SPATIAL ANALYSIS OF MULTIDIMENSIONAL DEPRIVATION AND STUNTING AMONG INDIAN CHILDREN

TEJAL LAKHAN[1], ANISHA DAS[2], SHIVANI GHARGE[1], NEETHU NAIK[1], NANDINI ROY[3] AND SAYEED UNISA[4]

ABSTRACT

Out of the total 150.8 million stunted children in the world, India is home to 31% of them, says the Global Nutrition Report 2018. As per the National Family Health Survey (NFHS) 2015-2016, stunting varied greatly from district to district (12.4% to 65.1%). Dealing with social exclusion is a key paradigm in government policy, and the current approach is to channel resources into smaller segments among deprived populations. This study intends to determine the hotspots of stunting and deprivation in India. The proposed paper is based on the data extracted from the fourth round of the NFHS-4 data set (2015-16). Moreover, this study employs the Multiple Deprivation Composite (MDC) index to achieve results. The MDC index is computed, taking into account five domains, including living environment, household wealth, financial resources, mother's education and mother's nutritional status. Also, data was statistically analysed using SPSS software Version 20, ARC GIS and GeoDa software was used to portray the prevalence of stunting through mapping technique. Results indicate around 39% of under-five children are stunted in India. The prevalence of stunting is very high in central and eastern India. It can be observed that around 71% of the districts in eastern India experience very high deprivation due to low basic facilities followed by central India. High geospatial clustering was observed for multiple deprivations with Moran-I value

1 *Ph.D. Research Scholar, International Institute for Population Sciences (IIPS), Mumbai, India*

2 *Statistical Quality Control and Operations Research, Indian Statistical Institute, Kolkata*

3 *Senior Manager M&E, Magic Bus, Kolkata, India*

4 *Professor and Head, Department of Mathematical Demography & Statistics, International Institute for Population Sciences (IIPS), Mumbai, India*

of 0.738 followed by geospatial clustering of stunting with Moran's I value of 0.631. We discovered that the deprivation score is primarily based on income, health and education domains rather than the living and environment and material domains. There was a statistically significant association between multiple deprivation and stunting among children. This paper is prominently grounded on the distribution of scores which depends on how the indices are constructed and do not necessarily identify determined targets. Scrutiny at the local level and validation of the measures is, therefore, preferable.

Keywords

Stunting, malnutrition, multiple deprivation, spatial clustering, hotspots.

Introduction

Concerned about stunting, the World Health Assembly has set a goal to bring down the prevalence of stunting to 40% by 2025.[1] The recent large-scale National Family Health Survey (NFHS 4) give the prevalence rates of stunting, wasting and underweight as 38%, 21% and 36% respectively.[2] About one-third of the total stunted children of the world reside in India.[3] Stunting is defined as the percentage of children aged 0 to 59 months (below 5 years) whose height for age is below minus two standard deviations.[4] According to NFHS 4, 20% of infants less than six months suffered from stunting indicating the initiation of growth failure since the prenatal stage. However, the prevalence of stunting was 46.9% in the 18–23 months age range and subsequently declined gradually to 40% in the 48-59 months age range. This characteristic demonstrates the best window period for the intervention that can revitalize linear growth which begins from the pre-conception period to the first two years of life.[5, 6] A target has been set by the India flagship programme known as POSHAN Abhiyaan*, to reduce stunting at 2% per annum to achieve a 25% decline in stunting by 2022. It was started initially in 1976. Stunting is a cause of concern as it is associated with diminished mental learning ability, poor school performance, increased risk in nutrition-related chronic diseases, such as diabetes, hypertension, and obesity at later ages.

If the stunting targets have to be achieved, it is critical to understand the pathways of different factors affecting stunting. Existing literature show that social inequalities affect linear growth among children. It may be noted that linear growth is one of the best indicators for measuring children's well-being.[7] Other studies consider stunting to be the result of the inter-generational flow of under-nutrition from mother to child. The mother's height is associated with childhood stunting.[8-11] However, others opined that only 10% of the variation in adult height could be explained by the inheritability of genes.[12] Diverse factors like poverty, water, sanitation, education and gender inequality affect an individual's nutrition status.[13-15] Studies also imply that apart from poverty there are different factors such as availability of food in different food availability zones which also influence an individual's nutritional status.[16]

Along with assessing the impact of various factors individually on stunting, it is of utmost importance to see the combined effect of various factors, to get a complete picture of how deprivation of different factors is associated with undernutrition among children. The economic status and mother's health are considered to be the two most crucial

* *National Nutritional Mission renamed as POSHAN Abhiyan (circular : NNM/61/2018-CPMU Government of India, Ministry of Women and Child Development, May 25, 2018.)*

domains of deprivations that affect nutrition among children. Likewise, a majority of stunting cases are found in a region primarily on account of these two domains. Nonetheless, the deprived population faces challenges with regards to multiple morbidities involving a higher prevalence of depression, mortality and higher costs.[17] A community-based index of multiple deprivations has inferred that higher regional deprivation is associated with higher mortality.[18] The geographical disparity in life expectancy can be elucidated by deprivation wherein life expectancy at birth is elevated in most affluent groups.[19] The multiple deprivation index has emerged as a global phenomenon in the present time, and it is also evident from the literature that most deprived are at a higher risk of dying. Dealing with social exclusion is a key paradigm in government policy, and the current approach is to channel resources into smaller segments with deprived populations.[20] The extent to which a child is at risk of getting stunted depends on the economic status of the family, food security, maternal nutrition, education of mother and his/her physical environment such as the source of drinking water facilities, sanitation facilities adopted in the household, which often becomes difficult to control. Often it is seen that the rural and the urban areas do not suffer from deprivation to the same extent. It's often argued that the difficulty lies in detecting the relation between multiple deprivations and health in rural regions.[21, 22] Yet, such a measurement of deprivation index has never been taken up earlier in the country like India.

We propose to develop a composite deprivation index and measure the extent of its influence on the stunting of the children using the NFHS-4 data set. The paper's objective is to examine the prevalence of stunting and spatial clustering of stunting. Secondly, we examined the association between the level of deprivation and the prevalence of stunting among children to provide policy and programmatic level directions.

Methodology

The paper is based on data extracted from the fourth round of the NFHS-4 dataset (2015-16) that has a nationally representative sample of 2,65,653 children below five years from 6, 01,509 households.

(a) Independent variable: Multiple Deprivation Composite (MDC) index: We have computed MDC index by taking into account five domains, i.e. living environment, household wealth, financial resources, mother's education and nutritional status all of which are described below.

