Original Article

Geospatial Analysis of Child Leprosy Cases and Block-Level Endemicity in Raigad District, Maharashtra (2018-19 to 2023-24)

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ABSTRACT

Background: Leprosy remains a public health Problem in few pockets of India, including the Raigad district, where prevalence rate exceeds 1/10000 population and child proportion is notably high. Understanding its spatial distribution is a crucial guide for targeted public health interventions as it reflects the community's ongoing case transmission especially in endemic areas due to possibility of close contact transmission and high exposure levels in community. **Aims:** The study aimed to analyse the spatial distribution and geographical patterns of child leprosy in Raigad district, Maharashtra to identify high-risk areas. **Methods**: A retrospective data analysis of 3,927 leprosy cases, including 572 children aged ≤14 years was conducted using open-source GIS software (Version 3.8) from April 2018 to March 2024. **Results:** Children constituted 12% of the cases, with a child rate of 3.3 per 100,000 population. The spatial analysis identified Karjat and Panvel as hotspots with over 100 new cases annually. Other blocks exhibited varying levels of endemicity with uneven distribution of Child leprosy cases. Kernel density estimation revealed high-density hotspots of PB and MB child leprosy cases in multiple habitats. **Conclusion:** The study highlights the heterogeneity in the spatial distribution of child leprosy, emphasizing that GIS mapping and spatial analysis can be essential tools for devising targeted strategies to reduce the incidence of child leprosy.

Key words: GIS, PB Child, MB Child, Grade II disability, Geospatial analysis

Despite a reduction in the global leprosy burden over the past decade, India still accounts for approximately 77% of leprosy cases in Southeast Asia and 54% of the global burden of pediatric leprosy .This depicts an active circulation of M. leprae bacilli building endemicity [1]. Child leprosy is a significant public health challenge in many regions of the world [2]. Therefore, in leprosy endemic countries like India, Brazil and Indonesia, the high detection rate of cases in children of under 15 years of age helps to monitor the endemic [3]. The World Health Organization (WHO) has set ambitious targets to aim for zero leprosy by 2030 [4].

Child leprosy percentage is a crucial indicator of the program's operational effectiveness reflecting the community's ongoing case transmission especially in endemic areas due to possibility of close contact transmission and high exposure levels in community [5, 6]. WHO global strategy emphasises global target of 90% reduction in rate per million children of new child cases with leprosy, thereby promoting early detection and reduction of transmission [4]. Current National Leprosy Eradication Programme (NLEP) data indicates 5,586 (5.38%) child leprosy cases and grade II disability among 2362(2.28%) of children in 2022-23 (NLEP 2022-23) [5, 7].

Geographic information systems (GIS) and spatial statistical techniques have proven instrumental in identifying high-risk areas, and factors contributing to disease transmission [8, 9]. GIS can serve as an important tool to determine geographic distribution; analysing spatial and temporal trends; mapping populations at risk and stratifying risk factors of leprosy [10, 11]. It further helps for planning and targeting interventions; and monitoring diseases and interventions over time [12]. The partial analysis and GIS maps have been reported to be used by the managers and service providers during the problem identification process,

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and referred to in resource allocation processes [13]. Several studies have emphasized the importance of spatial analysis in understanding the transmission dynamics and geographical clustering of leprosy cases [14,15]. A multitude of factors including socio-economic, environmental, and demographic characteristics, contribute to the intricate epidemiological landscape of leprosy. Through the utilization of geospatial analysis techniques, this study seeks to determine the distribution of child leprosy cases within high and low endemic blocks, delineating clusters of child leprosy cases at the habitat level. Moreover, the study aims to provide valuable insights into the spatial epidemiology of the disease, thereby guiding targeted interventions for its control and prevention.

MATERIAL AND METHODS

This retrospective record-based study focused on children aged ≤14 years diagnosed with leprosy between April 1, 2018, and March 31, 2024, in the high leprosy-endemic district of Raigad, Maharashtra, India. The district was selected due to the identification of geospatial analysis of Child leprosy, including hotspot identification and block-level endemicity categorization. Raigad district represents 2.34% of the state's populace and accounts for 8% of the total newly identified leprosy cases within the state. The cases were aggregated yearly and were then compiled. A total, of 3,927 newly diagnosed leprosy cases were mapped at the block and habitat levels, including 134 new cases with Grade II disabilities and 572 cases among children.

