Social Science Spectrum ISSN 2454-2806
Vol. 10, No. 4, December 2024, pp. 81-00

Geographic Disparities in ICDS Implementation and Child Malnutrition in India

Jitendra Gupta[1], Abhilasha Gupta[2], Dia Robyn Nensee[3*] and Amalia[4]

Abstract

This study investigates the socioeconomic, demographic and geospatial factors influencing the utilisation of Integrated Child Development Services (ICDS) and the prevalence of malnutrition among children under five in India. Using data from the National Family Health Survey (3 & 4), which includes a nationally representative sample of 238,945 children aged 0–59 months from 601,509 households, the findings highlight a slow decline in malnutrition rates, with stunting and underweight prevalence reducing by 9 per cent and 7 per cent respectively since NFHS-3 was conducted a decade ago. Analysis of spatial variation reveals significant clustering in ICDS utilisation and malnutrition, strongly associated with maternal education levels, higher proportions of scheduled castes and scheduled tribes and children of higher birth orders (three or more). Regression models incorporating spatial weights significantly improved predictive accuracy, underscoring the role of geospatial determinants in shaping health outcomes. Key factors negatively impacting children's nutritional status included maternal low body mass index, low birth weight, higher birth order and caesarean deliveries, all exhibiting notable spatial dependence with stunting and underweight. These findings underscore the need for geographically targeted, equity-focused interventions to enhance ICDS utilisation and address persistent disparities in child nutrition outcomes across India.

*Keywords**:** ICDS; stunting; underweight; Anganwadi Centres; autocorrelation.*

I. Introduction

Undernutrition among children under five years old remains a significant public health challenge in developing regions, particularly in sub-Saharan Africa and South Asia (WHO, 2021). Despite economic growth and urbanisation contributing to a global decline in child malnutrition, its burden persists. According to the World Health Organisation (WHO), 52 million children are wasted, 155 million are stunted and over 170 million are underweight globally, with Asia accounting for 55 per cent of stunted and 69 per cent of wasted children (Assembly, 216; UNICEF, 2017). Southern Asia, in particular, faces a critical public health emergency due to the severity of malnutrition (UNICEF, 2017). Malnutrition adversely affects children's growth, cognitive development, immunity and long-term productivity, contributing to 45 per cent of under-five deaths annually (Pelletier & Frongillo, 2003; Black et al., 2013). It is driven by complex factors, including poor diet, frequent illness, inadequate caregiving, inequities in food access, gender imbalances and environmental challenges (Ahmed & Ahmed, 2009). Global initiatives like the Millennium Development Goals (MDGs) and Sustainable Development Goals (SDGs) have sought to address malnutrition. However, progress remains uneven and achieving SDG-2-eradicating hunger and malnutrition by 2030 requires sustained and coordinated multi-sectoral efforts.

In India, child malnutrition rates surpass those of many sub-Saharan African countries. As of 2015–2016, 38 per cent of children were stunted and 36 per cent were underweight (Sheet, 2016).

---

[1] Assistant Professor & corresponding author, Symbiosis Medical College for Women, SIU, Lavale, Pune, India. Email: jitendra.gupta@smcw.siu.edu.in; Orcid ID: 0000-0002-2658-3131

[2] Rajarshi Tandon Open University, Allahabad; Email:guptabhilasha1992@gmail.com

[3*] PhD Scholar, Symbiosis International University, Lavale, Mulshi, Pune, Email: diarobynnensee@gmail.com (corresponding Author).

[4] London Geller College of Hospitality and Tourism, University of West London, London, UK.

Acknowledgement: The authors would like to thank anonymous reviewers for their helpful comments and suggestions for improving the paper.

This is despite significant economic development and the establishment of the Integrated Child Development Services (ICDS) scheme in 1975 which is a crucial government initiative aimed at improving the health, nutrition and early education of children under six years of age, along with pregnant and lactating mothers. It plays a vital role in providing essential services such as immunization, health check-ups, preschool education and nutritional support, contributing to the overall well-being of vulnerable population.

The world's largest early childhood nutrition programme ICDS currently serves only 110 million of India's out of 160 million eligible children under six years of age, highlighting substantial gaps in coverage (Awofeso & Rammohan, 2012). Complementary programmes exist, but malnutrition rates remain alarmingly high. To address these gaps, the government launched the POSHAN *Abhiyaan* in 2017 to reduce level of stunting, undernutrition, anaemia and low birth weight through phased implementation across districts, with key components including programme convergence, incentivizing states and union territories, strengthening human resources and fostering community engagement. Despite these efforts, malnutrition persists, necessitating a deeper understanding of ICDS utilization patterns and their impact on child nutrition (Awofeso & Rammohan, 2012).

The drivers of child malnutrition in India are multifaceted, including insufficient exclusive breastfeeding, inappropriate complementary feeding, inadequate food access, inequitable distribution, poor maternal and child care practices and environmental conditions such as poor sanitation and recurrent infections (Ahmed & Ahmed, 2009). Additional economic, environmental, geographical, cultural, health and governance factors further exacerbate malnutrition. Numerous studies have shown that malnutrition rates vary geographically due to factors such as altitude, rainfall, crop production, population density and disease patterns (Auchincloss et al., 2012). Spatial analysis offers critical insights into identifying high-risk areas, understanding malnutrition distribution and guiding targeted interventions (Miller, 2004; Pullan et al., 2012).

This study investigates the socioeconomic and demographic determinants and spatial variations in the utilisation of ICDS and the prevalence of malnutrition among under-five children in India. By leveraging spatial analysis, it identifies high-risk regions, prioritises nutrition-sensitive interventions and informs resource allocation to address malnutrition effectively. These findings aim to support policymakers and stakeholders in achieving equitable and impactful solutions to child malnutrition in India.

II. Materials and methods

This study utilises data from the fourth round of the National Family Health Survey (NFHS-4) conducted in 2015–2016 under the stewardship of the Ministry of Health and Family Welfare (MoHFW), Government of India. The International Institute for Population Sciences (IIPS), Mumbai, served as the nodal agency for this survey, which gathered demographic and health information at national, regional, state and district levels. NFHS-4 collected data from a nationally representative sample of 601,509 households and 699,686 women aged 15–49 years.

NFHS-4 employed a modular approach to data collection, focusing on malnutrition among children under five years of age. Height and weight measurements were taken for all children under five, regardless of their mothers' interview status. Weight was measured using an electronic SECA874 flat scale designed for mobile use, while height was measured using a SECA 213 Stadiometer for standing measurements or a SECA 417 Infantometer for recumbent length in children younger than 24 months. Data on the utilisation of the Integrated Child Development Services (ICDS) scheme, which provides health, nutrition and education services for children under six through Anganwadi Centres (AWCs), were collected for all children in surveyed households, irrespective of the maternal or caretaker interview status. Information on child malnutrition and ICDS utilisation is publicly available for all 640 districts in India.

Detailed methodologies, tools and protocols of NFHS-4 are documented in its national report, which is accessible in the public domain (Sheet, 2016). This study stops at 2016 because NFHS-4 represents the last stable, pre-pandemic dataset, allowing for an evaluation of ICDS effectiveness before the introduction of POSHAN Abhiyaan in 2017. The COVID-19 pandemic (2020–22) further disrupted public health services, delaying NFHS-5 (2019–21) data collection and exacerbating child malnutrition, making comparisons complex. Thus, NFHS-4 provides a critical reference point for understanding long-term trends without pandemic-induced anomalies.

Dependent variables

This study examines three dependent variables. The first is the utilisation of the ICDS scheme which is assessed based on reported engagement with health, nutrition and education services provided by *Anganwadi* Centres for children under six. The second is stunting, a measure of linear growth retardation and cumulative growth deficits. Children whose height-for-age Z-score falls below minus two standard deviations (−2 SD) from the median of the reference population are classified as stunted, reflecting chronic undernutrition. The third dependent variable is underweight, a composite index of acute and chronic undernutrition. Children whose weight-for-age Z-score is below minus two standard deviations (−2 SD) from the median of the reference population are classified as underweight.

Independent variables

A comprehensive set of independent variables was selected to explore the determinants of ICDS utilisation and malnutrition among children. Household characteristics include the type of residence, caste or tribe, religion and wealth quintile. Maternal characteristics include education level, exposure to mass media, nutritional status and parity. Child-specific factors include age, sex, birth order and birth weight. These variables provide a robust framework to analyze the underlying causes and variations in malnutrition and service utilisation patterns, enabling an in depth understanding of the issue.

Statistical methods

Bivariate and multivariate regression analyses were employed to assess the levels and changes in the nutritional status of children under six years of age. To determine the adjusted effects of various predictors on stunting, wasting and underweight, a binary logistic regression model was utilized. This model, commonly estimated through the maximum likelihood function, is expressed as follows:

$$\text{Log P} = \text{Ln}\ (P/1 - P) = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + \dots\dots\dots\dots + b_iX_i + e_i$$

Here, b_0, b_1, b_2, b_3 and b_i represent the coefficients of the predictor variables included in the model, while e is an error term. The term Ln $(P/1 - P)$ denotes the natural logarithm of the odds of the outcome occurring. The regression analysis produces odds ratios, which quantify the impact of each predictor variable on the likelihood of the outcome. In this study, the odds ratios measure the likelihood of stunting, wasting and underweight, adjusted for the independent variables included in the model. Odds ratios greater than one indicate an increased probability of these outcomes, while odds ratios less than one suggest a decreased probability.

