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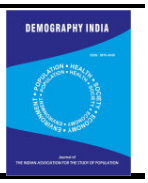

Child Undernutrition in North-East India: A Spatial Analysis of Disparities

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Abstract

India's economic growth has failed to reduce child undernutrition, spatial disparities persisting. Disparities in North-East India is particularly concerning, given its geographical remoteness and structural socio-economic constraints. Therefore, this study investigates the prevalence, determinants, and spatial variations of child undernutrition in North-East India, focusing on stunting, wasting, and underweight conditions. Using data from the fifth round of the NFHS (2019-21), this study examines child undernutrition among children under five years in North-East India. Statistical analyses, including chi-square tests and logistic regression models, were conducted to identify prevalence patterns and determine key influencing factors, yielding adjusted odds ratios for the associated variables. Child undernutrition remains a critical challenge in North-East India, with 35.6% of children stunted, 19.2% wasted, and 28% underweight. Logistic regression analysis revealed that children aged 48-59 months were significantly more likely to experience stunting (AOR=1.96) and underweight (AOR=1.85) but were less likely to be wasted (AOR=0.73) compared to those aged 0-11 months. Children born to educated mothers and from wealthier households had significantly lower odds of all forms of undernutrition. Additional factors such as birth size, rural-urban residence, and state-wise differences also emerged as significant determinants of child nutritional outcomes. The study underscores the urgent need for region-specific and targeted interventions to address the multifaceted drivers of child undernutrition in North-East India. Policies focusing on improving maternal education, reducing socio-economic disparities, and addressing regional and geographical barriers can facilitate sustainable improvements in child nutrition and overall well-being, securing a healthier future for children in the region.

Keywords

Child undernutrition, Determinants, NFHS-5, North-East India, Spatial disparities.

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Introduction

Good nutrition is the bedrock of child survival, growth, and development (UNICEF 2016). Ensuring that each child has access to adequate food may be the responsibility of parents to determinant of this right. But, nowadays increasingly seen that, undernutrition (insufficient intake of energy and nutrients) often steals the young lives of their dreams and hangs their future, and basically, it remains a major public health concern in low-and-middle-income countries (LMICs) (UNICEF 2023; WHO 2024). According to World Health Organization (WHO), poverty is clearly connected with undernutrition, also called 'silent emergency' and with this nearly half of deaths among under-5 children are linked (Priyanka et al. 2016; Yadav 2016). Despite considerable support from the United Nations International Children's Emergency Fund (UNICEF), WHO and the World Bank (WB) in achieving nutritional freedom, we are still far from a world without undernutrition. The WHO fact sheet published in March 2024, revealed insufficient progress towards the world health assembly (WHA) targets 2025 and the sustainable development goals (SDGs) set for 2030 (WHO 2024). The SDG indicator 2.1, 2.2 and 3.2, and the global strategy for women's, children's and adolescents' health (GSWCAH) set the relevant nutrition outcome targets by 2030 (UN 2015). Moreover, the UNICEF-WHO-WB Joint Child Malnutrition Estimates (JME) 2023 revealed that, stunting (too short for age), wasting (too thin for height) and underweight (low weight for age) have been declining steadily over the last decade with 22.3%, 6.8% and 12.3% of children under-5 worldwide affected in 2022, respectively (JME 2023). Asia bears a disproportionate burden of child undernutrition, accounting for 52% of the global share of stunted children (JME, 2023; DTE, 2023). More than three-quarters of the world's wasted children also reside in the region, while Southeast Asia alone reports an underweight prevalence of 23.6% among children under five, nearly double the global average (JME, 2023). Although substantial progress has been made in reducing child mortality in recent decades, undernutrition remains a critical underlying factor, contributing to 4.9 million deaths among children before their fifth birthday, largely linked to inadequate infant and young child nutrition (IYCN) including deficiencies in micronutrients such as vitamin A and iron, anemia, and diarrhea (WHO 2024; UNICEF 2024). Therefore, early detection of undernutrition is important for health systems to plan and implement timely interventions at the community level, especially in developing countries.

India is the largest contributor to global undernutrition and accounts for one third of the world's undernourished children (DTE 2013; WHO 2019). For India, high incidence of child marriage and teenage pregnancy are major causes of child undernutrition (Nair 2018; Nguyen et al. 2019; Shri et al. 2023). Needless to say, in the face of India's economic growth, nearly 2 million children under the age of 5 die each year - one every 15 seconds - the highest number of any place in the world (UN India 2018). Also, India slips to 111th position out of 125 countries in Global Hunger Index (GHI) 2023, indicating 'serious' category according to the GHI report (GHI 2023). The Government of India has launched the POSHAN Abhiyan as an overarching

initiative to address child malnutrition and improve nutritional outcomes across the country. Under this umbrella scheme, targeted interventions directly addressing child undernutrition include Hot Cooked Meals (HCM), Take Home Ration (THR) Additionally, programs under National Health Mission (NHM) such as the Pradhan Mantri Matru Vandana Yojana (PMMVY), Reproductive Maternal Newborn Child Adolescent Health plus Nutrition (RMNCAH+N) for children, and the use of Mother and Child Protection (MCP) Cards aim to ensure comprehensive support for maternal and child health, laying the foundation for improved nutrition and well-being. Further, the fifth round of National Family Health Survey (NFHS-5; 2019-21) report states, the prevalence of stunting among under-5 children was 35.5%, the prevalence of wasting was 19.3% and the prevalence of underweight was 32.1% (IIPS and ICF 2022). However, the trend has decreased compared to previous years but, not uniformly across all states and districts.

From the above-mentioned background, it is understood that the causes of undernutrition among children under 5 years of age in India have been explored in several studies. Despite that, there is a lack of region-specific evidence examining its multifactorial determinants remains limited, particularly for the North-Eastern states. This gap is significant given the region's distinct geographic and socio-cultural context. Comprising Sikkim, Meghalaya, Assam, Arunachal Pradesh, Nagaland, Tripura, Mizoram, and Manipur, the North-East is characterized by relative geographic isolation, mountainous terrain, infrastructural constraints, and diverse child-rearing practices that differ markedly from mainland patterns. These structural and cultural specificities may shape nutritional outcomes in ways not adequately captured in national-level analyses. Addressing this empirical gap, the present study focuses on the North-Eastern region to generate context-sensitive insights into the determinants of undernutrition. Such an approach is essential for informing locally responsive interventions rather than relying solely on generalized national strategies.

The aim of this study is to comprehensively investigate child undernutrition in North-East India, with a focus on stunting, wasting, and underweight conditions among children under five years of age. Specifically, the study seeks to determine the prevalence of stunting, wasting, and underweight among children under five across different socio-economic, demographic, and state-specific characteristics in North-East India; to identify the determinants associated with child undernutrition in the region; and to examine the spatial variations in child undernutrition across North-East India.

