GEOGRAPHICAL ANALYSIS

RESEARCH ARTICLE

Modelling the Determinants of Child Health in India: A Geospatial Approach

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Abstract

In general, as defined by the World Health Organization (WHO), health is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity. Although, there is much more care has to be provided in case of the children who are under the age 5. Child health is a fundamental important goal for the future generations to sustain healthy. Over the past few decades, the world has recoded a swift progress in improving the child health and reducing the child mortality. However, a UNICEF - 2019 report states, 6.1 million children and young adults have died, mostly from preventable causes; of which 5.2 million were newborn babies. India accounts one fifth (25 million) of the world's annual child births. Nearly, 3.5 million children are born too early, among them 1.7 million are born with defects. India, despite the increase in the number of health care Centres across the country, has to improve the quality of the health care services in those Centres to reduce the child mortality. Also, health care systems in the remote tribal areas, where 21 percent of the total deliveries are recorded, need much more ambitious plans and budget to be expended to increase their access to the health care systems. The current study, with the application of geospatial technology, maps the state level health care systems across India and models the relationship and prioritize the states for immediate action plans to attain the goals of the National Health Policy. The study utilized select data from the Annual Reports for the year 2019-2020 of Health Management Information System (HMIS) and Rural Health Survey (RHS).

Keywords: Child health; Healthcare systems; HMIS; RHS

Introduction

Reducing childhood mortality is an ambitious public health project of India. To achieve the expected results in the public health policies requires a deep understanding on the issues and strong implementation strategies (Joseph L Mathew, et al. 2011a). According to the India Human Development Survey (IHDS), analysis of the household data provides a broad overview of the implementation and success of the public policies and the future policy planning and the challenges involved in it. Assets and amenities provided for a household reflects the quality of life. While the availability and number of services/amenities and assets vary from every region. Sandip Mondal (2020) focused the spatial pattern of Household Quality of Living (HOL) in West Bengal corresponding

to the spatial location of cities and towns. HQL depends on three factors viz. quality of housing, access to basic services/amenities and asset ownership. The study has been carried out with the application of Anselin Moran I and Getis-Ord G* statistics to determine the spatial pattern of HQL.

Arjun Kumar (2015) stated access to basic amenities, like health and family welfare centres, is imperative for a good quality of life. These basic amenities are universally standard and playing a major role in the formulation of policies and programmes in India. In India, rural households have witnessed a gradual improvement in access to health centres; however, they experience high level of service. Access to such amenities in the rural India has been insufficient, which is reflected in the poor health. Providing an equal health service across the country is a challenging task, however, to provide such a service would be an ideal solution to reduce the disparity. Increase in the accessibility and availability of quality health services is shown to be an effective method to serve the needy and to improve the health system (Emily Oster, 2009).

Fabio Boncinelli et al. (2015) identified and evaluated the most important territorial services, infrastructure, and geographic factors in order to measure several dimensions of quality of life in rural areas. The study evaluates how the availability of services supplied in a rural area is able to influence local residents' quality of life.

More than half of deaths in children (age less than five years) occur in the neonatal period; infections (including sepsis, pneumonia, diarrhoea, and tetanus), prematurity, and birth asphyxia are the three major causes of death in this period. (Vinod Kumar Paul, et al. 2011; Chandrakant Lahariya, et al. 2010; Marion Krämer, et al. 2021; Dheeraj Shah, et al. 2012). Climate change, among the other factors, affects child health through direct and indirect pathways, with implications for determinants of child health as well as morbidity and mortality from a range of diseases related to vector borne, water and food borne, respiratory, pathogens etc. (Daniel Helldén, et al. 2021). Respiratory related diseases are one among the chief causes of child mortality in India (Joseph L Mathew, et al. 2011b). Despite the plans and policies implemented by the government of India, pre-natal and post-natal health care was not delivered to the fullest across all the parts of the country, especially those are poor and weaker sections of the society.

The geographical accessibily is another impediment for the mother and the child to get the health care service on time. stratification and clustering are an effective method to group the variables and infer valid inputs to draw effective strategies to strengthen the health care systems (Yuvaraj Krishnamoorthy, et al. 2020; Siddhartha Gogia. et al. 2011).

Despite the vast establishments of the health care units, home deliveries are high in India. The important limiting factors for home-based deliveries were myths and cultural beliefs, lack of awareness of mother and families regarding danger and postnatal complications, and hesitancy to contact health workers. On the other side the health workers, at times, lack clarity about job responsibilities, poor quality of training, skills building and supervision of front-line workers (Vaishali Deshmukh, et al. 2020).

