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Spatial analysis of leprosy incidence and associated socioeconomic factors

Análise espacial da incidência de hanseníase e fatores socioeconômicos associados

ABSTRACT

OBJECTIVE: To identify clusters of the major occurrences of leprosy and their associated socioeconomic and demographic factors.

METHODS: Cases of leprosy that occurred between 1998 and 2007 in São José do Rio Preto (southeastern Brazil) were geocoded and the incidence rates were calculated by census tract. A socioeconomic classification score was obtained using principal component analysis of socioeconomic variables. Thematic maps to visualize the spatial distribution of the incidence of leprosy with respect to socioeconomic levels and demographic density were constructed using geostatistics.

RESULTS: While the incidence rate for the entire city was 10.4 cases per 100,000 inhabitants annually between 1998 and 2007, the incidence rates of individual census tracts were heterogeneous, with values that ranged from 0 to 26.9 cases per 100,000 inhabitants per year. Areas with a high leprosy incidence were associated with lower socioeconomic levels. There were identified clusters of leprosy cases, however there was no association between disease incidence and demographic density. There was a disparity between the places where the majority of ill people lived and the location of healthcare services.

CONCLUSIONS: The spatial analysis techniques utilized identified the poorer neighborhoods of the city as the areas with the highest risk for the disease. These data show that health departments must prioritize politico-administrative policies to minimize the effects of social inequality and improve the standards of living, hygiene, and education of the population in order to reduce the incidence of leprosy.

DESCRIPTORS: Leprosy, epidemiology. Socioeconomic Factors. Geographic Information Systems, utilization. Epidemiologic Surveillance.

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RESUMO

OBJETIVO: Identificar áreas com maior ocorrência de casos de hanseníase e fatores socioeconômicos e demográficos associados.

MÉTODOS: Casos de hanseníase ocorridos entre 1998 e 2007 em São José do Rio Preto, SP, foram geocodificados e coeficientes de incidência foram calculados por setores censitários. Por meio da técnica de análise de componentes principais, obteve-se um escore para classificação socioeconômica. O uso do método de krigagem ordinária resultou em mapas temáticos para visualização da distribuição espacial da incidência de hanseníase, do nível socioeconômico e da densidade demográfica.

RESULTADOS: Enquanto a incidência para toda a cidade foi de 10,4 casos por 100.000 habitantes por ano, entre 1998 e 2007, as incidências por setores censitários foram heterogêneas, variando de zero a 26,9 casos por 100.000 habitantes por ano. Houve concordância entre áreas com valores mais altos de incidência e menores níveis socioeconômicos. Foram identificados aglomerados de casos de hanseníase. Não foi observada associação da doença com densidade demográfica. Detectou-se falta de relação entre os locais de moradia da maioria dos doentes e a localização dos serviços de saúde.

CONCLUSÕES: As técnicas de análise espacial utilizadas permitiram caracterizar as áreas mais deficitárias do município como as de maior risco para hanseníase.

DESCRITORES: Hanseníase, epidemiologia. Fatores Socioeconômicos. Sistemas de Informação Geográfica, utilização. Vigilância Epidemiológica.

INTRODUCTION

Leprosy is a chronic infectious disease that affects the skin and peripheral nervous system, and may cause irreversible physical lesions. The disease is often stigmatizing to patient, as they tend to be excluded and debilitated in their social relationships and economic activities.

Attempts by the World Health Organization to eliminate this disease have been unsuccessful, and leprosy is still a global public health problem. Among countries with populations larger than one million, Brazil, Nepal and East Timor still present disease prevalences of more than 10 cases per 100,000 inhabitants. In 2008, the prevalence of leprosy in Brazil was 24.0/100,000 inhabitants (45,847 cases in treatment) with a detection rate of 20.5/100,000 annually (39,125 new cases detected).^a

The Brazilian government's policies to eliminate leprosy predominantly include actions to be extended to the entire primary care sector, thus promoting the decentralization of disease control activities and public

information about the characteristics, signs, and symptoms of the illness.^b

The decentralization and amplification of medical assistance to the entire healthcare network requires knowledge of the spatial distribution of the disease, among other factors. The expected variations in the occurrence of leprosy in different regions^{7,13} associated with increasing rates of urbanization¹¹ point to a need for predicting disease incidence based on the geographic area or population characteristics. These estimates are necessary to identify possible environmental risk factors and to recognize areas of particular concern, thus allowing for a better allocation of resources and more effective planning for available services.⁷

Over the past few years, there has been an increase in the number of studies investigating healthcare issues using geographic information systems (GIS) and spatial analysis, reviving the importance of the role of the socio-cultural environment in the determination of

^a WHO Weekly epidemiological record. Geneva: WHO. 2008 [cited 2009 Sep 30]; 83(33):293-300. Available from: <http://www.who.int/lep/resources/wer8333.pdf>