Material and methods

Data source

The data for this analysis was derived from the fifth round of National Family Health Survey (NFHS-5) conducted in 2019-21. NFHS-5 is a nationwide survey conducted under the Ministry of Health and Family Welfare, aimed at gathering comprehensive information on various aspects of population health and well-being for India (including states and union territories). The NFHS-5 sample was designed to provide estimates of all key indicators at the national and State/UT levels, and for most key

indicators at the district level, covering all 707 districts in India as of March 31, 2017. The dataset includes information on demographic characteristics, socio-economic status, health indicators, and nutrition-related data, making it a valuable source for studying child undernutrition in North-East India. Out of the 232,920 births in the five years preceding the survey, 30,133 samples were selected for the current analysis.

Outcome variables

This study examines stunting, wasting, and underweight among children under 5, utilizing height-for-age (HAZ), weight-for-height (WHZ), and weight-for-age (WAZ) Z-scores derived from NFHS data. Stunting (HAZ < -2 SD), wasting (WHZ < -2 SD), and underweight (WAZ < -2 SD) were determined based on reference population medians (IIPS and ICF 2022; WHO 2006). The study directly assessed these conditions in children aged 0-59 months, with binary variables '1' for presence and '0' for absence of stunting, wasting, and underweight. NFHS data permitted anthropometric measurements, facilitating statistical analysis for nutritional status evaluation. HAZ indicates chronic undernutrition (stunting), WHZ denotes acute undernutrition (wasting), while WAZ combines both aspects.

Explanatory variables

Based on the review of determinants of child undernutrition and considering the relevance in the context of North-East India in this study. The independent variables considered in the analysis are summarized in Table 1.

Analytical measures

Statistical measures such as prevalence percentages, chi-square tests for association, adjusted odds ratios (AORs) from logistic regression analysis, 95% confidence intervals (CI), and significance levels (p-values) are utilized in the analysis. Prevalence percentages provide insights into the magnitude of child undernutrition, while chi-square tests assess associations between categorical variables. AORs help determine the odds of undernutrition based on different independent variables, controlling for confounding factors. The 95% CIs provide a range of values for the estimated odds ratios, indicating the precision of the results. Significance levels help identifies statistically significant associations between variables, guiding the interpretation of the findings and highlighting key factors influencing child undernutrition in North-East India. Thematic mapping technique was utilized to visualize the district-level prevalence of stunting, wasting, and underweight. This analysis facilitated the identification of geographical disparities, highlighting areas with higher prevalence rates and the need for targeted interventions.

Results

Sample Characteristics

Table 1 presents the demographic and socio-economic characteristics of children in North-East India, reflecting a diverse profile of the region. The data reveals that, 35.6% of children are stunted, 19.2% are wasted, and 28% are underweight. The age distribution is relatively uniform across the five categories, with each contributing around 20%.

Table 1 Demographic and socio-economic characteristics of children, North-East India

Background characteristics	%	n (30,133)	Background characteristics	%	n (30,133)
Stunting			**Maternal media exposure**		
No	64.4	19,514	No	63.5	18,235
Yes	35.6	10,619	Yes	36.5	11,898
Wasting			**Maternal BMI**		
No	80.8	25,461	Underweight	16.1	3,429
Yes	19.2	4,672	Normal	70.3	21,808
Underweight			Overweight	13.6	4,896
No	72.0	23,202	**Religion**		
Yes	28.0	6,931	Hindu	45.1	8,794
Age in months			Muslim	33.2	4,329
0-11	17.3	5,282	Christian	18.7	14,273
12-23	19.1	5,677	Others	3.0	2,737
24-35	20.6	6,117	**Social category**		
36-47	21.2	6,350	SC	10.6	2,099
48-59	21.8	6,707	ST	27.7	18,253
Sex of child			OBC	18.5	3,172
Male	50.1	15,150	Others	43.2	6,609
Female	49.9	14,983	**Wealth status**		
Size at birth			Poor	72.7	20,869
Large	19.2	5,307	Middle	15.7	5,449
Average	69.1	21,103	Rich	11.6	3,815
Small	9.9	2,709	**Household size**		
Don't know	1.8	1,014	<5	36.2	10,743
Birth order			5-8	54.9	16,808
1	41.4	11,081	>8	8.9	2,582
2-3	45.5	13,457	**Place of residence**		
4 & above	13.1	5,595	Urban	14.6	4,458
Maternal age			Rural	85.4	25,675
15-19	4.2	956	**States**		
20-29	61.8	17,054	Sikkim	0.6	485
30-39	30.8	10,659	Arunachal Pradesh	2.1	4,833
40-49	3.2	1,464	Nagaland	2.6	2,754
Maternal education			Manipur	5.6	2,924
No education	14.9	4,763	Mizoram	2.1	2,185
Primary	16.7	5,290	Tripura	7.2	1,796
Secondary	61.4	17,814	Meghalaya	10.6	5,981
Higher	7.0	2,266	Assam	69.2	9,175

Notes: Computed from NFHS-5 (2019-21), n= Sample size

Male and female children are almost equally distributed, with 50.1% for males and 49.9% for females. The majority has an average size at birth (69.1%), and the first-borns constitute 41.4% of the sample. The majority of mothers (61.8%) fall within the age bracket of 20-29 years. Most mothers (61.4%) have a secondary education, while 36.5% are exposed to media,

and 70.3% have a normal BMI. Moreover, Hindu is the predominant religion (45.1%) followed by Muslims (33.2%) and Christians (18.7%). Among the various social groups, ST comprise the largest social community segment (27.7%), and the majority of households (72.7%) fall into the poor wealth category. Additionally, most households are in rural areas (85.4%), with Assam contributing the largest proportion among states (69.2%).

Differential patterns and determinants of stunting in North-East India

The prevalence of stunting among under-5 children varies significantly across several demographic and socio-economic characteristics (Table 2). According to the table, infants aged 0-11 months have the lowest stunting rate at 26.5%, which rises among children of succeeding age group. Also, male children have a higher prevalence of stunting (36.5%) compared to females (34.7%), and small-sized infants at birth exhibit the highest stunting rate (40.1%) compared to those with average or large birth sizes. Birth order also matters, with larger families (four or more siblings) showed higher rates (45.8%) of stunting. Besides, maternal factors play a significant role, with older mothers (40-49 years) and underweight mothers correlate with higher stunting rates, while education and media exposure show protective effects. Additionally, stunting rates are higher in households that are poorer and larger in size. Religious and social community differences also contribute, with children belong to Muslim and ST showing higher prevalence. Rural areas have higher rates of stunting than urban areas, and marked interstate variation is evident, with prevalence ranging from 47% in Meghalaya to 20.7% in Sikkim.

