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Original Article

Investigating the Changing Landscape of Leprosy Cases and Geospatial Analysis: A Study of High and Low Endemic Districts in Maharashtra, India

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Despite significant reduction in prevalence of leprosy to elimination levels, achieving Leprosy Mukt Bharat by 2027 is still a far-fetched target. This article highlights trends and of distribution of leprosy in Gadchiroli (high endemic) and Sangli (low endemic) districts in Maharashtra, India between April 1, 2016 to November 31, 2022. The geospatial analysis revealed clustering of leprosy habitats in Gadchiroli comparatively more than Sangli where urban clusters of leprosy habitats were observed. In Sangli, there was a significantly higher proportion of multibacillary cases and grade I disabilities. Additionally, there was a noticeable shift in the age distribution of newly identified cases to the 36–65 years age group. In Gadchiroli, an increasing proportion of cases were observed in the 9–14 years age group. It suggests that environmental factors, socio-economic conditions, and healthcare access can influence age-specific patterns of leprosy transmission. Hence, understanding the intricacies of age shifting in leprosy cases is essential for developing tailored interventions within high and low endemic areas.

Keywords: Leprosy, Child leprosy, Elimination, Multibacillary, Paucibacillary, GIS, Maharashtra, India

Introduction

Despite a significant reduction in the prevalence rate (PR) of leprosy to 0.45 per 10,000 population and a decline in the annual new case detection rate (ANCDR) to 5.09 per 100,000 population as of 31st March 2022 (National Strategic Plan and Roadmap for Leprosy 2023–2027), achieving the goal of a "Leprosy Mukt Bharat" by 2027 is still a far-fetched target. As per data from the National Leprosy Eradication Programme, India (NLEP), leprosy states like Uttar Pradesh (20,492), Bihar (17,471), and Maharashtra (15,812) in India still contribute to high burden of leprosy (Sharma and Singh 2022). Maharashtra's PR was above 1 for past few years attributed to the poor performance of Vidarbha region with

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Gadchiroli district emerging as having high PR of 4.5/10,000 and ANCDR 50/100,000. Though current NLEP statistics (2020) reveal PR and ANCDR of Maharashtra as 0.79 and 12.91 per 100000 population respectively, it exceeds national average of PR of 0.57 and ANCDR of 8.13 per 10000 population (Directorate General of Health Services n.d.). Further, even within state of Maharashtra better performing districts like Satara and Pune (with PR around 0.5/10,000) show disparities with respect to gender, urban-rural area highlighting possibilities of high endemic clusters within low endemic zones (Mohite et al 2013, Katkar et al 2017). This uneven distribution of leprosy cases within low endemic zones warrant crucial need to identify high-risk clusters of leprosy cases for targeting intervention (Katkar et al 2017). The overarching goals of curtailing disease transmission and attaining zero disabilities among newly diagnosed childhood cases constitute pivotal pillars of contemporary strategy of World Health Organization (WHO) and NLEP (Gitte et al 2016). Considering this, the objectives of present research were to conduct the geospatial analysis and investigate trends and spatial distribution concerning leprosy cases, including considerations of age, gender, clustering dynamics, and types, within the confines of Gadchiroli, recognized as a high endemic zone, and Sangli, characterized as a low endemic zone, situated in the precincts of Maharashtra.

