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Original Research Article

Spatial mapping and analysis of anaemia cases in Gadag district, Karnataka: a GIS-based study

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ABSTRACT

Background: Anaemia is one of the chronic public health problems in India and it is associated with inequities in healthcare service, nutrition status and socioeconomic status. Knowledge of geographic distribution of anemia can help for the identification of high-risk areas, where focused interventions can be implemented. This study aimed to map and analyse the spatial distribution, clustering patterns and hotspots of laboratory confirmed anaemia cases in the Gadag District.

Methods: A retrospective cross-sectional study on 4,040 cases of laboratory-confirmed anaemia has been carried out using secondary data. Spatial clustering was analysed using the average nearest neighbour (ANN) test; Global and Local Moran's I tested for spatial autocorrelation along with hotspots and cold areas of anaemia patients.

Results: Significant clustering was detected by the ANN test ($p<0.001$). Different hotspots were identified by using Local Moran's I and Getis-Ord Gi tools mainly in the Shirahatti, Laxmeshwar and Mundargi taluks, whereas Global Moran's I did not detect any significant autocorrelation.

Conclusions: The spatial distribution of anaemia in the Gadag District is non-random, spatially heterogeneous, with well-defined hotspot zones. The use of GIS based surveillance at district level planning will help in early detection and targeted management of anemia.

Keywords: Anaemia, Clustering, GIS, Moran’s I, Spatial analysis

INTRODUCTION

Anemia is defined by a deficiency in both the amount and quality of red blood cells, leading to an inadequate capacity for oxygen transport to meet the body's physiological requirements, accompanied by a hemoglobin (Hb) concentration that is below a designated threshold. The physiological needs depend on the gender, age, habitation altitude, smoking habits, health condition and also based on the stages of pregnancy.[1,2] Anemia usually occurs as a result of infections, chronic disease, vitamin deficiencies, genetic disorders and poor dietary habits. Iron insufficiency is the predominant cause of anemia in India, however insufficient intake of vitamin A, folate, B12 or riboflavin may also lead to the anemia problem in India. Anemia may exacerbate if there is inadequate nutrient absorption, blood loss during menstruation, childbirth or parasitic infection.[1,2] Children with iron deficiency anemia experience difficulties in cognition and motor skills, while affected adults exhibit reduced work performance. The impacts are more pronounced during early development and infancy. Iron deficiency anemia during the antenatal period may cause - premature delivery, low birth weight infants and perinatal loss.[3] Anemia is one of the most common global health problems, 269 million children under five age and 500 million women aged 15–49 years were affected. Percentage of anemic pregnant women and anemic women in reproductive age group are 37% and 30%, respectively, across the world (2019). In India and according to the NFHS-5 (2019–21) report 59.1% adolescent girls, 57% women of age 15–49 years and 67.1% children were anemic respectively.[2] The regular epidemiological approaches may miss the changes in disease prevalence over time period and differences across regions. Geographic information system (GIS) technology has become a powerful tool to analyze the spatial trends of health-related problems. GIS-based epidemiology makes it easier to find high-risk areas and service delivery gaps by combining health data with demographic and environmental factors. It can also find geographical clusters and look at temporal patterns, which can make planning and carrying out targeted interventions much easier, especially in places where resources are limited.[4-6]

The spatial distribution and areas at risk of anemia cases in the Gadag district of Karnataka have not been previously studied. Finding such clustering of anemia cases is essential for targeted, both preventive and curative interventions. This study aimed to determine the geographic distribution of anemia cases in Gadag District utilizing GIS-based spatial visualization tools, along with analyzing clustering patterns and hotspot locations through hot spot analysis, global and local Moran's I and ANN methods.

METHODS

Study design and period

A retrospective cross-sectional study was designed to assess the spatial distribution of anemia cases across the Gadag district utilizing secondary data collected between 2019 and 2021.