- ✓ Living environment Deprivation: includes indicators related to adequate shelter, water and sanitation facilities.
- ✓ Material Deprivation: includes indicators related to material possession.
- ✓ Income Deprivation: includes indicator related to financial resources.
- ✓ Mothers education Deprivation: includes indicator related to the mother's highest educational status.
- ✓ Mothers health Deprivation: includes indicator related to the mother's nutritional status

The domains are combined according to their respective weights. The index has been constructed keeping in mind that each stage fulfils the definition of indices, data processing, producing a desired index and summary measures. The schematic diagram provides multiple deprivation pathways that affect stunting.

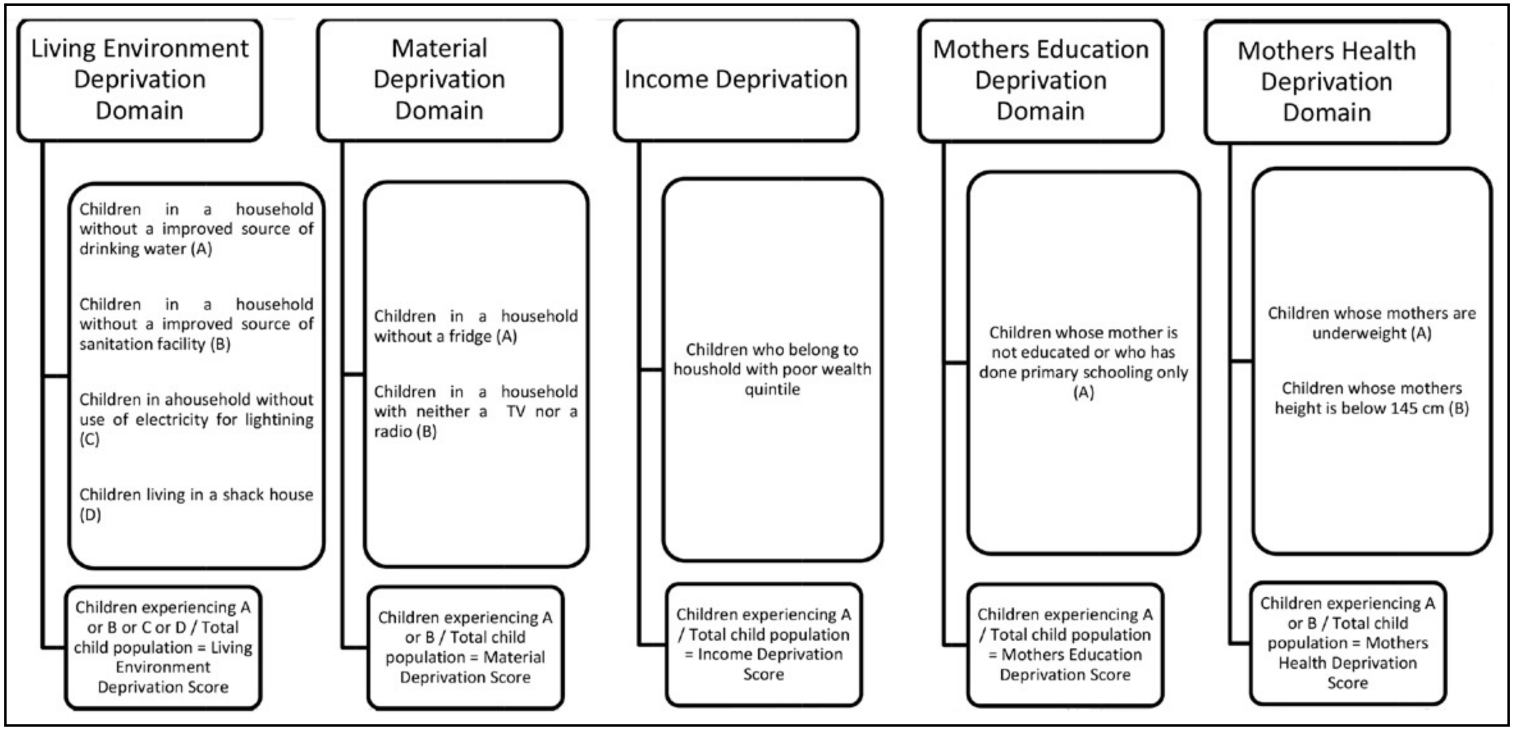
(b) Dependent variable: The key outcome variable was stunting and we have classified the children into two categories based on their height for age Z scores:

Never Stunted: Children whose height for age Z score was more than or equal to minus two standard deviations (-2 SD) and

Stunted: A child whose height for age Z score was below minus two standard deviations (-2 SD).

For the paper, we have considered five domains of deprivation, defined by the chosen parameters and indicators specific to each district, but the validity of the measures beyond these five domains depends on the individual features considered within districts.[23] The paper does not attempt to reproduce distinct socio-economic domains through factor analysis but rather seeks to create a composite index that would determine an empirical relation to summarizing multiple deprivations and stunting. Fig 1 illustrates the theoretical framework of multiple deprivation domains.

FIGURE 1
Multiple Deprivation domains



Shrinkage Technique

Once the key domains and indicators were identified and segregated, we moved on to the shrinkage technique to achieve the desired index*. The idea of shrinkage estimation or empirical Bayesian estimation was used to borrow strength from larger areas, to avoid creating unreliable small area data. In the absence of shrinkage, some smaller areas have scores which do not reliably describe the deprivation in the area due to chance fluctuations from region to region or year to year.[24]

The actual mechanism of the shrinkage procedure is to estimate deprivation in a small area using a weighted combination of district data and data from another more robust score. The weight attempts to increase the efficiency of the estimation, keeping in mind that the bias does not increase. The shrunk estimate of a smaller area (district) level proportion (or ratio) is a weighted average of the two raw proportions for the small area and the corresponding district. The weights used are determined by the relative magnitudes of the within-district area and between-district area variability. The shrinkage procedure is given in the appendix below.

The final step is to back-transform the shrunk-logit m_j^* using the anti-logit to obtain the shrunk district-area level proportion for each small area as

$$z_j = \frac{\exp(m_j^*)}{1 + \exp(m_j^*)}$$

The scores z_j have been divided among all districts – 0 if the district is non-deprived of a particular indicator and the respective score if the district is deprived of that particular indicator. When the scores have been assigned, we determine the mean deprivation score for each district.

Statistical Analysis

The data was analysed using SPSS software Version 20. The district-wise prevalence of stunting was estimated using frequencies and percentages. Bivariate analysis was performed using the chi-square test. Then the prevalence of stunting was mapped using Arc GIS software to graphically analyse the clusters of stunted children in India. District wise stunting prevalence was categorised into four categories based on WHO cut-off values for public health significance.[25] Those are low prevalence (<20%), moderate prevalence (20–29.9%), high prevalence (30-39.9%), and very high prevalence (≥40%).[25] The mean deprivation scores have been represented through a map to view the degree of deprivation in each of the districts across the country. The shapefile from ArcGIS was exported to GeoDa for advanced geospatial analyses. Spatial weights were generated using GeoDa. Contiguity based spatial weights were used to understand the spatial interdependence between the outcome variable and the exposure variable in the neighbouring regions. Queen's weight was utilised for estimating all the geospatial statistics and geo-spatial regressions. Moran-*I* statistics, Univariate LISA, Bivariate LISA and Geospatial regression were used to address the research questions.