Material and Methods

A retrospective record-based study was conducted among the population affected with leprosy between April 1, 2016, and November 31, 2022, in Gadchiroli and Sangli districts of Maharashtra. The district selection criteria were based on multifaceted epidemiological parameters, including the incidence of new cases, prevalence rates, occurrences of Grade II Disabilities among children, as well as demographic factors such as district population size and geographical expanse in square kilometers. Active case detection strategies were implemented according to micro plan. Village-level female workers and male volunteers conducted screenings for the entire population, identifying suspects who were later confirmed by medical officers and were then included in the study. All patients were categorized according to the WHO classification (Brandsma & van Brakel 2003). A leprosy case was defined as a person exhibiting one or more cardinal signs of leprosy, i.e., "definite loss of sensation in a hypopigmented or reddish skin patch; thickened or enlarged peripheral nerve, with loss of sensation and/or weakness of the muscles supplied by that nerve along with microscopic detection of bacilli in a slit-skin smear". Cases were further classified into Paucibacillary (PB) case having 1 to 5 skin lesions, without demonstrated presence of bacilli in a skin smear) and Multibacillary (MB) case having more than five skin lesions; or with nerve involvement or with demonstrated presence of bacilli in a slit-skin smear, irrespective of the number of skin lesions. Disability classification was based on the grading of severity of impairments in the hands, feet, and eyes, ranging from zero to two as per WHO Criteria i.e., Grade 0 – absence of disability with no visible damage or deformities in eyes (including lid closure), hands, and feet; Grade I – loss of protective sensibility in the eyes, hands, or feet, with no visible damage or deformities; and Grade II – presence of deformities or visible damage in the eyes, visible damage in hands or feet.

The data was recorded using ULF1 proforma i.e., age, sex, type of leprosy, disability. Data collection

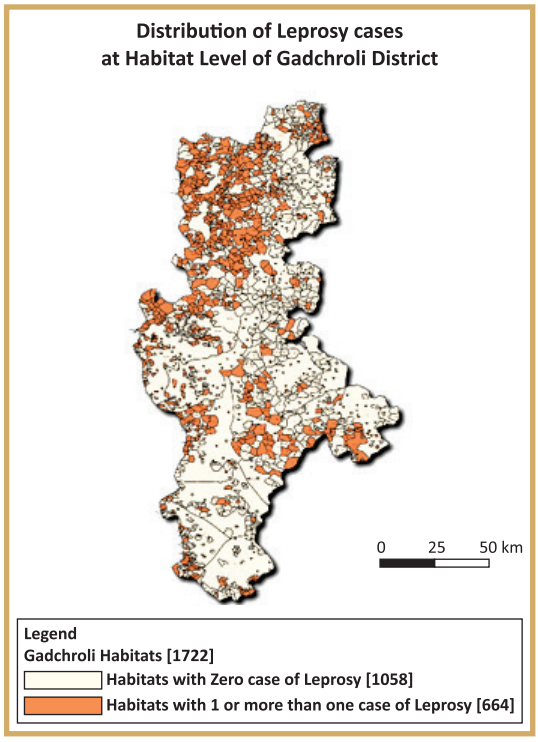
followed the standardized parameters outlined by the National Leprosy Eradication Programme. Program-related data was collected from Primary Health Centres (PHCs) and compiled at the district level after ensuring completeness. The data was entered in MS Excel for analysis to describe proportions, mean values, and statistical test were applied as applicable. The leprosy data, categorized by habitat, was entered into an Excel sheet. Subsequently, it was joined with shapefiles of districts and integrated into Open Geographic Information Systems (GIS) software to produce maps illustrating the number of cases and transmission/non-transmission zones in Sangli and Gadchiroli Districts.

Results

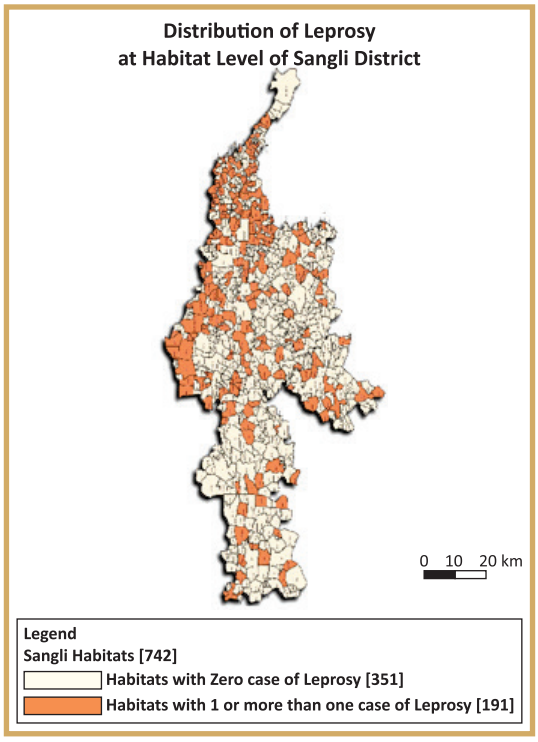
A total of 5869 cases were detected in Gadchiroli whereas 708 cases were detected in Sangli during the study period. All leprosy cases diagnosed during the study period were initially considered. However, to ensure data completeness, only cases with comprehensive information on leprosy classification, age, sex, type of leprosy, disability status, and postal address availability were included in the final analysis. Consequently, a total of 4,576 cases from Gadchiroli and 612 cases from Sangli were analysed.

