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Mapping Maternal Health Vulnerability in India using the Fuzzy Tools: Geospatial Insights

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ABSTRACT

Inequality in the maternal health situation across India is one of the significant public health challenges. While few states have achieved the global targets of Sustainable Development Goals (SDG), others have a high maternal health burden. Poor maternal health stresses their survival risk and leads to infant morbidity, mortality, and long-term health implications in adult life. Given this, an effort is made to map India's maternal health situation and identify the gaps. Using the Delphi technique, eight indicators were identified, which were later used for fuzzy data analysis and classification. The fuzzy classified maternal health vulnerability map shows the inter-regional gap in women's health and their accessibility to maternal health care. Northern and North-eastern states of India were found to be more vulnerable compare to the southern states. The government has launched several maternal health oriented programs in the recent past, and the release of the 5th NFHS report can highlight their outcomes. Besides improving the maternal health infrastructure, attention should also be on improving the road linkages for their better accessibility and medical coverage for curbing late maternity deaths.

Keywords: Maternal Health Vulnerability, Delphi method, Fuzzy Logic, Gender Sensitive Health Policy Framework.

Introduction

The health and wellbeing of babies are related to maternal health. Although progress has been recorded in the last two decades, maternal health has remained a significant public health issue in India. The total annual maternal deaths declined from 55,000 in 2010 to 35,000 deaths in 2017; this still translated to one maternal death every 20 minutes (UNICEF India, 2020). Maternal Mortality Rate, a measure of women's reproductive health in an area, is the death of a woman while pregnant or within 42 days of pregnancy termination from any cause related to or aggravated by the pregnancy or its management (WHO, 2020). The lifetime risk of maternal death, the probability that women of reproductive age (15-49) will die due to childbirth or pregnancy-related death, has reduced significantly from 2.44% in 1990 to 0.3% in 2016-18 in

India. However, some states still have rated higher than the world average of 0.5% (SRS, 2020). Maternal Mortality Ratio (MMR), the number of maternal deaths per 1,00,000 live births, has declined by 8 points from 130 in 2014-16 to 122 in 2015-17 and declined by 68.7% in the last 25 years (MoHFW, 2017-18). However, it is still far away to meet the global MMR goals of 70 per 1,00,000 live births "target 3.1 of Sustainable Development Goals (SDG)" set by the United Nations.

Studies have found substantial regional, geographic, and socioeconomic inequalities contributing to maternal health care's uneven availability in developing countries (Pathak, Singh, & Subramanian 2010; Jat, Ng, & San-Sebastian, 2011). The gaps in the risk of maternal deaths and maternal health care availability between rural and urban areas exist.(Singh, Rai, Alagarajan, & Singh, 2012; Chatterjee, 2017; Chakraborty & Bhattacharjee, 2017; Ali &Chauhan, 2020). At the state level, Assam continues with the highest MMR (300), followed by Uttar Pradesh (285) and Rajasthan (244). At the same time, Kerala, Tamil Nadu, Maharashtra, Telangana, and Andhra Pradesh have already reached the SDG target. Thus, the inequality in the burden of maternal deaths within the country is prejudiced by socioeconomic indicators such as poverty and education. They influence access to health care during pregnancy and postpartum. Under the National Rural Health Mission (NRHM), since 2005, multiple maternal health programs like the Janani Suraksha Yojana (JSY) - a cash-incentive scheme for promoting institutional deliveries; Accredited Social Health Activists (ASHA workers); Janani Shishu Suraksha Karyakaram (JSSK); were introduced to facilitate access to healthcare by impoverished or marginalized women.

The use of geospatial technologies is on the rise worldwide to understand the dynamics of women's health situations (Salehi & Ahmadian, 2017; Molla et al., 2017). Data visualization supported by mapping and geospatial analyses has emerged as a crucial tool to address the spatial investigation at a national or subnational scale. Molla et al. (2017) have argued that Geographical Information System (GIS) could contribute to the post-2015 United Nation's Sustainable Development Goals (SDGs) agenda in general and contribute to better maternal and neonatal health outcomes in low resource settings. Several studies regarding the use of GIS in the maternal health domain have focused on potential geographic access to maternal health care from the perspective of the spatial distribution of health facilities (Sudhof et al., 2013; Gething

et al., 2012) to geographic access on mortality and care utilization (Heard, Larsen, & Hozumi, 2004; Malqvist, Sohel, Do, Eriksson, & Persson, 2010; Gjesfjeld & Jung, 2011). However, despite its demonstrated utility in mapping maternal health, the usage of GIS technology in India is relatively limited.