We associated the mean deprivation scores obtained with the prevalence of stunting to find out the extent to which each of the deprived indicators is affecting the occurrence of the disease.

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* *The shrinkage technique is designed to tackle problems associated with small values in a smaller area. In some areas, particularly where the exposed population at risk is small, the data may turn out to be unreliable, as a result of which sampling and other sources of error may creep in.*

Moran's I is given by

$$Moran's\ I = C.\frac{\sum_i \sum_j w_{ij} z_i z_j}{\sum_i z_i^2}$$

where z_i is the standardized variable of interest, w_{ij} is the standardized weight matrix with zeroes on the diagonal and C is the multiplier equivalent to $\frac{N}{S_0}$, N being the number of spatial units indexed by i and $j;s_o$ being the sum of all $w_{ij}'s$.

Results

Table 1 shows the prevalence of stunting according to selected socioeconomic and demographic characteristics. Overall 39% of under-five children are stunted in India. Prevalence of stunting was highest among children with higher birth order i.e. 4+ as compared to those with lower birth order. Also, the prevalence of stunting was higher among children whose mother was thin i.e. 47% as compared to normal and overweight/obese mothers i.e. 37% and 27% respectively. In rural areas, stunting is more pre-dominant (41%) compared to the urban areas (32%). Share of stunted children was significantly more among households with poor wealth index (48%) compared to households with middle (36%) and rich wealth index (27%).

Figure 2 displays the district-wise prevalence map of stunting for children below five years of age showing the hotspot region. It's observed that the prevalence of stunting is very high in central India. About 104 districts out of 139 districts in central India have stunting prevalence of more than or equal to 40% followed by eastern India and western India (Table 2). Very few districts in south India i.e. 12 districts out of 107 districts have a very high prevalence of stunting. Thirty-six out of 86 districts in northeast India had a high prevalence of stunting i.e. between 30% to less than 40% followed by north India. Approximately 50% of the districts in southern India have a moderate level of stunting i.e. between 20% to less than 30%. Also, 10% of the districts in south India are having a low prevalence of stunting which is less than 20%.

Next, we plotted the district-wise mean deprivation map which highlighted the extent of impoverishment or deprivation that a district suffers. The map (Figure 3) makes it clear that mean deprivation exists in and around eastern and central India. It can be observed that around 71% of the districts in eastern India experience very high deprivation due to low basic facilities followed by central India (Table 3). On the contrary, lesser deprivation is experienced in the North (59%) followed by Western and Southern India.

Figure 4 and 5 represents the region-wise univariate LISA results for stunting among children aged less than five years and the mean deprivation. The LISA map represents high-high geographical clustering of stunted children in and around central and eastern parts of India along with few selected districts of west and south. High-high means that regions with high stunting rates also share boundaries with neighbouring regions that have high stunting rates referred to as hot spots areas of stunting. High-low means that regions with high stunting rates are surrounded by regions with a low prevalence rate of stunting. It's seen that districts in southern and northern India along with few districts of northeast and west have low-low geographical clustering, indicating that regions with a low prevalence of stunting also share boundaries with neighbouring regions with low stunting prevalence rate. Likewise, similar results are obtained for mean deprivation. The high prevalence of mean deprivation was observed in eastern India and low-low clustering was observed in northern, western, southern India and few districts of the northeast. Moran-I statistics explain the magnitude of geospatial clustering among the dependent and independent variable. High geospatial clustering was observed for multiple deprivations with Moran-I value of 0.738 followed by geospatial clustering of stunting with Moran-I value of 0.631.

To examine the spatial relationship between the exposure and the outcome variable bivariate LISA was used for regions in India. It was used to understand whether the regions which experienced high multiple deprivations were also having a high prevalence of stunting. Figure 6 shows that the regions which have a high multiple deprivations had a higher prevalence of stunting among the children below five years of age with a Moran-I value of 0.458. We found the hotspots as well as the cold spots for the geographical region.

Since considerable geospatial clustering was observed in the dependent variable i.e. stunting and the independent variable i.e. the multiple deprivations, we included the results of Spatial Error models to account for the geospatial clustering in the exposure and the outcome variables. We find that multiple deprivations were significantly associated with the stunting rates in India (Table 4). The advantage of the Spatial Error models over OLS models can be represented in Figure 7 and 8. The Moran-I value decline from -0.021 to -0.028.

Discussion

The paper examined the geographical clustering of the prevalence of stunting among children below five years of age and multiple deprivations in India using geospatial tools. We explored the association between the prevalence of stunting and multiple deprivations experienced by a region.

The empirical evidence illustrates that setting up of a deprivation index is a necessary pre-requisite to assess the shortcomings in the distribution of public health facilities in India. In the absence of direct measurement, it is necessary to judge the extent of deprivation at the household level. Therefore we recommend a straightforward approach of adjusting deprivation scores and comparing the deprivation score with the prevalence of stunting among children as an alternative method to plan the distribution of the public health delivery system. This is because we found that the Multiple Deprivation Index scores had a statistically significant association with the prevalence of stunting among children. The prevalence of stunting is high in deprived areas, particularly in eastern and central India,.

We considered the validity of adjusting indices of multiple deprivations by initially measuring the individual districts' scores based on selections of domains and indicators. Further, the weighting of these domains varies between the districts. This multi-dimensional aspect has led to the underpinning of the concept of multiple deprivations. We discovered that the deprivation score is primarily based on income, health and education domains rather than the living and environment and material domains. The majority of the Indians cannot afford the basic needs required for daily living and often do not consider stunting as a manifestation of chronic malnutrition and leave it untreated.

The variation in deprivation scores within districts is relatively small. In particular, the change in the score of the most deprived quintile is minimal. However, this may be partly attributed to the greater spread of high deprivation scores compared to the more clustered nature of less deprived scores. This feature gives us the confidence to use scores not only within the districts but also within India. The paper demonstrates the critical role played by income and education domains in determining multiple deprivations in the country.

Nonetheless, the method has certain limitations. Primarily, the data source is only cross-sectional, and so we are unable to find out the causation of stunting owing to the multiple deprivation factors; what we can find out at the most is the association between different factors.

CONCLUSION

Subnational studies have revealed a decreasing trend in the prevalence of stunting but, the rates are still high which is a major public health concern. Thus, the planners of any future nationwide prevalence survey should tackle the problem of undernutrition. Several other countries are now in the process of creating indices of multiple deprivations. These have today become one of the key tools to help the allocation of resources to the areas of utmost need.[26, 27] Our paper is largely based on the distribution of scores which depends on how the indices are constructed and do not necessarily identify specific targets. Scrutiny at the local level and validation of the measures is, therefore, desirable.