Demographic details and Leprosy epidemiological scenario in Gadchiroli:

The Gadchiroli district, located in the easternmost



(Fig. 1.1)



(Fig. 1.2)

Distribution of leprosy cases in the habitats of Gadchroli (Fig. 1.1) and Sangli (Fig. 1.2) districts.

part of Maharashtra, accounts for approximately 0.95% of the state's total population. As per the 2011 Census, Gadchiroli had a population of 1.07 million, predominantly tribal, with a population density of 74 persons per square kilometer and a geographical area of 14,412 square kilometers. The literacy rate was 70%, and the per capita income (PCI) was ₹43,058.

In Gadchiroli District, the epidemiological indicators of leprosy for the year 2022 were significantly higher, with a child leprosy rate of 3.22 per 100,000 population, Annual New Case Detection Rate (ANCDR) of 83.05 per 100,000 population, Prevalence Rate (PR) of 5.94 per 10,000 population, a Grade II disability percentage of 0.39%, and Multibacillary (MB) proportion of 43.7%.

Demographic details and Leprosy epidemiological scenario in Sangli:

Sangli district, in western Maharashtra, comprises 2.51% of the state's population. As of 2011, it had 2.88 million residents, higher urbanization, a population density of 329 per sq. km, an area of 8,572 sq. km, and a literacy rate of 82%. Its per capita income (₹71,196) surpassed that of Gadchiroli.

The epidemiological indicators of leprosy in Sangli District for the year 2022 showed a child leprosy rate of 0.45 per 100,000 population, Annual New Case Detection Rate (ANCDR) of 4.88 per 100,000 population, Prevalence Rate (PR) of 0.30 per 10,000 population, a Grade II disability percentage of 0.8%, and a Multibacillary (MB) proportion of 58.1%. In comparison, the leprosy epidemiological data indicated that Gadchiroli District had a significantly higher leprosy burden than Sangli District.

Habitat-Level Geospatial Mapping and Analysis of Leprosy in District Gadchiroli:

As depicted in Fig. 1.1, the analysis of leprosy transmission dynamics at the village level in Gadchiroli district showed that out of a total of 1,722 villages (habitats), 1,058 (61.4%) reported no leprosy cases, while 664 (38.6%) had one or more reported cases of leprosy. Gadchiroli exhibits a more widespread distribution of