Spatial analysis

Spatial analysis was conducted using two software tools: ArcGIS and GeoDa. ArcGIS was employed for data mapping and integration, while GeoDa facilitated the computation of univariate and bivariate Local Moran's I statistics to measure spatial autocorrelation. Moran's I, a generalization of Pearson's correlation coefficient, quantifies the degree to which data points are similar or dissimilar to their spatial neighbours. The Moran's I statistic is calculated as follows:

$$\text{Moran's I} = C \times \frac{\sum\sum w_{ij} z_i z_j}{\sum z_i^2}$$

Where z_i: represents the variable of interest; w_{ij}: is the standardized weight matrix, C is the multiplier and $C = n/ S_0$, where n is the number of observations. Positive spatial autocorrelation indicates that similar values cluster together in space, while negative values suggest dispersion. The values of Moran's I range from −1 (indicating perfect dispersion) to +1 (indicating perfect correlation), with zero representing a random spatial pattern. Univariate Local Indicators of Spatial Association (LISA) were employed to assess the correlation of neighbourhood values around specific spatial locations. Bivariate LISA, on the other hand, examined the association between regional characteristics and different outcomes. Cluster maps generated from LISA were categorized based on spatial autocorrelation types with red representing hotspots, deep blue indicating cold spots and lighter shades identifying spatial outliers.

To examine the spatial variation in the utilization of the ICDS scheme and malnutrition among children under five, Moran's I and bivariate LISA statistics were computed. Ordinary Least Squares (OLS) regression and Spatial Error Models (SEM) were then used to explore spatial autoregression. Initially, OLS regression was applied to estimate spatial autocorrelation in the error terms, which was quantified using Moran's I statistic. Significant spatial autocorrelation in the residuals indicated the necessity for a spatial error model. The OLS regression results were complemented by diagnostic tests, specifically the Lagrange Multiplier (LM) tests, to assess spatial dependence. Significant LM test results ($p < 0.001$) for both spatial lag and spatial error models warranted further comparison of Akaike Information Criterion (AIC) values to determine the best spatial fit. A very brief description of these two spatial models is presented in the following subsection;

Spatial Lag Model: The spatial lag model incorporates the influence of unmeasured independent variables while also accounting for the effect of neighbouring attribute values through a lagged dependent variable. The model is expressed as:

$$Y = \varrho W_y + X\beta + \varepsilon$$

Where W_y is an $N \times 1$ vector of spatial lags for the dependent variable, ϱ (Rho) is the spatial autoregressive coefficient and it is a scalar parameter that indicates the effect of the dependent variable in the neighbours on the dependent variable in the focal area; $X\beta$ is an $N \times K$ matrix of observations on the exogenous explanatory variables multiplied by a $K \times 1$ vector of regression coefficient β for each X and ε is an $N \times 1$ vector of normally distributed random error terms. This model assumes that the dependent variable in one region is influenced not only by the predictors in that region but also by the values of the dependent variable in neighbouring areas.

Spatial Error Model: The spatial error model evaluates the clustering of an outcome variable that cannot be explained by the measured independent variables. It accounts for the influence of unmeasured independent variables by modelling the spatial dependence in the error terms. The model consists of two equations:

$$y = X\beta + \varepsilon$$

$$\varepsilon = \lambda W_\varepsilon + u$$

Where y is an $N \times 1$ vector of observations on the dependent variable, X is an $N \times K$ matrix of observations on the explanatory variables; β is a $K \times 1$ vector of regression coefficients, ε is an $N \times 1$ vector of spatially lag autocorrelated error terms, W_ε is a spatial lag for the errors, λ (Lambda) is the autoregressive coefficient and u is another error term. The spatial error model captures the effect of unmeasured variables or omitted factors that exhibit spatial dependence, ensuring these influences are accounted for in the analysis.

III. Results

Utilization of the ICDS Scheme services

Table 1 presents the percentage of children under six years of age who received any service, specific services and among children aged 0–59 months, those who were weighed at an Anganwadi Centre (AWC) in the 12 months preceding the survey, categorized by background characteristics**.** More than half of children under six years old have received services from an Anganwadi Centre (AWC).

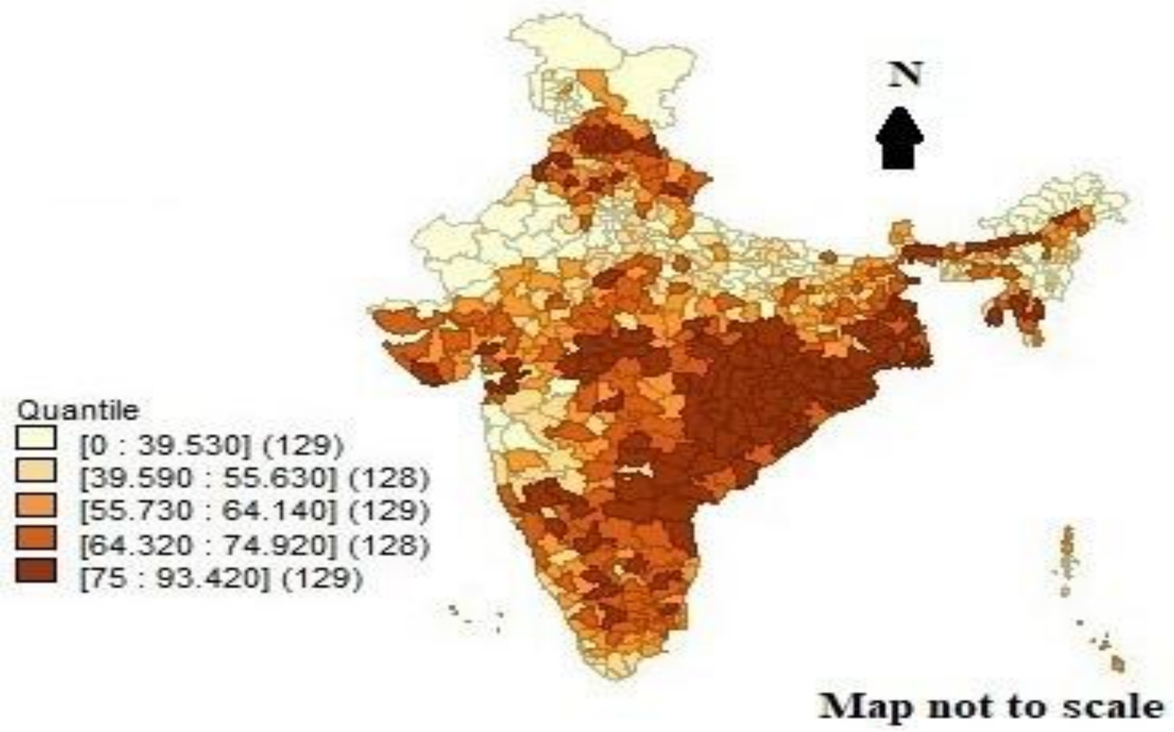
Table 1. Percentage of living children under aged six years who received any service, received specific services and among children aged 0-59 months who were weighed at an *Anganwadi* centre (AWC) in the last 12 months preceding the survey by background characteristics, India, 2015-16

Background characteristics	Children age 0-71 months who received any service	Children under age six years who:					N
		Received food supple ments[1]	Recei-ved immuni zations	Recei-ved health check-ups	Went for early childhood care/ preschool[2]	Were Weig-hed[3]	
India	53.6	48.1	39.8	39.7	38.2	43.3	238,945
Place of residence							
Urban	39.8	35.6	28.6	30.9	28.1	33.9	67,958
Rural	59.1	53.0	44.2	43.2	42.3	47.0	170,987
Mother's schooling							
No schooling	51.0	44.0	38.5	34.2	35.0	36.8	71,004
<5 years complete	62.3	57.3	44.5	47.6	49.1	51.6	14,240
5-7 years complete	60.0	55.0	45.3	46.5	45.4	50.6	38,852
8-9 years complete	58.5	53.2	43.2	45.0	41.7	49.0	39,507
10-11 years complete	55.6	51.3	41.7	44.3	40.1	48.5	28,999
12 or more years complete	43.9	39.1	31.3	32.9	28.5	36.4	46,343
Religion							
Hindu	55.0	49.3	41.7	41.0	39.2	44.8	187,795
Muslim	45.7	40.4	31.5	32.6	32.1	34.9	39,564
Christian	55.1	53.2	34.0	41.0	39.9	45.8	4,969
Sikh	60.0	56.9	39.4	44.3	43.0	46.5	2,963
Buddhist/Neo-Buddhist	55.8	53.0	43.3	50.4	52.2	51.8	1,878
Jain	22.8	21.7	12.7	19.9	8.5	27.4	262
Other	65.4	63.7	38.4	45.9	48.3	57.0	1,514
Caste/Tribe							
Scheduled caste	59.1	53.2	44.2	43.9	43.5	47.6	51,209
Scheduled tribe	63.8	60.4	47.7	51.0	48.9	55.7	25,051
Other backward classes	52.1	45.6	40.0	37.3	35.3	40.7	105,385
Others	47.0	42.7	32.2	35.6	34.1	38.7	55,206
Don't know	46.6	43.3	29.4	33.8	35.6	37.7	2,094
Wealth index							
Poorest	55.1	47.8	41.4	36.7	38.6	39.5	59,416
Poorer	60.6	54.8	45.2	45.1	45.2	48.7	52,153
Middle	59.5	54.6	44.2	46.2	43.8	50.7	47,494
Richer	51.8	47.4	38.3	41.0	36.5	45.1	43,896
Richest	35.3	31.1	25.1	26.9	22.1	29.8	35,986

Note: [1]Supplementary food includes both food cooked and served at an AWC on a daily basis or given in the form of take home rations; [2]Chil Children age 36-71 months; [3]Children age 0-59 months.