The data collection, as outlined by the NLEP, was carried out by medical officers using the USIS-LF1 (Upgraded Simplified Leprosy Information) proforma to document information. A leprosy case was defined and classified as Paucibacillary (PB) and Multibacillary (MB) types as per WHO Guidelines by trained medical officers [16].

A habitat-wise line listing of leprosy cases and associated details was compiled. This data was aggregated at the block level, and a master list of villages within each block was generated. Village and block names from the data files were matched with names and codes in the shapefile, and the files were merged using open-source QGIS software, version 3.8. Kernel density estimation was used to identify high intensity of leprosy areas (hot spots). The density of points in an area were calculated and population around those points was considered for hotspots [17, 18]. The resulting maps showed hot spots, areas with a high density of cases. The accuracy of the village-wise and block-wise attribute tables was verified. Geospatial analysis and mapping of leprosy cases were performed using open-source tools. Epidemiological indicators were also calculated, and weightage was assigned to classify block-level endemicity, providing a comprehensive overview of the leprosy burden at the block level. A cutoff was determined for categorizing the endemicity of the blocks. Blocks were classified into high endemic (total score greater than 204, corresponding to the 75th percentile), moderate endemic (total score between 52 and 204, corresponding to the 50th to 75th percentile), and low endemic (total score less than 52, corresponding to the 25th percentile)]

RESULTS

The cumulative Prevalence Rate (PR) was determined as 1.6 cases per 10,000 individuals in Raigad district over the past six years. Notably, the cumulative annual new case detection rate (ANCDR) stands at 23.6 cases per 100,000 population, with children constituting 12% of these cases, leading to a child rate of 3.3 cases per 100,000 population. The child leprosy constituted 14.56% cases of total new leprosy cases Additionally, the proportion of Grade II disabilities was observed to be 4.0 %.

Categorisation of leprosy endemicity and leprosy burden: The priority of blocks was determined by the weightage assigned to indicators and other epidemiological Indicators outlined in **Table 1**. Among all blocks, 4 (27%) were classified as high endemic, 8(53%) as moderate endemic, and 3(20%) as low endemics.

At the block level **(Fig. 1),** the distribution of average newly detected leprosy cases (PB and MB) was mapped. Two blocks in the northern part of the district, Karjat and Panvel, emerged as hotspots, each reporting over 100 new leprosy cases on average per year. In stark contrast, Tala and Poladpur reported the lowest average, with less than ten new cases annually. Khalapur, Pen, and Roha fell in the mid-range, with reported cases between 50 and 100 per year. Following closely behind were Sudhagad, Mangaon, and Mahad, each reporting an average of 30 to 50 new cases annually. The remaining five blocks reported an average of 10 to 30 new cases per year, contributing to the broader landscape of leprosy incidence across the district. All coastal blocks demonstrated a moderate level of endemicity for leprosy.

Geospatial Distribution of Child Leprosy at the Block Level: The occurrence of average child leprosy cases across the 15 blocks is illustrated in **Fig 2.1.** Although all blocks reported child leprosy cases, the frequency varied. The average number of child leprosy cases per block during the period indicates less than five cases in nine blocks, five to ten cases in three blocks, and more than ten cases in three blocks. Notably, six blocks (Uran, Alibag, Murud, Shrivardhan, Mangaon, Mahad) exhibited between one and five cases each, while three blocks (Panvel, Karjat, Khalapur) documented more than ten cases.

The child rate per one lakh population was mapped comprehensively across all blocks within the district **(Fig 2.2).** Sudhagad reported the highest average child leprosy rate of 11.8 per 100,000 Population, followed by Karjat with 9.1. Khalapur and Roha reported rates of 5.4 and 5.1, respectively. Mangaon, Mahsala, Alibag, and Poladpur each reported less than one, while the remaining seven blocks had an average child leprosy rate ranging from one to five per 100,000 Population.