Among the many intricate methods to understand health care systems and the associated pros and cons is the cross-sectional profile on how the health care systems like maternal, early child care Centres, family planning etc. were utilized by the locals around it (Shankar Prinja, et al. 2019; Shubhranshu Kumar Upadhyay, et al. 2020). Associating with the child mortality, breastfeeding is an important factor, especially in the India context, is attributed to the gender biased socio-cultural beliefs; in certain cases, which keeps the mothers to wean on feeding girl child and promotes to get a boy child (Seema Jayachandran, et al. 2011). This also affects the reproductivity cycles and the mother's health (Abhishek Singh, et al. 2012).

Data and Methods

Health Management Information System (HMIS) and Rural Health Survey (RHS) provide wide range of reports on health-related information up to village level across India. The data are valuable in evaluating the health condition and health care developments in providing the service with expected quality.

For the present study, child mortality, up to the age of five, has been aimed to study associating with number of other factors. The study has been carried out with the integration of spatial and statistical methods. Conventionally, the statistical methods have lacked the ability to visualize the results, while with the integration of these methods into the geospatial applications provides higher level of understanding about the problem.

The data available in the reports are to be generalized, inverted, and calculated into ratio before it can be used in the analysis. From the reports, 32 variables were selected for Hot-spot analysis and 20 variables were selected for regression analysis (Table 1 and Table 2). For regression, child death has been selected as the dependent variable and rest are treated as independent variables. Independent variables are further grouped into five categories namely, new born health condition, number of health care Centres (SC, PHC, CHC), grade of the health Centres, doctors, and Staffs available at the health Centres, and population characteristics.

Clustering and linear regression methods were implemented in the study. To cluster the values, Getis-Ord Gi method, and Ordinary Least Square method for finding the regression were adopted; both the methods were proved to be impactful.

Getis-Ord Gi was given as,

$$Gii^* = \frac{\Gamma^n W_{i,j} X_{i,j} - X \sum_{j=1}^{n} W_{i,i}}{s \left[n \sum^n \quad W^2 \equiv \Sigma^n \quad vvi_j^2 \right]}$$

Where, xj the attribute is value for feature j;

wi,j is the spatial weight between feature I and j; n is equal to the total number of features

$$\sum_{n}^{n} x_i$$

$$X\,i \quad \mathbf{S} = \sqrt{\frac{i}{n} - (X)^2}$$

The Gi* statistic is a z-score, so no further calculations are required.

Regression analysis is probably the most commonly used statistic in the social sciences. Regression is used to evaluate relationships between two or more feature attributes. Identifying and measuring relationships lets you better understand what's going on in a place, predict where something is likely to occur, or begin to examine causes of why things occur where they do.

Both the Multiple R-Squared and Adjusted R-Squared values are measures of model performance. Possible values range from 0.0 to 1.0. The Adjusted R-Squared value is always a bit lower than the Multiple R-Squared value, because it reflects model complexity (the number of variables) as it relates to the data and is consequently a more accurate measure of model performance. Adding an additional explanatory variable to the model will likely increase the Multiple R-Squared value but may decrease the Adjusted R-Squared value.

The coefficient for each explanatory variable reflects both the strength and type of relationship the explanatory variable has to the dependent variable. When the sign associated with the coefficient is negative, the relationship is negative

Ordinary Least Square method was given as,

$= Q_0 + Q_1 \times_1 + Q_2 \times 2 + \cdots Q_n \times_n + s$

In the formula,

(y): dependent variable;

(x): independent/Explanatory variables;

(β): regression coefficients; ε: random error term.

Factors of infant deaths below five years of age are categorized into 5 groups for regression analysis (Table 2).

Results and discussion

Hot-spot and regression analysis are powerful methods to derive realistic results; implementing them in the spatial analysis reveals intricate information about the pattern of things which are analyzed. The greatest advantage of these methods incorporated in spatial analysis is the capability of the software to display the numerical information as maps. The visual perception increases the ability to understand the problems effectively.

Hot-spot Analysis

A feature with a high value is interesting but may not be a statistically significant hot spot. To be a statistically significant hot spot, a feature will have a high value and be surrounded by other features with high values as well. The Gi* statistic returned for each feature in the dataset is a z-score. For statistically significant positive z-scores, the larger z-score, the more intense clustering of high values (hot spot). For statistically significant negative z-scores, the smaller z-score, the more intense clustering of low values (cold spot).