Approximately 40 per cent have benefited from immunization, health check-ups, early childhood care or preschool education and regular weighed. Notably, nearly 50 per cent have received nutritional support such as food supplements through the ICDS programme. The utilization of ICDS exhibits significant disparities across various demographic and socioeconomic groups in India. Notably, service uptake is 21 percent higher in rural areas compared with the urban counterparts, indicating a pronounced rural engagement with ICDS. An inverse relationship exists between maternal education and ICDS utilization: as maternal education levels rise, engagement with services such as food supplementation, health check-ups, early childhood care and growth monitoring declines with the exception of mothers without formal education. Religious affiliation also influences ICDS participation. Sikh children exhibit the highest utilization rates at 60 per cent, of food supplements (57%), immunisation, receiving health check-ups and were weighed under the age of six years, while children from scheduled tribes surpass 60 per cent engagement. In contrast, less than 50 per cent of children outside the scheduled castes, scheduled tribes, or other backward class categories access these services. Regarding economic status, no consistent pattern emerges between household wealth and AWC service utilization, suggesting that factors beyond economic standing may play a pivotal role in determining access and engagement.

Map 1. Utilization of any ICDS services among under five children across districts of India, 2015-16



Covariates of malnutrition among children

Over the past decade, India has made notable strides in improving the nutritional status of under-five years old children. Table 2 gives an account of malnutrition among children of India which shows a decline of more than nine percentage points in stunting and seven percentage points in underweight from 2005–2006 to 2015–2016. However, trends of wasting show a stagnant situation in the last decade which remains around 21 per cent with an increase of one per cent. Table further reveals that among children whose mothers are illiterate, 50 per cent are stunted and 47 per cent are underweight. Additionally, children of underweight mothers' exhibit higher rates of malnutrition: 46 per cent are stunted, 27 per cent are wasted and 48 per cent are underweight. Furthermore, there is a clear inverse relationship between household wealth and child malnutrition: as wealth quintiles increase, the prevalence of malnutrition indicators decreases.

Table 2. Malnutrition among children below the age of 5 years in India by background characteristics, 2005-2016

Background characteristics	Stunting		Wasting		Underweight	
	NFHS-3	NFHS-4	NFHS-3	NFHS-4	NFHS-3	NFHS-4
India	48.0	38.4	19.8	21.0	42.5	35.8
Sex of child						
Male	48.3	39.2	20.6	22.1	42.4	36.5
Female	48.3	38.1	19.3	20.3	43.4	35.7
Age of child (months)						
0-5	20.4	20.1	30.6	32.2	29.6	26.7
6-11	28.7	23.2	29.3	27.8	36.0	29.2
12-23	52.8	43.0	22.9	21.2	43.5	35.4
24-35	56.2	43.0	17.0	19.2	45.2	38.0
36+	52.8	42.0	15.7	18.0	45.8	39.1
Birth weight						
<2.5 kg	47.4	44.3	23.3	27.4	46.5	46.6
≥2.5kg	33.5	33.8	15.5	20.0	27.6	33.9
Mother's education						
No education	57.5	51.1	23.0	23.0	52.3	47.2
Primary	48.9	43.8	19.9	21.5	42.8	40.4
Secondary	38.3	33.1	16.6	20.8	32.5	31.4
Higher	19.6	21.1	13.3	18.2	15.9	19.2
Mother’s BMI						
Underweight	53.8	46.1	25.4	27.0	52.3	48.2
Normal	46.5	38.4	17.5	20.6	38.9	34.5
Overweight/obese	31.6	27.3	9.6	14.3	20.3	22.0
Breastfeeding						
Within 1 hour	42.5	35.3	20.3	21.3	38.3	33.8
After 1 hour	38.2	35.9	17.6	21.9	32.1	33.0
Birth order						
1-2	43.6	35.3	18.4	20.8	37.7	33.3
3-4	51.8	44.6	21.2	22.1	47.1	41.2
5+	59.4	53.5	24.0	22.6	54.4	48.5
Mother's age at birth						
12-19	53.6	41.5	19.3	20.7	46.2	38.7
20-14	46.8	38.6	19.6	21.4	40.6	36.3
25-29	45.9	37.0	20.3	20.8	41.8	34.2
30-39	50.6	40.2	21.8	21.9	47.1	37.5
C-section delivery						
No	50.1	41.1	20.5	21.9	44.5	38.5
Yes	28.6	27.2	15.0	18.0	24.6	24.5
Place of residence						
Rural	40.1	31.3	17.0	20.2	33.2	29.6
Urban	51.0	41.5	21.0	21.7	46.0	38.6
Religion						
Hindu	48.2	38.8	20.5	21.7	43.6	36.7
Muslim	50.5	40.1	18.9	19.5	42.1	35.3
Christian	39.3	30.2	16.1	19.0	30.6	27.5
Others	42.3	33.2	18.4	20.7	34.5	31.5
Caste/tribe						
Scheduled caste	54.2	43.1	21.1	21.5	48.1	39.6
Scheduled tribe	54.4	44.2	28.1	27.3	55.2	45.4
Other Backward Classes	49.1	39.0	20.3	20.8	43.6	36.0
Others	40.8	31.2	16.6	19.4	34.1	29.2
Wealth quintiles						
Poorest	60.2	51.8	25.3	24.4	57.1	49.0
Poorer	54.7	43.8	22.5	22.0	49.7	40.3
Middle	49.0	36.8	19.1	20.3	41.9	33.7
Richer	41.0	29.5	16.7	19.5	34.1	27.7
Richest	25.8	22.5	12.8	18.1	19.9	20.4
Received ICDS						
No	-	37.2	-	20.1	-	34.0
Yes	-	39.7	-	22.1	-	37.6

Table 3 presents adjusted odds ratios (ORs) for selected predictors influencing the nutritional status of children. The analysis indicates that female children have a significantly lower likelihood of being stunted compared with male children (OR = 0.90). Additionally, the probability of stunting increases with the child's age; 12–23 months are 2.75 times more likely, 24–35 months are 2.73 times more likely and 36 and older were 2.63 times more likely to be stunted compared with those aged 0–5 months. Furthermore, birth size emerges as a crucial determinant of a child's height-for-age, with smaller birth size associated with an increased risk of stunting.

Children with normal or high birth weights are 36 per cent less likely to be stunted compared with those with low birth weights (OR = 0.64). Maternal education significantly influences stunting as children of mothers with higher education levels are 41 per cent less likely (OR = 0.59) and those of mothers with secondary education have a 27 per cent reduced likelihood (OR = 0.73), compared with children of illiterate mothers. Maternal nutritional status also plays a critical role; children of overweight or obese mothers are 36 per cent less likely and those of mothers with normal BMI are 17 per cent less likely to be stunted. Birth order is strongly associated with stunting risk, with children of fifth or higher birth order being 47 per cent more likely and those of third or fourth birth order 21 percent more likely to be stunted compared with first or second-born children. Caste affiliation also affects stunting, with children from other castes being 23 per cent less likely (OR = 0.77), other backward classes 7 per cent less likely (OR = 0.93) and scheduled tribes 10 per cent less likely (OR = 0.90) to be stunted compared with scheduled caste children.

Socioeconomic status is a major determinant as children from the richest and richer households are 53 per cent and 44 per cent less likely to be stunted respectively compared with those from the poorest households. Middle-income households reduce stunting risk by 29 per cent and poor households by 15 per cent, compared with the poorest households. The use of ICDS services significantly reduces stunting as children who did not utilize them are 7 per cent more likely to be stunted.

The results for wasting reveal that female children have a 13 per cent lower likelihood of being wasted (OR = 0.87) compared with male children. Age-specific patterns show reduced risks for older children with children aged 36 months and above being 50 per cent less likely to be wasted (OR = 0.50), those aged 24–35 months 43 per cent less likely (OR = 0.57), those aged 12–23 months 40 per cent less likely (OR = 0.60) and those aged 6–11 months 22 per cent less likely (OR = 0.78) compared with children aged 0–5 months. Birth weight emerges as a critical determinant with normal and above-average birth weight children being 29 per cent less likely to experience wasting (OR = 0.71) than their low-birth-weight peers. Maternal BMI significantly impacts wasting as children of overweight and obese mothers have a 49 per cent reduced likelihood (OR = 0.51) and those of mothers with normal BMI have a 26 per cent lower likelihood (OR = 0.74). Religious affiliation also shows significant associations with children from Christian families being 48 per cent less likely and those from other religions 13 per cent less likely to experience wasting compared with children from Hindu households. Children who did not benefit from ICDS services are 7 per cent more likely to suffer from wasting.

