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ORIGINAL ARTICLE

Unveiling the Spatial Pattern and Determinants of Child Anaemia in India - National Family Health Survey-5 Chronicles (NFHS-5)

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Abstract

Background/Aim: Childhood anaemia continues to persist as a prominent nutritional disease and a public health challenge in India despite several initiatives by the Government of India. This study aimed to identify predictors and regional disparities for targeted interventions.

Methods: This study utilised data from a nationally representative cross-sectional survey from the fifth round of the National Family Health Survey (NFHS-5), encompassing 177,695 children aged 6-59 months across 707 districts and 36 states and union territories of India. It employed multivariate logistic regression and spatial analysis at district levels to examine socio-demographic predictors and spatial patterns of childhood anaemia in the country.

Result: Multivariate logistic results revealed, women aged 15–19 were 2.43 times more likely to have an anaemic child compared to those aged 35–49 and uneducated mothers had a 29 % higher likelihood of having an anaemic child. There was positive spatial autocorrelation (Moran's I value = 0.579) at the district level in India, with 108 identified hotspots in regions including Jammu and Kashmir, Ladakh, Gujarat, Maharashtra, Telangana, Uttar Pradesh, Rajasthan, Jharkhand, Chhattisgarh and Bihar. The spatial error model (SEM) indicated that mother's anaemia (0.53) and maternal education (0.23) were key predictors of child anaemia in India.

Conclusion: The study findings provide valuable understanding regarding the socio-demographic predictors associated with childhood anaemia such as adolescent motherhood, low education, lack of media exposure, higher birth order and rural residence. Also, the spatial study provides the spatial heterogeneity of childhood anaemia at the district level and advocates more attention toward hotspot regions in the country.

Key words: Childhood anaemia; Logistic regression; LISA; Spatial error model.

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Introduction

Anaemia among children continues to be a serious public health issue in low- and middle-income nations. The poor world is still battling with catastrophic issues like poverty, starvation and malnutrition in the modern-era world, where rich nations are moving toward new technologies and successes. Due to socioeconomic developments and the emergence of international

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market systems, they are more susceptible to anaemia as they go through a transitional period.[1, 2] The definition of anaemia by World Health Organization (WHO) is: "Anaemia is defined as a haemoglobin concentration below a specified cut-off point; that cut-off point depends on the age, gender, physiological status, smoking habits and altitude at which the population being assessed lives." Anaemia among children under 5 years is defined as the threshold haemoglobin level less than 11.0 g/d.[3] Iron deficiency, linked to low nutritional iron consumption is one of the critical causes of childhood anaemia in India.[4] Other risk factors equally associated with childhood anaemia include vitamin deficiencies, especially folate, vitamin B_{12} and A, infections with malaria parasite, hookworm and haemoglobinopathies.[5-7] In India the prevalence of anaemia among children aged 6-59 months (haemoglobin levels ≤ 11.0 g/dL) increased dramatically from 59 % National Family Health Survey-4 (NFHS-4) to 67 % (2019–21, NFHS–5).[8] Additionally, with significant regional variation, India is reported to have greatest frequency of anaemia among developing nations.[9] In the absence of timely interceding, these children grow up anaemic and frequently marry beforehand, giving birth to babies with lower iron reserves who turn anaemic within the first months after birth.[10] Hence, there's a need to intermediate in this intergenerational anaemia to insure good health of the overall population.[11-13] Despite India's numerous programs, like POSHAN Abhiyaan and the National Iron Plus Initiative for Anaemia Control, the rate of reduction of child anaemia is not up to the mark and in fact, it has been observed to increase in recent years.[1]

Spatial heterogeneity is a type of seen or unobserved heterogeneity that varies throughout a vast territory or landscape provided by social structure. Spatial heterogeneity (sometimes called sub-regional variation) is the uneven distribution of a trait, event or indication over a region. India has several diverse districts in socioeconomic and demographic statistics. The spatial variance of anaemia cases in Indian districts is little understood.[14] Due to its high sample size, the NFHS-5 provided estimates for a number of crucial anaemia indicators in children. These estimates help to identify district differences and the implementation of customised programs.

The aim of this study was to assess socio-demographic predictors of childhood anaemia in India. Regional heterogeneity and anaemia correlations in Indian districts were also examined.

Methods

The study utilised data from the fifth wave of the National Family Health Survey (NFHS-5), conducted in 2019-21 in India. This nationally representative cross-sectional survey, overseen by the Ministry of Health and Family Welfare, covered all 28 states, 8 union territories and 707 districts. The survey focused on child health and employed a two-stage stratified sampling design. After excluding children with missing data, the final analytic sample comprised 177,695 children aged 6-59 months across all districts and states.

The study's outcome variable was child anaemia prevalence. Explanatory variables, determined through in-depth literature review, encompassed mother's age, residence, education, media exposure, wealth quintile, mother's anaemia, birth order, child's sex, religion and caste.

The study employed multivariate logistic regression to analyse socioeconomic disparities in child anaemia in India. Spatial patterns and clustering of child anaemia were assessed using Moran's I, univariate local indicator of spatial association (LISA), bivariate LISA and a LISA cluster map. The spatial weight matrix (w) of order 1 has been generated using the Queen's contiguity method to quantify the spatial proximity between each possible pair of observational entities in the dataset.[15, 16] Positive spatial autocorrelation suggests that points with comparable attribute values are tightly distributed in space, whereas negative autocorrelation shows that closely associated points are more distinct. Moran's I values range from -1 to +1, with positive and negative values indicating clustering of similar and dissimilar values, respectively. A zero value indicated a random spatial pattern with no spatial autocorrelation. Univariate LISA measured the correlation of neighbourhood values around a specific spatial location. It determined the extent of spatial randomness and clustering present in the data.[17-19]

Four types of spatial autocorrelation were generated:

1. **Hot spots:** High-value areas with similar neighbours (High-High).
2. **Cold spots:** Low values area, with similar neighbours (Low-Low).
3. **Spatial outliers:** High-value areas with low-value neighbours (High-Low).
4. **Spatial outliers:** Low values area with higher values neighbours (Low-High).

To see the potential regional correlates of child anaemia spatial regression analysis which includes ordinary least square (OLS) model and spatial error model (SEM) was performed.[20] Non-spatial analysis was conducted using the trial version of Statistical Package for Social Sciences (SPSS) software v. 26; (IBM Inc, Chicago, IL), while spatial analysis was carried out using trial versions of ArcGIS 10.7 and GeoDa 1.20.

Results

Nearly 90 % out of 177,695 children had mothers aged 20–34 (Table 1). Rural youngsters made up nearly three-quarters of participants. Around half of the women completed their secondary level of education. Anaemia affected 59.8 % of women who gave birth in the five years prior to the survey. Nearly half of the children were of second or third birth order. About one-third of women belonged to schedule caste/ schedule tribe (SC/ ST). Nearly half (46.5 %) of the women were below middle-class category. Media access were unavailable to 28 % of mothers.