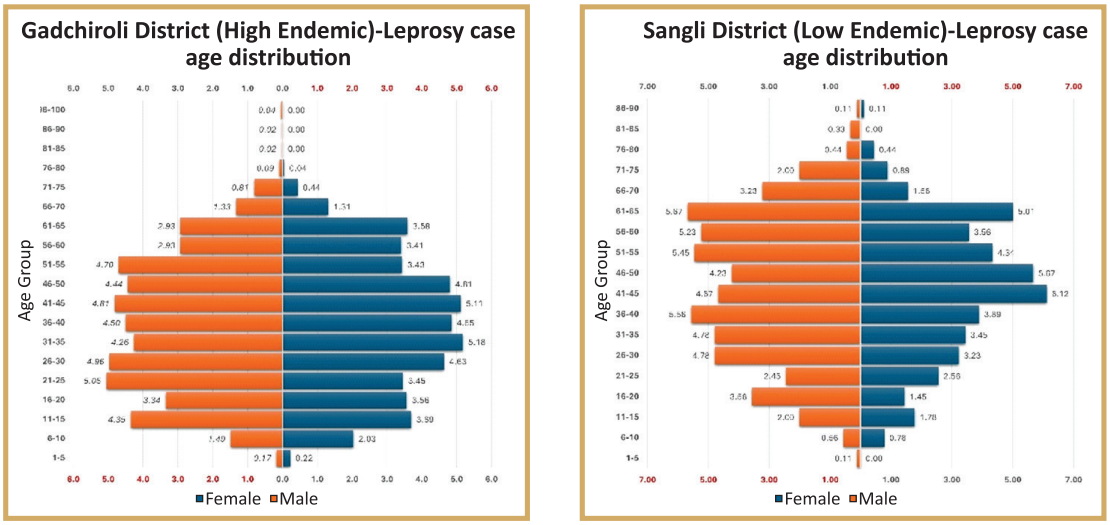


Fig. 2: Age distribution of leprosy cases in Gadchiroli and Sangli districts.

affected habitats. Notably, Gadchiroli exhibited a higher degree of clustering, with leprosy habitats concentrated in specific rural and tribal areas. A geospatial analysis of leprosy habitats in Gadchiroli districts revealed clustering patterns of leprosy cases in three endemic blocks.

Habitat-Level Geospatial Mapping and Analysis of Leprosy in District Sangli:

As depicted in Fig. 1.2, the analysis of leprosy transmission dynamics at the village level in Sangli district revealed that out of 742 villages (habitats), 551 (74.3%) had no reported leprosy cases, while 191 (25.7%) reported one or more cases of leprosy. Sangli district displayed a more dispersed pattern, with urban clusters of leprosy habitats emerging as a prominent feature. This divergence in clustering patterns may be attributed to differences in socioeconomic factors, healthcare access, and environmental conditions between the two districts.

Age-Wise Patterns of Leprosy in Gadchiroli and Sangli Districts:

As illustrated in Fig. 2, our analysis reveals a notably higher prevalence of leprosy among adolescents aged 11-15 years in Gadchiroli (4.35%) compared to Sangli (3.59%). Conversely, a higher incidence of leprosy is observed among the elderly population in Sangli, particularly in the age groups of 26-30 (7.0%), 36-40 (5.07%), 51-55 (5.23%), and 61-65 (5.72%) years, compared to similar age groups in Gadchiroli.

Table 1 : Characteristics of patients identified in the two Gadchiroli and Sangli districts of Maharashtra as per State Health Records from April 2016 to Nov 2022.

S No.	Leprosy cases characteristics		Gadchiroli district	Sangli district
1.	Total patients detected		5869	708
2.	Total patients analysed in the analysis*		4576 (77.97%)	612 (86.4%)
3.	Type of leprosy according to operational classification	PB	2654 (57.99%)	226(36.93%)
		MB	1922(42.01%)	386(63.07%)
4.	Disabilities observed	Total disabilities	199 (4.35%)	109 (17.81%)
		Grade 1	113(2.47% of total cases, 56.78% of total disabilities)	102(16.67% of total cases, 93.58% of total disabilities)
		Grade 2	86 (1.88% of total cases, 43.21% of total disabilities)	7 (1.14% of total cases, 6.42% of total disabilities)
5.	Gender	Male	2299 (50.24 %)	357 (58.33 %)
		Female	2277 (49.76%)	255 (41.67 %)
6	Place of living	Rural	4329(94.6%)	484(79.08%)
		Urban	247(5.4%)	128(20.92%)

- To ensure completeness of data, only cases with comprehensive information on leprosy classification, age, sex, type of leprosy, disability status, and postal address availability were included in the final analysis. Consequently, a total of 4,576 cases from Gadchiroli and 612 cases from Sangli were analysed.
- PB- Paucibacillary, MB- Multibacillary

Table 2 : Age distribution of leprosy cases in Gadchiroli and Sangli District of Maharashtra as per State Health Records from April 2016 to Nov 2022.