Table 2 Differentials and determinants of stunting among under-5 children, North-East India

Background characteristics	Prevalence (%)	n (10,619)	χ^2 value & sig. level	AOR	95% CI
Age in months					
0-11	26.5	1,266		Ref.	
12-23	39.9	2,208		2.13***	1.95, 2.32
24-35	35.4	2,217	374.04***	1.90***	1.75, 2.07
36-47	38.2	2,475		2.15***	1.97, 2.34
48-59	36.7	2,453		1.96***	1.80, 2.14
Sex of child					
Male	36.5	5,554	29.91***	Ref.	
Female	34.7	5,065		0.86***	0.82, 0.91
Size at birth					
Small	40.1	1,113		Ref.	
Average	34.9	7,269	120.76***	0.77***	0.71, 0.84
Large	34.2	1,758		0.72***	0.65, 0.80
Don't know	49.3	479		1.03	0.88, 1.20
Birth order					
4 & above	45.8	2,438	237.22***	Ref.	
2-3	35.3	4,684		0.84***	0.78, 0.91
1	32.6	3,497		0.76***	0.70, 0.83

Maternal age					
15-19	36.3	322	13.10***	Ref.	
20-29	35.3	5,998		0.96	0.83, 1.11
30-39	35.4	3,721		0.88	0.75, 1.02
40-49	40.7	578		0.87	0.72, 1.06
Mother BMI					
Underweight	42.5	1,506	232.22***	Ref.	
Normal	35.8	7,751		0.76***	0.70, 0.82
Overweight	26.3	1,362		0.66***	0.60, 0.73
Maternal education					
No education	44.0	2,013	409.36***	Ref.	
Primary	42.7	2,229		0.97	0.90, 1.06
Secondary	33.3	5,860		0.84***	0.78, 0.90
Higher	20.7	517		0.73***	0.64, 0.83
Maternal Media exposure					
No	38.7	7,015	211.06***	Ref.	
Yes	30.0	3,604		0.88***	0.83, 0.93
Religion					
Muslim	39.2	1,718		Ref.	
Hindu	31.9	2,798	121.49***	0.84***	0.76, 0.94
Christian	38.4	5,258		0.88**	0.74, 1.00
Others	32.7	845		0.90	0.76, 1.04
Social category					
ST	36.4	6,529		Ref.	
SC	34.6	715	24.09***	1.06	0.95, 1.19
OBC	31.5	1,000		0.95	0.86, 1.06
Others	37.0	2,375		0.97	0.87, 1.07
Household size					
<5	34.1	3,516		Ref.	
5-8	36.4	6,114	49.81***	1.07**	1.01, 1.13
>8	36.2	989		1.12**	1.01, 1.23
Wealth status					
Poor	39.3	8,165		Ref.	
Middle	29.2	1,622	511.11***	0.84***	0.78, 0.90
Rich	20.8	832		0.62***	0.56, 0.68
Place of residence					
Rural	36.9	9,354	108.03***	Ref.	
Urban	27.9	1,265		1.04	0.96, 1.12
States					
Meghalaya	47.0	2,830		Ref.	
Sikkim	20.7	118		0.52***	0.41, 0.65
Arunachal Pradesh	27.9	1,309		0.50***	0.45, 0.55
Nagaland	33.4	964		0.67***	0.61, 0.74
Manipur	23.4	732	707.10***	0.44***	0.40, 0.49
Mizoram	28.1	690		0.69***	0.61, 0.77
Tripura	32.8	600		0.63***	0.55, 0.73
Assam	35.8	3,376		0.69***	0.62, 0.77

*Notes: Computed from NFHS-5 (2019-21); *p<0.1, **p<0.05, ***p<0.01; Ref. = Reference category.*
n= Sample size

Table 2 presents crucial insights into the determinants of stunting among under-5 children in North-East India. It shows that as children age, the likelihood of stunting increases, with older children having higher odds of stunting compared to younger ones. Gender differences are also observed, with girls having a lower likelihood of stunting than boys (AOR = 0.86; 95% CI: 0.82, 0.91). Additionally, birth size is another significant factor, with average and large-sized infants having lower odds of stunting than small-sized infants (AOR = 0.77; 95% CI: 0.71, 0.84 and AOR = 0.72; 95% CI: 0.65,0.80, respectively). Birth order is also important, as the birth order increases the chance of stunting increases.

With this, maternal factors significantly influence stunting rates, as children of normal-weight (AOR = 0.76; 95% CI: 0.70, 0.82) and overweight mothers (AOR = 0.66; 95% CI: 0.60, 0.73) exhibit lower odds compared to those born to underweight mothers. Maternal education (AOR = 0.73; 95% CI: 0.64, 0.83 for higher education) and media exposure (AOR = 0.88; 95% CI: 0.83, 0.93) also offer protective effects. Religious affiliations correlate with stunting, with lower odds among Hindu (AOR = 0.84; 95% CI: 0.76, 0.94) and Christian (AOR = 0.88; 95% CI: 0.74, 1.00) children compared to Muslim children. Household dynamics show larger households (AOR = 1.12; 95% CI: 1.01, 1.23) and medium-sized households (AOR = 1.07; 95% CI: 1.01, 1.13) with higher stunting risks and wealth status reveals lower odds for children from middle (AOR = 0.84; 95% CI: 0.78, 0.90) and rich households (AOR = 0.62; 95% CI: 0.56, 0.68) compared to poor households. State-level differences highlight varying stunting odds, with Sikkim, Arunachal Pradesh, Manipur, and Mizoram showing the lowest rates (AOR ranging from 0.44 to 0.69), followed by Nagaland, Tripura, and Assam with significantly lower odds than Meghalaya, the reference state.

Figure 1 illustrates the uneven geographic distribution of stunting among children under-5 in North-East India between 2019-21, revealing substantial disparities at the district level. For instance, the East district in Sikkim records a low stunting rate (12.7%), whereas West Khasi Hills in Meghalaya reports a high rate (59.5%), illustrating the localized nature of nutritional challenges. Within states, notable disparities are also observed. In Meghalaya, South-West Khasi hills stand out with a notably high prevalence (51.3%), forming a cluster of districts with severe stunting issues alongside East Jantia Hills, South-West Khasi Hill, and West Khasi Hills. Similarly, in Assam, districts like Bongaigaon, Dhubri, and Morigaon exhibit high stunting rates, forming another cluster of concern. Moreover, Assam showcases considerable diversity, with urban districts like Kamrup Metropolitan report a rate of 23.1%, while rural districts like Dhubri display a higher rate of 48.7%. Nagaland shows mixed rates, with Zunheboto, Tuensang, and Kiphire having high prevalence rates, forming a cluster of concern. Arunachal Pradesh and Tripura also exhibit varied rates, with certain districts showing elevated stunting prevalence compared to others (See Appendix 1).