Women with poor health have a high possibility to give birth to low-weight infants. Therefore, in this study, GIS technology was applied to identify the high priority areas that need intensive maternal health care interventions while understanding the present situation of maternal health in India. The present research makes three-fold assumptions: first, women suffer a heavier burden of ill-health than men, and greater attention must be paid to their health needs. The second assumption points that women who perform nurturing, protecting, and caring and who suffer the most in conflicts require more sensitive healthcare facilities. The third assumption is methodological-driven, assuming that geospatial technology and geo-analytics help decision-makers set a spatial framework for enabling gender sensitive health policies.

Methods

The present study is conducted in four stages (figure 1). In stage one, to achieve an unbiased result, opinions of the experts' from different disciplines (Medical, Psychology, Sociology, Economics, Population Studies, and Geography), who are working with Gender health issues for more than a decade, have been collected following Delphi technique. The Delphi process aims to achieve a consensus opinion among a panel of experts about a given issue. Delphi technique is conducted through questionnaires. After exploring more than 50 indicators on gender health, the following eight health indicators/variables were identified: Maternal Mortality Rate, Maternal Mortality Ratio (MMR), Women suffering from moderate to severe anemia, Modern methods of contraceptive used, Women visited Antenatal care (ANC), Delivery at home, Delivery by skilled persons - births delivered with the assistance of doctors, auxiliary nurse midwives, nurses, midwives, and lady health visitors, and Sex Ratio – number of females per 1000 males. Data were drawn from the National Family Health Surveys (NFHSs) - 4 and Census of India 2011.

In the second stage, data were processed under a GIS environment using each variable's fuzzy membership functions. The fuzzy tools available in ArcGIS software were used for the

geoprocessing. The Fuzzy Membership tool transforms the input raster data to a 0 (non-member) to 1 (member) scale based on the possibility of being a member of a specified set. In the present study, the fuzzy linear transformation function that assigns membership to the user-specified minimum and maximum values is used. Under a positive linear relationship (a positive slope), anything below the minimum is assigned as 0, and anything above the maximum is assigned as 1. A negative linear relationship (a negative slope) is established when the minimum is greater than the maximum. For vulnerability mapping, a positive fuzzy linear transformation function is assigned to Maternal Mortality Rate, MMR, Women suffering from moderate to severe anemia (%), Delivery at home (%). In contrast, a negative fuzzy linear transformation function is assigned to Modern methods of contraceptive used (%), Women who visited ANC (%), Delivery by skilled persons (%), and Sex-Ratio.

In stage three, the generated fuzzy vulnerability maps for all the selected variables were integrated with the intersection based 'AND' operator. To determine the maternal health vulnerability that best meets all criteria/indicators, i.e., have a high likelihood of membership in all sets—the Fuzzy Overlay tool is used. When combining multiple indicators, the Fuzzy Overlay tool explores each cell's likelihood of being a member of each set defined by the multiple criteria. In the last step, the generated map was further correlated to the temperature coefficient variance and terrain distribution for identifying the possible influence of the given geographical factors, if any, on the women's health status in India.

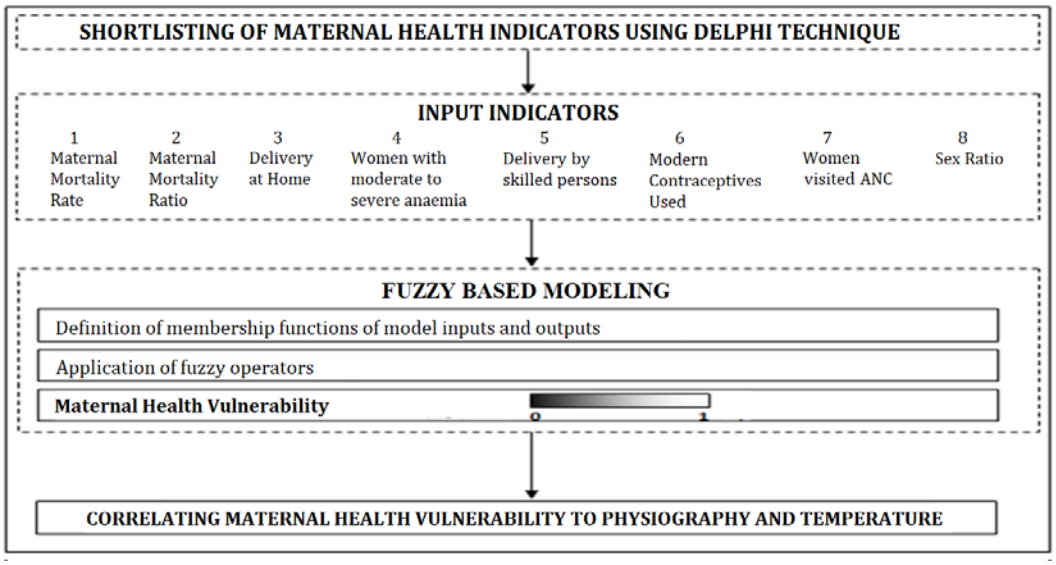

Figure 1: Conceptual framework.