Age wise distribution of Leprosy cases	Gadchiroli district	Sangli district
Total cases*	4576	612
1 to 14 years	448(9.79%)	46 (7.52%)
15 to 45 years	2557(55.88%)	318 (51.96%)
More than 45 years	1557(34.33%)	248 (40.52%)

*Total patients analysed in the analysis

Furthermore, statistical analysis revealed a significant difference in the mean age of leprosy cases between high and low endemic areas, with the 9-14 years age group exhibiting a higher mean age in the high endemic Gadchiroli district compared to the low endemic Sangli district.

Comparative Analysis of Key Leprosy Variables in Gadchiroli and Sangli Districts :

As shown in Table 1, males were significantly more affected in Gadchiroli ($p<0.001$) whereas the number of females identified in both the districts were proportionately lower with male to female ratio of 1:0.9 and 1:0.7 in Gadchiroli and Sangli respectively indicating a gender disparity in disease distribution. The male-to-female disparity among newly detected leprosy cases was more pronounced in Sangli compared to Gadchiroli. Further, it was observed that Multibacillary cases were significantly higher in Sangli whereas paucibacillary presentation was more common in Gadchiroli ($p<0.001$). The analysis of Grade I and Grade II disability ratios versus patient identified ratios in Gadchiroli and Sangli districts revealed distinct patterns. In Gadchiroli district, the Grade I disability ratio was approximately 1:40.4, indicating that 2.47% of patients identified had Grade I disability. Similarly, the Grade II disability ratio was 1:53, suggesting that 1.88% of patients identified had Grade II disability. In contrast, Sangli district exhibited a significantly higher Grade I disability ratio of 1:6, corresponding to 16.67% of patients identified. Conversely, the Grade II disability ratio in Sangli district was 1:87, indicating a lower proportion of patients with Grade II disability compared to Gadchiroli district.

As may be seen in Table 2, leprosy cases were proportionately higher in age group of more than 45 years in low endemic district (Sangli). In contrast, the proportion of cases among individuals aged up to 14 years was slightly higher in Gadchiroli at 9.79% compared to 7.52% in Sangli. It was observed that leprosy infected menopausal women were proportionately lower in both the districts [550 (24.15%) in Gadchiroli and 68(16.67%) in Sangli] without any significant association amongst them.

Discussion

India shoulders a significant burden of leprosy compared to the global scale, yet there is noticeable geographical variation and pocket endemicity across different regions. Despite this, the phenomenon of age shifting observed in high and low endemic areas remains relatively understudied, with a limited understanding of the underlying factors influencing this trend.

This study presents the first report from India investigating the spatiotemporal dynamics of

leprosy cases, geospatial analysis to elucidate trends in high-endemic (Gadchiroli) and low-endemic (Sangli) districts in Maharashtra, India. A comparative analysis of these districts, characterized by disparate per capita income (PCI) levels, revealed significant economic disparities, with Gadchiroli exhibiting the lowest PCI in the state (Gadchiroli has lowest per capita income in state | Nagpur News - Times of India n.d.). This socioeconomic divergence may have implications for the epidemiology and prevention and control of leprosy in these regions.

Annual case detection of childhood cases was 9.57% and 7.51% in Gadchiroli and Sangli respectively aligning with earlier studies (Ghunawat et al 2018). It was observed that all epidemiological indicators of the National Leprosy Eradication Program (NLEP) in Gadchiroli exceed the national and state averages (Directorate General Of Health Services n.d.).