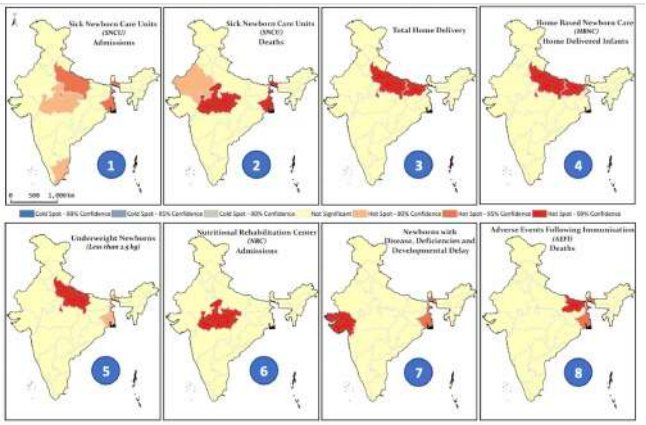

Fig. 1. Shows hot spot maps for the variables 1 to 8

Sick new-borns (map #1) and mortality rates are highly correlated and they are affected in number of ways. Sick new-borns are highly associated with the insufficient pre-natal care. Uttar Pradesh, West Bengal, Madhya Pradesh and Tamil Nadu have hot-spots where the values are high and dominating. Deaths related to the recorded sick new-borns manged new-born shot-spots. India is one of the major countries where high number of un-institutionalised high child mortality rate. In cases of home deliveries, sometimes, the deliveries were not reported properly to provide primary care and knowledge on maternal and post-natal care. Map#3 shows Uttar Pradeshhot-spot, where home deliveries are still highly prevalent; in relation with it both the states have recorded the most number of Home BasedNew-born Care (HBNC)) (map #4). New-borns be treated with utmost care to sustain their life until they are aged 5. Uttar Pradesh and West hot-spots Centres important factor associated with the child mortality is the new-borns and defects at the time of birth. Gujarat and West Bengal have recorded to have more cluster of the category (map#7). Adverse Effects Following Immunization (AEFI) are under reported yet an important factor in the child mortality across the globe, especially in

Table 1. Selected criterion for the hotspot analysis

	HMIS Data		
Vari-able	**Description**		
1	Total Sick New-born Care Units (SNCU) Admission	12*	Total Infant Deaths up to 4 weeks (excluding deaths within 24 hours)
2	Total Home delivery	13*	Infant Deaths (1 -12 months) due to Pneumonia
3	Number of new-borns received 7 Home Based New-born Care (HBNC) visits in case of home delivery	14*	Infant Deaths (1 -12 months) due to Diarrhoea
4	Number of new-borns having weight less than 2.5 kg	15*	Infant Deaths (1 -12 months) due to Fever related
5	Number of children admitted in Nutritional Rehabilitation Centre (NRC)	16*	Infant Deaths (1 -12 months) due to Measles
6	Number of children identified with Disease, deficiencies, and Developmental delay	17*	Infant Deaths (1 -12 months) due to Others
7*	Adverse Events Following Immunisation (Deaths)	18*	Total Infant Deaths from 1 to 12 Months
8*	Infant Deaths within 24 hrs (1 to 23 Hrs) of birth	19*	Total Infant Deaths
9*	Infant Deaths up to 4 weeks due to Sepsis	20	Community Health Centres - Not Eligible to Grade
10*	Infant Deaths up to 4 weeks due to Asphyxia	21	Public Health Centres - Not Eligible to Grade
11*	Infant Deaths up to 4 weeks due to other causes	22	Rural Public Health Centres - Not Eligible to Grade
	RHS Data		
23	Sub-Centre (SC) and Population ratio	29	Shortfall of Lab Technician
24	Primary Health Centre (PHC) and Population ratio	30	Percent of PHCs functioning on 24x7 basis
25	Community Health Centre (CHC) and Population ratio	31	Average Rural Population covered by a Sub-Centre (Not in Hot spot analysis)
26	Shortfall of Doctors	32	Average Rural Population covered by a PHC
27	Population Density - Rural	33	Average Rural Population covered by a CHC
28	Shortfall of Paediatrician		

* Dependent variables; rest are independent variables.
Source: HMIS and RHS survey reports 2019-2020 (Compiled by author).

Table 2. Factors of infant deaths

Factors	**Variables**
New-born health	1, 2, 3, 4, 5, 6
Number of health care centres (SC, PHC, CHC)	23, 24, 25, 30
Grade of the health centres	20, 21, 22
Doctors and Staffs	26, 28, 29
Population characteristics	27, 31, 32, 33

Source: HMIS and RHS survey reports 2019-2020 (Compiled by author)

the developing Asianand African countries. West Bengal and Bihar are the major states in India have influencing cluster of AEFI.