Underweight results highlight the combined effects of acute and chronic malnutrition. Female children are 8 per cent less likely to be underweight (OR = 0.92) than males. Age is a significant factor as children aged 36 months and above are 1.68 times and those aged 24–35 months are 1.62 times more likely to be underweight compared with those aged 0–5 months. Birth weight is strongly associated with underweight outcomes with children of normal and above average birth weight being 47 per cent less likely (OR = 0.53) to be underweight compared with low-birth-weight children. Maternal education is a key predictor; children of mothers with higher education are 38 per cent less likely and those with secondary education are 24 per cent less likely to be underweight compared with children of illiterate mothers. Maternal BMI has a significant influence as children of overweight or obese mothers are 57 per cent less likely and those of mothers with normal BMI are 37 per cent less likely to be underweight compared with children of underweight mothers.

Table 3. Odds ratios (ORs) for selected predictors influencing the nutritional status of children, 2015-16

Background characteristics	Stunting		Wasting		Underweight	
	AOR	CI at 95%	AOR	CI at 95%	AOR	CI at 95%
Sex of child						
Male®						
Female	0.90***	(0.88,0.92)	0.87***	(0.85,0.90)	0.92***	(0.90,0.94)
Age of child (months)						
0-5®						
6-11	1.13***	(1.07,1.20)	0.78***	(0.74,0.82)	1.01	(0.96,1.06)
12-23	2.75***	(2.62,2.88)	0.60***	(0.57,0.63)	1.36***	(1.30,1.42)
24-35	2.73***	(2.60,2.86)	0.57***	(0.54,0.59)	1.62***	(1.54,1.69)
36+	2.63***	(2.51,2.75)	0.50***	(0.48,0.53)	1.68***	(1.61,1.76)
Birth weight						
<2.5 kg®						
≥2.5kg	0.64***	(0.63,0.66)	0.71***	(0.69,0.74)	0.53***	(0.51,0.54)
Mother's education						
No education®						
Primary	0.89***	(0.86,0.92)	0.93***	(0.90,0.97)	0.90***	(0.87,0.94)
Secondary	0.73***	(0.71,0.75)	0.93***	(0.90,0.96)	0.76***	(0.74,0.79)
Higher	0.59***	(0.56,0.61)	0.92***	(0.87,0.97)	0.62***	(0.59,0.65)
Mother’s BMI						
Underweight®						
Normal	0.83***	(0.81,0.85)	0.74***	(0.72,0.76)	0.63***	(0.61,0.65)
Overweight/obese	0.66***	(0.63,0.69)	0.51***	(0.49,0.54)	0.43***	(0.41,0.45)
Breastfeeding						
Within 1 hour®						
After 1 hour	1.03**	(1.01,1.05)	1.00	(0.97,1.02)	1.03**	(1.00,1.05)
Birth order						
1-2®						
3-4	1.21***	(1.17,1.24)	1.01	(0.98,1.05)	1.16***	(1.12,1.19)
5+	1.47***	(1.39,1.55)	1.00	(0.94,1.06)	1.32***	(1.25,1.40)
Mother's age at birth						
12-19®						
20-14	0.93***	(0.90,0.97)	1.05**	(1.00,1.10)	0.95***	(0.91,0.99)
25-29	0.86***	(0.83,0.90)	1.04	(0.99,1.09)	0.89***	(0.86,0.93)
30-39	0.80***	(0.76,0.84)	1.07**	(1.01,1.13)	0.85***	(0.81,0.90)
C-section delivery						
No®						
Yes	0.88***	(0.85,0.91)	0.87***	(0.84,0.90)	0.84***	(0.82,0.87)
Place of residence						
Rural®						
Urban	0.93***	(0.91,0.96)	0.90***	(0.87,0.93)	0.86***	(0.83,0.88)
Religion						
Hindu®						
Muslim	1.08***	(1.04,1.12)	0.94***	(0.90,0.98)	0.96*	(0.93,1.00)
Christian	0.90***	(0.85,0.94)	0.52***	(0.49,0.56)	0.52***	(0.49,0.55)
Others	0.91***	(0.86,0.97)	0.87***	(0.82,0.93)	0.81***	(0.76,0.86)
Caste/tribe						
Scheduled caste®						
Scheduled tribe	0.90***	(0.87,0.94)	1.15***	(1.10,1.20)	1.00	(0.96,1.04)
Other Backward Classes	0.93***	(0.90,0.95)	1.01	(0.98,1.05)	0.97*	(0.94,1.00)
Others	0.77***	(0.75,0.80)	0.92***	(0.89,0.96)	0.80***	(0.77,0.83)
Wealth quintiles						
Poorest®						
Poorer	0.85***	(0.82,0.87)	0.88***	(0.85,0.92)	0.81***	(0.78,0.83)
Middle	0.71***	(0.68,0.73)	0.83***	(0.80,0.86)	0.65***	(0.63,0.68)
Richer	0.56***	(0.54,0.59)	0.81***	(0.77,0.85)	0.55***	(0.53,0.57)
Richest	0.47***	(0.45,0.50)	0.77***	(0.73,0.82)	0.46***	(0.44,0.48)
Received ICDS						
No®						
Yes	1.07***	(1.04,1.09)	1.07***	(1.04,1.10)	1.13***	(1.11,1.16)

Note: ®Reference category, AOR-adjusted Odds Ratio, CI-Confidence Interval, *p<0.1, **p<0.05, ***p<0.01.

Further urban residence confers a protective effect with urban children being 14 per cent less likely (OR = 0.86) to be underweight than their rural counterparts. Economic status is another critical factor as children from the richest and richer households are 54 per cent and 45 per cent less likely respectively to be underweight compared with those from the poorest households.

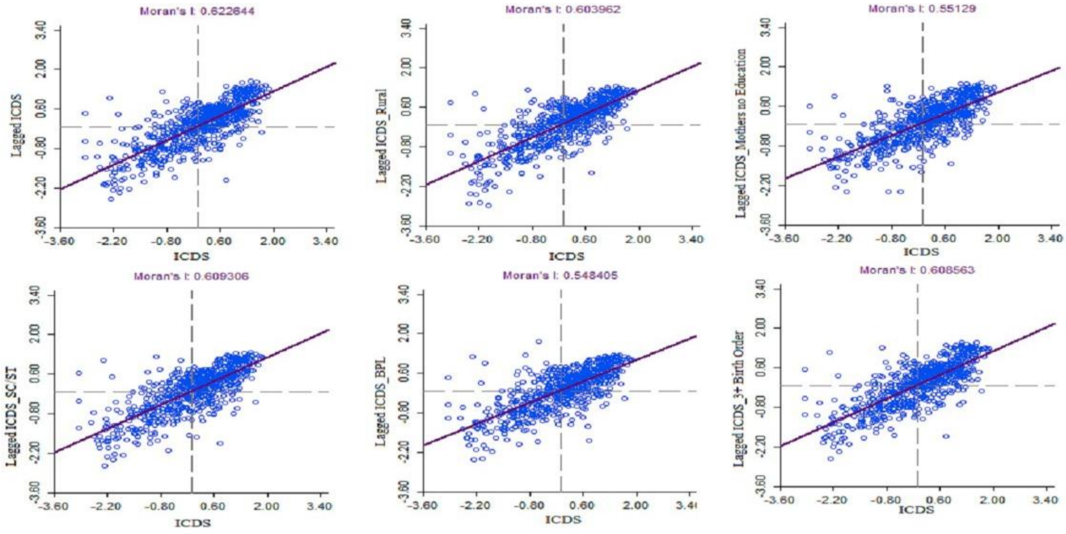
Finally, ICDS services significantly reduce underweight risk as children who did not utilize these services have a 13 per cent higher likelihood of being underweight compared with the beneficiaries. Children with normal or high birth weights are 36 per cent less likely to be stunted compared with those with low birth weights (OR = 0.64). Maternal education significantly impacts child nutrition as children of mothers with higher education levels are 41 per cent less likely to be stunted (OR=0.59) and those whose mothers have secondary education have a 27 per cent reduced likelihood (OR=0.73) compared with children of illiterate mothers. Maternal nutritional status also plays a crucial role as children of overweight or obese mothers are 36 per cent less likely and those of mothers with normal BMI are 17 per cent less likely to experience stunting. Birth order correlates with stunting risk: children of fifth or higher birth order are 47 per cent more likely and those of third or fourth birth order are 21 per cent more likely to be stunted compared with first or second-born children. Caste affiliation shows significant associations since children from other castes are 23 per cent less likely (OR = 0.77), OBCs 7 per cent less likely (OR = 0.93) and STs 10 per cent less likely (OR = 0.90) to be stunted compared with SC children. Socio-economic status significantly influences children's growth with wealthier households exhibiting lower stunting rates. Specifically, children from the richest and richer households are 53 per cent and 44 per cent less likely to be stunted respectively compared with those from the poorest households. Additionally, children from middle-wealth households are 29 per cent less likely and those from poor households are 15 per cent less likely to experience stunting than their counterparts from the poorest households.

Anganwadi centres, established under the ICDS programme play a crucial role in combating maternal and child malnutrition by providing supplementary nutrition, growth monitoring and nutrition and health education. The data indicate that children who did not utilize ICDS services are 7 per cent more likely to be stunted than those who did, highlighting the programme's positive impact on reducing acute malnutrition.