In comparison to mothers who were anaemic, mothers without anaemia were 40 % less likely to have an anaemic child (odds ratio (OR): 0.601; 95 % confidence interval (CI): 0.589–0.614). Child anaemia exhibited significant associations with the age of mothers, particularly among younger age groups. For instance, women aged 15–19 years and 20–34 years were 2.431 times (OR: 2.431; 95 % CI: 2.219–2.665) and 1.357 times (OR: 1.357; 95 % CI: 1.29–1.41) more likely to have an anaemic child, respectively, compared to women aged 35–49 years. Furthermore, the education level of mothers emerged as a significant predictor of child anaemia, with higher maternal education associated with reduced odds of child

Table 1: Prevalence of child anaemia with various background characteristics in India (NFHS-5, 2019-21)

Variables	Variable's categories	Weighted frequency (%)	Logistic regression model	
			OR	95 % CI
Age group	15-19	3,580 (2.0)	2.431*	[2.219-2.665]
	20-34	158,870 (89.4)	1.357*	[1.306-1.410]
	35-49	15,246 (8.6)	Ref.	-
Place of residence	Urban	46,559 (26.2)	0.965*	[0.940-0.991]
	Rural	131,136 (73.8)	Ref.	-
Education level of mother	No education	38,010 (21.4)	1.291*	[1.239-1.346]
	Primary	22,094 (12.4)	1.192*	[1.143-1.244]
	Secondary	90,868 (51.1)	1.129*	[1.095-1.164]
	Higher	26,724 (15.0)	Ref.	-
Media exposure	No	50,694 (28.5)	1.082*	[1.053-1.112]
	Yes	127,002 (71.5)	Ref.	-
Wealth index	Poorest	43,640 (24.6)	1.072*	[1.026-1.120]
	Poorer	38,869 (21.9)	1.050*	[1.010-1.093]
	Middle	35,128 (19.8)	1.034	[0.996-1.073]
	Richer	32,850 (18.5)	0.986	[0.952-1.021]
	Richest	27,208 (15.3)	Ref.	-
Anaemia in mother	No	71,482 (40.2)	0.601*	[0.589-0.614]
	Yes	106,213 (59.8)	Ref.	-
Birth order	1st	68,691 (38.7)	0.732*	[0.677-0.792]
	2nd or 3rd	87,878 (49.5)	0.802*	[0.743-0.866]
	4th or 5th	17,046 (9.6)	0.878*	[0.811-0.950]
	≥ 6th	4,081 (2.3)	Ref.	-
Sex of child	Male	92,219 (51.9)	1.003	[0.983-1.023]
	Female	85,476 (48.1)	Ref.	-
Religion	Hindu	141,852 (79.8)	1.268*	[1.207-1.332]
	Muslim	28,082 (15.8)	1.258*	[1.190-1.33]
	Others	7,761 (4.4)	Ref.	-
Caste	Schedule caste	41,491 (23.3)	1.106*	[1.071-1.142]
	Schedule tribe	18,042 (10.2)	1.251*	[1.199-1.305]
	OBC	77,001 (43.3)	0.952*	[0.927-0.978]
	Other	41,161 (23.2)	Ref.	-

*: $p < 0.05$; OR: odds ratio; CI: confidence interval; OBC: other backward class;

anaemia in India. Specifically, women without any formal education and those with only primary education were 29 % and 19 % more likely to have an anaemic child, respectively, compared to women with higher education.

First-birth order children were 27 % less likely to be anaemic (OR: 0.732; 95 % CI: 0.677–0.792) compared to a child having six or above birth order. Religion also displayed an association with child anaemia, with Hindu and Muslim women being 27 % and 26 % more likely to have anaemic children, respectively, compared to women of other religions. Additionally, children belonging to the scheduled caste (SC) and scheduled tribe (ST) categories were 1.106 times and 1.251 times more likely to have an anaemic child, respectively, when compared to children from other caste groups, excluding SC, ST and other backward class (OBC) categories. No exposure to any kind of media emerged as significant risk factor for child anaemia as women without media exposure were 1.081 times more likely to have anaemic children (OR: 1.082; 95 % CI: 1.053–1.112) compared to their counterparts. Lastly, women from the poorest wealth quintile were 1.072 times more likely to have anaemic children (OR: 1.06; 95 % CI: 1.01–1.12) compared to women from the richest wealth quintile. However, other wealth quintile categories of women, such as those classified as middle and richer, did not exhibit statistically significant differences compared to women in the richest wealth quintile.

Figure 2 represents a LISA scatter plot along with the corresponding Moran's I value (0.579), univariate cluster map and significance map of child anaemia (6-59 months) in the districts of India showing overall clustering of similar behaving districts ie, either high-high or low-low. Out of the 707 districts in India, 108 were identified as hotspots. These hotspots included districts in Jammu Kashmir, Ladakh, Gujarat, Maharashtra, Telangana and several districts in Uttar Pradesh, Rajasthan, Jharkhand and Bihar. Additionally, almost 84 districts were identified as cold spots, indicating that these districts had a low prevalence of child anaemia and were surrounded by districts with similarly low prevalence. These cold spot districts encompassed the entire southern