Study place

The study was conducted in the Gadag District of Karnataka, located in southern part of India, between 15.15°N and 15.80°N latitude and 75.50°E and 76.30°E longitude. The district has seven taluks: Gadag, Gajendragad, Ron, Shirhatti, Nargund, Lakshmeshwar and Mundargi.

Study population and data collection

A total of 4,040 laboratory confirmed anemia cases were included in this study, individuals aged more than one year, which includes children, adolescents, adults and elderly of both sexes. Data were collected from primary health centers (PHCs), community health centers (CHCs), taluk hospitals and school health check programs (RBSK). Along with hemoglobin values from health records, demographic information such as age and sex was documented. To ensure accurate geographic identification of each case, field health staff including ASHA workers, Anganwadi worker, ANM and MPW took GPS enabled photographs at the location where each case was identified, typically the individual's residence. The latitude and longitude coordinates obtained from these geotagged images were verified and then imported into a spatial database for mapping.

Case definition and classification

Anemia is a hematological disorder characterized by a reduction in hemoglobin concentration or red cell mass below the physiologically appropriate range for an individual's age, sex and biological status, leading to compromised oxygen delivery to tissues. Severity classification was based on WHO hemoglobin cut-off values.1

Geographic information system mapping and spatial analysis

Administrative boundary shapefiles of Gadag district including all the taluk, were obtained from the Survey of India and Bhuvan repositories. All spatial data were converted to the WGS 84 coordinate system and analyzed using ArcGIS version 10.7. Various spatial statistical tools were applied to explore patterns and clusters of anemia cases. The ANN tool was used to measure the overall spatial clustering. Global Moran's I statistic was used to evaluate district-wide spatial autocorrelation, while Local Moran's I (Anselin LISA) identified local clusters and spatial outliers. The Getis-Ord Gi* statistic was applied to detect statistically significant hotspots and cold spots. Th methods allowed to the identification of spatial heterogeneity and high-risk zones within the study area.

Statistical analysis

Descriptive statistics, including frequencies and percentages, were estimated using Jamovi software version 2.7.

Ethical approval and funding

Ethical approval was obtained from institutional ethics committee of gadag institute of medical sciences, Karnataka. As the study depends on only secondary data with no personal interview with study participants, informed consent was not required. GPS-enabled location data were collected solely for spatial mapping, without capturing identifiable personal information. The research was conducted without external funding support.

RESULTS

A total of 4,040 anemia cases were included in the study across the seven talukas of Gadag districts. Around 46.7% included individuals are under the age of 20. The highest percentages were observed in the age group of 1–10 years (24.7%) than 11–20 years (22.0%) groups and followed by the 21–30 years (19.5%) (Table 1). By gender, females constituted 77.1% of the total study population, while males accounted for 22.9% (Table 2).

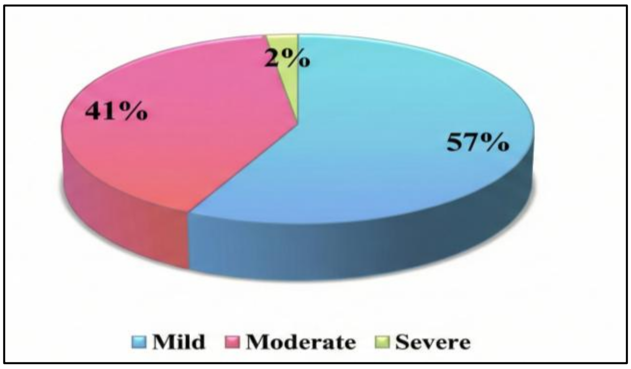

Figure 1: Distribution of study population by severity of anemia.

