://doi.org/10.1111/mcn.13277>
- Hess, S. Y., Owais, A., Jefferds, M. E. D., Young, M. F., Cahill, A., & Rogers, L. M. (2023). Accelerating action to reduce anemia: Review of causes and risk factors and related data needs. *Annals of the New York Academy of Sciences*, 1523(1), 11–23. <https://doi.org/10.1111/nyas.14985>
- Inusah, A., Jagha, T., Head, M., Seidu, A., & Ziblim, S. D. (2026). Trends, regional disparities, and projected burden of anemia among women of reproductive age in Ghana, 2000–2030. *Reproductive Health*, 23(1), Article 130. <https://doi.org/10.1186/s12978-026-02345-6>
- Klu, D., Kyei-Arthur, F., Appiah, M., & Odame, M. L. (2024). Multilevel predictors of anaemia among pregnant women in Ghana: New evidence from the 2019 Ghana Malaria Indicator Survey. *PLOS Global Public Health*, 4(9), Article e0003673. <https://doi.org/10.1371/journal.pgph.0003673>
- Kulldorff, M. (1997). A spatial scan statistic. *Communications in Statistics: Theory and Methods*, 26(6), 1481–1496. <https://doi.org/10.1080/03610929708831995>
- Mare, K. U., Aychiluhm, S. B., Sabo, K. G., Tadesse, A. W., Kase, B. F., Ebrahim, O. A., Tebeje, T. M., Mulaw, G. F., & Seifu, B. L. (2023). Determinants of anemia level among reproductive-age women in 29 Sub-Saharan African countries: A multilevel mixed-effects modelling with ordered logistic regression analysis. *PLoS ONE*, 18(11), Article e0294992. <https://doi.org/10.1371/journal.pone.0294992>
- Marshall, R. J. (1991). Mapping disease and mortality rates using empirical Bayes estimators. *Journal of the Royal Statistical Society: Series C (Applied Statistics)*, 40(2), 283–294. <https://doi.org/10.2307/2347593>
- Martel, P., Mbofana, F., & Cousens, S. (2021). The polychoric dual-component wealth index as an alternative to the DHS index: Addressing the urban bias. *Journal of Global Health*, 11, Article 04003. <https://doi.org/10.7189/jogh.11.04003>