Spatial variation in utilization of ICDS and malnutrition among children

According to the theory, Moran's I is a correlation coefficient that measures the overall spatial autocorrelation between response and predictor variables presented in Graph 1. In other words, it measures how one object is similar to others surrounding it.

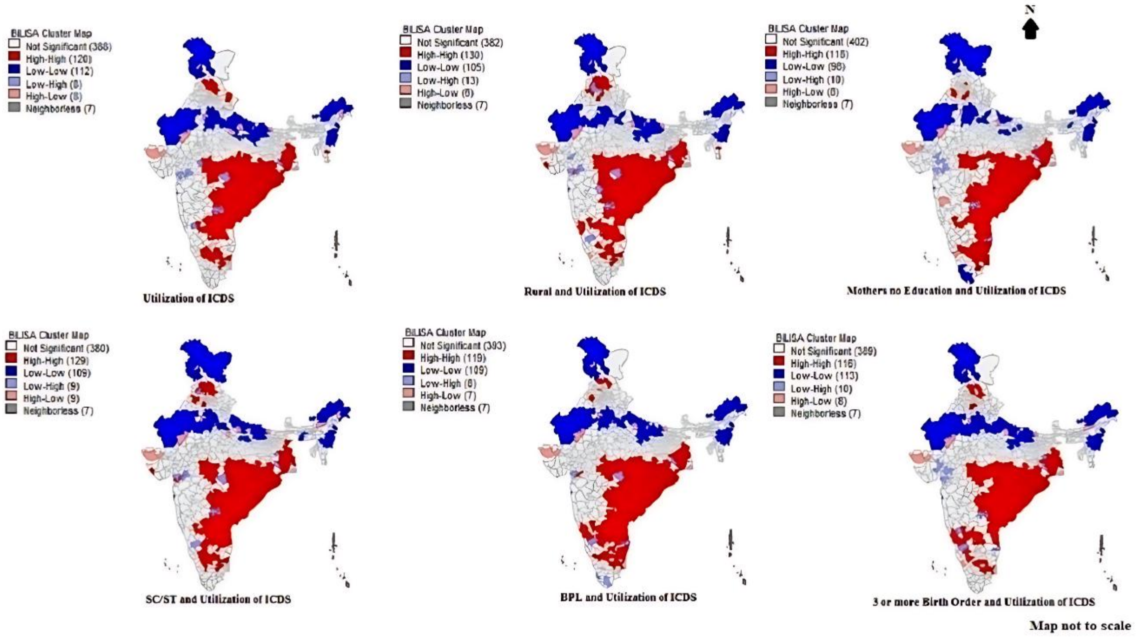
Graph 1. Moran's I and scatter plot for utilization of ICDS



Bivariate LISA maps are important for spatial analysis as they depict the association between selected independent variables and utilization of ICDS at the local level (Map 2). The analysis reveals a high clustering of ICDS utilization and rural residence in 20.3 per cent of districts (129 out of 640), as evidenced by Moran's I value of 0.60. In contrast, 16.4 per cent of districts exhibit low clustering of ICDS utilization and rural residence. The identified hotspot districts are predominantly located in Himachal Pradesh, West Bengal, Odisha, Jharkhand, Chhattisgarh, Telangana, Andhra Pradesh and Tamil Nadu.

Further analysis demonstrates Moran's I value of 0.55 (Graph 1) for the clustering of ICDS utilization and mothers with no education. A total of 118 districts are classified as hotspots, while 96 districts emerge as cold spots (Map 2).

Map 2. Bivariate LISA for utilization of ICDS among under five children in India



Utilization of ICDS

Rural and Utilization of ICDS

Mothers no Education and Utilization of ICDS

SC/ST and Utilization of ICDS

BPL and Utilization of ICDS

3 or more Birth Order and Utilization of ICDS

Map not to scale

Among these, several districts in the southern regions such as Ernakulam, Malappuram, Coimbatore, Idukki, Kotaiyam, Kollam, Thiruvananthapuram, Kanyakumari, Tirunelveli, Thoothukuddi, Virudhunagar, Ramanathapuram, Shiv Ganga, Madurai, Theni, Dindigul and Pudukottaiare prominently clustered, particularly along the eastern-coastal region.

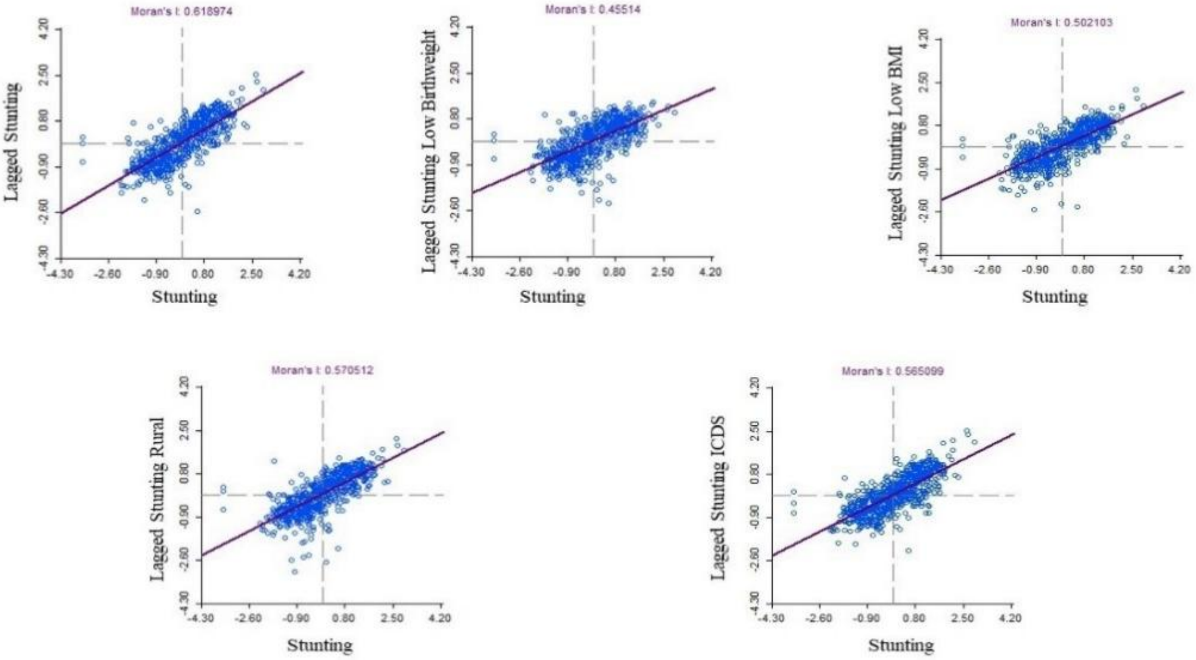
Spatial autocorrelation between ICDS utilization and SC/ST population is also significant as indicated by Moran's I value of 0.61 (Graph 1). Approximately 20.2 per cent districts are identified as hotspots for SC/ST population, while 109 districts are categorized as cold spots. These spatial correlations are further illustrated through Bi-LISA maps (Map 2).

Moran's I value of 0.55 indicates a significant spatial correlation between ICDS utilization and the Below Poverty Line (BPL) population. Among the 119 districts identified as hotspots, a substantial number are situated in southern regions including Ernakulam, Malappuram, Coimbatore, Idukki, Kotaiyam, Kollam, Thiruvananthapuram, Kanyakumari, Tirunelveli, Thoothukuddi, Virudhunagar, Ramanathapuram, Shiv Ganga, Madurai, Theni, Dindigul and Pudukottai, many of which are concentrated along the eastern coast.

The spatial correlation between ICDS utilization and higher birth orders (three or more) is similarly significant with Moran's I value of 0.61 (Graph 1). A total of 116 districts are identified as hotspots, while 113 districts exhibit low spatial autocorrelation. The hotspots for this indicator are concentrated in states such as Himachal Pradesh, West Bengal, Odisha, Jharkhand, Chhattisgarh, Telangana, Andhra Pradesh and Tamil Nadu.

Regarding malnutrition, Graph 2 highlights the spatial clustering of stunting among children under five years at the district level. The overall Moran’s I value for stunting is 0.62, indicating significant clustering of districts with high stunting prevalence. This clustering is particularly pronounced in rural districts with Moran’s I value of 0.57. Among ICDS beneficiaries, a similar clustering pattern is observed also with Moran’s I value of 0.57. Graph 2 further illustrates the spatial clustering of underweight prevalence among children. Moran’s I value for underweight is 0.72, signifying pronounced clustering at the district level. This clustering is especially evident in rural localities, where Moran’s I value is 0.68. Notably, children utilizing ICDS programmes also exhibit spatial clustering of underweight prevalence as reflected by Moran’s I value of 0.65.