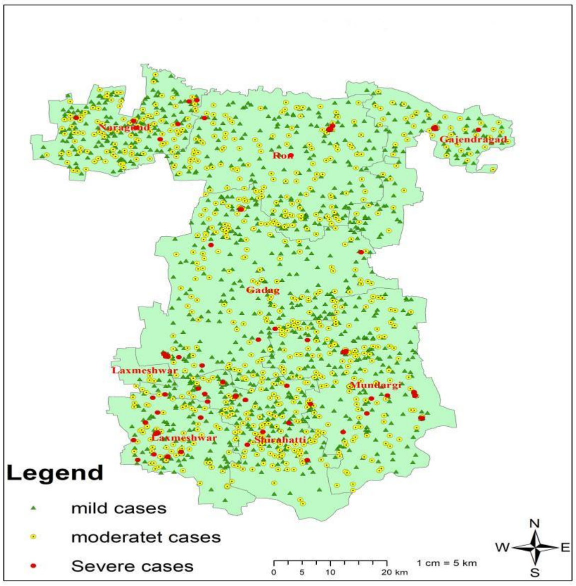

Figure 2: Geo-spatial distribution of anemia cases.

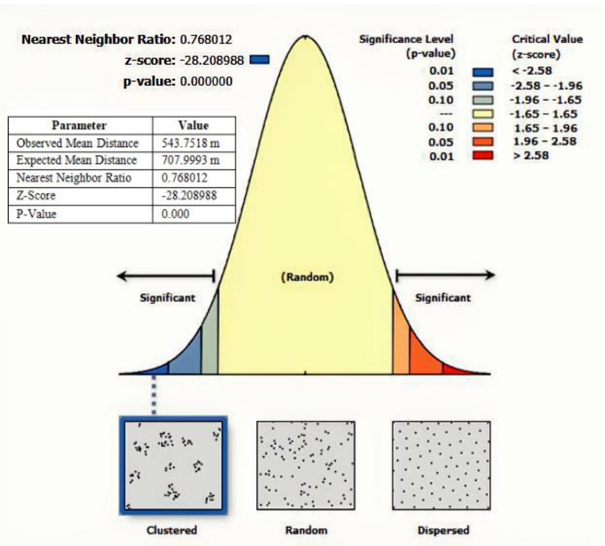

Figure 3: Spatial pattern of anemia cases based on ANN analysis.

According to hemoglobin values, 57% of study participants were identified with mild anemia, 41% with moderate anemia and 2% with severe anemia. These categories were used for subsequent spatial mapping. Figure 2 presents a geographic representation of anaemia cases categorized by severity, with mild cases represented as green points, moderate cases as yellow points and severe cases as red points across the district (Figure 1).

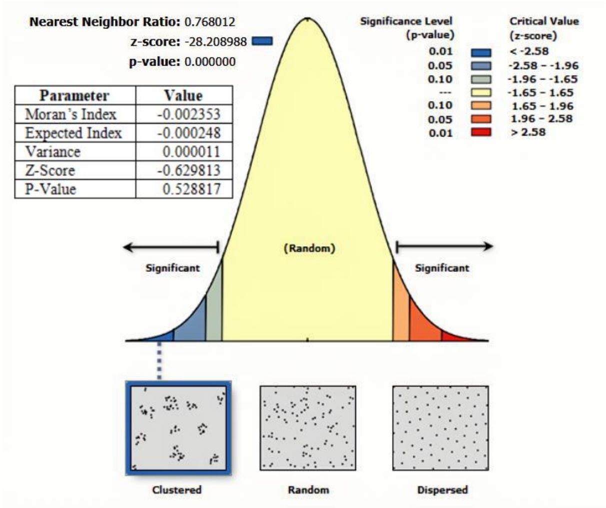

Figure 4: Global spatial autocorrelation of anemia cases in Gadag district (Moran's I analysis).