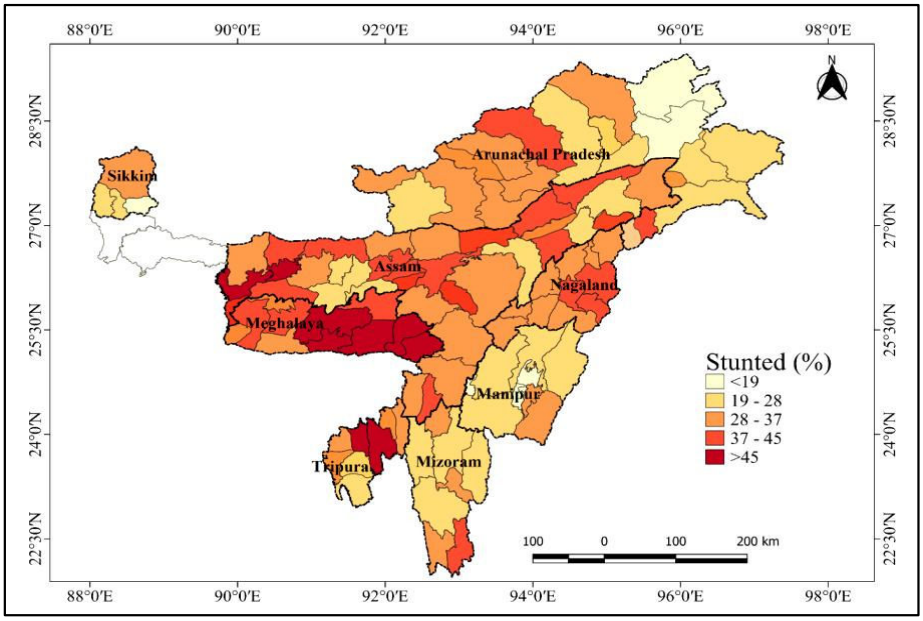

Figure 1 District-wise prevalence of stunting among under-5 children

Differential patterns and determinants of wasting in North-East India

Table 3 presents a detailed analysis of wasting patterns among children under-5, revealing several significant trends. Wasting prevalence is highest among infants aged 0-11 months and decreases with age, with males showing a higher prevalence than females. Factors such as small infant size, higher birth order, younger maternal age (15-19 years), underweight mothers, lower maternal education, Muslims, ST communities, poor household wealth status, and rural residence are associated with elevated wasting rates. The state-wise breakdown reveals significant disparities, with Assam having the highest prevalence, while Manipur and Mizoram report the lowest rates, underscoring the complex and varied nature of nutritional issues in the region.

Table 3 provides insights into the determinants of wasting among children under-5 in North-East India. The findings reveal that older children (36-47 months and 48-59 months) have significantly lower odds of wasting compared to infants (0-11 months), indicating a reduced risk with age. Female children also exhibit lower odds of wasting AOR = 0.88, 95% CI: 0.82, 0.93) compared to males. Factors associated with reduced odds of wasting include being born with average (AOR = 0.85, 95% CI: 0.76, 0.94) or large size birth (AOR = 0.77, 95% CI: 0.68, 0.88), having mothers with normal (AOR = 0.89, 95% CI: 0.81, 0.97) or overweight (AOR = 0.64, 95% CI: 0.56, 0.73) BMI, and exposure to media (AOR = 0.93, 95% CI: 0.86, 1.00). However, children from the OBCs show higher odds of wasting (AOR = 1.14, 95% CI: 1.00, 1.30) compared to ST children. Also, children from larger family-sized have lower odds of wasting (AOR = 0.85, 95% CI: 0.75, 0.97) compared to those from smaller family-sized. At the state level, Mizoram had the lowest likelihood of wasting, closely followed by Manipur, Meghalaya,

Sikkim, Arunachal Pradesh, and Nagaland, highlighting the significant state-wise disparities in addressing nutritional challenges.

Table 3 Differentials and determinants of wasting among under-5 children, North-East India

Background characteristics	Prevalence (%)	n (4,672)	χ^2 value & sig. level	AOR	95% CI
Age in months					
0-11	22.3	921		Ref.	
12-23	18.7	898		0.88**	0.79, 0.97
24-35	22.0	1,084	77.00***	1.01	0.92, 1.11
36-47	17.2	874		0.76***	0.69, 0.84
48-59	16.6	895		0.73***	0.66, 0.81
Sex of child					
Male	20.4	2,471	15.10***	Ref.	
Female	18.0	2,201		0.88***	0.82, 0.93
Size at birth					
Small	22.1	498		Ref.	
Average	19.2	3,238	21.44***	0.85***	0.76, 0.94
Large	18.2	799		0.77***	0.68, 0.88
Don't know	16.4	137		0.79**	0.64, 0.98
Birth order					
4 & above	19.2	810	5.66*	Ref.	
2-3	19.6	2,108		0.98	0.89, 1.09
1	18.9	1,754		0.96	0.85, 1.08
Maternal age					
15-19	20.3	170		Ref.	
20-29	20.0	2,802	35.28***	1.09	0.91, 1.31
30-39	17.6	1,497		1.04	0.86, 1.27
40-49	18.4	203		1.11	0.87, 1.42
Mother BMI					
Underweight	23.0	691		Ref.	
Normal	19.9	3,458	145.50***	0.89**	0.81, 0.97
Overweight	11.3	523		0.64***	0.56, 0.73
Maternal education					
No education	22.0	771		Ref.	
Primary	21.0	886	25.40***	1.10*	0.99, 1.24
Secondary	18.5	2,735		0.97	0.88, 1.07
Higher	15.1	280		0.91	0.77, 1.07
Maternal Media exposure					
No	21.3	3,048	51.66***	Ref.	
Yes	15.7	1,624		0.93**	0.86, 1.00
Religion					
Muslim	22.5	937	272.0***	Ref.	
Hindu	19.6	1,568		0.88*	0.77, 1.01
Christian	13.7	1,878		0.98	0.81, 1.18
Others	11.2	289		0.78**	0.63, 0.96
Social category					
ST	14.7	2,427	180.47***	Ref.	