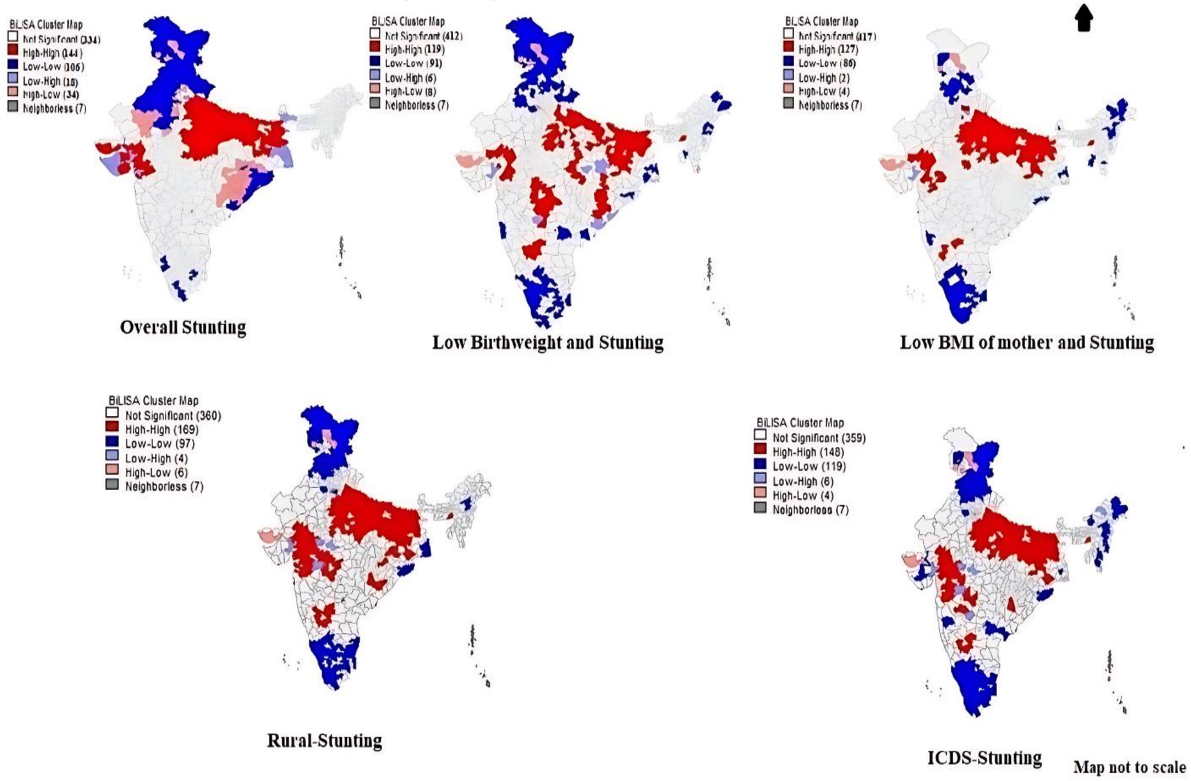
Graph 2. Moran’s I and scatter plot for stunting



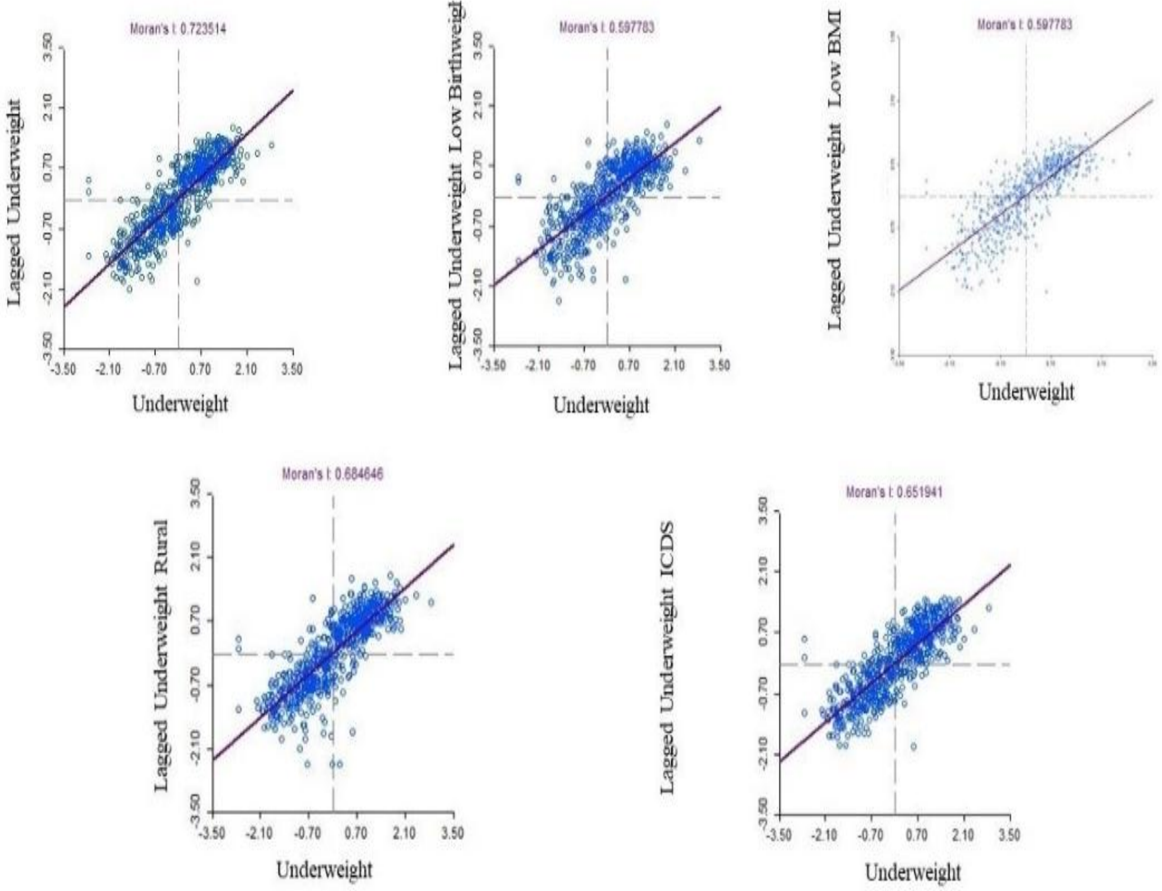
The bivariate LISA cluster map confirms that a cluster of 144 districts shows the highest level of clustering. Most of these districts belong to Uttar Pradesh, Bihar and Gujarat (Map 3). The analysis reveals that 127 districts out of 640 exhibit a high prevalence of stunting and low maternal BMI. Most of these districts are concentrated in specific states, mirroring previous patterns. However, the distribution shifts when examining the prevalence of stunting and low birthweight. A total of 127 districts are classified as hotspots for this indicator, predominantly located in Bihar, Uttar Pradesh, the eastern part of Maharashtra and the western part of Odisha. The spatial clustering of rural residence and high stunting prevalence identifies 169 districts as hotspots, highlighting a significant overlap of rural contexts with elevated stunting rates. Similarly, 148 districts are identified as hotspots for the highest levels of ICDS beneficiaries and high stunting prevalence.

The bivariate LISA map (Map 4) depicts district-level clustering of underweight children under the age of five. A total of 186 districts are classified as hotspots with a majority situated in Madhya Pradesh, Uttar Pradesh, Bihar, Chhattisgarh, Rajasthan, Maharashtra and Karnataka. Furthermore, 145 districts exhibit clustering of low maternal BMI and underweight prevalence among children, while 160 districts show clustering of low birthweight and high underweight prevalence. The analysis also highlights 191 districts as hotspots for rural residence and underweight prevalence among children, reinforcing the spatial link between rural settings and malnutrition outcomes. Additionally, the map identifies 183 districts as hotspots for ICDS beneficiaries with a high prevalence of underweight children underscoring the critical role of ICDS services in these areas.

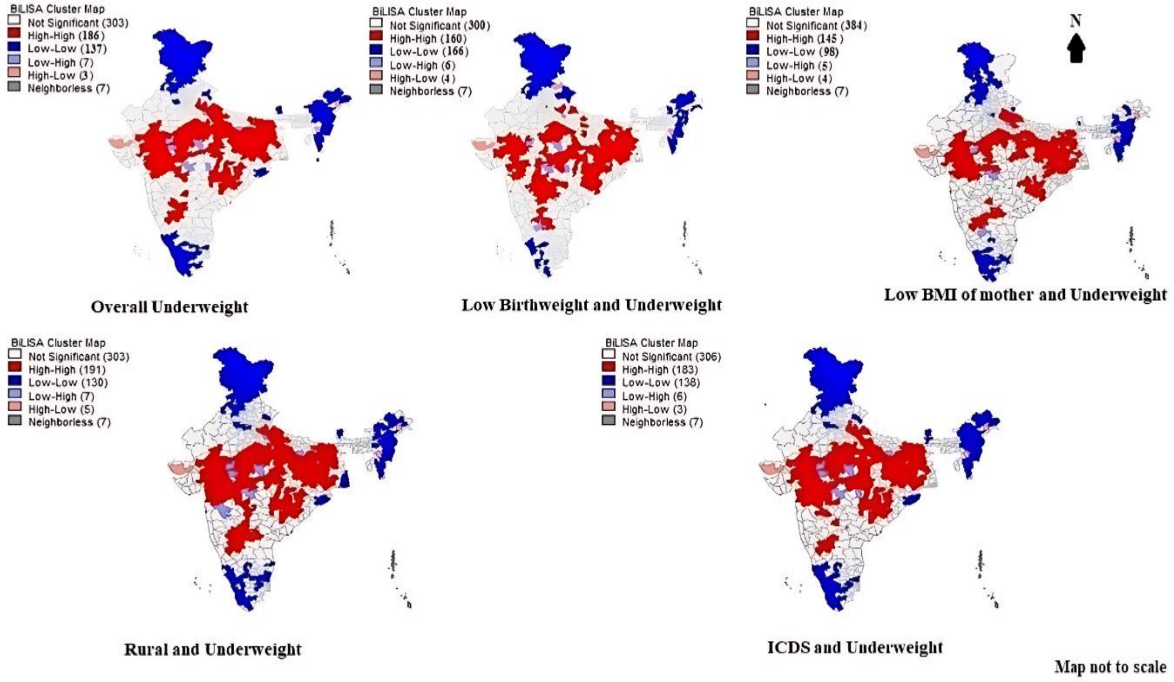
Map 3. Bivariate LISA for stunting among under five children in India