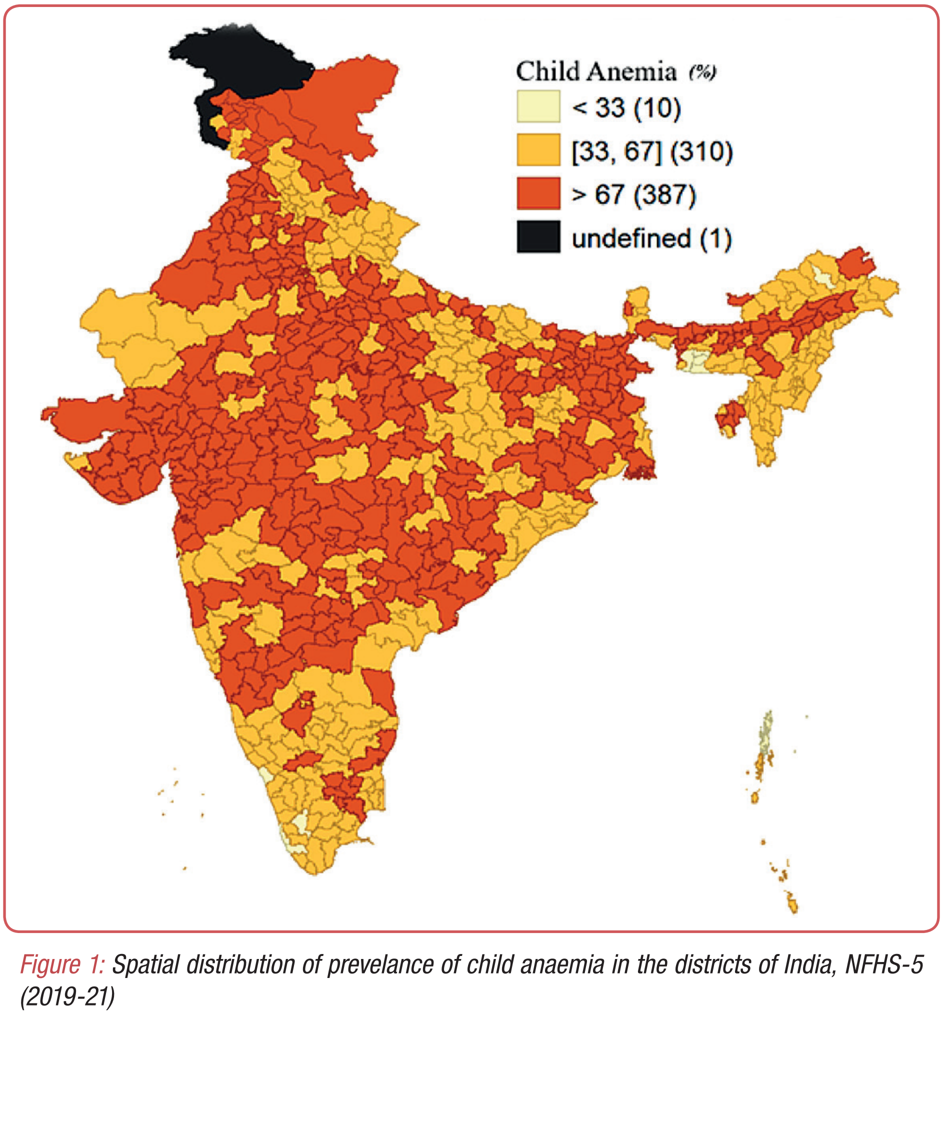


Figure 1: Spatial distribution of prevelance of child anaemia in the districts of India, NFHS-5 (2019-21)

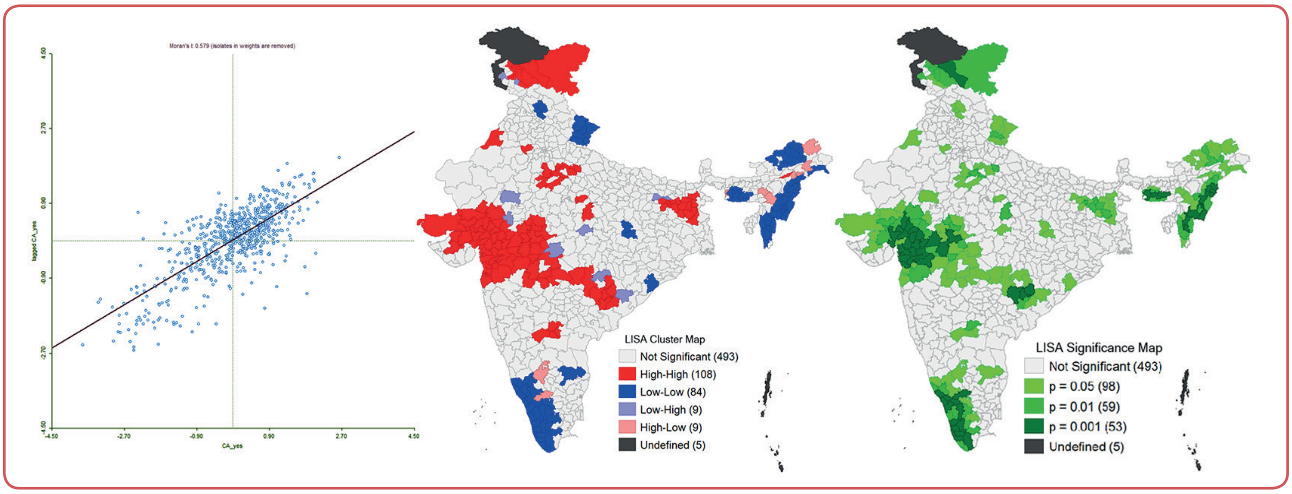


Figure 2: Univariate cluster and local indicator of spatial association (LISA) map showing spatial correlation of child anaemia in the districts level of India, NFHS-5, (2019-21)

LISA cluster map: light grey: not significant (493); dark red: high-high (108); dark blue: low-low (84); light blue: low-high (9); light red: high-low (9); dark grey: undefined (5);

LISA significance map: light grey: not significant (493); light green: p = 0.05 (98); green: p = 0.01 (59); dark green: p = 0.001 (53); dark grey: undefined (5);

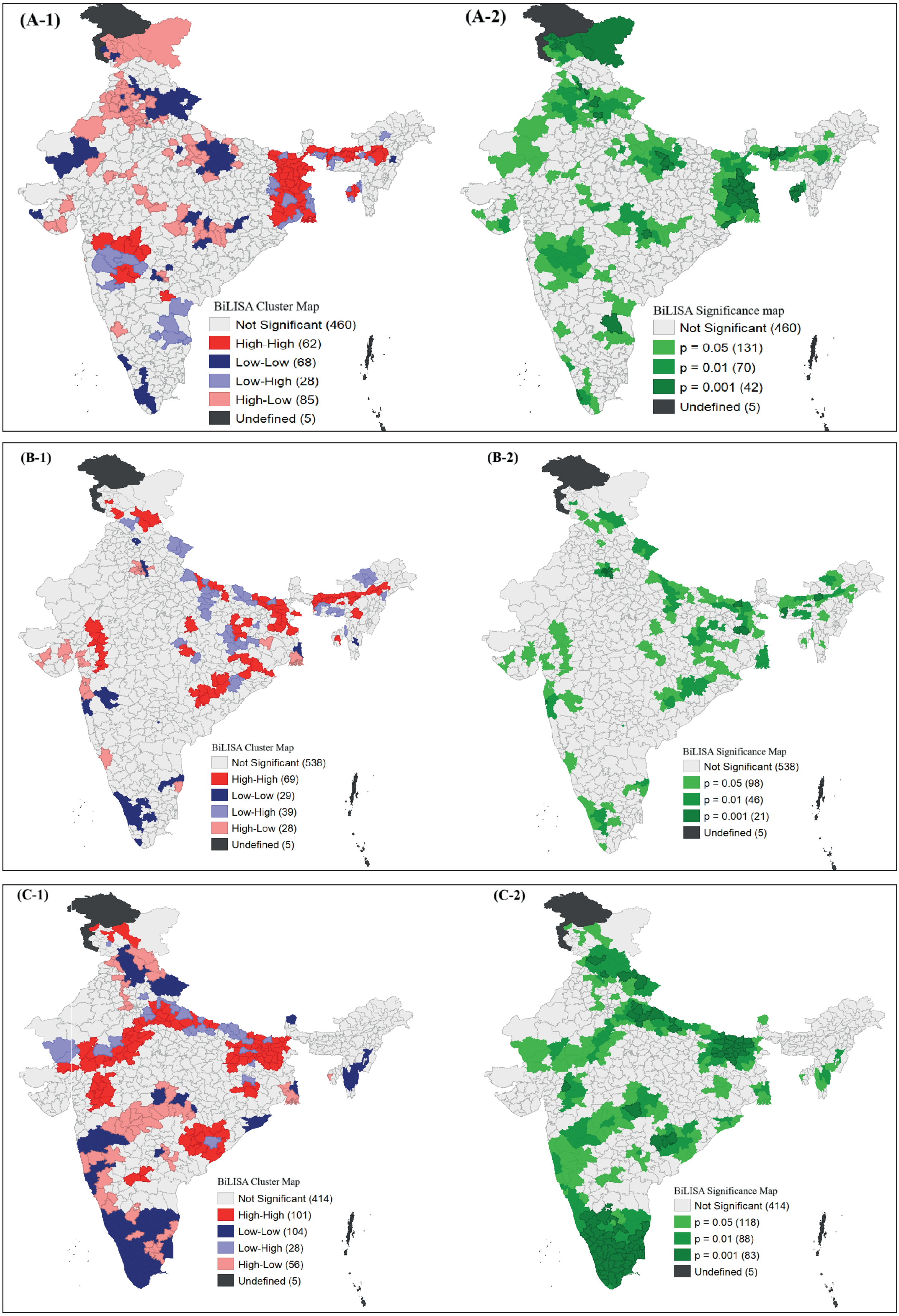
and north-eastern parts of India, including Kerala, Tamil Nadu, Karnataka, Arunachal Pradesh, Meghalaya, Nagaland, Mizoram, Manipur, as well as Himachal Pradesh and Uttarakhand in northern India.