SC	20.0	354		0.99	0.86, 1.15
OBC	20.6	619		1.14**	1.00, 1.30
Others	21.3	1,272		1.04	0.91, 1.19
Household size					
<5	18.8	1,705	8.64***	Ref.	
5-8	19.8	2,617		0.99	0.92, 1.06
>8	17.32	350		0.85**	0.75, 0.97
Wealth status					
Poor	20.6	3,456	62.87***	Ref.	
Middle	16.9	754		0.99	0.90, 1.08
Rich	13.8	462		0.97	0.85, 1.10
Place of residence					
Rural	19.8	4,104	30.50***	Ref.	
Urban	16.0	568		0.92	0.83, 1.03
State					
Assam	21.8	1,955	475.90***	Ref.	
Meghalaya	12.0	711		0.50***	0.43, 0.58
Sikkim	14.2	52		0.54***	0.40, 0.73
Arunachal Pradesh	12.9	621		0.65***	0.56, 0.74
Nagaland	19.0	481		0.79***	0.67, 0.93
Manipur	9.8	298		0.47***	0.40, 0.55
Mizoram	9.4	211		0.44***	0.36, 0.54
Tripura	17.9	343		0.93	0.82, 1.07

*Notes: Computed from NFHS-5 (2019-21); *p<0.1, **p<0.05, ***p<0.01; Ref.= Reference category.*
n= Sample size

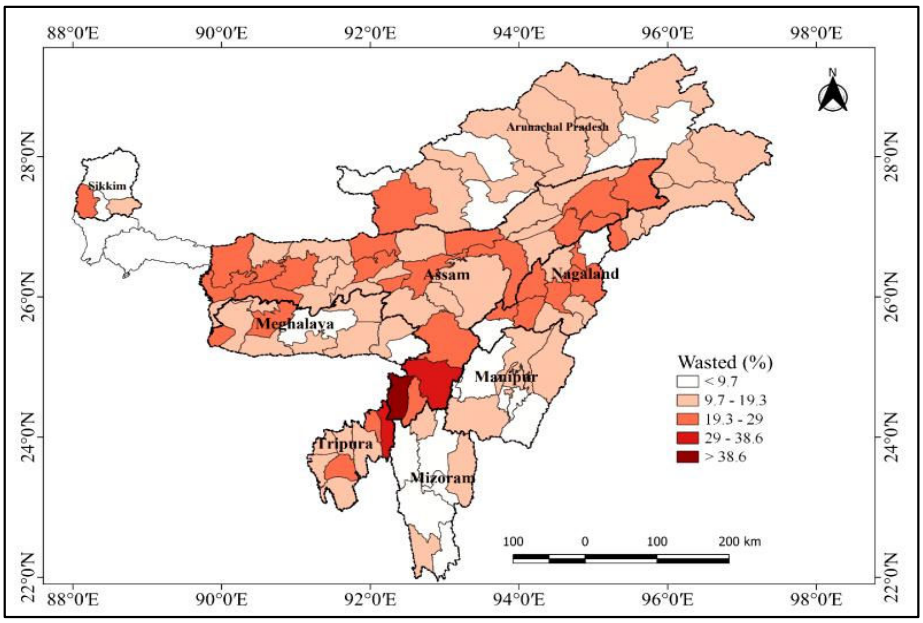

Figure 2 District-wise prevalence of wasting among under-5 children

Figure 2 represents the spatial distribution of wasting in North-East India, offering a clear overview of the nutritional status across the region. Sikkim and Manipur generally exhibit lower wasting rates, with most districts falling

into the below 9.7%, and 9.7%-19.3% index categories. However, Nagaland and Mizoram show mixed rates, with specific districts such as Zunheboto, Tuensang, and Lawngtlai reporting higher wasting prevalence, forming localized clusters of concern. Similarly, Meghalaya displays a varied pattern, with districts like South Garo Hills and East Garo Hills showing elevated wasting rates. Notably, Assam stands out with several districts reporting high wasting rates, particularly Cachar and Karimganj forming a cluster of districts with significant wasting prevalence. Arunachal Pradesh and Tripura also exhibit diverse rates across districts, highlighting pockets of high wasting prevalence within these states (See Appendix 1).

Differential patterns and determinants of underweight in North-East India

Table 4 provides a comprehensive analysis of differentials in the prevalence of underweight, revealing several crucial findings. Age emerges as a critical factor, with older children exhibiting the highest prevalence of underweight, indicating potential vulnerabilities as children grow. Gender disparities are evident, with males showing a higher prevalence compared to females, highlighting gender-specific nutritional challenges. Birth size also plays a significant role, with small-sized births exhibiting a substantially higher prevalence of underweight than average and large-sized births. Maternal age, BMI, education, media exposure, religion, social communities, household wealth, and rural-urban disparities all contribute to variations in underweight prevalence, showcasing the complex interplay of socio-economic and demographic factors. Further, state-level variations are notable, with Assam reporting the highest prevalence and Sikkim the lowest, emphasizing the need for targeted interventions addressing these disparities across different regions.

In North-East India, various background characteristics of under-5 children are significantly associated with the likelihood of being underweight, as evidenced by the AORs presented in Table 4. Notably, age is a critical factor, with older children having higher odds of underweight. Female children exhibit lower odds of underweight (AOR = 0.86, 95% CI: 0.82, 0.91) than males, while average-sized (AOR = 0.72, 95% CI: 0.66, 0.79) and large-sized (AOR = 0.67, 95% CI: 0.60, 0.75) infants, as well as those with a first birth order (AOR = 0.89, 95% CI: 0.81, 0.99), show lower odds. Maternal education is also pivotal, with higher education levels associated with reduced odds of underweight. Children of mothers with media exposure (AOR = 0.83, 95% CI: 0.78, 0.89) and those from Hindu (AOR = 0.79, 95% CI: 0.70, 0.89) and Christian (AOR = 0.80, 95% CI: 0.68, 0.95) communities also have decreased odds of underweight. However, children from other commnities, including SC, OBC, and others, have higher odds of underweight compared to ST children. Household wealth status shows a clear gradient, with children from poor households facing elevated odds of underweight. State-level variations are significant, with most states having lower odds of underweight compared to Assam, highlighting regional disparities in nutritional outcomes.

Table 4 Differentials and determinants of underweight among under-5 children, North-East India

Background characteristics	Prevalence (%)	n (6,931)	χ^2 value & sig. level	AOR	95% CI
Age in months					
0-11	22.4	874		Ref.	
12-23	27.8	1,298		1.54***	1.39, 1.70
24-35	30.1	1,518	162.03***	1.75***	1.59, 1.92
36-47	28.5	1,543		1.72***	1.56, 1.90
48-59	30.1	1,698		1.85***	1.68, 2.03
Sex of child					
Male	29.3	3,651	20.73***	Ref.	
Female	26.6	3,280		0.86***	0.82, 0.91
Size at birth					
Small	34.2	1,155		Ref.	
Average	27.4	4,706	85.87***	0.72***	0.66, 0.79
Large	26.4	807		0.67***	0.60, 0.75
Don't know	32.9	263		0.78***	0.66, 0.93
Birth order					
4 & above	31.8	1,447	37.33***	Ref.	
2-3	28.2	3,085		0.94	0.86, 1.03
1	26.6	2,399		0.89**	0.81, 0.99
Maternal age					
15-19	30.8	224	13.84***	Ref.	
20-29	28.8	4,030		1.03	0.87, 1.21
30-39	26.0	2,323		0.99	0.83, 1.19
40-49	28.8	354		1.04	0.84, 1.29
Mother BMI					
Underweight	39.0	1,252		Ref.	
Normal	27.6	4,993	576.79***	0.62***	0.57, 0.67
Overweight	16.8	686		0.44***	0.40, 0.50
Maternal education					
No education	35.8	1,344		Ref.	
Primary	33.4	1,457	296.04***	0.98	0.90, 1.08
Secondary	26.3	3,847		0.84***	0.77, 0.91
Higher	13.5	283		0.66**	0.56, 0.77
Maternal media exposure					
No	31.7	4,802	289.61***	Ref.	
Yes	21.6	2,129		0.83***	0.78, 0.89
Religion					
Muslim	34.5	1,476		Ref.	
Hindu	25.9	2,083	453.71***	0.79***	0.70, 0.89
Christian	23.3	2,977		0.80**	0.68, 0.95
Others	16.3	395		0.78***	0.64, 0.94
Social category					
ST	22.7	3,657		Ref.	

