District level meso scale nexus of poverty and child malnutrition across India

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Background

Though undernutrition affects all age group, children under five-year age group are at higher risk. Globally, 156 million children under five years of age are stunted, 93 million are underweight and 50 million are wasted [1]. Goal 1 of MDGs aimed at eradication of poverty and hunger and targeted of reducing the number of underweight children by half by 2015 from 1990 level. Achieving the targets continued through the Sustainable Development Goals (SDGs) and Goal 2 of SDGs is aimed to end hunger and all forms of malnutrition by 2030. Despite concerted efforts globally and nationally, the prevalence of undernutrition remained high in India.

The conceptual framework by UNICEF mentioned the immediate causes (inadequate dietary intake, lack of care; and disease), underlying causes (inadequate access to food, improper care of mothers and children and scarcity of health services) and the basic causes (an unhealthy environment and inadequate education, formal and non-formal institutions, political and ideological superstructures, economic structures and a lack of potential resource) of malnutrition in the developing countries [2]. And both the underlying and the immediate causes of undernutrition are due to inadequate food intake and are directly associated with poverty. Studies also identified the contextual factors (individual, household and community level factors) that affect child nutrition. Individual level factors which affect child nutrition are further classified into proximal and distal risk factors [3]. The proximal risk factors include breastfeeding, full vaccination, hygienic practice of sanitation, immunization against infectious diseases and minimum acceptable diet with vitamin A supplementation [4]. The distal risk factors include maternal age at child birth, age at marriage, education, height and body mass index of mother [2, 5]. The other socio and bio demographic correlates associated with child nutrition are sex of the child, birth order, caste, religion, place of residence.

India has experienced sustained economic growth, increase in per capita income and significant diminution in population living below poverty line. The GDP growth rate was above five percent in last two decades and the percentage of population living below poverty line has declined from 50 percent (in 1993-94) to 22 percent by 2011-12 [6]. On the composite index of human development the overall index value has increased from 0.439 in 1990 to 0.61 by 2015 (an increase of 39percent) [7]. However economic growth and poverty reduction in India is not accompanied with reduction in undernutrition. The percentage of stunted children has declined from 52 percent (in 1992-93) to 38percent by 2015-16. [8].Though there has been some decline in undernutrition, the level and variation remain large in the population. On the other hand, Indian districts are best suitable to understand the spatial pattern of nutrition and poverty and the associated nexus of undernutrition with the meso scale correlates because the no of districts (640) are large and the inter-district variation is enormous in terms of the meso scale indicators including child stunting. In this context the prime objective of this study is to understand the spatial heterogeneity of stunting and the identification of the correlates across the districts of India.

Malnutrition is strongly associated with economic well-being of households. In the last decades, a large number of studies examined the economic gradient of undernutrition in developing countries [9-11]. Also the pattern of income poverty and undernutrition is not consistent across developing countries. While South Asia tend to have high undernutrition with moderate poverty, Africa tends to have high poverty and moderate undernutrition [12]. In this direction, some other studies suggest a strong and positive association between consumption expenditure and child's undernutrition [13, 14]. So, lack of resources and food unavailability due to poverty causes pathways to retard the level of nutrition among people in a country. The Global Hunger Index shows us that there is a huge variation on the index values over the states of India and as country India ranks 97th globally [15]. Studies also suggest that poverty-nutrition trap do exist in India [16]. Hence, this study is an attempt to understand the spatial heterogeneity in undernutrition and its correlates at the district level.

Data and Methods

Data

Data from National Family Health Survey round four (NFHS-4), 2015-16 is primarily used in the analysis. NFHS 4 for the first time provides estimates of under nutrition for all districts of India. And it is the fourth in the series of health survey; provides information on several aspects of population and its health and especially on child nutrition across India.