The findings suggested that females diagnosed with leprosy in both the districts were proportionately lower. However, male to female ratio observed was 1:0.9 and 1:0.7 in Gadchiroli and Sangli respectively in contrast to earlier reports indicating higher proportion among males (GD01: Leprosy-related disability in India: highlighting the gender gap 2021). The present study reveals a striking disparity in the number of female cases identified in both Gadchiroli and Sangli districts suggesting possible differences in disease transmission or detection patterns based on endemicity, with females comprising only about 1/9th to 1/10th of the male cases as well as the total cases. The observed disparity may be attributed to various factors, including underreporting of female cases, socioeconomic barriers, cultural and social factors, and biological factors. These factors may influence females' willingness to seek medical attention, disclose their symptoms, or access healthcare services. As a result, the actual number of female cases may be higher than reported, highlighting the need for targeted interventions to address the specific needs and barriers faced by females. However, The study reported an increasing proportion of cases in 9-14 years in high endemic zones as reported by Scheelbeek et al (2013) leprosy control authorities believe that leprosy transmission and incidence (as evidence by continuing new case detection in both adults and children. This higher prevalence of leprosy among adolescents in Gadchiroli suggests ongoing transmission of the disease within the community, likely due to increased exposure to infected individuals environments (Sakral et al 2022) and possibly due to immature immune responses. Further, hormonal changes at this age and multiple physiological processes may also probably contribute to increase prevalence in this age group. However, this needs to be explored in future research (Jin 2024, Sarkar & Pradhan 2016). Conversely, study showed shift in the age distribution of newly identified cases to the elderly population from 36 to 65 years in Sangli (low endemic district). This could be due to late-onset manifestations of leprosy, reflecting varied and prolonged incubation periods of manifesting disease after exposure to *Mycobacterium leprae*. This observation underscores variations in age-specific susceptibility and exposure patterns influencing disease dynamics within different epidemiological settings. Age plays a crucial role in leprosy epidemiology, with distinct age groups exhibiting varying levels of susceptibility to infection and disease progression as well as transmission of infection in the recent years.

While much emphasis has been placed on overall prevalence rates and regional variations, the nuanced patterns of age-specific susceptibility and transmission dynamics have received comparatively less scrutiny. Furthermore,

environmental factors, socio-economic conditions, and healthcare access can also influence age-specific patterns of leprosy transmission (Sakral et al 2022). For example, impoverished communities with limited access to healthcare may experience higher rates of transmission among younger age groups due to inadequate preventive measures and delayed diagnosis.

Furthermore, the increased proportion of MB cases in low endemic region may result from delayed detection (Masatkar et al 2023). Additionally, higher proportion of disabilities in low-endemic district is likely to suboptimal diagnostic practices by clinicians or healthcare workers in low-endemic areas, potentially resulting from inadequate training. The observed disparities in disability ratios between high-endemic (Gadchiroli) and low-endemic (Sangli) leprosy districts indicates strengthening of Disability Prevention and Medical Rehabilitation (DPMR) Programme at Primary health care level. The findings suggest that early detection of cases and continued surveillance and monitoring of leprosy cases are crucial in minimizing disability in both districts. By informing evidence-based strategies for leprosy control and prevention, these efforts can ultimately reduce the burden of leprosy-related disability in endemic regions. This also necessitates need of identifying hot clusters within low endemic zones for timely intervention through Focused Leprosy Campaign (FLC). For this purpose, GIS can serve as an important tool to determine geographic distribution of leprosy through contextualized spatial approach which can be upscaled to detect at-risk population clusters more precisely (Taal et al 2022, WHO 2006, WHO 2018). Moreover, GIS can be useful for planning and targeting interventions; and monitoring diseases and interventions over time (Bakker et al 2009). It can be used by the managers and service providers during the problem identification process, and referred to in resource allocation processes as emphasized in earlier reports (Robin et al 2019).

Conclusively, unravelling the intricate dynamics of age-specific susceptibility is essential for developing targeted interventions and preventive strategies tailored to the specific needs of different age groups within high and low endemic areas.

Limitations: The study utilized operational data from public health facilities, which was constrained to a limited set of disease-related variables and lacked information on socioeconomic and environmental factors due to data unavailability. This limitation restricted the understanding of underlying determinants of disease distribution. The analysis focused on spatial distribution at the habitat level, excluding other disease-related variables. Furthermore, the absence of geocoordinates for certain public health facilities hindered the assessment of health service accessibility, a critical factor in evaluating the equity and effectiveness of healthcare delivery within the study area.

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