Table 1- Epidemiological indicators (Cumulative) and endemicity of the blocks of Raigad District (1st April 2018 -31st March 2024)

Blocks	New leprosy cases	Grade II Disabilities among new cases	Balance cases	New child cases	** Categorisation of Blocks
Panvel	736	15	591	108	High endemic
Karjat	730	18	425	131	High endemic
Khalapur	426	14	257	76	High endemic
Pen	385	25	249	52	High endemic
Roha	328	23	211	51	Moderate endemic
Sudhagad	241	12	172	54	Moderate endemic
Mahad	228	4	155	20	Moderate endemic
Mangaon	216	0	161	13	Moderate endemic
Uran	160	1	109	27	Moderate endemic
Alibag	149	13	96	12	Moderate endemic
Murud	107	2	65	13	Moderate endemic
Shrivardhan	90	1	69	8	Moderate endemic
Mahsala	74	2	57	4	Low endemic
Poladpur	35	1	22	1	Low endemic
Tala	22	3	13	2	Low endemic
Total cases	**3927**	**134**	**2652**	**572**	

*[**"The geometric mean was calculated for each leprosy data element (new cases, G2D, child cases, registered prevalence, i.e., balance cases). Weighting was applied as follows: new case detection (40%), number of new cases with G2D (20%), number of child cases (20%), and registered prevalence (20%). A cutoff was determined for categorizing the endemicity of the blocks. Blocks were classified into high endemic (total score greater than 204, corresponding to the 75th percentile), moderate endemic (total score between 52 and 204, corresponding to the 50th to 75th percentile), and low endemic (total score less than 52, corresponding to the 25th percentile)]*

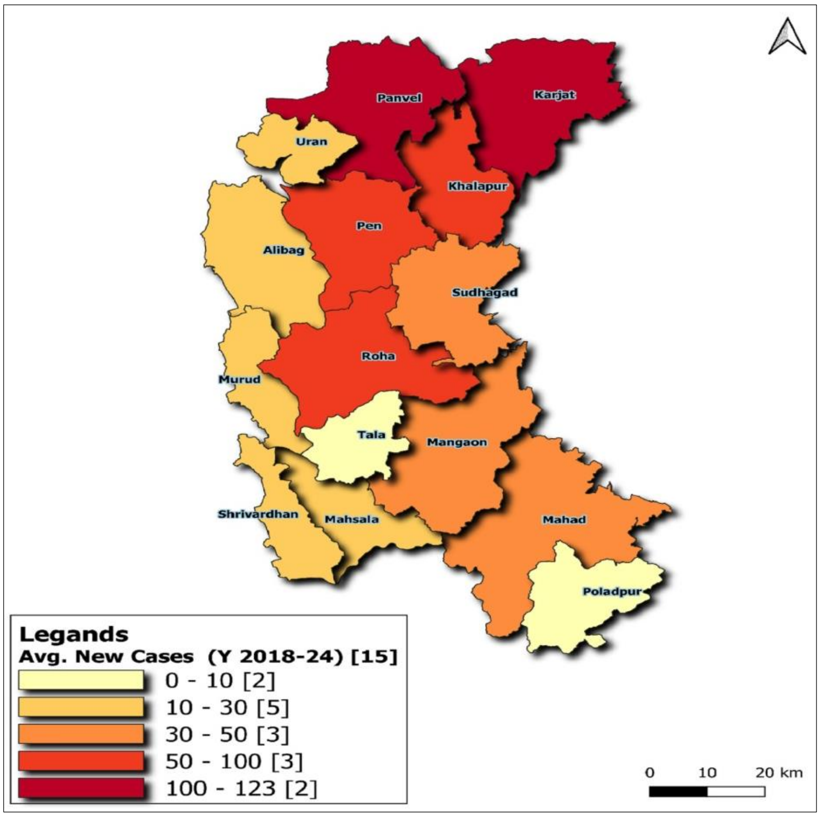

Figure 1: Distribution of average newly detected leprosy cases across all blocks of Raigad District.