NFHS-4 covered a nationally representative sample of 699,686 women aged 15-49 years and 103,525 men aged 15-54 years across the districts of India. The average no of households surveyed in each district was about 940. As a brief description of the districts and to check the performances of those districts in terms of child nutrition and different socio-economic, demographic indicators the necessary variable information are summarised in Table 1. The socio-economic and demographic variables include poverty head count ratio, women with 10 or more years of schooling, full immunization among children, children who are breastfed and received adequate diet, electricity connection in the household, safe drinking water, improved sanitation and use of clean fuel in the household. These data were compiled from NFHS 4. District level estimates on poverty head count ratio (PHCR) are taken from a published source [17].

Outcome variables

The anthropometric indicators of nutritional status of children namely stunting is the dependent variable in this study. Stunting is measured through the standardized measures of height-for-age (HAZ) anthropometric score of the children under age five. Any child having a HAZ score below two standard deviations from median height for age z-score of the reference population is defined as stunted [18]. Stunting measures the chronic nutritional deprivation among the children [19]. As districts are the unit of analyses, the district level prevalence of stunting across India are modeled to examine the objective of the study.

Independent variables

After an exhaustive review of literatures and performing bivariate statistical analyses a set of independent variables were identified and included in this study. Though there are different potential risk factors which influence child stunting but subject to the availability of data at the district level for India, the following variables were chosen– The key variable of the study is PHCR, the district level values on PHCR gives the proportion of population lives below the national poverty line which is a consistent estimator of poverty and the purchasing power of the population. BMI status of women which signifies maternal health and educational attainment among women, are the two maternal variables included in this study. The available information on BMI gives the district wise proportion of women whose BMI status is below normal, i.e. less than 18.5kg/m^2 and the variable information on women's formal education gives the proportion of women with ten or more years of schooling. The proximate factors include child feeding practices, full immunization, improved sanitation condition and electricity connection across the districts. In particular, the district level proportion of children who are breastfed and received adequate diet used as a proxy for child feeding practice. Maternal health care utilization during delivery was proxied through proportion of institutional births in the districts.

Methods

To examine the poverty dependence and social gradients of child malnutrition, the following statistical analyses were done. Descriptive analysis, Moran's I statistics and ordinary least square spatial regression methods wereused in the analysis. Descriptive analyses are carried out to understand the variation in stunting and other study variables across the districts of India.

A multiple linear regression model was used to execute the preliminary check between stunting and the set of independent variables. The mathematical form of the model is given by the following:

$Y_i = \alpha + \beta_1 BMI_i + \beta_2 PHCR_i + \beta_3 WEDU_i + \beta_4 ID_i + \beta_5 FI_i + \beta_6 CFP_i + \beta_7 IS_i + \beta_8 ELECT_i$ ……(1)

Where Y_i denotes the proportion of children malnourished in the i-th district; Here α denotes the constant (intercept value) of the equation

β_j denotes the coefficient value for the jth variable where j = 1 (1) 8

i (1, 2,…, 640) denotes the no of districts.

For the i-th district; BMI denotes the percentage of women below normal body mass index (<18.5 kg/m^2) , PHCR means the corresponding value of poverty head count ratio, WEDU denotes the percent women with 10 or more years of schooling, ID is the percentage of institutional delivery, FI is the percentage of full immunization in the district; CFP is the percentage of children who are breastfed and received adequate diet; IS is the percentage of households with improved sanitation and ELECT denotes the percentage of households with electricity connection.

Though OLS is a popular and strong regression technique to check the empirical association between outcome and predictor, but this method fails to identify the spatial relationship taking the spatial autocorrelation into account. As this study is focused to identify the district level heterogeneity of stunting, thus it is necessary to consider the district level spatial autocorrelation of outcomes while building up the model. To assess the extent of spatial autocorrelation among the errors in the OLS model the corresponding Moran's I statistic value for the residuals was computed and statistically tested. A statistically significant Moran's I indicated the presence of spatial autocorrelation and thus we chose to build the spatial models (*i*) spatial lag model (*ii*) spatial error model. The spatial lag model assumes that the dependent variable in one area is affected by the dependent variable in the nearby areas [20]. Whereas the spatial error model is used to consider the effect of those variables which are not present in the regression model but have an effect on the outcome variable. In this case considering the neighbourhood dependency in the error terms the spatial dependence structure is built up in the SEM model.