Results and Discussion

The present study has revealed gaps in the maternal health scenario and identified the areas that need intensive measures to reach SDG targets. Owing to the diversity in physiography, cultures, religions, and development levels among India's states and union territories (UTs), the women's maternal health also varies greatly (Table-1). Among the selected variables, many north-eastern states can be found as the least performing states, while Kerala stands out as the best-performing state in most (Figure 2).

Table 1: Performance of maternal health indicators in India.

Sl No.	Indicators	India	Least performing States/UTs.	Best performing States/ UTs
1	Maternal Mortality Rate	7.3 %	Uttar Pradesh (17.8 %)	Kerala (2.1%)
2	MMR	113 per 100,000 live births	Assam (215)	Kerala (43)
3	Women suffering from moderate to severe anemia	13 %	Andaman & Nicobar Islands (23.7 %)	Mizoram (4.4 %)
4	Delivery at home	21.1 %	Meghalaya (49.6 %)	Puducherry (0.1 %)
5	Modern methods of contraceptive used	48 %	Manipur, Bihar, and Meghalaya (24% each)	Punjab (76%)
6	Women visited ANC	83 %	Bihar (55.7 %)	Andhra Pradesh (98.8 %)
7	Delivery by skilled persons	81 %	Nagaland (41 %)	Kerala, Lakshadweep, Puducherry (100 % each)
8	Sex-Ratio	933 females per 1000 males	Daman and Diu (618)	Kerala (1084)

ANC visits increases the likelihood of institutional Delivery. NFHS-4 found that in India, fifty-seven percent of births to mothers who had no ANC visits, compare with ninety-one percent of births to mothers who had four or more ANC visits were delivered in a health facility. Antenatal care has also been a strong predictor of safe Delivery in India's rural areas (Sugathan, Mishra, & Retherford, 2001; Ram and Singh, 2005). Globally sixty percent receive four antenatal care visits, while in India, it is fifty-one percent. Births at home in non-hygienic conditions or are not attended by trained/skilled medical staff are more likely to have severe complications for both the mother and the child. The assistance of doctors, auxiliary nurse midwives, nurses, midwives, and lady-health visitors during childbirth can influence the birth outcome. Since the last decade, India has recorded a substantial increase in skilled assistance during deliveries. Southern states of India are better performers than those of the north and north-east.

Recognizing that maternal mortality can be minimized by discouraging home delivery and facilitating institutional, the Ministry of Health and Family Welfare in India launched Janani Suraksha Yojana (JSY). However, this measure was criticized because the outcome was below satisfaction (Bose, 2007; Jain, 2010; Sinha, 2015). They highlighted that instead of cash assistance to low-income families undergoing institutional deliveries, the government should improve health infrastructure, including road connectivity in the rural areas. A survey conducted by UNICEF and the Ministry of Women and Child Development (MWCD) in 2013–14 on maternal and child health status showed that JSY has got some positive development in the number of deliveries through skilled professionals. Institutional deliveries in India have risen sharply from 47% in 2007-08 to over 78.9% in 2015-16 (NFHS-4), while Safe Delivery has simultaneously climbed from 52.7% to 83.2% in the same period.

Globally one-third of women of reproductive age group 15-49 years have anemia (WHO, 2020). The prevalence of anemia was highest in south Asia and central and west Africa (WHO, 2014). India records fifty-three percent of reproductive age group women to be anemic (NFHS-4, India). Menstruation and childbirth are iron depleting processes in women; thus, an iron-rich diet or supplements is essential to avoid anemically. Anemia varies by maternity status—58 percent of women who are breastfeeding are anemic, compared with 50 percent of pregnant women and 52 percent of women who are neither pregnant nor breastfeeding (NFHS-4, India). This study

has considered moderate to severe anemic cases, which shows that except for Kerala, Tamil Nadu, Goa, Punjab, Himachal Pradesh, and some NE states, the rest have a high vulnerability.