Rajasthan and West Bengal are the states with intense cluster of infant deaths within 24 hours of birth. It centres equipments labours. Maps from 10 to 14 shows infant mortality from 24 hours to 4weeks. Clusters of mortality related to sepsis (map #10) and asphyxia (map #11) major causes of death (map#12) are found in the Rajasthan, Madhya Pradesh, West Bengal and Sikkim states. The total infant deaths occurring in this category are highly concentrated around the Rajasthan and Madhya Pradesh. From maps 14 to 20, the infant deaths occurring from one diarrhoea, measles and other fever related deaths are high in numbers (map#14to#19). Madhya Pradesh, Haryana Similar to also reported significant cluster in the Rajasthan and Madhya Pradesh; additionally, WestBengalalso reported to be a significant cluster.

The maps from 21 to 23 shows the clusters of states where health centres that are not eligible for grading on a scale of 1 to 5. Grading is applied to the Community Health Centres,

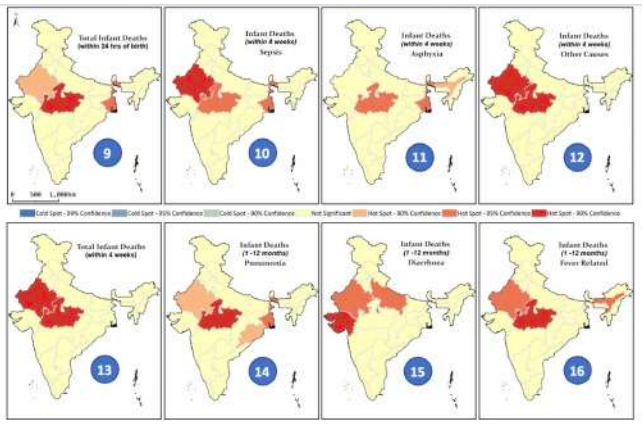

Fig. 2. Shows hot-spot maps for the variables 9 to 16

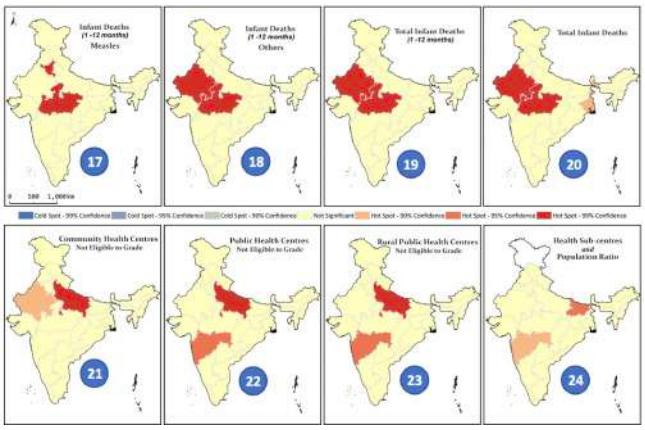

Fig. 3. Shows hot-spot maps for the variables 17 to 24

Primary Health Centres and Sub-centres. These health centres lack key infrastructures in order to meet the minimum standards to serve at their expected levels. The cluster were found in Uttar Pradesh, Maharashtra, Rajasthan, and Bihar states.

Population ratio with respect to the health centres are displayed in the maps numbered from 24 to 26. The hot-spots were calculated once the ratio is found by the formula,

Total population in the stat / Total health centres in each category

The formula infers the number of people served by a particular health center. The assumption is that high number population served by a health centre would impact the quality of the service provided, considering the infrastructure and human resource characters. Bihar, Jharkhand, West Bengal, and Maharashtra are the states with significant hot-spot clusters of population and health centre ratio as shown in the maps from 24 to 26. In the health centres, availability of health care professionals is another important variable in controlling the infant mortality. Shortfall of Doctor, Pediatrician, and Lab technician can adversely affect the infant mortality rate.