^b Ministério da Saúde do Brasil (BR), Secretaria de Vigilância Sanitária, Departamento de Vigilância Epidemiológica, Programa Nacional de Eliminação da Hanseníase. Plano Nacional de eliminação da hanseníase em nível municipal 2006-2010, Brasília (DF); 2006.

diseases and the importance of a critical analysis of access to resources.⁶

Several studies have employed spatial analysis techniques for leprosy, including investigations of spatial dependence of average leprosy detection rates in the state of São Paulo,^{14,16} the control of communicants in a town within São Paulo,^c an evaluation of the susceptibility to leprosy from communicants among residents on a small island in Indonesia,⁴ and the search for spatial and spatial-temporal clusters of leprosy cases.^{9,10}

Faced with the necessity of reorganizing disease control strategies, directing resources, consolidating recent advances, assisting in decision making, and stimulating innovative actions in the surveillance of leprosy, this study aimed to identify clusters of major occurrences of leprosy as well as the socioeconomic and demographic factors associated with the disease.

METHODS

São José do Rio Preto is located in the northwestern region of the State of São Paulo (S20°49'11" and W49°22'46") and has an area of 575 km² with a population estimated to be 419,633 in 2009. It is a regional center for 101 municipalities and is a major urban center in the region, drawing a large number of people from neighboring towns and states in search of services linked to commerce, health, and education.

This is a territory-based ecological study. Study units were defined by census tracts allotted by the Brazilian Institute of Geography and Statistics (IBGE) using data from the census carried out in 2000.^d

All new leprosy cases diagnosed from January 1st, 1998 to December 31st, 2007 in residents of the city of São José do Rio Preto who had their addresses geocoded in the Leprosy Project¹⁵ database were included in this study.

The geocodification of leprosy cases was achieved utilizing the Mapinfo computer program version 7.0 that matched the addresses of cases to locations on a street map provided by the city hall of São José do Rio Preto. The analysis and automatic standardization of addresses consisted of dividing the addresses into two parts, the street name and number of the residence. Standardization modified these components, when necessary to follow the criteria adopted by the Brazilian Address System.

A geocode for each address was obtained by linearly interpolating the number of the residence to the corresponding street segment identified by the range of street

numbers.²⁰ Then, leprosy cases were grouped according to the 432 urban census tracts using tools in the ArcGIS computer program version 9.2. The incidence rate for each sector was calculated by dividing the number of cases in that sector by a population estimate from 2002 multiplied by 100,000.

Characterization of the socioeconomic level of each census tract was based on the following variables: average years of education of the breadwinner (A), average years of education of the female breadwinner (B), average income of the breadwinner (C), average income of the female breadwinner (D), percentage of illiterate people (E), percentage of illiterate women (F), and percentage of residences with five or more inhabitants (G). These variables were analyzed using the STATA computer program version 7.0 using principal component analysis. This statistical method produces factors that are not correlated with one another and that represent the important aspects characterized by correlations among the variables.¹ From the factors identified, one was responsible for the greatest proportion of the total variation (87%) and was chosen as the socioeconomic factor (SF). The greater its value, the better the socioeconomic level of the inhabitants in a given census tract. This factor was calculated for each sector using the following formula:

$$SF = 0.97A + 0.94B + 0.85C + 0.85D - 0.89E - 0.89F - 0.56G$$

The demographic density was calculated for each census tract by dividing the population of each sector by its area using information available from the IBGE for the 2000 census.

Choropleth maps allowed the visualization of the spatial distribution of leprosy incidence rates, the socio-economic score factor, and the demographic density from the urban area of the municipality. Centroids were assumed to be geographical representations of the ecological units (census tracts). Samples of these processes were modeled in the stochastic Gaussian approach as a continuous point pattern on the physical environment.²

Geostatistical estimation by the kriging method, also known as generalized weighted least squares on general linear modeling, was used to produce the response surfaces for thematic mapping after establishing the mathematical parameters including semivariogram, anisotropy, distance, sill, and nugget.² The response surfaces were broken up into quintiles – five partitions with 20% relative frequency each – for leprosy incidence rate and the socioeconomic factor, and sextiles – six partitions – for demographic density.

^c Mencaroni DA. Análise espacial da endemia hansênica no município de Fernandópolis, SP [doctorate thesis]. Ribeirão Preto: Universidade de São Paulo, Escola de Enfermagem de Ribeirão Preto; 2003.

^d Fundação Instituto Brasileiro de Geografia e Estatística. Base de informações por setor censitário para o município de São José do Rio Preto [CD ROM]. Rio de Janeiro; 2002.