SC	26.6	501	258.88***	1.16**	1.02, 1.33
OBC	28.0	840		1.30***	1.16, 1.46
Others	31.7	1,933		1.20***	1.06, 1.35
Household size					
<5	27.5	2,366	9.03***	Ref.	
5-8	28.7	3,960		1.04	0.98, 1.11
>8	25.7	605		1.03	0.93, 1.16
Wealth status					
Poor	31.7	5,487	460.79***	Ref.	
Middle	22.1	984		0.89***	0.82, 0.97
Rich	12.7	460		0.67***	0.59, 0.76
Place of residence					
Rural	29.3	6,165	100.02***	Ref.	
Urban	20.1	766		1.03	0.93, 1.13
State					
Assam	31.1	2,844	1.1e+0.3***	Ref.	
Meghalaya	26.5	1,584		0.99	0.87, 1.12
Sikkim	7.9	43		0.34***	0.25, 0.48
Arunachal Pradesh	13.7	606		0.46***	0.41, 0.53
Nagaland	27.1	752		1.15*	0.99, 1.33
Manipur	12.4	371		0.45***	0.39, 0.52
Mizoram	11.8	288		0.55***	0.46, 0.66
Tripura	23.3	443		0.83***	0.77, 1.02

*Notes: Computed from NFHS-5 (2019-21); *p<0.1, **p<0.05, ***p<0.01; Ref.= Reference category.*
n= Sample size

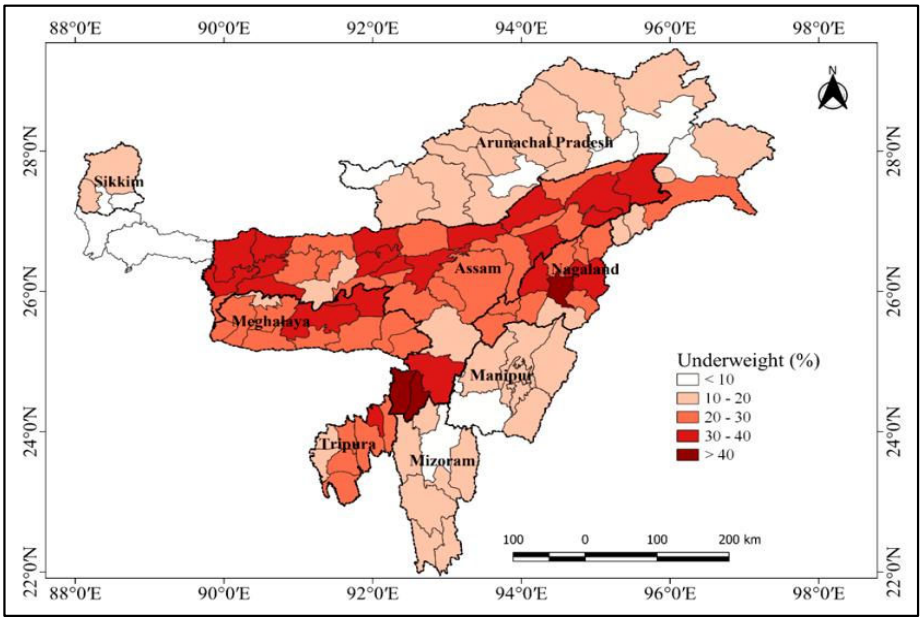

Figure 3 District-wise prevalence of underweight among under-5 children

Figure 3 illustrates the district-wise prevalence of underweight in North-East India, revealing a complex geographic pattern marked by substantial regional variations and disparities. Sikkim and certain parts of Manipur state demonstrate lower underweight rates, with most districts falling into the below 10%, and 10-20% index categories. However, Assam, Meghalaya and specific districts in Tripura and Nagaland exhibit higher underweight prevalence. Assam stands out with several districts displaying high underweight rates, notably Cachar, Karimganj, and Hailakandi, forming a cluster of districts with significant underweight prevalence (See Appendix 1).

Discussion

The analysis of the prevalence and determinants of stunting, wasting and underweight among under-5 children in North-East India based on NFHS-5 data, reveals crucial insights into the complex nature of child undernutrition in the region. These findings underscore the multifaceted factors contributing to nutritional disparities and highlight the importance of tailored interventions to address these challenges effectively.

The age-related vulnerability observed in stunting and underweight rates among children under-5 in North-East India highlights an increasing risk as children grow, consistent with previous studies (Chauhan et al. 2022; Sinha et al. 2018; Victora et al. 2008). This vulnerability underscores the evolving nutritional needs of children as they grew up; emphasizing the importance of age-specific interventions, such as early breastfeeding initiation and appropriate complementary feeding practices (Finnane et al. 2017). However, the relationship between age in months and wasting in children can be complex, influenced by factors like physiological weight loss in early infancy and rapid growth in young children (Fontaine et al. 2023). Gender disparities reveal a lower risk of undernutrition among female children, aligning with global trends, though this may vary based on biological factors (Singh et al. 2024; Myatt et al. 2018; Khara et al. 2017; Jawaregowda and Angadi 2015; Mondal et al. 2012). However, some studies have found no significant association between gender and undernutrition (Sethy et al. 2017; Manjunath et al. 2014). Birth size emerges as a critical determinant, with small-sized infants facing higher rates of stunting, wasting, and underweight (Rao et al. 2005), emphasizing the importance of early initiation of nutritional and antenatal care. Low birth weight (LBW), often resulting from intrauterine growth restriction (IUGR) or other adverse prenatal conditions, reflects compromised fetal development and limited nutrient reserves at birth. Consequently, these infants are biologically more vulnerable to subsequent undernutrition, particularly in the absence of adequate postnatal feeding and care. Factors such as early initiation and sustained breastfeeding, appropriate complementary feeding, access to healthcare, and socio-economic conditions significantly influence the nutritional outcomes of LBW infants and their risk of undernutrition in childhood (Black et al. 2013; Victora et al. 2008). Higher birth order, indicating a later position among siblings, has been associated with an increased risk of stunting and underweight in children (Khan and Raza 2014). This can be attributed to factors such as reduced maternal resources and attention, shorter durations of exclusive

breastfeeding or delayed complementary feeding, limited access to healthcare and nutrition services, and potential sibling competition for resources within the household (Victora et al. 2008).