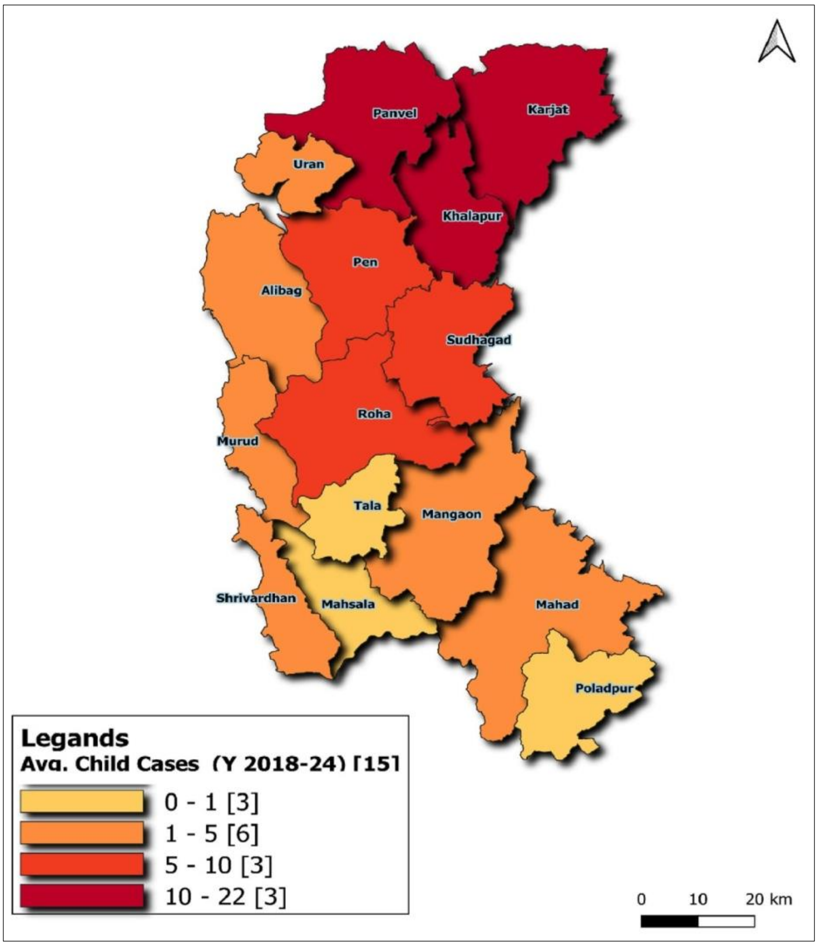

Figure 2.1: Geospatial distribution of average child leprosy cases across all blocks of Raigad District.

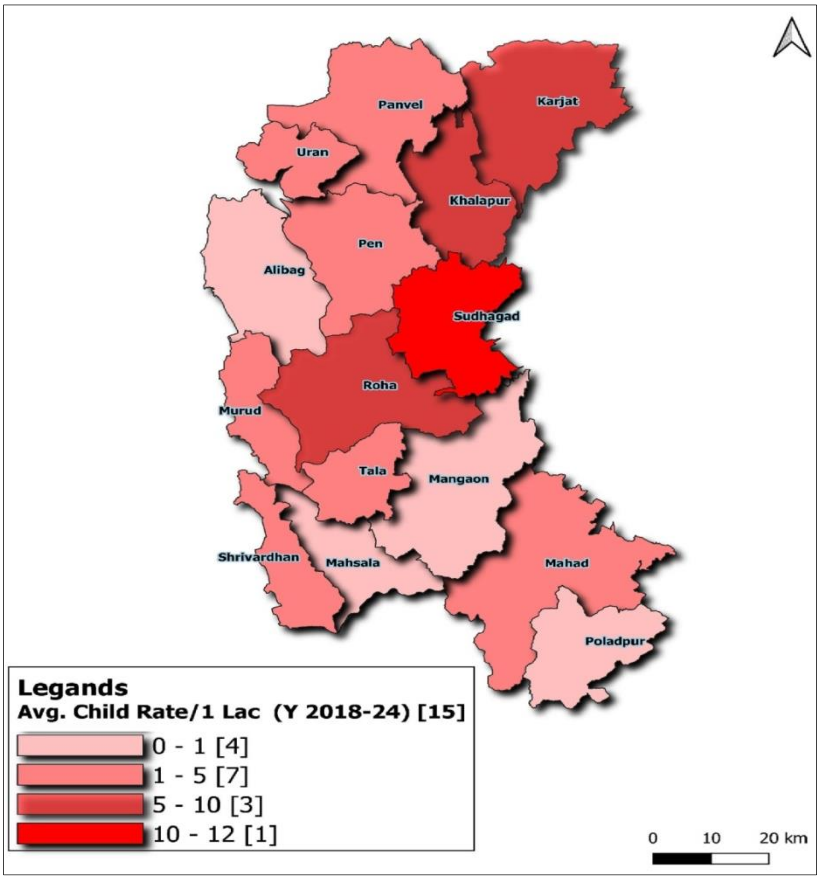

Figure 2.2: Geospatial distribution of average child rate per one-lac population across all blocks of Raigad District.

Geospatial distribution of Child leprosy at Habitat level:

Out of 1,860 habitats, 225 (12.1%) had reported new cases, each reflecting varying frequencies of transmission. Analysis of the distribution of child MB cases at the habitat level revealed that, out of 1,860 habitats, 61 (3.3%) had MB cases. One habitat each in Pen and Roha, two in Panvel, and one in Khalapur showed the highest numbers of MB child cases of leprosy. Nevertheless, 48 habitats (2.58%) reported a solitary case of MB child leprosy, with eight habitats documenting more than one to five MB cases. Moreover, five habitats indicated more than five to 11 MB cases of child leprosy.