Family planning options to space or limit births can effectively be done if modern contraception methods are available. It is proven that this family planning option is an effective strategy in decreasing maternal and child mortality/morbidity (Mbizvo et al., 2013; Ackerson & Zielinski, 2020). Regarding the current contraceptive use, NFHS-4 reports that between 2005-06 and 2015-16, the use of modern contraceptives has remained unchanged among married women, at just under 50 percent. Female sterilization, used by 36 percent of currently married women, is still the most popular contraceptive method. A relatively low proportion of currently married women uses contraceptive methods in all the smaller states in the northeast region except for Sikkim and Tripura. In large states like Maharashtra, Madhya Pradesh, and Rajasthan, a relatively low proportion of modern contraceptive methods is found.

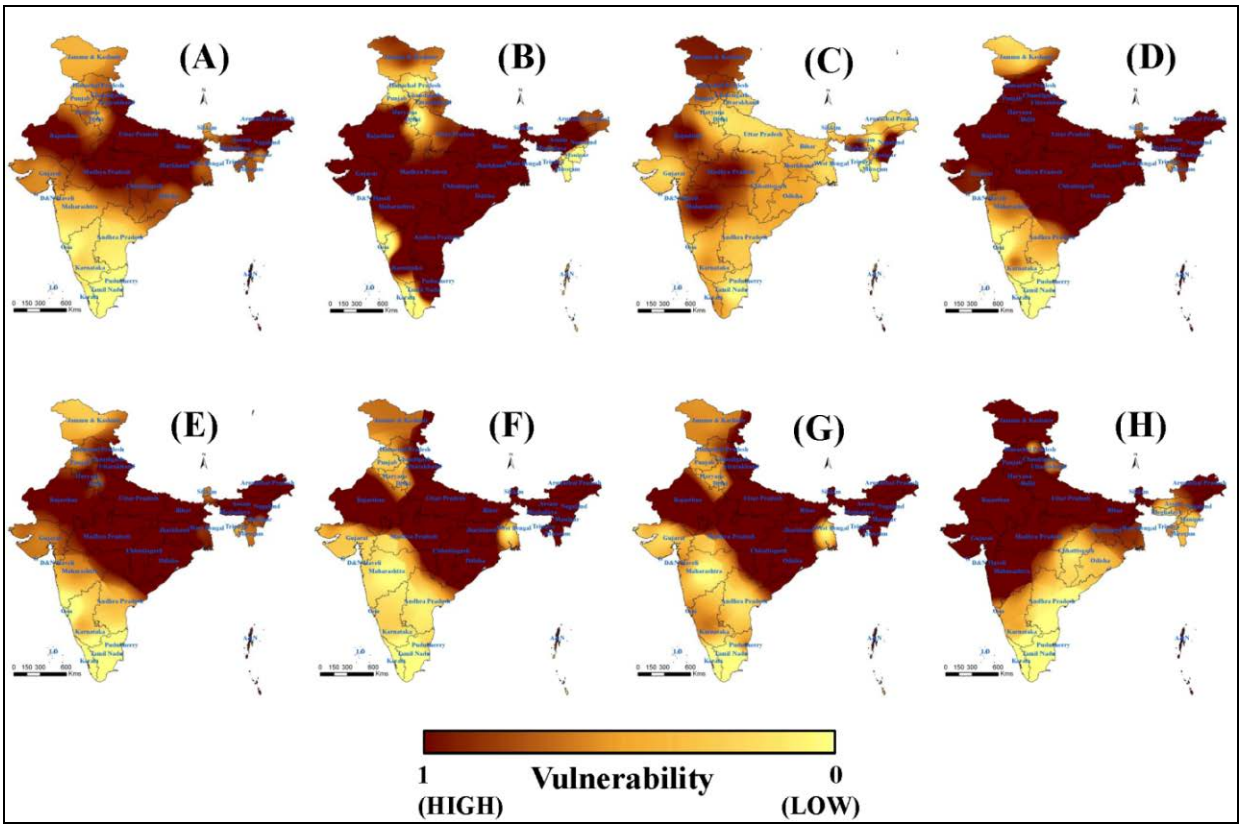

Figure 2: Fuzzy membership vulnerability maps: (A) Women visited ANC; (B)Women suffering from moderate to severe anemia; (C) Modern methods of contraceptive used; (D) Delivery at

home; (E) Delivery by skilled persons; (F) Maternal Mortality Rate; (G) MMR and (H) Sex-Ratio.