The study did not find an association between maternal age and the nutritional status of children (Dinachandra Singh et al. 2015). However, another study revealed that children born to adolescent mothers are at a higher risk of being underweight, although the risk of wasting was not statistically significant (Welch et al. 2024). Children's nutritional status is strongly correlated with women's health, as measured by BMI (Khan and Raza 2014; Hiền and Hoa 2009; Rao et al. 2005). Children of underweight mothers are more likely to be malnourished than those of healthy mothers. Maternal undernutrition or overnutrition during pregnancy significantly impacts fetal development and subsequent childhood nutritional outcomes. Maternal BMI influences breastfeeding practices, household dietary patterns, and healthcare utilization, contributing to variations in children's nutritional status. Addressing maternal BMI through preconception and antenatal care, promoting healthy breastfeeding practices, and providing nutrition education are crucial for ensuring optimal childhood nutritional outcomes (Black et al. 2013; Victora et al. 2008; Fall et al. 2015). Furthermore, maternal education and exposure to media significantly affects children's nutritional status. This study shows that children of educated mothers with media exposure are less likely to be malnourished. These findings align with several other studies from India (Chauhan et al. 2022; Pathak et al. 2020; Rah et al. 2010; Ladusingh and Singh 2005). To improve children's nutritional status in North-East India, key intervention areas include fostering social networks among women and implementing intensive door-to-door Information, Education, and Communication (IEC) activities. These efforts should focus on educating women about good childcare practices and preserving the nutritional value of foods.

Most states in North-East India are predominantly inhabited by STs and are also characterized by diverse healthcare practices, beliefs, and feeding habits. STs and SCs tend to exhibit healthier feeding and eating practices, while other communities often have dietary habits more similar to those of the broader Indian population. Findings from this study show that children from ST communities have lower levels of undernutrition than children from other communities (Das et al. 2023; Chauhan et al. 2022; Singh et al. 2015; Dinachandra Singh et al. 2015). Additionally, children from Muslim households were found to have poorer nutritional outcomes compared to those from Christian and Hindu households (Rao et al. 2005). Christian children may experience better nutritional status due to a combination of factors such as emphasis on education and health awareness within Christian communities, improved access to resources including nutritious foods and healthcare facilities, strong social support networks, and potential involvement of faith-based organizations in providing nutritional support and healthcare services.

Household wealth and size are significant determinants of undernutrition, with poorer and larger households facing higher risks (Jith and Bedamatta 2021). This finding is

supported by studies conducted in Chhattisgarh and Tamil Nadu (Shirisha et al. 2022), Nagaland (Thingnganing et al. 2017), Bangladesh (Hong et al. 2006). Wealthier households can provide better nutrition, access to healthcare, education, health awareness, improved living conditions, and food security, all contributing to better nutritional outcomes in children (Bershteyn et al. 2015; Vollmer et al. 2014). However, larger household sizes may increase the risk of stunting due to resource constraints and food competition within the household, as highlighted in some studies (Fotso 2006). The relationship between household size and wasting is less consistent, with some studies indicating increased wasting risk in larger families, particularly in contexts like South Ari District of Southern Ethiopia (Toma et al. 2023).

The study did not find an association between place of residence and children's nutritional status in North-East India. In the contrary, a study conducted in Maharashtra reported that rural areas have the highest percentage of children with undernutrition (Khadse and Chaurasia 2019). State-level variations further highlight the localized nature of nutritional challenges, with some states exhibiting significantly lower prevalence rates of children undernutrition compared to others. For instance, Sikkim demonstrated better nutrition outcomes for children, while Meghalaya recorded significantly poorer levels. High prevalence clusters of child undernutrition were identified in Meghalaya and Assam (Singh et al. 2022), with certain pocket districts in Nagaland and Tripura also showing higher levels. These patterns are largely attributed to economic vulnerability and exposure to recurring floods, as supported by various studies (Khan and Mohanty 2018; Nair et al. 2013; Ravindranath et al. 2011). Traditional dietary practices, such as a heavy reliance on rice, fermented foods, and smoked meats, dominate across states but often lack the diversity required for balanced nutrition (Das et al. 2016). Food taboos, particularly affecting pregnant and lactating women, further restrict the intake of essential nutrients. Moreover, the early introduction of inappropriate complementary foods undermines the practice of exclusive breastfeeding (Wright and Gupta 2017). Additionally, some districts have experienced decades-long influxes of illegal immigrants, and challenges like rugged terrain and remoteness continue to exacerbate persistent nutritional issues in parts of Nagaland and Meghalaya (Singh et al. 2022; SATP Report 1998). Another study highlighted unacceptably high levels of child undernutrition and micronutrient deficiencies in the West Khasi Hills District of Meghalaya (Chyne et al. 2017), stressing the need for education and behavioral change communication regarding nutrition during pregnancy, lactation, and child feeding practices to improve child undernutrition. The findings emphasize the necessity of district-level analysis and localized strategies to address community-specific challenges. These results suggest the importance of context-specific interventions tailored to the unique socio-economic, geographic, and cultural challenges faced by each state and district in North-East India.

Necessary policy interventions

Policymakers must prioritize targeted interventions to improve maternal and child

health outcomes. These include enhanced access to antenatal care, the promotion of exclusive breastfeeding, micronutrient supplementation, and ensuring comprehensive immunization coverage. Maternal nutrition programs focusing on education, counseling, and nutritional support can significantly reduce the risk of undernutrition and positively impact child health. Strengthening healthcare infrastructure, especially in rural and remote areas, is essential, alongside deploying mobile health units to serve hard-to-reach communities, promoting nutrition-sensitive agriculture practices, and empowering women through education and economic opportunities. Telemedicine and digital health solutions can also facilitate healthcare delivery and monitoring. Addressing geographical disparities and adopting an inter-sectoral approach are essential for achieving equitable child health outcomes. Recognizing spatial heterogeneity in stunting prevalence and understanding local contexts are key to designing effective policies.

Social protection programs, including cash transfers, food assistance, and nutrition supplementation schemes play a vital role in mitigating the impact of poverty on child nutrition. The 'Take Home Ration' (THR) strategy, a supplementary nutrition program (SNP) under the Integrated Child Development Scheme (ICDS), exemplifies the integration of health and nutrition policies. Lastly, regional collaboration and partnerships among governments, international organizations, non-governmental organizations (NGOs), academia, and private sector stakeholders are essential for a coordinated and holistic approach to addressing child undernutrition across North-East India.