ArcGIS, GeoDa and STATA 12.0 packages were used for analyzing the data. Univariate LISA and bivariate LISA maps are utilized in this study to identify the spatial clusters. Univariate LISA map gives the geographical clustering of different variables used in this study. Bivariate LISA explores the association between the exposure and outcome subject to the geography of India and will give an understanding of the fact that those regions which are underprivileged on the subjects of stunting, poverty and other meso scale indicators.

The district level shape file (digital map) of India was obtained from GitHub at https://github.com/datameet/maps/tree/master/Districts. The digital map has been used under the Creative Commons Attributions 2.5 India license.

Results

Table 1 presents the descriptive statistics of variables used in the study. On an average, about one-third of women had 10 or more years of schooling. About 88 percent households had electricity connection while less than half of the households had improved sanitation. Around three-fifth of the children were immunised. About one-third population was living below poverty line.

Fig 2 ((a) - (d)), presents the scatter plots of stunting and selected variables under the study framework. Districts with higher incidence of poverty showed significantly higher prevalence in stunting. Descriptive statistics revealed a substantial differential in the prevalence of undernutrition across the districts of India (Table 2). The average prevalence of stunting was 30 percent in districts with PHCR of less than 30% compared to 44 percent in districts with PHCR of more than 60 percent.

Fig 2 (b) showed the scatteredness of stunting by the gradients of women health (BMI status) across the districts. The scatter plot clearly depicts a positive slope between district wise proportion of women with their BMI below normal and stunting prevalence. And the prevalence of stunting showed an increasing pattern with the increasing rate of women's below normal BMI status. Districts where more than 30 percent of the total women have their BMI level below normal show a quite higher prevalence of undernutrition (stunting prevalence-45; underweight prevalence 45 and wasted prevalence-26) compared to the rest of the districts (Table 2).

On the other hand women's educational attainment and improved sanitation condition across the districts showed a negative slope indicating negative relationship between the two meso scale indicators and child stunting. Table 2 provides a detailed understanding of stunting prevalence across the districts by the variation in meso scale indicators.

Spatial distribution of Stunting

Figure 1 presents the spatial pattern of stunting across the districts of India. It was found that stunting prevalence was as high more than 46 percent in 110 districts. This stunting prevalence was in the range of 26-46 percent in 410 districts and rest of the 120 districts were carrying a stunting prevalence of less than 26 percent. This shows that India's districts carry a significant burden of stunting among under-five children. And the districts with high prevalence of stunting are from the poorer states like Bihar, Uttar Pradesh, Madhya Pradesh and Rajasthan.

Appendix1 presents the univariate Moran's *I* statistics depicting the extent of spatial autocorrelation of malnutrition and the meso scale variables. The Moran's *I* value was 0.65 for stunting. The district level estimates on poverty head count ratio (PHCR) showed Moran's *I* value of 0.59. Of all the study variables, the Moran's *I* value was observed to be highest for improved sanitation and lowest for full immunisation. This confirmed the clustering of districts in terms of stunting among children under age five, poverty and other district level socio-demographic indicators.

Table 3 presents the values of Bivariate Moran's I statistics for stunting against the correlates. It was found that the spatial autocorrelation of stunting and poverty was 0.46 and that with BMI was 0.52. Overall, poverty and women's BMI showed high and positive spatial correlation with child stunting. On the other hand, women's education, institutional delivery, children's immunization status, feeding practices and household level sanitation showed a negative spatial autocorrelation with stunting. Figure 3 (a) present the bivariate LISA cluster map which indicated that about128 of 640 districts (20% of all the districts) had highest prevalence of stunting and highest level of poverty. These districts were mostly from the states of Uttar Pradesh, Bihar, Jharkhand, Madhya Pradesh, Rajasthan, Maharashtra and

Gujarat. A total of 104 districts formed cold spots (low poverty and low stunting) from the states of Tamil Nadu, Kerala, Punjab, Himachal Pradesh and some districts of Jammu & Kashmir and Nagaland. Similarly the hot spots and cold spots were identified in terms of women's BMI, educational attainment and sanitation condition. Other than poverty, women's health (BMI status) showed strong correlation (Bivariate LISA=0.52, z-value=23.77) with child stunting prevalence across the districts.