Similarly, the distribution of PB Child cases was seen in 192 habitats. It showed higher frequency in the northern blocks of Raigad district. Panvel, Karjat, and Sudhagad had habitats with a higher number of PB Child cases. Nonetheless, 120 habitats (2.58%) reported a singular case of PB child leprosy, with 59 habitats exhibiting more than one to five PB cases. Furthermore, 13 habitats documented more than five to 24 PB cases of child leprosy.

Child leprosy Hot spots - The analysis, conducted using interpolation kernel density estimation, calculated the density of these hotspots with precision. Hot spot mapping of PB **(Fig. 3.1)** and MB **(Fig. 3.2)** child cases at the habitat level revealed several high-density areas. The maps highlighted significant concentrations (kernel density estimation) of PB child leprosy cases in Panvel, Khalapur, Pen, and Roha, while MB hotspots were located in the habitats of Panvel, Khalapur, Pen, Alibag, Sudhagad, Roha and Uran.

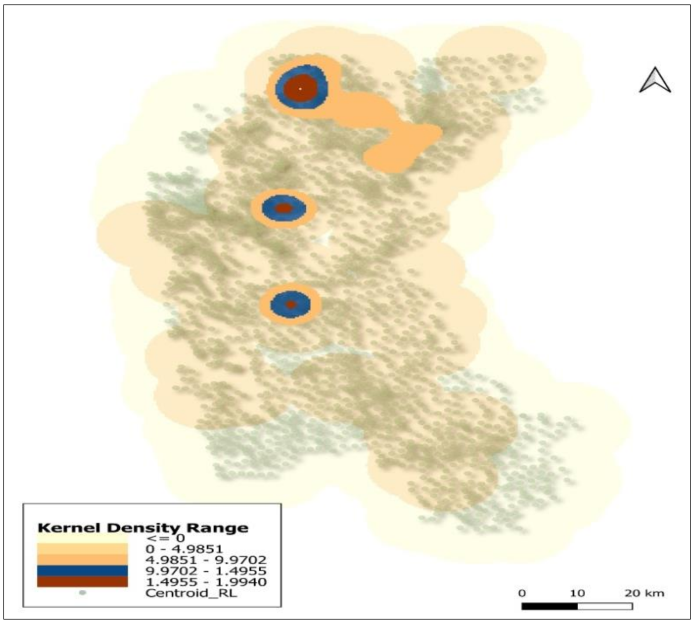

Figure 3.1: Hotspot mapping of Paucibacillary (PB) child leprosy cases at the habitat level in Raigad District.

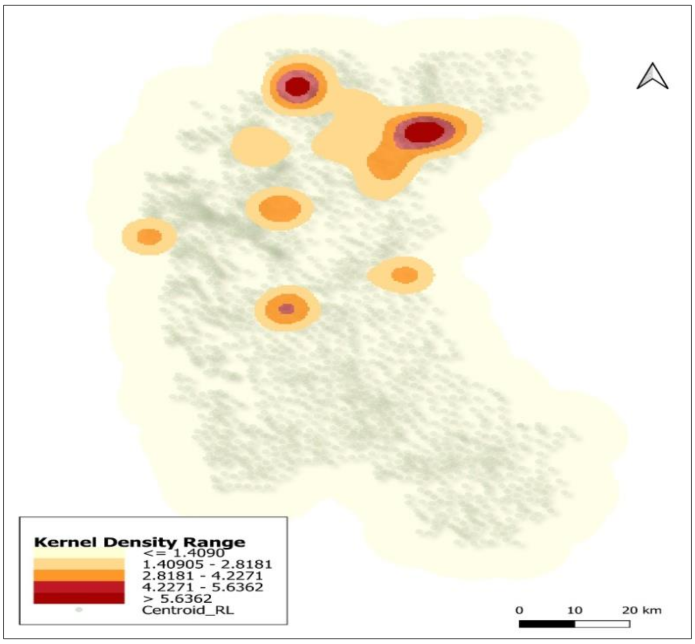

Figure 3.2: Hotspot mapping of Multibacillary (MB) child leprosy cases at the habitat level in Raigad District.