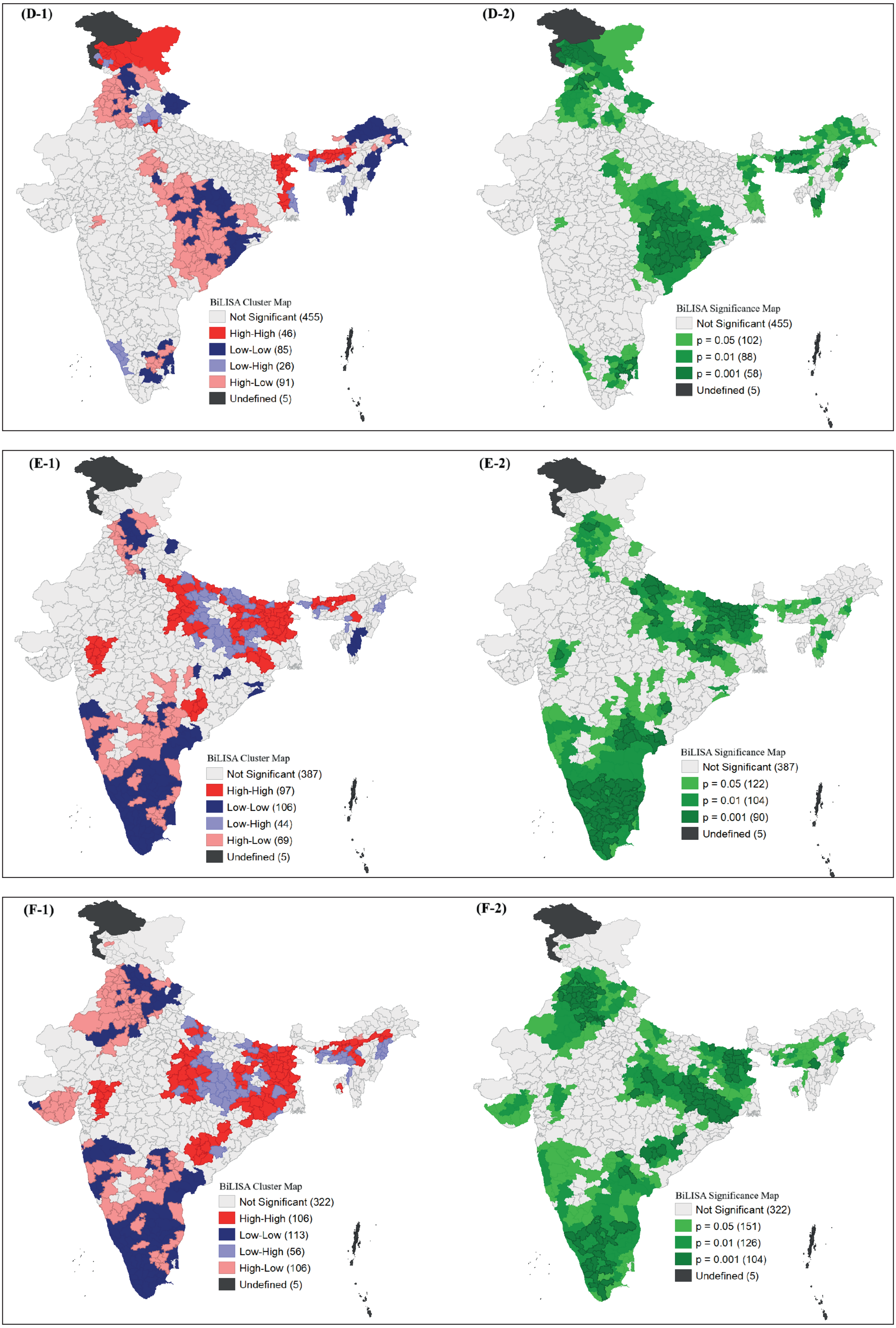
Figure 3 depicts the bivariate LISA map and its corresponding significance map, illustrating the prevalence of child anaemia based on various independent variables in India. Approximately 62 out of the 707 districts exhibited hotspots for child anaemia associated with mothers aged 15–19. These hotspots encompassed states such as Bihar, Jharkhand, West Bengal, Assam, Tripura and certain regions of Maharashtra (map A-1). Among various hotspots and cold spots, 42 districts were coming out to be highly significant ($p = 0.001$). These districts were mostly concentrated in the Jammu and Kashmir regions and West Bengal (map A-2). Map B-1, shows nearly 69 out of the 707 districts as hotspots for child anaemia, with a substantial concentration in areas characterised by a predominantly rural population. These districts span Jammu and Kashmir, Himachal Pradesh, Gujarat, Odisha, Chhattisgarh, Jharkhand, West Bengal, Assam and Tripura. However, only 21 districts were highly significant ($p = 0.001$) followed by 46 and 98 districts with p-values of 0.01 and 0.05, respectively (map B-2). About 101 out of the 707 districts formed hotspots for child anaemia linked to uneducated mothers in India. These hotspots included states such as Uttar Pradesh, Madhya Pradesh, Maharashtra, Bihar, West Bengal and specific regions in Jammu and Kashmir, Gujarat, Odisha, Telangana, Andhra Pradesh and Jharkhand (map C-1). In this, highly significant districts were concentrated in the southern region of Kerala, Tamil Nadu and also a few districts of northern regions like Uttar Pradesh, Bihar etc (map C-2). Nearly 48 out of the 707 districts have been identified as hotspots for child anaemia associated with the Muslim religion, covering areas in Jammu and Kashmir, Ladakh, West Bengal and Assam. Also, districts in the Jammu and Kashmir region and eastern regions like Orissa etc were highly significant (map D-1 and D-2).