Strengths and limitations of the study

This study boasts several notable strengths, including its use of robust and generalizable NFHS-5 data, a multidimensional analysis of socio-economic, demographic, and state-specific factors, and spatial analysis highlighting regional disparities to inform targeted policies. By focusing on North-East India, the study addresses a critical knowledge gap, providing meaningful evidence to reduce undernutrition.

Despite its contributions, this study has several limitations. The cross-sectional design of NFHS-5 data precludes causal inferences about the relationships between underlying factors and undernutrition outcomes. Furthermore, the study may overlook the distinct cultural, dietary, and environmental influences in the North-East region. Administrative boundaries may constrain the spatial analysis, potentially masking intra-district disparities. Therefore, there is a gap for future research on the mentioned issues.

Conclusion

The in-depth analysis of child undernutrition in North-East India highlights the urgency of implementing context-specific interventions and targeted policies to address the complex interplay of demographic, socio-economic, and geographical factors influencing nutritional outcomes. By adopting a holistic approach that prioritizes maternal and child health, strengthens healthcare infrastructure, promotes Nutri-gardens or Poshan Vatikas (PVs), empowers women, implements social protection measures, utilizes data-driven

decision-making, and fosters regional collaboration, stakeholders can work towards sustainable improvements in child nutrition and health outcomes, ensuring the well-being and future prosperity of children in the region.

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Ethics statement

This study did not need ethics approval.

Conflicts of interest

Authors hereby declare that there are no conflicts of interest.

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Appendix 1 District-wise prevalence of undernutrition in North-East region of India

District	Stunted %	Wasted %	Underweight %
Sikkim	**20.7**	**14.2**	**7.9**
North District	30.0	3.4	14.7
West District	25.8	21.7	14.7
South District	26.7	8.2	2.6
East District	12.7	15.3	6.0
Nagaland	**33.4**	**19.0**	**27.1**
Mon	36.1	7.0	23.5
Mokokchung	31.4	11.8	22.6
Zunheboto	44.1	26.9	46.7
Wokha	28.7	23.8	30.3
Dimapur	28.8	24.6	28.5
Phek	30.3	11.9	15.7
Tuensang	37.3	25.2	33.7
Longleng	33.7	20.0	25.5
Kiphire	37.2	11.0	26.7
Kohima	29.2	26.8	22.7
Peren	35.2	9.0	22.1
Manipur	**23.4**	**9.8**	**12.4**
Senapati	27.0	10.7	12.4
Tamenglong	27.8	9.5	17.5
Churachandpur	25.5	11.8	9.0
Bishnupur	15.6	7.6	10.5
Thoubal	30.7	8.4	14.3
Imphal West	15.7	8.9	8.6
Imphal East	18.8	11.5	14.0
Ukhrul	27.0	12.1	15.2
Chandel	35.0	8.4	12.6
Mizoram	**28.1**	**9.4**	**11.8**
Mamit	26.5	7.4	12.2
Kolasib	30.3	10.5	12.0
Aizawl	24.0	6.8	9.2
Champhai	26.7	11.2	11.4
Serchhip	31.1	8.3	13.9
Lunglei	25.8	9.2	10.8
Lawngtlai	31.7	16.2	15.9
Saiha	44.1	7.8	16.4
Meghalaya	**47.0**	**12.0**	**26.5**
South Garo Hills	30.2	18.5	21.3
Ribhoi	42.8	17.7	30.1
East Khasi Hills	45.9	11.2	23.9
East Garo Hills	39.7	20.2	26.7
East Jantia Hills	49.8	8.4	23.3
North Garo Hills	34.4	11.5	14.0
South West Garo Hills	32.2	20.0	22.3
South West Khasi Hill	51.3	10.2	27.8
West Garo Hills	40.0	14.7	26.0
West Jaintia Hills	48.8	9.7	28.3
West Khasi Hills	59.5	7.8	31.0
Assam	**35.8**	**21.8**	**31.1**
Kokrajhar	34.4	21.2	34.9
Goalpara	40.7	24.2	31.2
Barpeta	30.7	19.7	25.0
Morigaon	43.7	15.7	30.2
Lakhimpur	39.8	18.4	33.1
Dhemaji	37.2	17.5	25.4
Tinsukia	32.7	21.3	30.2
Dibrugarh	27.4	20.8	31.6
Golaghat	26.2	19.6	22.9

Dima Hasao	30.3	23.8	19.7
Cachar	29.1	30.5	35.5
Karimganj	31.7	48.3	48.6
Hailakandi	44.1	21.6	41.3
Bongaigaon	46.2	20.5	33.2
Chirang	43.9	19.2	37.9
Kamrup	21.6	15.1	17.9
Kamrup Metropolitan	23.1	18.8	24.3
Nalbari	27.8	14.9	26.0
Baksa	44.2	17.5	29.7
Darrang	40.6	25.9	32.6
Udalguri	34.7	21.6	30.4
Biswanath	45.0	26.6	39.1
Charaideo	40.4	24.0	34.5
Dhubri	48.7	21.2	36.8
Hojai	38.8	12.2	28.9
Jorhat	39.5	15.0	30.3
Karbi Anglong	31.8	16.9	27.1
Majuli	33.7	14.3	23.3
Nagaon	39.4	20.0	31.0
Sivasagar	26.2	21.4	24.9
Sonitpur	36.5	13.2	21.9
South Salmara Mancach	38.0	18.4	26.9
West Karbi Anglong	42.1	23.4	28.4
Tripura	**32.8**	**17.9**	**23.3**
Dhalai	46.0	16.0	27.8
Gomati	22.1	28.0	24.6
Khowai	47.0	16.3	25.1
North Tripura	30.1	29.9	23.3
Sepahijala	33.8	15.0	19.6
South Tripura	24.4	15.1	21.0
Unakoti	31.5	19.8	32.2
West Tripura	31.2	10.3	19.3
Arunachal Pradesh	**27.9**	**12.9**	**13.7**
Tawang	28.3	7.2	7.9
West Kameng	23.7	23.0	14.4
East Kameng	36.0	15.5	13.0
Papum Pare	30.7	8.6	12.0
Upper Subansiri	37.8	11.8	17.3
Upper Siang	29.6	12.7	11.7
Changlang	26.7	16.5	23.1
Lower Subansiri	29.9	11.6	7.5
Dibang Valley	17.0	17.1	12.6
Lower Dibang Valley	13.1	7.3	5.9
Anjaw	25.0	12.9	14.6
East Siang	24.3	8.2	9.3
Kra Daadi	28.4	9.2	11.8
Kurung Kumey	29.3	14.0	13.9
Lohit	23.7	12.5	10.0
Longding	16.4	20.3	10.7
Namsai	28.1	12.5	17.0
Siang	20.4	10.6	7.8
Tirap	38.3	13.8	15.0
West Siang	24.3	14.7	13.2
North-East India	**35.6**	**19.2**	**28.0**