- McCullagh, P. (1980). Regression models for ordinal data. *Journal of the Royal Statistical Society: Series B (Methodological)*, 42(2), 109–127. <https://doi.org/10.1111/j.2517-6161.1980.tb01109.x>
- Negussie, S. T., & Nigatu, R. G. (2023). Trends in regional inequalities in childhood anemia in Ethiopia: Evidence from the 2005–2016 Ethiopian Demographic and Health Surveys. *Discover Social Science and Health*, 3(1). <https://doi.org/10.1007/s44155-023-00038-0>
- Nyarko, S. H., Boateng, E. N. K., Dickson, K. S., Adzrago, D., Addo, I. Y., Acquah, E., & Ayebeng, C. (2023). Geospatial disparities and predictors of anaemia among pregnant women in Sub-Saharan Africa. *BMC Pregnancy and Childbirth*, 23(1), Article 743. <https://doi.org/10.1186/s12884-023-06008-3>
- Ord, J. K., & Getis, A. (1995). Local spatial autocorrelation statistics: Distributional issues and an application. *Geographical Analysis*, 27(4), 286–306. <https://doi.org/10.1111/j.1538-4632.1995.tb00912.x>
- Petry, N., Wirth, J. P., Adu-Afarwuah, S., Wegmüller, R., Woodruff, B. A., Tanumihardjo, S. A., Bentil, H., Donkor, W. E. S., Williams, T. N., Shahab-Ferdows, S., Selenje, L., Mahama, A., Steiner-Asiedu, M., & Rohner, F. (2021). Risk factors for anaemia among Ghanaian women and children vary by population group and climate zone. *Maternal & Child Nutrition*, 17(2), Article e13076. <https://doi.org/10.1111/mcn.13076>
- Stevens, G. A., Paciorek, C. J., Flores-Urrutia, M. C., Borghi, E., Namaste, S., Wirth, J. P., Suchdev, P. S., Ezzati, M., Rohner, F., Flaxman, S. R., & Rogers, L. M. (2022). National, regional, and global estimates of anaemia by severity in women and children for 2000–19: A pooled analysis of population-representative data. *The Lancet Global Health*, 10(5), e627–e639. [https://doi.org/10.1016/S2214-109X\(22\)00084-5](https://doi.org/10.1016/S2214-109X(22)00084-5)
- Sullivan, K. M., Mei, Z., Grummer-Strawn, L., & Parvanta, I. (2008). Haemoglobin adjustments to define anaemia. *Tropical Medicine & International Health*, 13(10), 1267–1271. <https://doi.org/10.1111/j.1365-3156.2008.02143.x>
- Tesema, G. A., Tessema, Z. T., Angaw, D. A., Tamirat, K. S., & Teshale, A. B. (2021). Geographic weighted regression analysis of hot spots of anemia and its associated factors among children aged 6–59 months in Ethiopia: A geographic weighted regression analysis and multilevel robust Poisson regression analysis. *PLoS ONE*, 16(11), Article e0259147. <https://doi.org/10.1371/journal.pone.0259147>
- Tetteh, A., Adanu, R. M. K., Folson, G., Agyabeng, K., Dwomoh, D., & Aryeetey, R. (2023). Drivers of anaemia reduction among women of reproductive age in the Eastern and Upper West regions of Ghana: A secondary data analysis of the Ghana Demographic and Health Surveys. *African Journal of Food, Agriculture, Nutrition and Development*, 23(116), 22248–22274. <https://doi.org/10.18697/ajfand.116.23075>
- Tireore, L. L., Areba, A. S., Habte, A., Desalegn, M., & Kebede, A. S. (2024). Prevalence and associated factors of severity levels of anemia among women of reproductive age in sub-Saharan Africa: A multilevel ordinal logistic regression analysis. *Frontiers in Public Health*, 11, Article 1349174. <https://doi.org/10.3389/fpubh.2023.1349174>
- Van de Poel, E., Hosseinpoor, A. R., Jehu-Appiah, C., Vega, J., & Speybroeck, N. (2007). Malnutrition and the disproportional burden on the poor: The case of Ghana. *International Journal for Equity in Health*, 6, Article 21. <https://doi.org/10.1186/1475-9276-6-21>
- Versele, V., Stas, L., Aerenhouts, D., Deliens, T., Clarys, P., Gucciardo, L., Bogaerts, A., & Devlieger, R. (2023). Changes in maternal and paternal body composition during the transition to parenthood (TRANSPARENTS). *Obesity*, 31(1), 225–233. <https://doi.org/10.1002/oby.23586>
- Wegmüller, R., Bentil, H., Wirth, J. P., Petry, N., Tanumihardjo, S. A., Allen, L., Williams, T. N., Selenje, L., Mahama, A., Amoafu, E., Steiner-Asiedu, M., Adu-Afarwuah, S., & Rohner, F. (2020). Anemia, micronutrient deficiencies, malaria, hemoglobinopathies and malnutrition in young children and non-pregnant women in Ghana: Findings from a national survey. *PLoS ONE*, 15(1), Article e0228258. <https://doi.org/10.1371/journal.pone.0228258>
- World Health Organization. (2011). *Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity* (WHO/NMH/NHD/MNM/11.1). <https://www.who.int/publications/i/item/WHO-NMH-NHD-MNM-11.1>
- World Health Organization. (2025). *WHO global anaemia estimates: Key findings*. <https://www.who.int/publications/i/item/9789240113930>
- Young, M. F., Oaks, B. M., Rogers, H. P., Tandon, S., Martorell, R., Dewey, K. G., & Wendt, A. S. (2023). Maternal low and high hemoglobin concentrations and associations with adverse maternal and infant health outcomes: An updated global systematic review and meta-analysis. *BMC Pregnancy and Childbirth*, 23(1), Article 264. <https://doi.org/10.1186/s12884-023-05489-6>
- Zhang, Q., Lu, X., Zhang, M., Yang, C., Lv, S., Li, S. F., Zhong, C.Y., & Geng, S.-S. (2021). Adverse effects of iron deficiency anemia on pregnancy outcome and offspring development and intervention of three iron supplements. *Scientific Reports*, 11(1), Article 1347. <https://doi.org/10.1038/s41598-020-79971-y>

©2026 Ali M, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License 4.0 International License.

Cite this article as: Siddiq AI, Arthur-Gyimah T, Aitee GD, Oku NAJ, Vondee E, et al. Spatial Distribution and Socioeconomic Correlates of Anaemia among Women of Reproductive Age in Ghana: A Hotspot Analysis of the 2022 Demographic and Health Survey.. *Glob Open Access J Sci*. 2026;2(3):88–104.