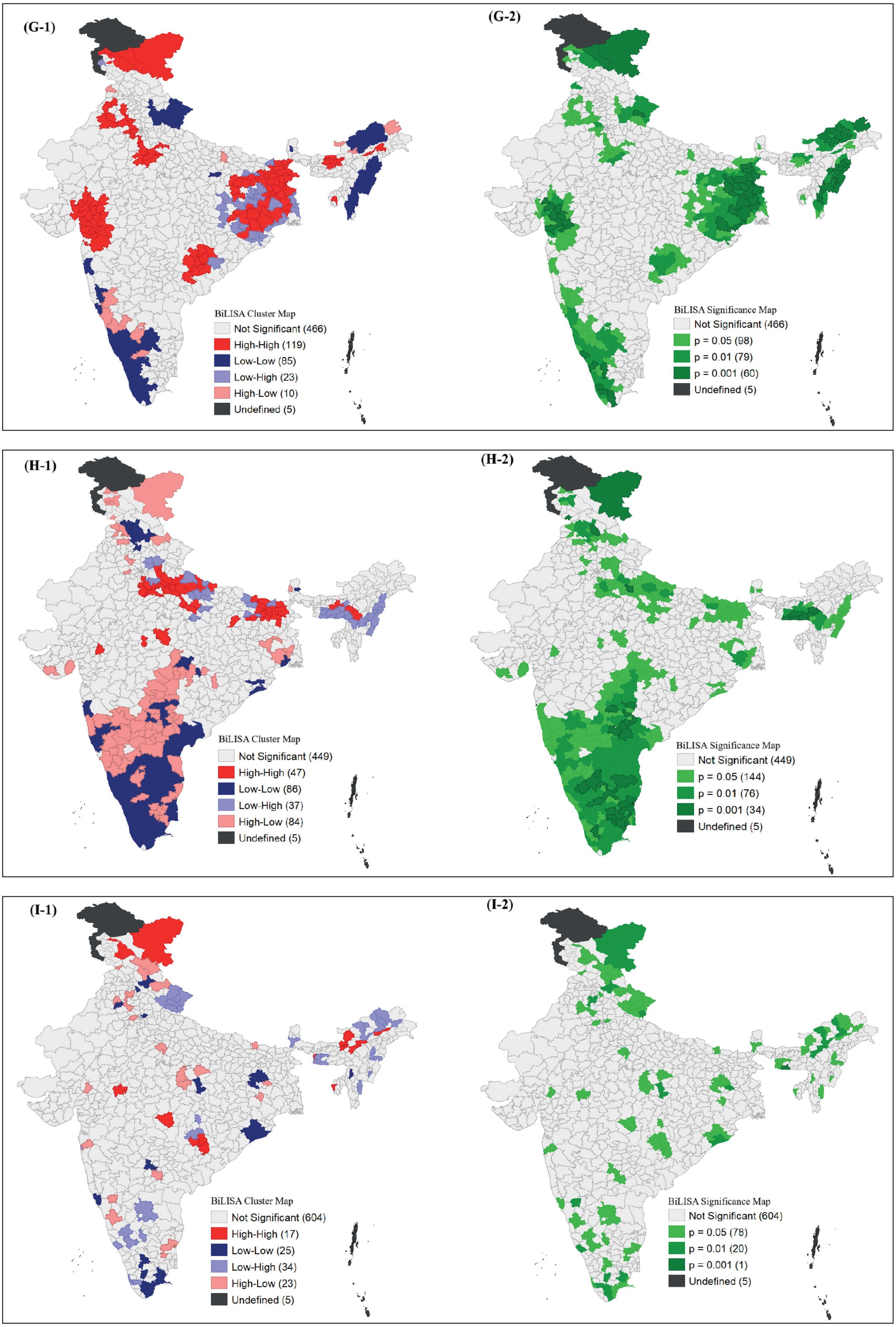
Out of the 707 districts, 97 have been pinpointed as hotspots due to a lack of media exposure, while 106 districts have been identified as hotspots based on the poorest wealth index. These hotspots were distributed across both the western and eastern parts of India, encompassing regions such as Gujarat, Odisha, West Bengal and certain districts in Haryana, Punjab, Bihar and Assam (map E-1, F-1).

Almost 119 out of the 707 districts have emerged as hotspots for child anaemia and anaemic mothers, including the states of Ladakh, Jammu and Kashmir, Punjab, Delhi, Haryana, Gujarat, Andhra Pradesh, Odisha, Jharkhand, West Bengal, Bihar, and specific districts in Assam and Tripura (map G-1). Out of these 60 districts were highly significant ($p = 0.001$) which are mostly concentrated in the Ladakh region and eastern and northeastern states (map G-2).

Among the 707 districts, 47 have been identified as hotspots in terms of higher birth order children (map H-1), while 17 districts and 68 dis-


(A-1)
BiLISA Cluster Map
Not Significant (460)
High-High (62)
Low-Low (68)
Low-High (28)
High-Low (85)
Undefined (5)
(A-2)
BiLISA Significance map
Not Significant (460)
p = 0.05 (131)
p = 0.01 (70)
p = 0.001 (42)
Undefined (5)
(B-1)
BiLISA Cluster Map
Not Significant (538)
High-High (69)
Low-Low (29)
Low-High (39)
High-Low (28)
Undefined (5)
(B-2)
BiLISA Significance Map
Not Significant (538)
p = 0.05 (98)
p = 0.01 (46)
p = 0.001 (21)
Undefined (5)
(C-1)
BiLISA Cluster Map
Not Significant (414)
High-High (101)
Low-Low (104)
Low-High (28)
High-Low (56)
Undefined (5)
(C-2)
BiLISA Significance Map
Not Significant (414)
p = 0.05 (118)
p = 0.01 (88)
p = 0.001 (83)
Undefined (5)