TABLE 1

Prevalence of stunting among children according to socio-demographic characteristics.

Background characteristics	Stunting (%)	P-value	Number
Child Characteristics			
Age in months			
< 6 months	20.6%	0.000	18923
6-11 months	24.0%		22966
12-23 months	42.8%		45289
24-35 months	42.8%		45096
36-47 months	44.4%		47410
48-59 months	40.6%		45318
Sex of the child			
Male	39.7%	0.000	116360
Female	38.0%		108642
Size of the child at birth			
Large	35.3%	0.000	38071
Average	38.3%		155838
Small	46.3%		26224
Birth order			
1	34.3%	0.000	83046
2	37.4%		69784
3	42.5%		36228
4+	49.0%		35944

Background characteristics	Stunting (%)	P-value	Number
Mothers Characteristics			
Mothers educational status			
No education	50.1%	0.000	68978
Primary	43.8%		32835
Secondary	33.4%		102191
Higher	21.5%		20998
Nutritional status			
Thin	46.6%	0.000	50500
Normal	37.4%		125727
Overweight/Obese	26.7%		28715
Socio-demographic Characteristics			
Place of residence			
Urban	32.1%	0.000	53483
Rural	41.1%		171519
Religion			
Hindu	39.6%	0.000	163089
Muslim	40.2%		35241
Others	33.0%		26537
Caste			
SC	43.8%	0.000	42540
ST	40.2%		44440
OBC	40.0%		88803
Others	31.1%		39399
Wealth Index			
Poor	47.5%	0.000	111492
Middle	36.4%		45136
Rich	26.6%		68374
Water facility			
Unimproved source	36.9%	0.000	38017
Improved source	39.3%		186985
Toilet facility			
Unimproved source	45.4%	0.000	117797
Improved source	31.8%		107205
Mass media exposure			
No or less than one week	48.3%	0.000	82910
At least once a week	34.9%		122064
Total	38.9%		225002

TABLE 2

Number of districts characterized by the proportion of stunted children (aged less than five years) in India, 2015/16.

Number of districts characterized by the proportion of stunted children (aged less than five years) in selected states of India, 2015/16.					
STATES	**Stunted children (%)**				
	Low (< 20%)	**Medium (20% - 30%)**	**High (30% - 40%)**	**Very High (≥ 40%)**	**Total Districts**
NORTH	**4**	**51**	**54**	**22**	**131**
Chandigarh	0	0	1	0	1
Haryana	0	7	9	5	21
Himachal Pradesh	2	7	3	0	12
Jammu & Kashmir	1	13	6	2	22
Delhi	0	5	4	0	9
Punjab	1	15	4	0	20
Rajasthan	0	1	18	14	33
Uttarakhaand	0	3	9	1	13
CENTRAL	**0**	**1**	**34**	**104**	**139**
Chattisgarh	0	1	9	8	18
Madhya Pradesh	0	0	17	33	50
Uttar Pradesh	0	0	8	63	71
EAST	**3**	**10**	**28**	**70**	**111**
Bihar	0	0	3	35	38
Jharkhand	0	0	3	21	24
Odisha	3	4	13	10	30
West Bengal	0	6	9	4	19
NORTHEAST	**4**	**32**	**36**	**14**	**86**
Arunachal Pradesh	2	8	4	2	16
Assam	0	6	15	6	27
Manipur	0	4	5	0	9
Meghalaya	1	0	2	4	7
Mizoram	0	4	4	0	8
Nagaland	0	7	3	1	11
Sikkim	0	1	2	1	4
Tripura	1	2	1	0	4
WEST	**2**	**14**	**23**	**27**	**66**
Dadra & Nagar Haveli	0	0	0	1	1
Daman & Diu	1	0	1	0	2
Goa	1	1	0	0	2
Gujarat	0	5	7	14	26
Maharashtra	0	8	15	12	35
SOUTH	**11**	**53**	**31**	**12**	**107**
Andaman & Nicobar Islands	0	3	0	0	3
Andhra Pradesh	0	12	9	2	23
Karnataka	0	10	10	10	30
Kerala	8	6	0	0	14
Lakshadweep	0	1	0	0	1
Puducherry	1	1	2	0	4
Tamil Nadu	2	20	10	0	32
Total	**24**	**161**	**206**	**249**	**640**

TABLE 3

Number of districts characterized by the proportion of deprivation experienced in India, 2015/16.

Number of districts characterized by the proportion of deprivation experienced in selected states of India, 2015/16.					
STATES	**Mean Deprivation (%)**				**Total Districts**
	Low	**Medium**	**High**	**Very High**	
	(≤ 0.17)	**(0.17 – 0.23)**	**(0.23 – 0.27)**	**(> 0.27)**	
NORTH	**77**	**25**	**23**	**6**	**131**
Chandigarh	1	0	0	0	1
Haryana	19	0	2	0	21
Himachal Pradesh	11	0	1	0	12
Jammu & Kashmir	5	10	6	1	22
Delhi	9	0	0	0	9
Punjab	20	0	0	0	20
Rajasthan	8	6	14	5	33
Uttarakhaand	4	9	0	0	13
CENTRAL	**8**	**24**	**32**	**75**	**139**
Chattisgarh	0	3	6	9	18
Madhya Pradesh	2	7	14	27	50
Uttar Pradesh	6	14	12	39	71
EAST	**1**	**12**	**19**	**79**	**111**
Bihar	0	2	1	35	38
Jharkhand	0	2	4	18	24
Odisha	0	2	9	19	30
West Bengal	1	6	5	7	19
NORTHEAST	**12**	**14**	**31**	**29**	**86**
Arunachal Pradesh	1	4	8	3	16
Assam	1	1	10	15	27
Manipur	0	1	4	4	9
Meghalaya	0	2	3	2	7
Mizoram	6	1	1	0	8
Nagaland	2	2	3	4	11
Sikkim	2	2	0	0	4
Tripura	0	1	2	1	4
WEST	**25**	**22**	**13**	**6**	**66**
Dadra & Nagar Haveli	0	1	0	0	1
Daman & Diu	2	0	0	0	2
Goa	2	0	0	0	2
Gujarat	15	6	3	2	26
Maharashtra	6	15	10	4	35
SOUTH	**33**	**37**	**29**	**8**	**107**
Andaman & Nicobar Islands	3	0	0	0	3
Andhra Pradesh	1	9	12	1	23
Karnataka	3	9	11	7	30
Kerala	14	0	0	0	14
Lakshadweep	1	0	0	0	1
Puducherry	4	0	0	0	4
Tamil Nadu	7	19	6	0	32
Total	**156**	**134**	**147**	**203**	**640**