Spatial Modeling

OLS estimation showed the preliminary check of the association between stunting and the meso scale indicators without considering the spatial structure of the data (Appendix 2). From the regression result it was confirmed that BMI status of the mothers and poverty situation across the districts closely determine the burden of child stunting across the districts of India. Among the other meso scale correlates mother's education, breastfeeding pattern and sanitation condition found to be the statistically significant predictors of stunting. After diagnosing the OLS model we found that the residuals in the OLS model were spatially auto-correlated (Moran's I = 0.31, p value = 0.000001). This suggested that the prevalence of stunting among the children was not distributed uniformly across the districts of India and occurred in particular clusters. Hence, we rejected the null hypothesis and accepted that there is a positive spatial autocorrelation in the prevalence of stunting and we further estimated the spatial autoregressive models to consider the autocorrelation into account. Spatial lag and error models were fitted in the data. Based upon the model diagnostics we found the spatial error model to be better performing and hence the error model gave the final estimates of the association. Appendix 3 gives the estimated results from the spatial lag model for all the three indicators of malnutrition.

The SEM model gave the final and the spatial endogeneity corrected estimates of the correlates for stunting, underweight and wasted prevalence across India (Table 4). Among the two estimated spatial models, the SEM model showed a lower AIC value. The results from SEM model showed that, the estimated coefficient was largest for BMI (β = 0.23, 95% CI: 0.14, 0.33) followed by institutional birth (β = −0.13, 95% CI: -0.18, − 0.08) and mother's educational attainment (β = − 0.10, 95% CI: -0.17,-0.03). While the estimated coefficient of PHCR was found to be 0.07 (95% CI: 0.03-0.10). Thus the coefficient estimate for BMI confirmed that a 10 point increase in the proportion of women with their BMI below normal across the districts was associated with 2.3 point increase in the stunting prevalence. On the other hand, the poverty association of stunting suggested that a 10 point increase in terms of PHCR was supposed to increase stunting prevalence by 0.7 point across the districts. Similarly, a 10 point increase in the institutional births across the districts was associated with 1.3 point decrease in the stunting prevalence whereas a 10 point increase in the proportion of the educated mothers across districts was statistically supposed to bring down the stunting prevalence by 1 point. The corresponding value of the lag coefficient from the stunting model was 0.6 (p-value< 0.001). It was observed that, compared the other models, the stunting model showed a lower AIC value with a pseudo R square value of 0.72 indicating the explained variability of the model.

Discussion

This study designed a district level analysis to study the 640 districts across India to understand the geographic patterning of child stunting and the associated meso scale nexus with poverty situation. Appropriate statistical methods and spatial analyses were carried out. We have utilised the latest data on undernutrition of children making the study more relevant and potentially strong on the understanding of child malnutrition.

Our findings suggest statistically significant evidences for spatial correlation of stunting and poverty, mother's BMI, educational attainment of women and improved sanitation at the meso scale. Meso scale indicators across the districts in India vary largely in terms of poverty, Women's education, BMI status, health care utilization (ANC care Institutional delivery) immunization coverage, birth registration, child feeding practices which are directly or indirectly associated with child's nutritional status. At the same time physical infrastructure like electricity connection in the households, safe drinking water availability and sanitation condition also determines nutritional status among the children.

This study shows a strong association of maternal BMI status with stunting among children. Districts with higher percentage of women with a BMI less than 18.5 kg/m^2 are significantly more likely to carry a higher burden of stunting. Findings is consistent with earlier studies that maternal BMI and nutritional status is an important risk factor of poor intrauterine growth and low birth weight during pregnancy [5, 21]. Mother's nutritional status biologically determines child's nutritional outcome starting from the uterine growth *in utero* upto six months post delivery when the new born is supposed to be exclusively breastfed for all nutrients supply from the mother [22, 23].