(D-1)
BiLISA Cluster Map
Not Significant (455)
High-High (46)
Low-Low (85)
Low-High (26)
High-Low (91)
Undefined (5)
(D-2)
BiLISA Significance Map
Not Significant (455)
p = 0.05 (102)
p = 0.01 (88)
p = 0.001 (58)
Undefined (5)
(E-1)
BiLISA Cluster Map
Not Significant (387)
High-High (97)
Low-Low (106)
Low-High (44)
High-Low (69)
Undefined (5)
(E-2)
BiLISA Significance Map
Not Significant (387)
p = 0.05 (122)
p = 0.01 (104)
p = 0.001 (90)
Undefined (5)
(F-1)
BiLISA Cluster Map
Not Significant (322)
High-High (106)
Low-Low (113)
Low-High (56)
High-Low (106)
Undefined (5)
(F-2)
BiLISA Significance Map
Not Significant (322)
p = 0.05 (151)
p = 0.01 (126)
p = 0.001 (104)
Undefined (5)


(G-1)
BiLISA Cluster Map
Not Significant (466)
High-High (119)
Low-Low (85)
Low-High (23)
High-Low (10)
Undefined (5)
(G-2)
BiLISA Significance Map
Not Significant (466)
p = 0.05 (98)
p = 0.01 (79)
p = 0.001 (60)
Undefined (5)
(H-1)
BiLISA Cluster Map
Not Significant (449)
High-High (47)
Low-Low (86)
Low-High (37)
High-Low (84)
Undefined (5)
(H-2)
BiLISA Significance Map
Not Significant (449)
p = 0.05 (144)
p = 0.01 (76)
p = 0.001 (34)
Undefined (5)
(I-1)
BiLISA Cluster Map
Not Significant (604)
High-High (17)
Low-Low (25)
Low-High (34)
High-Low (23)
Undefined (5)
(I-2)
BiLISA Significance Map
Not Significant (604)
p = 0.05 (78)
p = 0.01 (20)
p = 0.001 (1)
Undefined (5)

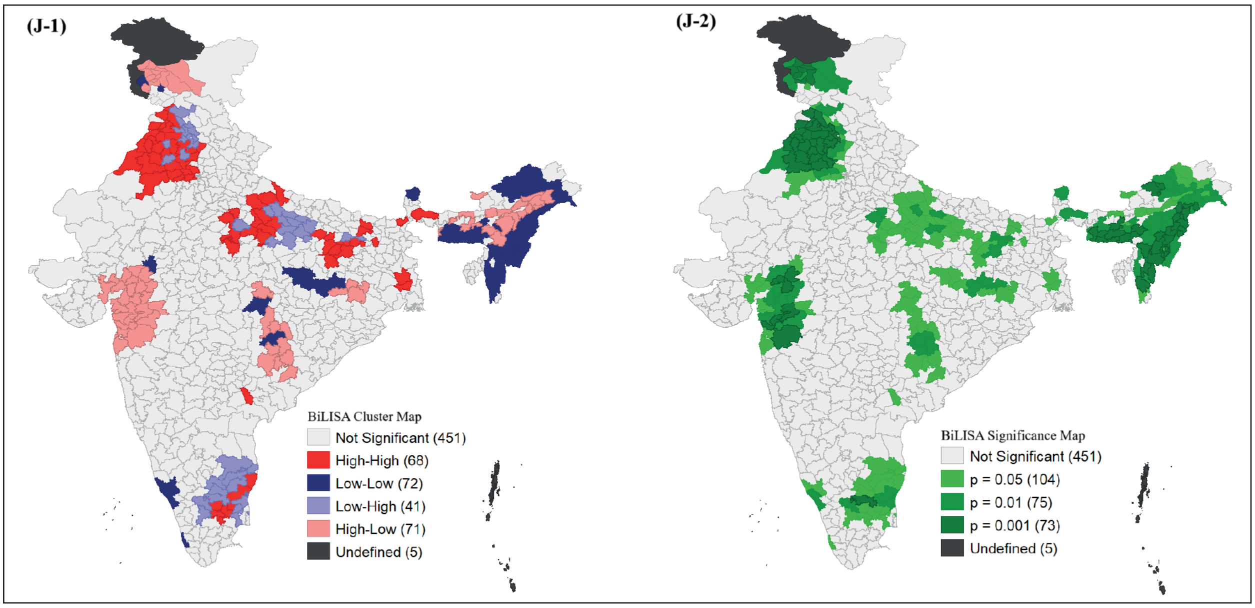


Figure 3: Bivariate local indicator of spatial association (LISA) cluster map and significance map of child anaemia with selected predictor variables

LISA cluster map: light grey: not significant; dark red: high-high; dark blue: low-low; light blue: low-high; light red: high-low; dark grey: undefined;
LISA significance map: light grey: not significant; light green: p = 0.05; green: p = 0.01; dark green: p = 0.001; dark grey: undefined;
Child anaemia related to: A: mother age (15-19); B: residence (rural); C: education of mother (no education); D: religion (Muslim); E: media exposure (no exposure); F: wealth index (poorest); G: anaemia in mothers (yes); H: birth order (higher); I: gender (female); J: Caste (schedule caste);

Table 2: Result of the ordinary least square (OLS) model and spatial error model (SEM) assessing determinants of child anaemia in districts of India, NFHS-5 (2019–21)

Indicators	OLS		SEM	
	Coeff	p-value	Coeff	p-value
% Mother age (15-19 years)	0.067	0.731	0.195	0.374
% Rural population	-0.007	0.699	-0.024	0.192
% Uneducated mother	0.289 *	0.000	0.225 *	0.000
% Muslim religion	-0.017	0.351	0.012	0.609
% No media exposure	0.129 *	0.002	0.069	0.117
% Poorest wealth index	-0.199 *	0.000	0.094 *	0.009
% Mother anaemia	0.594 *	0.000	0.531 *	0.000
% Birth order (≥ 6th)	-0.696 *	0.000	0.357 *	0.020
% Female child	-0.027	0.772	-0.030	0.699
% SC population	-0.022	0.453	0.051	0.154

**significant at α = 5 %; Coeff: coefficient; Akaike information criterion (AIC) value = OLS: 5036.11, SEM: 4875.26; LAMBDA: SEM: 0.597; R^2 = OLS: 0.526; SEM: 0.652; SC: schedule caste;*

tricts have been designated as hotspots concerning female children and SC populations, (map I-1, J-1) respectively.

Table 2 shows spatial regression models namely the OLS model and SEM to determine a special dependence of various predictors on child anaemia at the district level in India. The Akaike information criterion (AIC) value of the special error model came out to be 4875.26, which was comparatively lower than the OLS model. Hence this model better fitted the predictors for the explained variable. The SEM revealed that a 10 % increase in the proportion of uneducated mothers in a district, resulted in a 2.2 % increment in child anaemia (Coefficient (Coeff) = 0.225; $p < 0.05$). Similarly, a 10 % rise in the poorest wealth index within a district led to a 0.09 % increase in child anaemia (Coeff = 0.094; $p < 0.05$). Additionally, anaemic mothers significantly contributed as a risk factor for child anaemia in a district; for example, there was a 5.3 % increase in child anaemia for every 10 % rise in the proportion of mothers with anaemia in a particular district (Coeff = 0.531; $p < 0.05$). Among other predictors, a higher childbirth order was a notable risk factor for child anaemia in a district (Coeff = 0.357; $p < 0.05$).