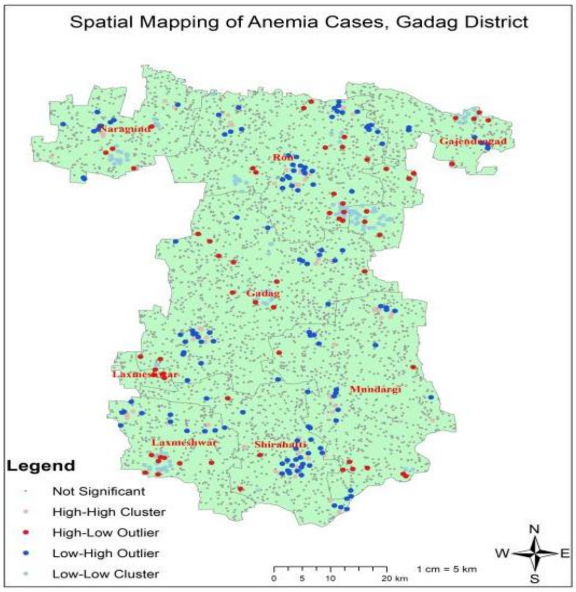

Figure 5: Local spatial clustering of anemia cases using Anselin Local Moran's I in Gadag district, Karnataka.

The ANN analysis yielded a nearest neighbour ratio (NNR) of 0.768, signifying that anemia cases exhibited more spatial concentration compared to expected by random distribution. The measured mean distance (543.75 m) was significantly less than the expected mean distance (707.99 m), with a z score of −28.21 and a p value of less than 0.001. As seen by the critical value distribution, z scores below−2.58 signify substantial clustering at the 99% confidence level. The findings validate that the distribution of anemia patients in Gadag district is significantly concentrated and statistically significant (Figure 3).

The Global Moran's I generated an index of −0.002, a z score of−0.63 and a p value of 0.53, indicating no evidence of significant global autocorrelation. While the ANN test demonstrated clustering, Moran's I indicate that this cluster is not spatially uniform throughout the district. Consequently, aggregation is confined to particular areas rather than spanning district-wide (Figure 4).

The map shows spatial clusters and outliers of anemia prevalence across the seven taluks of Gadag District. High–high clusters (red dots) indicating anemia hotspots are concentrated in Shirahatti, Laxmeshwar and Mundargi, while low–low clusters (light blue) appear in Ron and Gajendragad, suggesting lower prevalence. High–low (dark red) and low–high (dark blue) outliers occur in Naragund, Gadag, Ron and Mundargi, marking transitional zones between high- and low-burden areas. Grey dots denote regions without significant clustering (Figure 5).

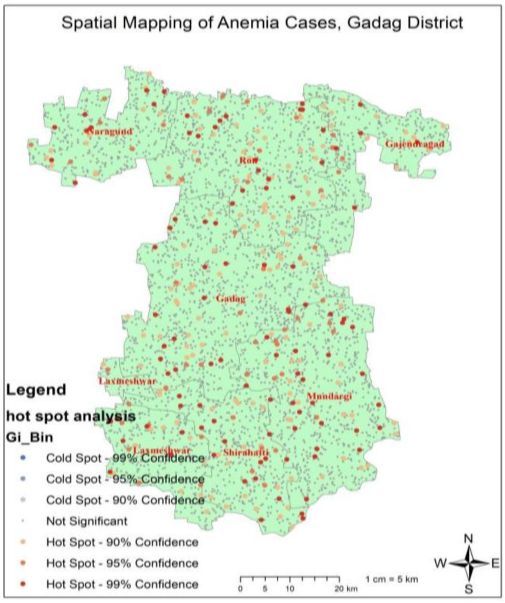

Figure 6: Hot spot analysis of anemia cases in Gadag District, Karnataka (Getis-Ord Gi).

The map depicts statistically significant hotspots and cold spots of anemia incidence throughout the seven taluks of Gadag District, utilizing the Getis-Ord Gi statistic. Hotspots (red to orange dots) signify regions with high anemia prevalence and significant spatial clustering of high values, particularly observed in Shirahatti, Laxmeshwar and Mundargi taluks at 99% and 95% confidence levels. On the other hand, cold spots (blue shades) are seen in Ron, Naragund and Gajendragad, indicating lower anemia prevalence. The spatial distribution pattern indicates a non-random concentration of anemia, with the southern and central taluks constituting the primary hotspot region of the district (Figure 6).