Table 4

OLS and Spatial Error model to assess the association between stunting and multiple deprivation, India, 2015/16

Variable	LM Spatial error stunting		Aspatial OLS for stunting	
	Coefficient	Probability	Coefficient	Probability
CONSTANT	0.190	0.000	0.068	0.000
Mean Deprivation Score	0.787	0.000	0.441	0.000
LAMBDA	0.741	0.000		
Number of observations	643.000		643.000	
Log-likelihood	887.908		827.874	
AIC	-1771.820		-1649.750	
R-square	0.691		0.600	

Figure 2

Prevalence of Stunting among children (aged below 5 years), 2015-16

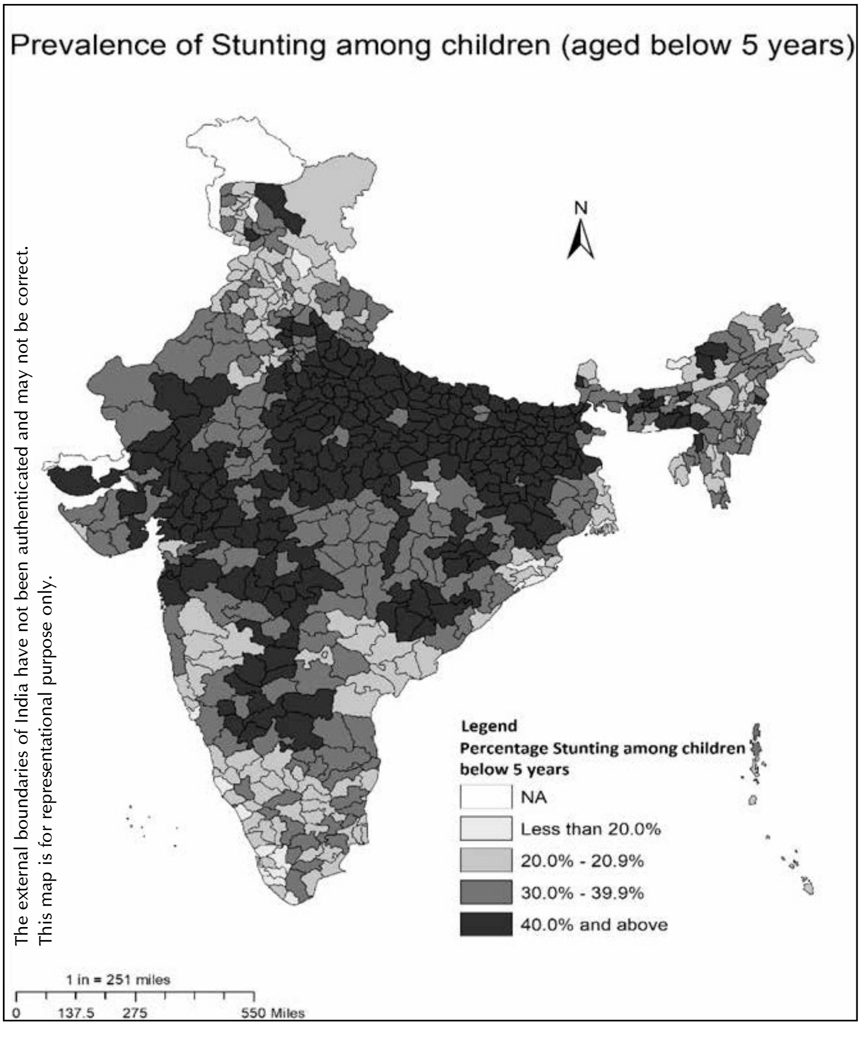


FIGURE 3
Mean Deprivation in India, 2015-2016