Discussion

Analysis of NFHS-5 (2019-21) data has unveiled several significant determinants of childhood anaemia in India like anaemia status of mothers, mother age, maternal education, birth order, media exposure, wealth quantile etc. Some scholars have suggested the existence of multiple pathways linking childhood anaemia to the iron status of both children and their mothers.[21] For instance, antenatal anaemia can affect birth weight and increase the risk of premature deliveries, a key factor in childhood anaemia.[22]

Maternal age showed a significant effect on anaemia status of their children. Mothers age (35 years and above) showed a protective effect for anaemia in children. This could be due to low maternal age contributing to low birth weight (LBW) babies, in turn, LBW in children might contribute to low haemoglobin levels thus resulting in anaemia.[23-26] Supporting presented findings, conclusions from other studies also suggest that women with a low educational level are more likely to have anaemic children, highlighting a significant association between education and anaemia.[27-29] This could be because the mother's level of education, influences the practices related to the child's health care.[30, 31] This study highlights statistically significant associations between household wealth and anaemia.

Presented study shows Hindu and Muslim women were more likely to anaemic children compared to women of other religion. Also, likelihood of child anaemia is higher in SC and ST categories against other castes. Social factors were found to be significantly associated with the prevalence of anaemia among children reported by other studies as well. This could be due to the limited educational opportunities, discrimination and social inequality which affect the awareness about healthcare practices and nutrition among SC and ST communities.[32-34]

In this study it was observed that, children with lower birth orders were less likely to be anaemic compared to those with higher birth order, which is supported by various other studies as well.[35, 36] This could be because an increase in the number of children associated with increased health problems due to competition for food, infections and cross contaminations.[34]

This study also indicated that children from mothers with no media exposure were more likely be anaemic compared to those from mothers with media exposure. This finding is supported by other studies where children from mothers with no media exposure were more likely to report anaemia compared to their counterparts.[34, 36] The reason could be that the mothers' media exposure may affect childcare practices through enhancing the knowledge of mothers on child feeding activities, disease prevention practices and improving health-seeking behaviours.[37]

Presented study observed that trend and pattern was the same over different states but varied slightly in magnitude. Severe anaemia prevalence was seen among western and central zone states. The states identified were Gujarat, Rajasthan, Madhya Pradesh, Haryana, Jammu and Kashmir, Karnataka and Maharashtra. More focus should be placed on these states. In this study child anaemia also exhibited a positive autocorrelation with its covariates among Indian districts, with hotspots identified in the western and central regions, including states such as Gujarat, Rajasthan, Madhya Pradesh, Haryana, Jammu and Kashmir, Ladakh and certain districts in Uttar Pradesh, Bihar, West Bengal, Odisha and Andhra Pradesh. These findings are consistent with a district-level study in India, which observed similar patterns and hotspot regions for child anaemia.[25]

These analyses provide region-specific spatial information which can help in decision-making, policy formulation and effective assessment of anaemia prevention and control among children. The current study has however a few limitations that need to be acknowledged. Firstly, the NFHS dataset lacked information on the underlying causes of anaemia, precluding their inclusion in analysis. Secondly, haemoglobin levels were measured using the battery-operated portable *HemoCue Hb 201+* analyser, which raised concerns about its accuracy compared to lab-based methods. Future research in this area is recommended to explore this association and gain a more profound understanding of its implications.

Conclusion

Several important issues emerged from the study such as maternal education, socio-economic status, media exposer etc were found to be key factors of childhood anaemia in India. The present study does not only contribute to highlighting remarkable factors affecting the anaemia in children but also examines the geographical variations in anaemia. Comprehensive intervention strategies such as educating mothers, specially residing in rural areas about the harmful impacts of anaemia should be implemented and should target the hot spot districts with the highest prevalence of anaemia.

Ethics

This study was a secondary analysis based on the currently existing dataset from the recent NFHS-5 survey with no identifiable information on the survey participants and did not directly involve with human participants or experimental animals. NFHS-5 obtained the consent before and during the survey. This dataset is available in the public domain for research use, therefore the ethics approval was not required in this paper.

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Conflicts of interest

The authors declare that there is no conflict of interest.

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Data access

The data can be accessed from the DHS website at: https://dhsprogram.com/data/.

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References

1. Kapil U, Kapil R, Gupta A. National Iron Plus Initiative: current status & future strategy. The Indian journal of medical research. 2019 Sep;150(3):239. doi: 10.4103/ijmr.ijmr_1782_18.
2. Habte D, Asrat K, Magafu MG, Ali IM, Benti T, Abtew W, et al. Maternal risk factors for childhood anaemia in Ethiopia. Afr J Reproduc Health. 2013 Sep 1;17(3):110-8. PMID: 24069773.
3. World Health Organization. Anemia. [Internet]. [Cited: 1 Jan 2023]. Available at: https://www.who.int/health-topics/anaemia.
4. Anand T, Rahi M, Sharma P, Ingle GK. Issues in prevention of iron deficiency anemia in India. Nutrition. 2014 Jul 1;30(7-8):764-70. doi: 10.1016/j.nut.2013.11.022.
5. Thankachan P, Walczyk T, Muthayya S, Kurpad AV, Hurrell RF. Iron absorption in young Indian women: the interaction of iron status with the influence of tea and ascorbic acid. Am J Clin Nutr. 2008 Apr;87(4):881-6. doi: 10.1093/ajcn/87.4.881.
6. Calis JC, Phiri KS, Faragher EB, Brabin BJ, Bates I, Cuevas LE, et al. Severe anemia in Malawian children. N Engl J Med. 2008 Feb 28;358(9):888-99. doi: 10.1056/NEJMoa072727.
7. Schneider JM, Fujii ML, Lamp CL, Lönnerdal B, Dewey KG, Zidenberg-Cherr S. Anemia, iron deficiency, and iron deficiency anemia in 12-36-mo-old children from low-income families. Am J Clin Nutr. 2005 Dec;82(6):1269-75. doi: 10.1093/ajcn/82.6.1269.
8. International Institute for Population Sciences (IIPS) and ICF, 2021. National Family Health Survey (NFHS-5), 2019–21: India. [Internet]. [Cited: 1 Jan 2023]. Available at: https://main.mohfw.gov.in/sites/default/files/NFHS-5_Phase-II_0.pdf.
9. Kalaivani K, Ramachandran P. Time trends in prevalence of anaemia in pregnancy. Indian J Med Res. 2018 Mar;147(3):268-77. doi: 10.4103/ijmr.IJMR_1730_16.
10. Subramaniam G, Girish M. Iron deficiency anemia in children. Indian J Pediatr. 2015 Jun;82:558-64. doi: 10.1007/s12098-014-1643-9.
11. Sekhar DL, Murray-Kolb LE, Kunselman AR, Weisman CS, Paul IM. Association between menarche and iron deficiency in non-anemic young women. PloS One. 2017 May 9;12(5):e0177183. doi: 10.1371/journal.pone.0177183.
12. Bentley ME, Griffiths PL. The burden of anemia among women in India. Eur J Clin Nutr. 2003 Jan;57(1):52-60. doi: 10.1038/sj.ejcn.1601504.