This study showed that districts with higher incidence of poverty are at higher risk of increased prevalence of stunting, underweight and wasting. A higher value of PHCR for a particular district suggests that a larger portion of the population in that district lives below the poverty line with a low purchasing capacity for food which causes them low and inadequate food consumption, this eventually make more vulnerable the young age group to be malnourished due to poor nutrition. So, the poverty condition in a household creates the pathways to malnourishment among the children. Previous studies also found that in the developing countries poverty has remained a major cause of malnutrition [24]. Though poverty and malnutriton nexus is complex in different country settings but our results confirmed that poverty significantly affects child's nutritional staus in districts of India.

This study also confirms that mother's formal education is associated with child under-nutrition. An improvement in the mother's education can make substantial difference in child's nutritional status. This finding is also consistent with the previous studies which establish the impact of mother's education on her child's nutritional status [25, 26].

The child feeding practice across districts was found to be significantly associated with stunting. Districts where children were breastfed and received adequate diet are less likely to be burdened with the prevalence of stunting. Breastfeeding pattern and initiation of complementary feeding and quality of the complementary food could be the possible reason which helped the prevalence of child undernutrition go down and reduced in those districts [27, 28]

The study findings also get a clear linkage of household level sanitation status and child nutrition. An improved sanitation shows a lower prevalence of undernutrition across the districts of India. It is known that children are more prone to infection than adults and low sanitation in the households aggravates the situation among children to become affected with different disease like diarrhoea and other infectious diseases which significantly determines the nutritional outcome of the children [29, 30].This study corroborates the findings from the previous studies reinforcing the fact that an improved sanitation condition will surely help to fight against the child malnutriton reducing the prevalence across India.

Conclusion

This study illustrates the spatial heterogeneity of malnutrition among the children in districts of India. The findings could be useful for public health planning and targeting the underlying meso scale factors associated with child nutrition in India. It also suggests allocation of health resources and the implementation of child health specific interventions in the geographical hotspots of higher malnutrition prevalence. The spatial clustering of malnutrition is found in those geographical pockets where poverty is high, women's education is low, BMI level among women is below normal. The malnutrition indicator also significantly falls in terms of other distal and proximate factors, which reinforces the need for intersectoral co-ordination in fighting malnutrition in India. An integrated approach; a multisectoral co-ordination of reduction of poverty, increasing sanitation coverage and maternal nutrition can help to reduce child malnutrition in India.

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Table 1: Descriptive Statistics of the selected indicators/variables, India, 2015-16

Variables (district level percentages)	Mean	Standard Deviation	Coefficient of variation	Minimum	Maximum
Stunting	36	9.9	27.5	12.4	65.1
Women whose BMI is below 18.5kg/m^2	22.2	8.9	40.1	3.3	47.5
Poverty Head Count ratio	33.8	18.7	55.3	0.3	95
women with 10 or more years schooling	34.5	14.4	41.7	9	86.3
Institutional births	78.9	17.3	21.9	9.6	100
Children fully Immunized	62.2	17.3	27.8	7.1	100
Children breastfed & received adequate diet	9.7	7.6	78.4	0	39.5
Households with improved sanitation	48	22.6	47.1	6.9	99.5
Households with electricity	88	14.7	16.7	25.6	100
No of districts			640		

Table 2: Average prevalence of stunting in India, NFHS, 2015-16, India	
District level Meso scale correlates (%)	Stunting
Women whose BMI is below 18.5 kg/m^2	
<15	27.5
15-30	36.9
>30	44.5
Poverty Head Count ratio	
<30	30.2
30-60	40.6
60+	44
Percent women with 10 or more years schooling	
<30	41.5
30-50	33.7
>50	25.6
Percentage of institutional births	
<60	41
60-80	40.5
80+	32.4
Percent children fully Immunized	
<50	39.2
50-70	37.5
>70	31.8
Percent Children breastfed and received adequate diet	
10-40	41.7
40-70	39.9
>70	37.3
Percent households with improved sanitation	
<30	45.1
30-50	35.8
>50	29
Percent households with electricity	
25-60	49.5
61-90	41.5
>90	31.7