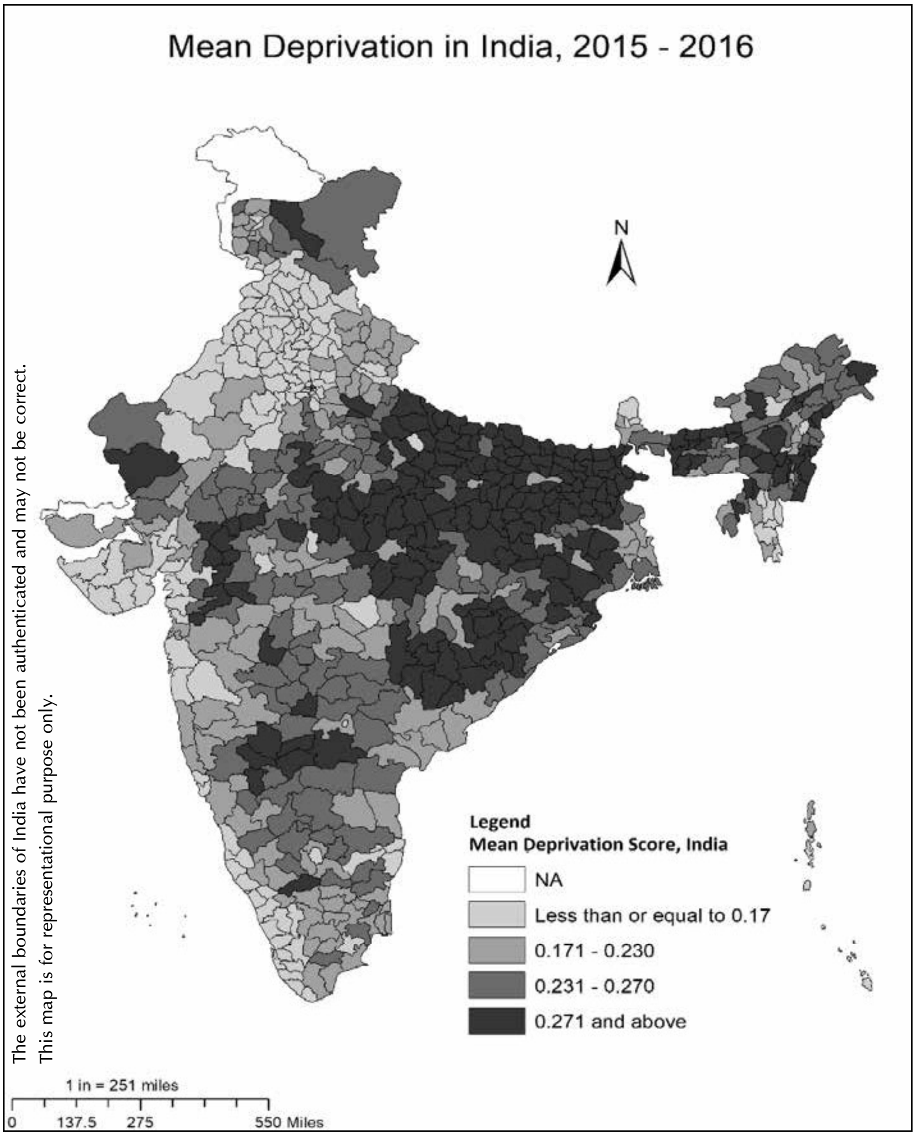


FIGURE 4

Univariate Lisa Map for the prevalence of Stunting

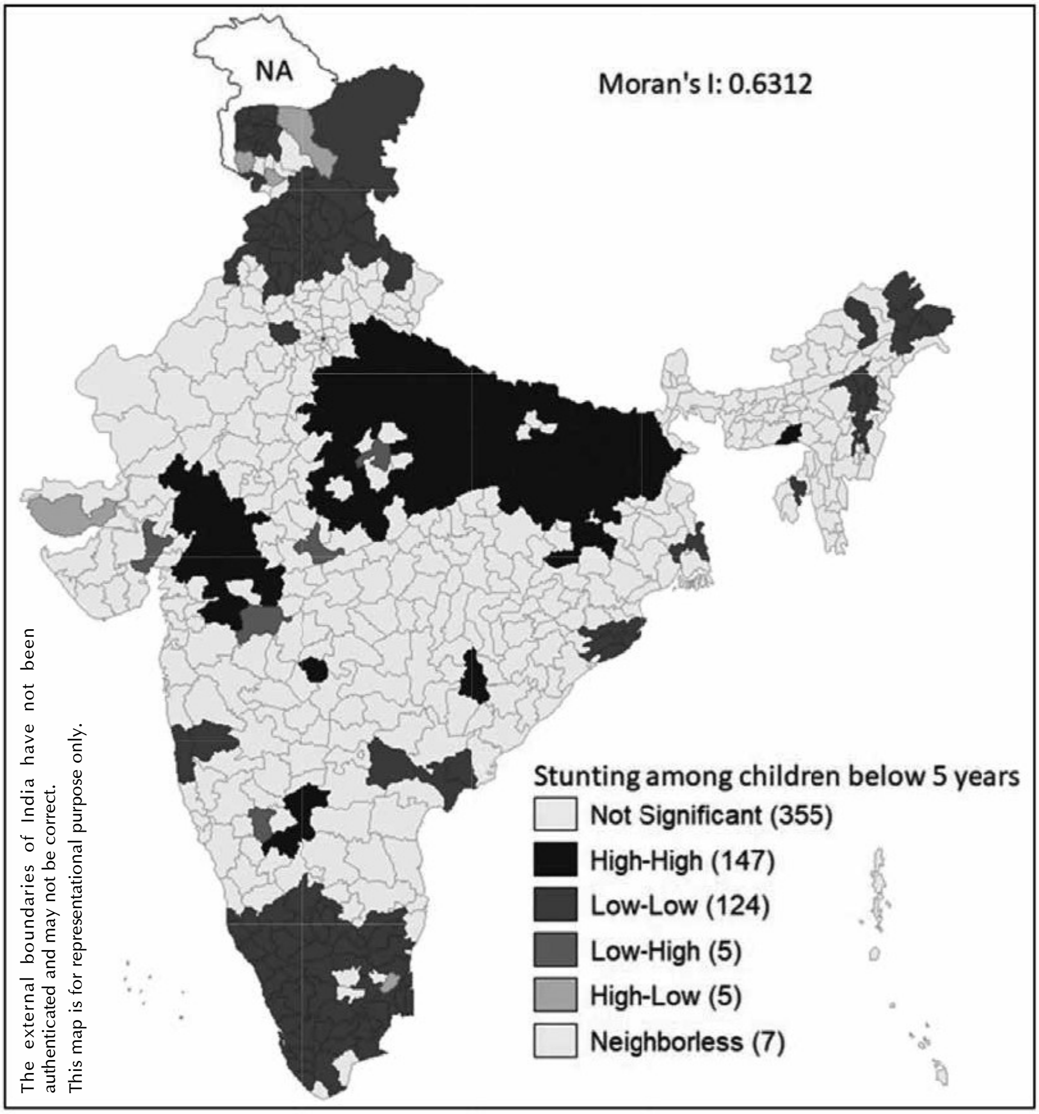


FIGURE 5
Univariate Lisa Map for Mean Deprivation

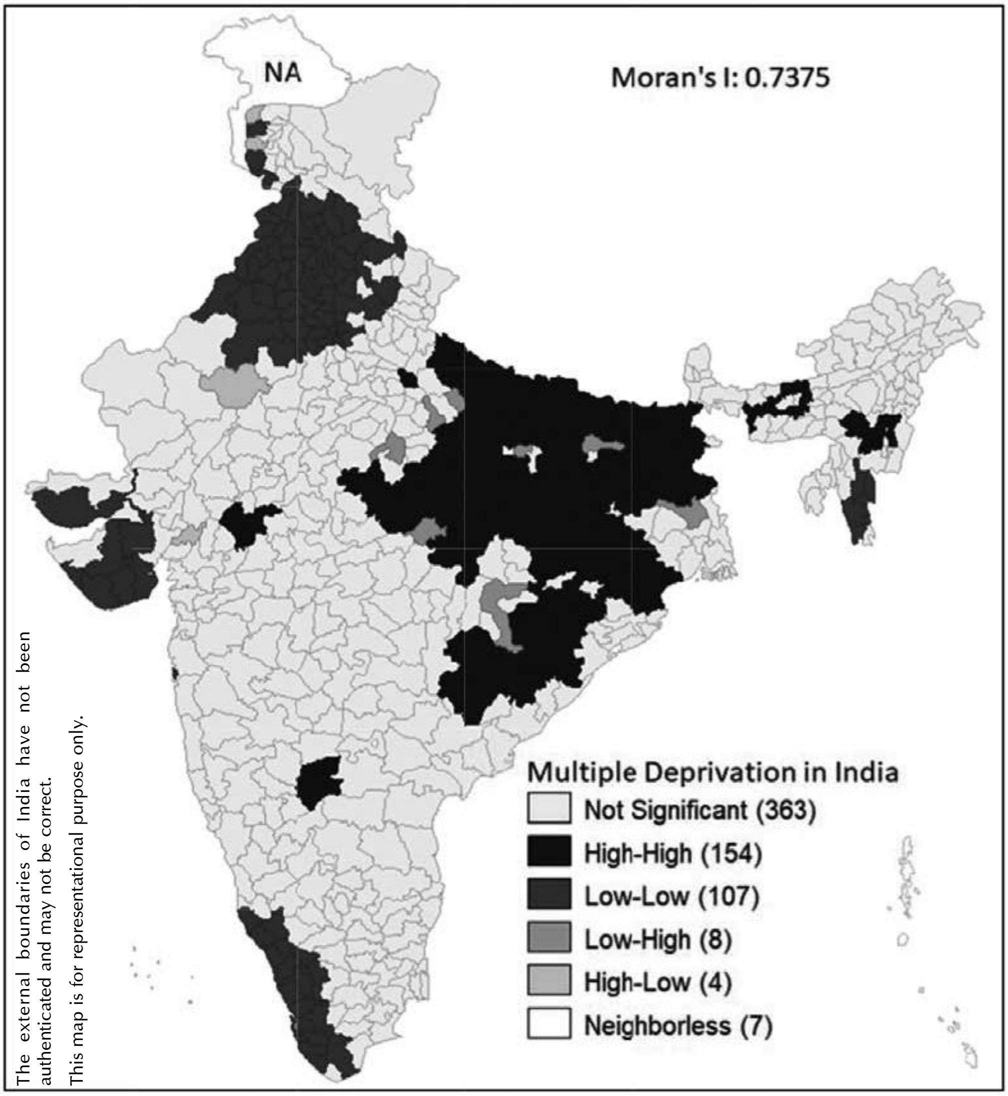


FIGURE 6

Bivariate Lisa Map for the association between Stunting and Multiple Deprivation

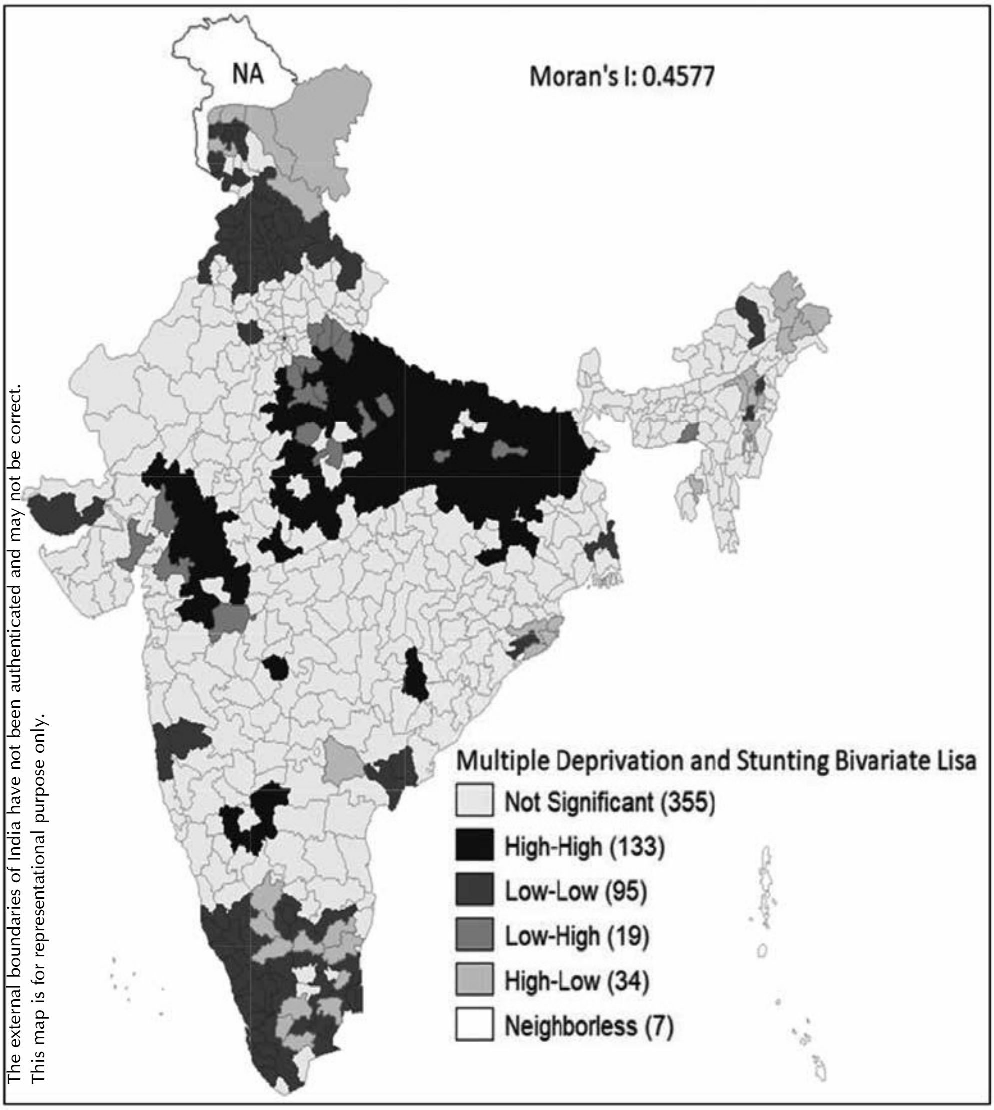


FIGURE 7

Residual maps of Spatial Error Models for stunting, India

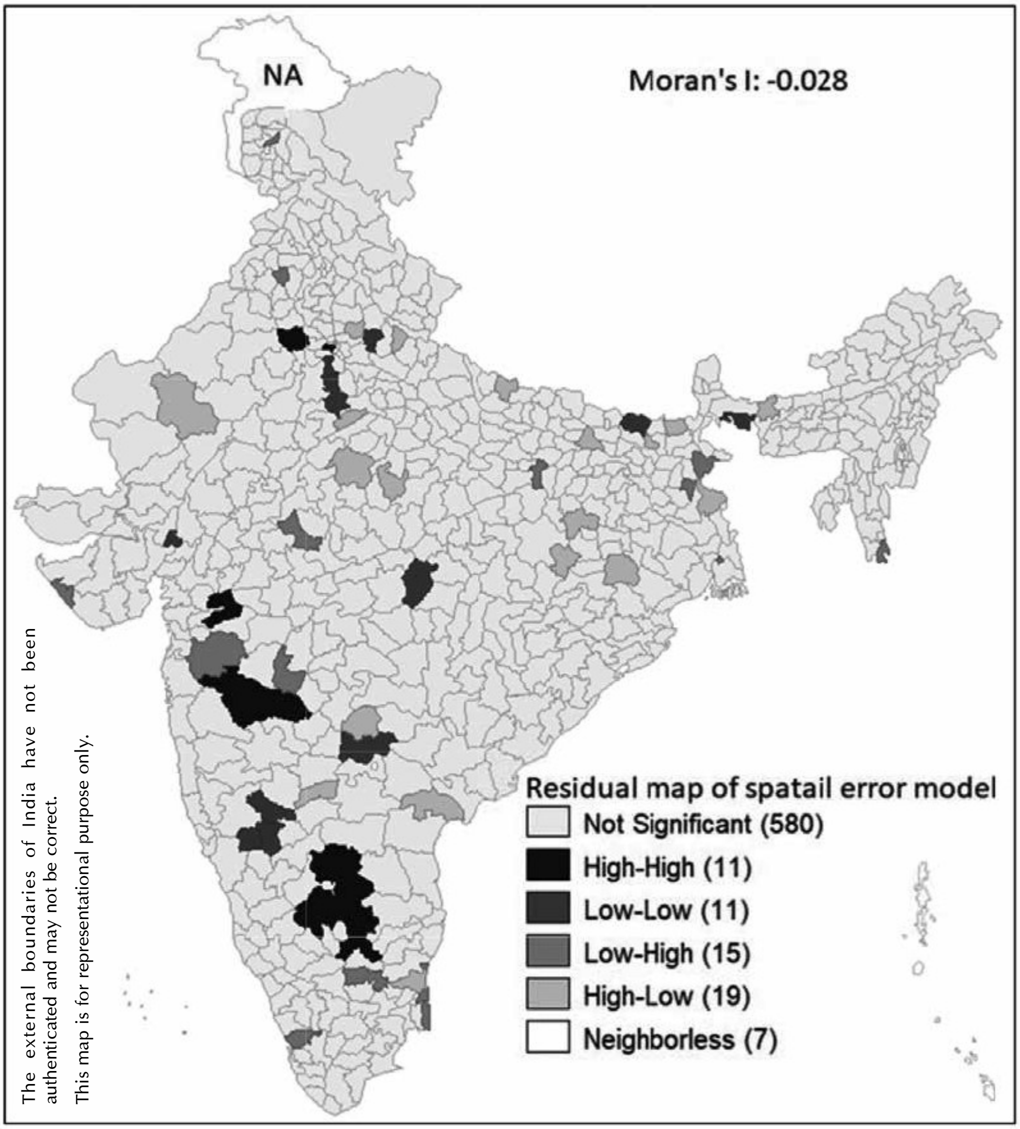
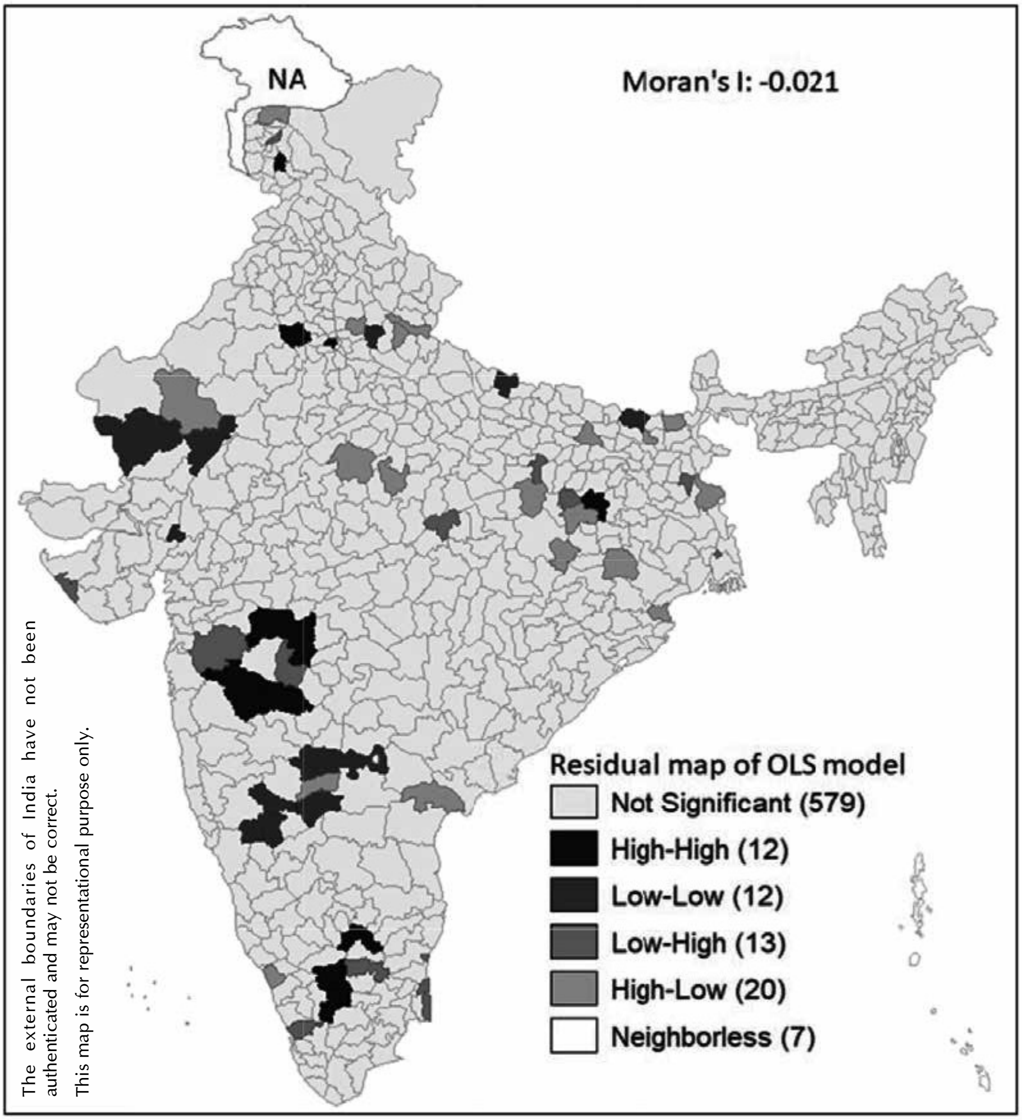


FIGURE 8
Residual maps of OLS Models for stunting, India



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APPENDIX