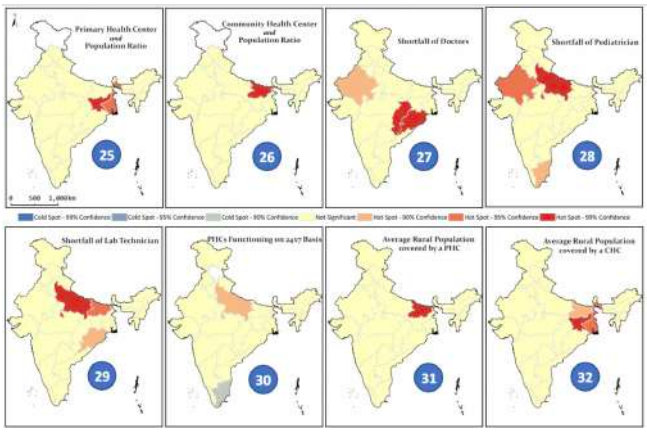

Fig. 4. Shows hot-spot maps for the variables 25 to 32

Orissa, Chhattisgarh, Uttar Pradesh, Rajasthan, Bihar, and Tamil Nadu have high value clusters in this category. Also, functioning of health care centres in schedule manner could increase the rate of infant mortality.

Regression

Regression is used to evaluate relationships between two or more feature attributes. Identifying and measuring relationships lets you better understand what's going on in a place, predict where something is likely to occur, or begin to examine causes of why things occur where they do.

The analysis has been carried out with five factors each with multiple variables.

- New-born health: infant health at the time of birth like sickness, defects, disease, deficiency etc.
- Number of health care centres (SC, PHC, CHC): the number of health centres.
- Grade of the health centres: number of ineligible health centres in each category.
- Health care professionals: total number of shortfall of health care professionals according to their nature of work.
- Population characteristics: Population and health care ratio, average population served by a health care category in each state.

The maps from the regression analysis displays the dependent variable i.e., total infant deaths are correlated with each of the selected variables. The selected variables are highly significant in the states of Madhya Pradesh, Rajasthan and significant in Gujarat, Maharashtra, Karnataka, Orrisa, West Bengal and Sikkim as shown in the Figure 5 . Health care centres are influential in the states of Madhya Pradesh and Rajasthan, Gujarat, Maharashtra, Tamil Nadu West Bengal and Sikkim states as shown in the Figure 6.

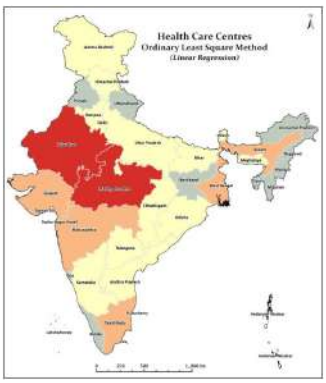

Fig. 5. New-born health

Fig. 6. Health care centres

Fig. 7. Health care centres – ineligible for grade

Figure 7 exhibits the states that have ineligible hospitals which influenced infant mortality in the respective states. Madhya Pradesh, Rajasthan, Gujarat, Tamil Nadu, Bihar, and Sikkim have positive correlation with the grade of the health care centres and infant mortality. Doctors and health care professionals have high correlation with the infant mortality in Madhya Pradesh, Haryana Rajasthan, Gujarat, Maharashtra, Andhra Pradesh, West Bengal, and Sikkim.

Fig. 8. Doctors and health care professionals

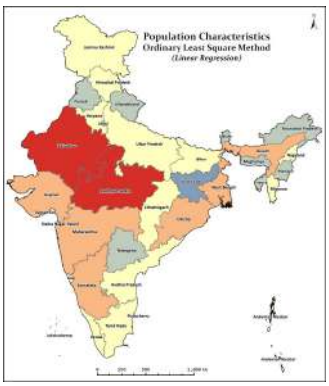

Fig. 9. Population characteristics

Conclusion

The Universal Health Care (UHC) resolution in the United Nations highlighted the need for national strategic direction on Quality of Care (QoC) and made a strong call to expand the provision and prioritization of primary health Care (PHC) for more sustainable, people-centred and integrated health systems. The resolution reaffirmed the commitment to the 2030 Agenda for Sustainable Development and the achievement of UHC by 2030.

With reference to the Sustainable Development Goals 2015, India targets to reduce the neonatal mortality to as low as 12/1000 live births and under five years mortality to 25/1000 live births. To attain the target, major improvisations and intensification of the efforts are needed at the root level.

As part of evaluation of the efforts in the implementation of the plans, the sub-district level flow of data at yearly interval through the Health Information Management System (HMIS) is a valuable data resource to provide insightful information to the policy makers and health workers.

The tools are very effective in manipulating the data and the results are realistic, which can be verified with further round of validation with a select sampling method. The detailed report from the study can be very insightful to

the policy makers and implementing agencies for effective outcome.

The study has vast scope for further investigation while the major limitation is data. Currently the data is available at state level, is insufficient to carry out the research deeper like at district level.

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