According to most epidemiologic literature, the sex ratio denotes males per 1,000 females in a given population. However, in India, it is the number of females per 1,000 males in the defined population. Based on countries where equal care is given, the adult sex ratio is at least 1.05 women-to-men. While in India, the sex ratio between age group 15 and 59 years is 0.94 women-to-men (Census, 2011). Studies have found that in countries where sex-selective abortions are high, adult, and child sex ratios are the most skewed (Shahni et al., 2008; Pham, Hall, & Hill, 2011). Reproductive health decision making is mostly in the hands of either husbands or in-laws in India (Roberts & Montgomery, 2016). So, maternal health is often compromised for sex-selective abortions and pressure to have children until they have at least one son (Chor, Patil, Goudar, Kodkany, & Geller, 2012).

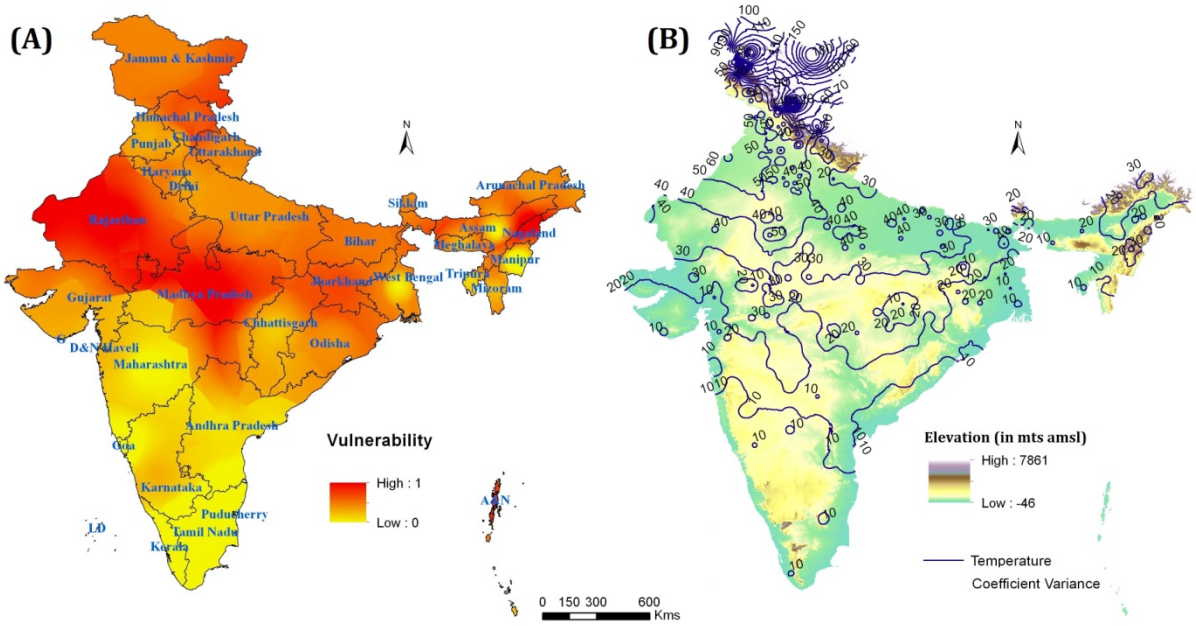

Figure 3: (A) Maternal Health Vulnerability Map of India; (B) Temperature and Elevation

The Maternal Health Vulnerability Map shows that northern states of India are more vulnerable towards maternal health, and therefore, need intensive measures to reach the targets of SDG (Figure 3A). Rajasthan, Madhya Pradesh, and Nagaland are found to be the most

vulnerable. The maternal health vulnerability has no significant correlation with temperature coefficient variance, while a moderately weak correlation (r = 0.3, p=0.05) is found with elevation. This suggests that accessibility of health care services is related to the terrain of a region. The parameter like women visited ANC, Delivery at home, and Delivery by skilled persons of states in the Himalayan region have performed lower than other states.

Considering that the survival and wellbeing of mothers are essential to solve the broader economic, social and developmental challenges of India, Government has taken some key strategies to accelerate the pace of decline in MMR in the last few years, like Pradhan Mantri Surakshit Matritva Abhiyan (PMSMA), Menstrual Hygiene Scheme, sanctioning of Maternal and Child Health Wings (MCH Wings) at District Hospitals/District Women's Hospitals are among few. The NFHS-5 data, yet to be released in 2020, may direct some light if these programs positively affect the maternal health situation in India.

Conclusion

The present study highlights India's maternal health situation and identifies the vulnerable states that need a focused intervention. The indicators and the methodology applied in the study have efficiently captured the maternal health vulnerable regions in India. Besides improving the maternal health infrastructure, the attention should also be on improving the road linkages for their better accessibility and medical coverage for curbing late maternity deaths. A district-level study is needed for a broader analysis to identify the maternal health gaps at the micro-level.

Disclosure statement

The authors report no conflict of interest.

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