Table 1: Distribution of study population by age.

Age in years	Number (n=4040)	(%)
1 to 10	999	24.7
11 to 20	888	22.0
21 to 30	787	19.5
31 to 40	510	12.6
41 to 50	394	9.8
51 to 60	247	6.1
61 to 70	157	3.9
71 plus	58	1.4

Table 2: Distribution of study population by gender.

Gender	Number (n=4040)	(%)
Female	3114	77.10
Male	926	22.90

DISCUSSION

This study shows that anemia occurrences in Gadag District exhibit geographic clustering rather than random distribution, with specific local hotspots identified in the southern and central taluks. The clustering revealed by the ANN and Local Moran's I analyses aligns with results from earlier Indian research that have reported notable regional variability in anemia prevalence. Singh et al, identified similar clustering among males in 707 districts throughout India, exhibiting significant spatial autocorrelation (Moran's I=0.66) as well as different hotspot areas in the eastern and central regions.[7] Ghosh et al similarly discovered a Moran's I of approximately 0.62 for women of reproductive age, indicating over 120 hotspot districts with continuous high-risk clusters.[8]

The NNR of 0.768 and z-score of −28.21 (p<0.001) demonstrate a highly significant deviation from spatial randomization. This data indicates that the factors affecting anemia, such as dietary status, socioeconomic deprivation and healthcare access are spatially concentrated rather than uniformly distributed. The lack of global spatial autocorrelation (Moran's I=−0.002, p=0.53) indicates that clustering is dispersed into isolated areas rather than being consistent throughout the district. Comparable patterns of localized aggregation have been identified in geographic analyses of anemia among women and children in India, where local clustering persisted as significant despite minimal global autocorrelation.[9] This emphasizes the need of localized spatial targeting rather than homogeneous regional initiatives.[13] The identified hotspots in Laxmeshwar, Shirahatti and Mundargi reflect national trends indicating that elevated anemia prevalence frequently correlates with regions characterized by low literacy, poverty and insufficient access to healthcare facilities.[7,11] Research from many states has associated these clusters with dietary iron deficiency, elevated parity and inadequate sanitation.[10,12]

Bharati et al indicated that socioeconomic and dietary factors were responsible for almost two-thirds of the spatial heterogeneity in anemia among Indian states.[9] The correlation between the current study's hotspots and areas of severe anemia strengthens these correlations, indicating that structural deprivation and environmental factors influence both the prevalence and severity of anemia. Future study should employ spatial regression models to measure the impact of explanatory variables and evaluate geographical dependence. The current study presents important district-level evidence on the spatial distribution of anemia through GIS-based tools, thereby strengthening its utilization for public health planning. The fact that laboratory-confirmed cases and the standardized WHO criteria form part of the findings, may enhance its validity. There are of course some limitations to be respected. The entire population of Gadag District was not studied leading to possibility of underestimation in the prevalence of anemia. The survey was conducted over a short 3 years period and seasonal or long-term trends could not be assessed. The study relied on retrospective data and did not involve real time GIS mapping or live-monitoring tools. In addition, socioeconomic status (SES), culture, environment and feeding practices were not considered; the incorporation of those factors in future research may provide a more in-depth explanation of the spatial distribution within anemia.

CONCLUSION

The geographic distribution of anaemia in Gadag District was non-random heterogeneous, with significant hotspots in Shirahatti, Laxmeshwar and Mundargi and cold spots in Ron and Gajendragad. These data underscore the need to geographically-target anaemia control efforts, focusing interventions in high-burden taluks while continuing prevention activities in low-prevalence areas. The incorporation of GIS-based spatial surveillance as an integral part in district-level health planning would contribute greatly to early detection, priority setting and outcome evaluation. Expanded nutrition programs, community awareness campaigns and decentralized healthcare services are essential for lowering anaemia prevalence and attaining sustainable improvements in public health.

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Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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