Table 3: Bivariate LISA measure of stunting and correlates in the districts of India, 2015-16

	Stunting	
Meso scale variables	Bivariate LISA	Z value
Women whose BMI is below 18.5kg/m^2	0.52	23.77
Poverty Head Count ratio	0.46	20.89
women with 10 or more years schooling	-0.47	-23.19
Institutional births	-0.3	-14.28
Children fully Immunized	-0.27	-13.43
Children breastfed & received adequate diet	-0.31	-16.26
Households with improved sanitation	-0.52	-25.06
Households with electricity	-0.51	-24.36

Table 4: Estimated results from the spatial error model, India, 2015-16

	Stunting	
District level meso scale correlates	Coef. (95% CI)	p-value
Percent women with below normal BMI	0.23 (0.14,0.33)	0.000
Poverty Head Count ratio	0.07 (0.03,0.10)	0.000
Percent women (10 or more years education)	-0.10 (-0.17,-0.03)	0.003
Percentage of Institutional births	-0.13 (-0.18,-0.08)	0.000
Percent children fully Immunized	0.01 (-0.03,0.05)	0.567
Percent children breastfed & received adequate diet	-0.02 (-0.05,0.02)	0.384
Percent households with improved sanitation	-0.06 (-0.11, -0.01)	0.006
Households with electricity (%)	-0.05 (-0.11, 0.00)	0.051
Lambda Value (Lag coefficient)	0.60	0.000
AIC value	3837	
Pseudo R Square	0.7246	
No of districts	640	

Appendix 1: Moran's I Statistics showing the spatial dependence for the district level prevalence of stunting and the meso scale indicators in India, 2015-16

District level Meso scale Indicators/Variables	Moran's I values	Z value
Stunting	0.65	25.13
Women whose BMI is below normal	0.69	27.13
Poverty Head Count ratio	0.59	21.71
women with 10 or more years schooling	0.69	27.66
Institutional births	0.66	23.95
Children fully Immunized	0.55	20.24
Children breastfed & received adequate diet	0.64	25.56
Households with improved sanitation	0.74	30.3
Households with electricity	0.70	23.35

Appendix 2: Result of regression analysis (OLS) showing the adjusted coefficients of the correlates for stunting in India, 2015-16.

	Stunting	
District level meso scale correlates	Coef. (95% CI)	p-value
Percent women with below normal BMI	0.30 (0.21,0.39)	0.000
Poverty Head Count ratio	0.07 (0.04,0.11)	0.000
Percent women (10 or more years education)	-0.05 (-0.11,0.00)	0.062
Percentage of institutional births	-0.09 (-0.13,-0.05)	0.000
Percent children fully Immunized	-0.02 (-0.05,0.01)	0.230
Children breastfed & received adequate diet	-0.18 (-0.25,-0.11)	0.000
Households with improved sanitation (%)	-0.05 (-0.08,-0.01)	0.019
Households with electricity (%)	-0.13 (-0.18,-0.08)	0.000
R^2 Value	0.63	
No of districts	640	

Appendix 3: Estimated results from Spatial lag model, India, 2015-16.

District level meso scale correlates	Stunting Coef. (95% CI)	p-value
Percent women whose BMI is below 18.5kg/m^2	0.21 (0.13,0.29)	0.000
Poverty Head Count ratio	0.06 (0.02,0.09)	0.001
Percent women (10 or more years education)	-0.07 (-0.12,-0.02)	0.005
Percentage of Institutional births	-0.07 (-0.10,-0.03)	0.000
Percent children fully Immunized	-0.02 (-0.05,0.01)	0.265
Percent children breastfed & received adequate diet	-0.04(-0.07,-0.01)	0.006
Percent households with improved sanitation	-0.03 (-0.06,0.01)	0.149
Households with electricity (%)	-0.06 (-0.11,-0.02)	0.004
Rho Value (Lag coefficient)	0.362	
AIC value	3870.54	
Pseudo R Square	0.6924	
No of districts	640	

Figure 1: Map of India showing the geographic distribution of the rates of stunting India, 2015-16