Graph 3. Moran's I and scatter plot for underweight



Map 4. Bivariate LISA for underweight among children below age of five in India



The spatial autocorrelation with an application of bivariate LISA maps and Moran's I in Table 4 (a & b) put forward a need to analyze the spatial dependence in the prevalence of utilization of ICDS among children aged 0–59 months across different districts of India. Districts demonstrating better performance in reducing stunting and underweight prevalence are clustered in regions including Punjab, Jammu and Kashmir, Kerala, Tamil Nadu and north-eastern India.

Table 4 (a). Summary of spatial error model and maximum likelihood estimation for utilization of ICDS, stunting and underweight by different background characteristics across districts of India, 2015-16

Coefficient	OLS			Spatial Regression (Error Model)		
	ICDS	Stunting	Underweight	ICDS	Stunting	Underweight
R-squared	0.321	0.687	0.714	0.665	0.757	0.805
Log likelihood	-2695.13	-2035.05	-2104.67	-2518.861	-1978.57	-1997.61
Akaike info criterion	5402.26	4086.1	4227.35	5049.72	3973.14	4015.22
Schwarz criterion	5429.06	4121.83	4267.54	5076.52	4008.87	4059.88

Table 4 (b). Background characteristics included in auto regression model

Background characteristics	Coefficient			z-value			Probability		
	ICDS	Stunting	Underweight	ICDS	Stunting	Underweight	ICDS	Stunting	Underweight
Constant	37.657	6.056	-14.333	13.412	3.227	-4.569	0.000	0.001	0.000
Rural place of residence	0.329	-0.020	0.127	9.762	-1.375	3.458	0.000	0.169	0.000
Mothers having no education	-0.235	-	-	-3.733	-	-	0.000	-	-
Belonging to SC/ST caste	0.063	-0.0427	-0.035	2.004	-3.299	-3.476	0.045	0.000	0.000
Belonging to below poverty line	0.039	-	-	0.780	-	-	0.436	-	-
3+ Birth order	-0.098	0.352	0.176	-1.100	10.529	6.505	0.271	0.000	0.000
C-section Delivery	-	0.207	0.082	-	7.243	3.309	-	0.000	0.000
Low BMI of Mother	-	0.247	0.419	-	7.265	13.251	-	0.000	0.000
Low birth weight (<2.5 Kg)	-	0.105	0.051	-	2.319	1.325	-	0.020	0.185
No ICDS	-	-0.035	-0.074	-	-2.104	-5.143	-	0.035	0.000
Lambda	0.774	0.582	0.477	27.061	13.957	16.039	0.000	0.000	0.000

To assess the suitability of models for analyzing spatial dependence, two sets of tests, Lagrange Multipliers (LM) and robust LM were conducted using the White test in the OLS model. The White test produced significance values for both LM (lag) and LM (error). Based on the results, robust LM (lag) and robust LM (error) were compared. A relatively larger value of LM (error) compared to LM (lag), coupled with a higher adjusted. R^2, lower Akaike Information Criterion (AIC) and Schwarz criterion values, indicated the superior suitability of the LM (error) model. This guided the application of the LM (error) model for analyzing the spatial dependence of ICDS utilization and the LM (lag) model for analyzing spatial dependence among children with various predictors included in the model.

The spatial error model for ICDS utilization among children aged 0–59 months is presented in Table 4 (a & b). The results demonstrate that including spatial weights in the model improved its predictive power from 32 per cent in the OLS model to nearly 67 per cent in the spatial regression model. The autoregressive coefficient for ICDS utilization is 0.77, indicating significantly higher spatial clustering in the outcome variable, reflecting the geographical distribution of both measured and unmeasured independent variables. These findings underscore that spatial factors play a crucial role in the utilization of ICDS services among children in India. Key predictors of ICDS utilization include rural residence, SC/ST caste affiliation and maternal illiteracy. However, maternal illiteracy shows a negative association with ICDS utilization, significantly affecting spatial variation in its use.

Similarly, protocols for model selection to analyze spatial dependence of malnutrition reveal a larger LM (error) value compared with LM (lag), along with higher adjusted R^2 values which supported the use of the LM (error) model for stunting and the LM (lag) model for underweight. The spatial error model results for stunting and spatial lag model results for underweight, reveal autoregressive coefficients of 0.58 and 0.48 respectively indicating significant spatial clustering in the prevalence of these conditions. The inclusion of spatial weights in the models improved predictive power from 69 per cent in OLS to 76 per cent in the spatial regression model for stunting and from 71 per cent in OLS to 81 per cent for underweight.

The analysis highlights the critical role of proximate determinants and mesoscale variables in explaining the spatial dependence of malnutrition outcomes. Poor maternal nutrition (BMI < 18.5 kg/m^2), low birth weight (<2.5 kg), higher birth order (3 or more) and cesarean deliveries are significant predictors of stunting and underweight among children aged 0–59 months. Additionally, the use of ICDS services in the last 12 months significantly impacts the spatial variation in stunting prevalence; however, the association is negative. This negative association underscores the issue of selectivity as children from socio-economically deprived sections of society are more likely to access ICDS services for supplementary nutrition, health check-ups, or immunizations. The findings reaffirm that spatial factors are critical to understanding the prevalence of malnutrition and the utilization of ICDS services in India. Incorporating spatial weights into regression models significantly enhances their predictive capacity, providing a more nuanced understanding of the interplay between geographical, socio-economic and health-related factors.

IV. Discussion

This study investigates the socioeconomic and behavioral determinants of malnutrition and the utilization of the ICDS scheme along with the spatial clustering of these phenomena across districts in India. Despite a decade of progress, with a 10 per cent reduction in stunting and a 7 per cent decline in underweight prevalence, malnutrition rates in India remain alarmingly high compared to global averages. In 2016, the global prevalence of stunting and wasting among under-five children was 23 per cent and 8 per cent respectively (UNICEF, 2017). In contrast, India reported stunting and underweight prevalence rates of 38.4 per cent and 35.8 per cent respectively contributing to 40 per cent of the world's undernourished children (Haddad et al., 2016). This poses a significant challenge to achieving SDG which aims to eradicate hunger and ensure universal access to safe, nutritious and sufficient food by 2030 (Resilience, 2017) which do not seem to be possible for India without putting astonishing efforts.

Household socioeconomic status significantly influences child malnutrition, mediated by interrelated factors. Key determinants include child age, birth weight, maternal education, maternal body mass index (BMI), caste and wealth quintile. Higher birth order correlates with increased stunting risk as children of fifth or higher birth order are 47 per cent more likely to be stunted and those of third or fourth birth order are 21 per cent more likely to be stunted compared with the first or second-born children. These findings align with previous research indicating that older children and those with low birth weight face a heightened risk of malnutrition (Arifeen et al., 2018; Islam et al., 2018, Mistry et al., 2019; Shrimpton et al., 2001).

A mother's education can be seen as one of the important predictors which shows a significant positive association with being underweight. Children of highly educated mothers were 41 per cent less likely to be stunted and those with mothers having secondary education were 27 per cent less likely to be stunted compared with children of illiterate mothers. Education empowers mothers with better knowledge of hygiene, disease management and optimal child feeding practices, enhancing child nutritional health outcomes (Islam et al., 2018, Mistry et al., 2019; Shrimpton et al., 2001). Similarly, maternal BMI plays a pivotal role. Children of overweight or obese mothers were 36 per cent less likely to be stunted and those with mothers of normal BMI were 17 per cent less likely to be stunted compared to children of underweight mothers. These findings reinforce the well-documented association between maternal and child nutrition (Chirande et al., 2015; Dekker et al., 2010).