DISCUSSION

India achieved elimination of leprosy as a public health problem but there are high endemic pockets with variable endemicity. The current PR of India is 0.57 with Maharashtra still showing PR more than one [7, 19]. with Raigad district reporting a high PR of 1.8 per 10,000 in 2010 [20]. The study showed child rate of 3.3 cases per 100,000 population. Additionally, the proportion of Grade II disabilities was observed to be 4.0 %. The childhood leprosy constituted 14.56% cases of total new leprosy cases which is higher than earlier reports from eastern India (10.4%) [21], north India (4.81%) [22], Chhattisgarh (7.56%) [23]. This reflects high rates of ongoing transmission in Raigad and possible gaps in leprosy elimination. The study further assessed the temporal and spatial trends of leprosy in Raigad district, Maharashtra, India.

It is probably first report from Indian settings adopting GIS and sophisticated spatial analysis techniques to map the distribution of child leprosy cases within high and low endemic blocks, delineating clusters of cases at the habitat level in India. Our analysis revealed that the epidemiological metrics of Raigad district exceeded state (Maharashtra with PR of 1.103and national averages (India having PR of 0.57), underscoring its high endemicity with pronounced ongoing transmission of leprosy depicting a modest decline in PR to 1.6 per 10,000. It further covered spatial analysis of child leprosy cases in whole Raigad district compared to earlier study reporting trends and spatial clustering of leprosy cases in only one (Panvel) block of Raigad district [20]. It showed disparity within the blocks and habitats of Raigad district with respect to endemicity such as all coastal blocks demonstrating a moderate level of endemicity for leprosy. Hence, block and district approaches for leprosy intervention may turn helpful to define population-level elimination strategies [19].

The emergence of new child leprosy constituted merely 3% (MB) and 4% of (PB). Furthermore, our analysis reveals a notable aggregation of such cases within regions characterized by heightened endemicity [24]. Additionally, child leprosy cases exhibited spatial heterogeneity, showing significant clustering of all childhood leprosy cases in some habitats similar to studies reported from Brazil and Nigeria [15, 25]. Thus, the habitat-level analysis provided insights into the distribution of leprosy cases within local communities and GIS maps provided visual representations of the distribution of child leprosy, facilitating a comprehensive assessment of disease burden and hotspot identification. This emphasizes that a contextualized spatial approach can identify clusters in high-endemic districts more precisely than a standard statistical approach [26].

The study also showed that the GIS mapping approach differentiates between MB and PB cases. The higher number of child PB cases indicates the importance of active case detection in these areas whereas high percentage of MB cases highlights a significant gap in early case detection and treatment in these areas. This approach enables a more nuanced understanding of disease dynamics as also reported in earlier studies [27], to guide intensified case management or contact tracing which is a crucial aspect as source of infection in children could be familial or nonfamilial close contacts. GIS can play an integral role in guiding contact tracing efforts and active case finding when index case is child [28, 29]. Identification of child cases signifies an urgent need for timely detection of new cases and prompt MDT treatment to halt the ongoing spread of the disease The presence of Grade II disability in childhood leprosy cases is indicative of delayed diagnosis at primary level which warrants the need of devising strategies for early detection and completion of MDT of all cases in a community as per the basic tenets of the enhanced WHO's global strategy [30].

The findings of this research, highlight the complex spatial epidemiology of leprosy in Raigad district emphasizing the importance of understanding the spatial distribution and geographical patterns of child leprosy for effective disease control. The spatial analysis in this study elucidates the high incidence of early childhood leprosy transmission. This approach will identify hotspots and enable targeted interventions aiming to achieve the key milestone of zero child cases in leprosy elimination [31, 32].

Limitations: The study relied on operational data from public health facilities, which included only a limited set of disease-related variables and lacked details on Socioeconomic and environmental factors due to data unavailability, limiting the understanding of underlying causes. The study focused on spatial distribution at the habitat level, excluding other disease variables. Further, Public health facilities without geocoordinates also prevented the assessment of health service accessibility.

CONCLUSION

The study highlights the heterogeneity in the spatial distribution of child leprosy, emphasizing that GIS mapping and spatial analysis can be essential tools for devising targeted interventions to reduce the incidence of child leprosy. In conclusion, by leveraging GIS mapping techniques, public health authorities can identify high-risk areas to allocate resources efficiently, and implement context-specific interventions. However, further research envisaging implementation of GIS technologies to address childhood leprosy may be undertaken to accelerate progress towards leprosy elimination goals.

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