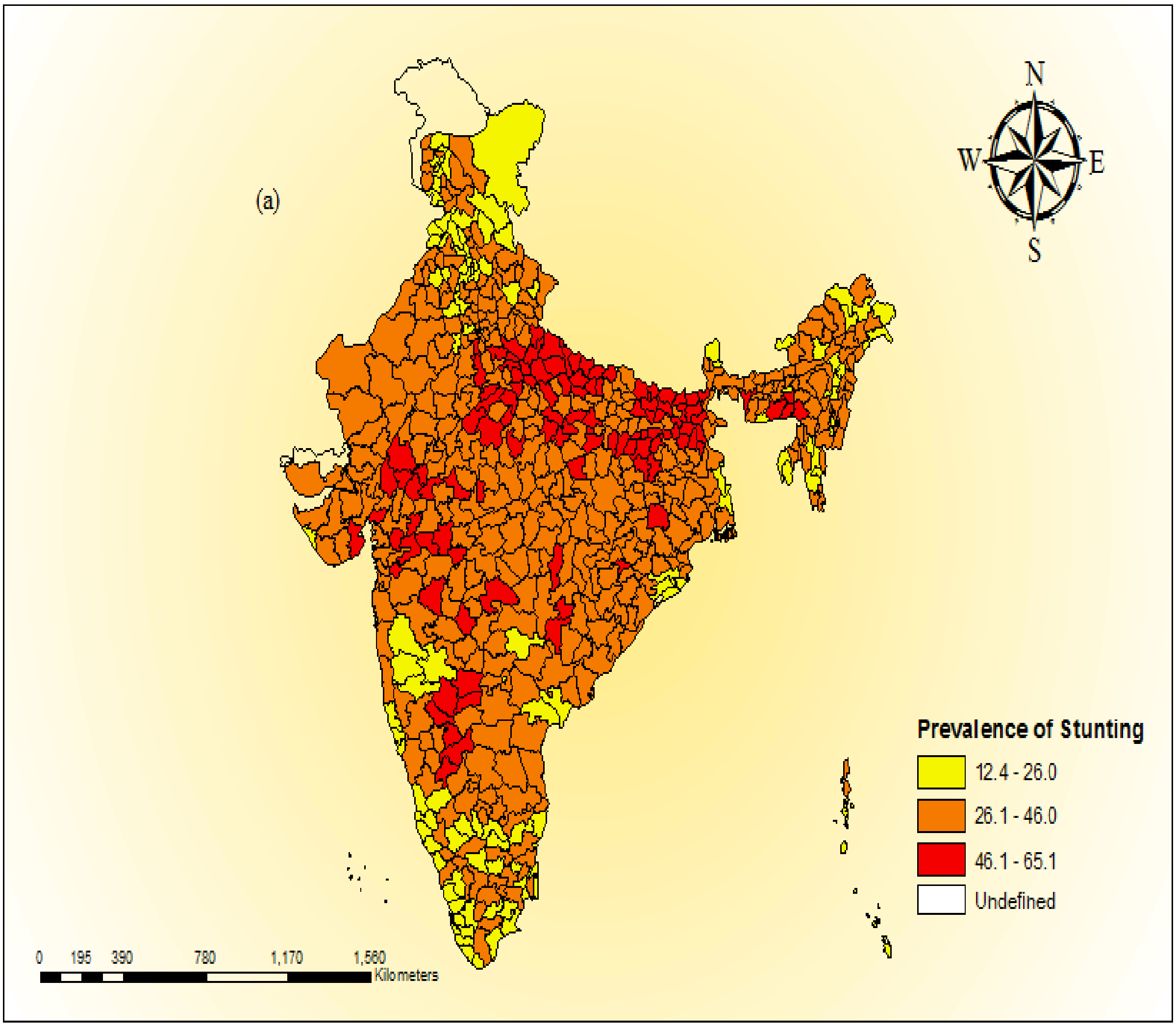

Figure 2: Graphs visualizing the scatter plots between (a) PHCR vs stunting (b) BMI vs stunting (c) women's education vs stunting (d) improved sanitation vs stunting, India, 2015-16