Urban residence confers a protective advantage with urban children being 14 per cent less likely to be underweight than their rural counterparts. While significant improvements have been observed in the nutritional status of children across rural, urban and tribal areas, disparities persist. Participation in ICDS services emerges as a key determinant of improved nutritional outcomes. Children who did not utilize ICDS services were more likely to be stunted, wasted and underweight compared to beneficiaries. However, the negative association between ICDS participation and malnutrition could reflect selectivity bias as the programme primarily serves socio-economically disadvantaged population (Kapil & Pradhan, 1999). Female children were less likely to experience stunting than males, indicating gender-based differences in nutritional outcomes. The spatial analysis underscores significant clustering of malnutrition indicators. Positive Moran's I values for stunting and underweight reveal that districts with high prevalence rates are spatially clustered, particularly in states such as Uttar Pradesh, Bihar and Madhya Pradesh. These patterns highlight the persistence of geographical inequalities in malnutrition, corroborating findings from previous research on regional disparities (Barankanira et al., 2017; Fenn et al., 2004; Hagos et al., 2017; Haile et al., 2016; Khan & Mohanty, 2018). For stunting, spatial clustering is strongly associated with socio-economic and proximate determinants such as low maternal BMI, higher birth order and lack of education. Similarly, underweight prevalence shows spatial clustering in districts with higher proportions of low-birth-weight children and socio-economic deprivation. These findings emphasize the importance of geographically targeted interventions to address malnutrition. This study highlights the critical role of socioeconomic, maternal and geographical factors in shaping malnutrition outcomes among under-five children in India. The findings stress the urgent need for targeted, equity-focused policies to enhance the utilization of ICDS services and address the persistent regional disparities in malnutrition. Achieving SDG 2 by 2030 will require sustained and coordinated efforts that prioritize vulnerable populations, particularly in high-prevalence regions.

V. Conclusion

The bivariate LISA cluster map of India reveals that the highest number of clustered districts for stunting is concentrated in Uttar Pradesh and Bihar. This indicates that these states not only exhibit a higher prevalence and significant volume of malnourished children but also have most of their districts classified as hotspots for stunting. A similar pattern emerges for the spatial clustering of low birth weight and stunting, low maternal BMI and stunting, rural residence and stunting and ICDS utilization and stunting, underscoring the influence of these intervening factors on stunting prevalence. Likewise, districts with a higher prevalence of underweight demonstrate notable clustering with a considerable number of hotspots identified in Uttar Pradesh, Bihar, Madhya Pradesh, Chhattisgarh, Jharkhand, Odisha, Maharashtra and Karnataka (Khan & Mohanty, 2018). Transitional factors such as low birth weight, low maternal BMI, rural residence and suboptimal performance of ICDS services also display a comparable spatial pattern strongly associated with the high prevalence of underweight. Conversely, districts demonstrating better performance in reducing stunting and underweight prevalence are clustered in regions including Punjab, Jammu and Kashmir, Kerala, Tamil Nadu and north-eastern India. This confirms that most districts in southern and northern India are performing better, contributing to a lower average prevalence of malnutrition among under-five children in these states.

The spatial dependence observed in the prevalence of stunting and underweight confirms a significant correlation between these indicators and geographical location. Additionally, factors such as low maternal BMI, low birth weight, higher birth order and cesarean deliveries exhibit spatial dependence, further emphasizing their critical role in influencing stunting and underweight prevalence. An important finding of this analysis is the negative association of ICDS services with the spatial variation of stunting and underweight, which reflects the socio-economic status of ICDS beneficiaries. Since the programme predominantly serves socio-economically disadvantaged populations, maintaining adequate nutritional outcomes for these already vulnerable children remains a formidable challenge for the ICDS programme.

The emergence of maternal nutrition and maternal education as significant predictors of malnutrition among children below the age of five indicates an urgent need to embark upon nutrition interventions keeping various dimensions of women’s empowerment as the central issues of interventions. Some of the key issues may be women’s education, employment, maternal nutrition, kinship and patriarchy and decision-making about the healthcare of their own as well as their children. Another critical area for strengthening nutrition and health programs may be aligning the health care delivery system under NHM to nutrition needs and providing universal coverage of essential nutrition interventions. This may be achieved through building safe and supportive environments for nutrition and creating a sustainable and resilient food system for healthy diets by reorganizing and strengthening the ICDS scheme. In addition, providing social protection and nutrition-related education and counseling to all through capacity building of frontline workers associated with health and women and child development should be strengthened. These efforts may be helpful in reducing disparity in elevating nutrition problems in India and helping in achieving sustainable development goals, particularly those related to the eradication of extreme poverty, hunger and child survival.

References

Ahmed, T., & Ahmed, A. S. (2009). Reducing the burden of malnutrition in Bangladesh. *Bmj*, *339*.

Arifeen, S. E., Ekström, E. C., Frongillo, E. A., Hamadani, J., Khan, A. I., Naved, R. T., ... & Persson, L. Å. (2018). Cohort profile: the maternal and infant nutrition interventions in Matlab (MINIMat) cohort in Bangladesh. *International Journal of Epidemiology*, *47*(6), 1737-1738e.

Assembly, U. G. (2016). United Nations Decade of Action on Nutrition (2016-2025): Resolution/adopted by the General Assembly.

Auchincloss, A. H., Gebreab, S. Y., Mair, C., & Diez Roux, A. V. (2012). A review of spatial methods in epidemiology, 2000–2010. *Annual Review of Public Health*, *33*(1), 107-122.

Awofeso, N., & Rammohan, A. (2011). Three decades of the Integrated Child Development Services Program in India: Progress and problems. *Health management: Different approaches and solutions*, *14*, 243-258.

Barankanira, E., Molinari, N., Msellati, P., Laurent, C., & Bork, K. A. (2017). Stunting among children under 3 years of age in Côte d’Ivoire: Spatial and temporal variations between 1994 and 2011. *Public Health Nutrition*, *20*(9), 1627-1639.

Black, R. E., Victora, C. G., Walker, S. P., Bhutta, Z. A., Christian, P., De Onis, M., ... & Uauy, R. (2013). Maternal and child undernutrition and overweight in low-income and middle-income countries. *The Lancet*, *382*(9890), 427-451.

Chirande, L., Charwe, D., Mbwana, H., Victor, R., Kimboka, S., Issaka, A. I., ... & Agho, K. E. (2015).

Determinants of stunting and severe stunting among under-fives in Tanzania: evidence from the 2010 cross-sectional household survey. *BMC Pediatrics*, *15*(1), 165.

Dekker, L. H., Mora-Plazas, M., Marín, C., Baylin, A., & Villamor, E. (2010). Stunting associated with poor socioeconomic and maternal nutrition status and respiratory morbidity in Colombian schoolchildren. *Food and Nutrition Bulletin*, *31*(2), 242-250.

Fenn, B., Morris, S. S., & Frost, C. (2004). Do childhood growth indicators in developing countries cluster? Implications for intervention strategies. *Public Health Nutrition*, *7*(7), 829-834.

Haddad, L., Hawkes, C., Udomkesmalee, E., Achadi, E., Bendech, M. A., Ahuja, A., ... & Shyam, T. (2016). *Global nutrition report 2016: from promise to impact: ending malnutrition by 2030*. International Food Policy Research Institute.

Hagos, S., Hailemariam, D., WoldeHanna, T., & Lindtjørn, B. (2017). Spatial heterogeneity and risk factors for stunting among children under age five in Ethiopia: A Bayesian geo-statistical model. *PLoS One*, *12*(2), e0170785.

Haile, D., Azage, M., Mola, T., & Rainey, R. (2016). Exploring spatial variations and factors associated with childhood stunting in Ethiopia: spatial and multilevel analysis. *BMC Pediatrics*, *16*(1), 49.

Islam, M. M., Sanin, K. I., Mahfuz, M., Ahmed, A. S., Mondal, D., Haque, R., & Ahmed, T. (2018). Risk factors of stunting among children living in an urban slum of Bangladesh: findings of a prospective cohort study. *BMC Public Health*, *18*(1), 197.

Kapil, U., & Pradhan, R. (1999). Integrated Child Development Services scheme (ICDS) and its impact on nutritional status of children in India and recent initiatives. *Indian Journal of Public Health*, *43*(1), 21-25.

Khan, J., & Mohanty, S. K. (2018). Spatial heterogeneity and correlates of child malnutrition in districts of India. *BMC Public Health*, *18*(1), 1027.

Miller, H. J. (2004). Tobler's first law and spatial analysis. *Annals of the Association of American Geographers*, *94*(2), 284-289.

Mistry, S. K., Hossain, M. B., Khanam, F., Akter, F., Parvez, M., Yunus, F. M., ... & Rahman, M. (2019). Individual-, maternal-and household-level factors associated with stunting among children aged 0–23 months in Bangladesh. *Public Health Nutrition*, *22*(1), 85-94.

Pelletier, D. L., & Frongillo, E. A. (2003). Changes in child survival are strongly associated with changes in malnutrition in developing countries. *The Journal of Nutrition*, *133*(1), 107-119.

Pullan, R. L., Sturrock, H. J., Magalhaes, R. J. S., Clements, A. C., & Brooker, S. J. (2012). Spatial parasite ecology and epidemiology: a review of methods and applications. *Parasitology*, *139*(14), 1870-1887.

Resilience, B. U. I. L. D. I. N. G. (2017). The State of food security and nutrition in the world. *Rome: Building resilience for peace and food security*.

Sheet, H. F. (2016). *National Family Health Survey-4: Mumbai: International Institute for Population Sciences*.

Shrimpton, R., Victora, C. G., de Onis, M., Lima, R. C., Blossner, M., & Clugston, G. (2001). Worldwide timing of growth faltering: implications for nutritional interventions. *Pediatrics*, *107*(5), e75-e75.

Unicef. (2017). Levels and trends in child malnutrition: UNICEF/WHO/World Bank Group joint child malnutrition estimates. New York: UNICEF.

World Health Organization. (2021). *World Health Day 2012: Adding Life to Years*.