Shrinkage procedure

If the rate for a particular indicator in district *j* is r_i events out of a population n_j, of , the empirical logit for each district area may be given by

$$m_j = \log[\frac{(r_j + 0.5)}{(n_j - r_j + 0.5)}]$$

Whose estimated standard error is the square root of

$$s_j^2 = \frac{(n_j + 1)(n_j + 2)}{n_j(r_j + 1)(n_j - r_j + 1)}$$

The corresponding counts *r* out of for the district in which the area *j* lies, gives the district-level logit

$$M = \log[\frac{(r + 0.5)}{(n - r + 0.5)}]$$

The shrunk district area level logit is then the weighted average

$$m_j^* = w_j m_j + (1 - w_j)M$$

Where w_j is the weight given to the raw district area *j* data and ($1-w_j$) is the weight given to the overall rate for the respective district. w_j Can be determined using

$$w_j = \frac{\frac{1}{s_j^2}}{\frac{1}{s_j^2} + \frac{1}{t^2}}$$

Here t^2 is the inter-district variance for the k areas in the district, calculated as

$$t^2 = \frac{1}{k-1}\sum_{j=1}^{k}(m_j - M)^2$$

Thus it stands out that large district areas where precision $\frac{1}{s_j^2}$ is relatively large, have weight $w_j$close to 1 and so shrinkage has little effect. The shrinkage effect is greatest for small district areas in relatively homogeneous districts.