13. Kedar PS, Harigae H, Ito E, Muramatsu H, Kojima S, Okuno Y, et al. Study of pathophysiology and molecular characterization of congenital anemia in India using targeted next-generation sequencing approach. Int J Hematol. 2019 Nov;110:618-26. doi: 10.1007/s12185-019-02716-9.
14. Anselin L. Thirty years of spatial econometrics. Pap Reg Sci. 2010 Mar;89(1):3-25. doi: 10.1111/j.1435-5957.2010.00279.x
15. Getis A, Ord JK. The analysis of spatial association by use of distance statistics. Geogr Anal. 1992 Jul;24(3):189-206. doi: 10.1111/j.1538-4632.1992.tb00261.x.
16. Getis A, Ord JK, Anselin L, Rey SJ. Perspectives on spatial data analysis. Berlin, Germany: Springer; 2010. doi: 10.1007/978-3-642-01976-0.
17. Anselin L. Local indicators of spatial association—LISA. Geogr Anal. 1995 Apr;27(2):93-115. doi: 10.1111/j.1538-4632.1995.tb00338.x
18. Clark PJ, Evans FC. Distance to nearest neighbour as a measure of spatial relationships in populations. Ecology. 1954 Oct 1;35(4):445-53. doi: 10.2307/1931034.
19. Cliff AD, Ord K. Spatial autocorrelation: a review of existing and new measures with applications. Econ Geogr. 1970 Jun 1;46(sup1):269-92. doi: 10.2307/143144.
20. Anselin L. Spatial regression. The SAGE handbook of spatial analysis. California, USA: SAGE Publications, Ltd 2009;1:255-76. doi: 10.4135/9780857020130.
21. Pasricha SR, Black J, Muthayya S, Shet A, Bhat V, Nagaraj S, et al. Determinants of anemia among young children in rural India. Pediatrics. 2010 Jul 1;126(1):e140-9. doi: 10.1542/peds.2009-3108.
22. Wharton BA. Iron deficiency in children: detection and prevention. Br J Haematol. 1999 Aug;106(2):270-80. doi: 10.1046/j.1365-2141.1999.01511.x.
23. Chen K, Zhang X, Li TY, Chen L, Qu P, Liu YX. Co-assessment of iron, vitamin A and growth status to investigate anemia in preschool children in suburb Chongqing, China. World J Pediatr. 2009 Nov;5:275-81. doi: 10.1007/s12519-009-0052-z.
24. Skalicky A, Meyers AF, Adams WG, Yang Z, Cook JT, Frank DA. Child food insecurity and iron deficiency anemia in low-income infants and toddlers in the United States. Matern Child Health J. 2006 Mar;10(2):177-85. doi: 10.1007/s10995-005-0036-0.
25. Rutstein SO, Kiersten J. The DHS Wealth Index. Calverton, Maryland. Report; 2004. doi: 10.13140/2.1.2806.4809.
26. Bhutta ZA, Das JK, Rizvi A, Gaffey MF, Walker N, Horton S, et al. Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost? Lancet. 2013 Aug 3;382(9890):452-77. doi: 10.1016/S0140-6736(13)60996-4.
27. Sharma H, Singh SK, Srivastava S. Socio-economic inequality and spatial heterogeneity in anaemia among children in India: Evidence from NFHS-4 (2015–16). Clin Epidemiol Glob Health. 2020 Dec 1;8(4):1158-71. doi: 10.1016/j.cegh.2020.04.009.
28. Mehrotra M, Yadav S, Deshpande A, Mehrotra H. A study of the prevalence of anemia and associated sociodemographic factors in pregnant women in Port Blair, Andaman and Nicobar Islands. J Family Med Prim Care. 2018 Nov-Dec;7(6):1288-93. doi: 10.4103/jfmpc.jfmpc_139_18.
29. Ngesa O, Mwambi H. Prevalence and risk factors of anaemia among children aged between 6 months and 14 years in Kenya. PLoS One. 2014 Nov 25;9(11):e113756. doi: 10.1371/journal.pone.0113756.
30. Desai S, Alva S. Maternal education and child health: Is there a strong causal relationship?. Demography. 1998 Feb 1;35(1):71-81. PMID: 9512911.
31. Paul S, Paul S, Gupta AK, James KS. Maternal education, health care system and child health: Evidence from India. Soc Sci Med. 2022 Mar;296:114740. doi: 10.1016/j.socscimed.2022.11474.
32. Kumar P, Chauhan S, Patel R, Srivastava S. Anaemia among mother-father-child pairs in India: examining co-existence of triple burden of anaemia in a family. BMC Public Health. 2021 Dec;21(1):1-8. doi: 10.1186/s12889-021-11408-1.
33. Ghosh K, Desai GS. Prevalence and detecting spatial clustering of anaemia among children 6–59 months in the districts of India. Clin Epidemiol Glob Health. 2021 Oct 1;12:100845. doi: 10.1016/j.cegh.2021.100845
34. Anteneh ZA, Van Geertruyden JP. Spatial variations and determinants of anemia among under-five children in Ethiopia, EDHS 2005–2016. Plos One. 2021 Apr 1;16(4):e0249412. doi: 10.1371/journal.pone.0249412.
35. Melku M, Alene KA, Terefe B, Enawgaw B, Biadgo B, Abebe M, et al. Anemia severity among children aged 6–59 months in Gondar town, Ethiopia: a community-based cross-sectional study. Ital J Pediatr. 2018 Sep 3;44(1):107. doi: 10.1186/s13052-018-0547-0.
36. Gebremeskel MG, Tirore LL. Factors associated with anemia among children 6–23 months of age in Ethiopia: a multilevel analysis of data from the 2016 Ethiopia demographic and health survey. Pediatric Health Med Ther. 2020 Sep 16;11:347-57. doi: 10.2147/PHMT.S258114.
37. Simieneh MM, Mengistu MY, Gelagay AA, Gebeyehu MT. Mothers' health care seeking behavior and associated factors for common childhood illnesses, Northwest Ethiopia: community based cross-sectional study. BMC Health Serv Res. 2019 Jan 23;19(1):59. doi: 10.1186/s12913-019-3897-4.