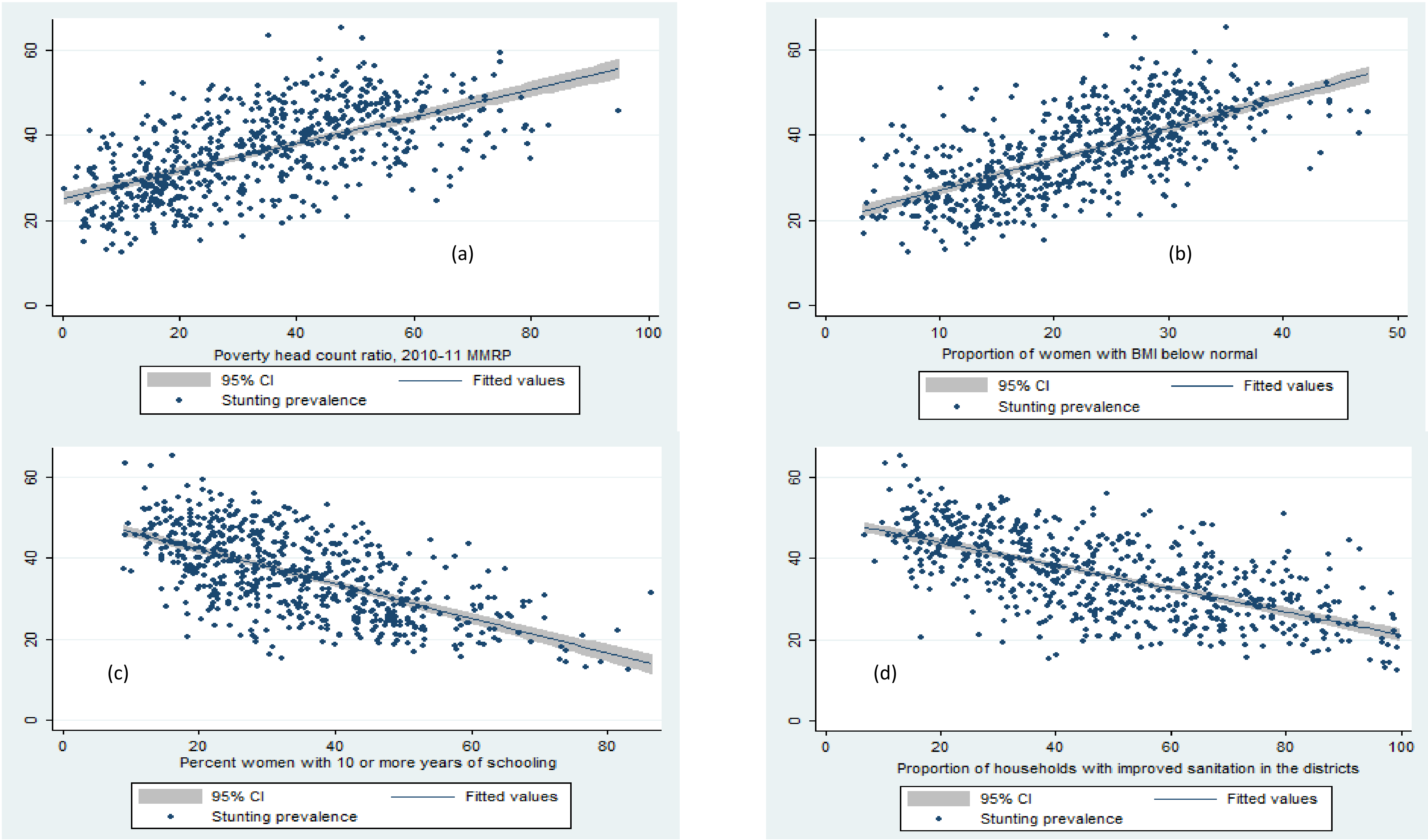

Figure 3: Bivariate LISA cluster maps of India showing the geographic clustering of (a) poverty vs stunting (b) BMI vs stunting (c) education vs stunting & (d) sanitation vs stunting, India, 2015-16