The ArcGis computer program version 9.2 was used for the production of these thematic maps and for the statistical interpolation of the municipal boundaries and the delimitation of the urban area using digital cartography of the census tracts provided by IBGE.

Chi-square statistical tests were used to assess the association between the leprosy incidence and socioeconomic factor. Both continuous variables were transformed into categorical variables using quartiles as cutoff points.

This research project was approved by the Ethics and Research Committee at The Faculdade de Medicina de São José do Rio Preto (São José do Rio Preto Medicine School) (protocol number 120/2004).

RESULTS

Figure 1 shows that the leprosy prevalence and detection rates in 2006 and 2007 were less than 10 cases per 100,000 inhabitants.

Of the 414 total cases of leprosy reported between 1998 and 2007, 398 (96%) were geocodified. Of these, 379 occurred in the urban area and were included in this study. The lighter choropleth categories in Figure 2 represent areas with low incidence rates while darker categories represent areas with higher incidence rates. Although the incidence for the municipality as a whole between 1998 and 2007 was 104.1 cases per 100,000 inhabitants (that is, 10.4 cases per 100,000 per year), Figure 2 shows that the incidence rates were heterogeneous within the urban area, with values that ranged from zero to 269.5 cases per 100,000 inhabitants (that is, 0 to 26.9 cases per 100,000 inhabitants annually). Figure 2 depicts a large cluster of leprosy cases in the northern area of the city and two smaller clusters in the extreme eastern and southeastern areas.

In the choropleth presentation of the distribution of socioeconomic factor scores (Figure 3), the darker areas characterize regions in which the population is most dependent on government assistance; in essence, these areas' inhabitants were socially excluded in terms of the promotion of healthcare, education, nourishment, work, housing, and a healthy environment. On the other hand, the lighter areas represent clusters with higher socioeconomic levels, and thus are representative of social inclusion and the percentage of the population that profits from economic production.

In Figure 4 the lighter areas represent higher population densities and the darker areas, lower densities. Figure 5 shows, among other geographic features, government and private schools, daycare facilities, government healthcare clinics, hospitals, and reference centers for leprosy in the city.

Areas with lower socioeconomic levels are located in the northern, northeastern, and southeastern areas of the city, coinciding with areas that have the highest leprosy incidence rates (Figures 2, 3). The demographic density varies in these regions; some areas are highly populated while some have a smaller number of people per square meter due to protected woodlands on the banks of the rivers that cut through the northern and northeastern regions (Figure 4).

The western region, which is characterized by the city's main industrial park, the airport, a cemetery, and green-belt, has a moderate socioeconomic level and a medium to low demographic density. The leprosy incidence rates were intermediate, with the highest values occurring closest to the northern region (Figures 2, 3, 4).

The southwestern and central regions showed high socioeconomic levels and low leprosy incidence rates, though the former also had a low demographic density

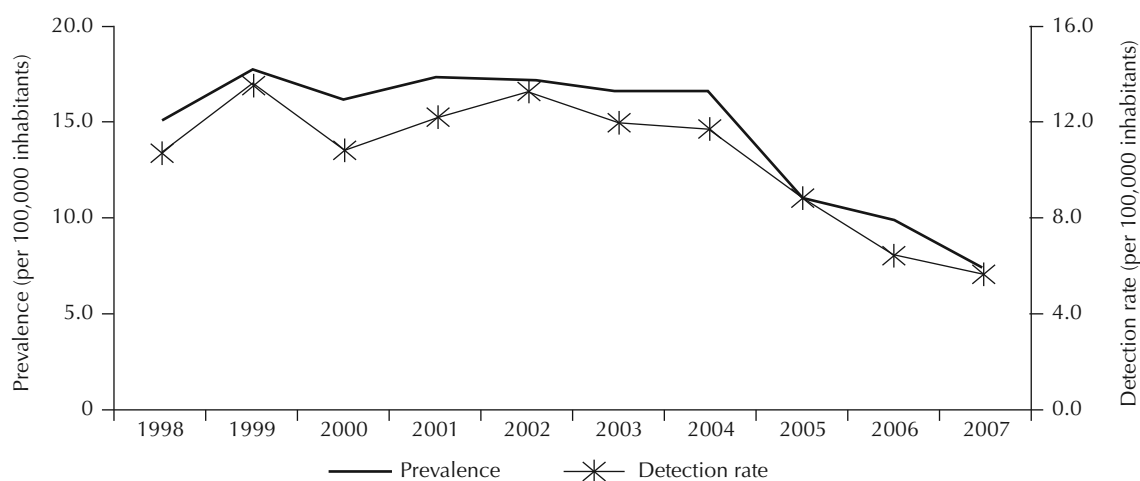


Figure 1. Prevalence and detection rate of leprosy. São José do Rio Preto, Southeastern Brazil, 1998-2007.

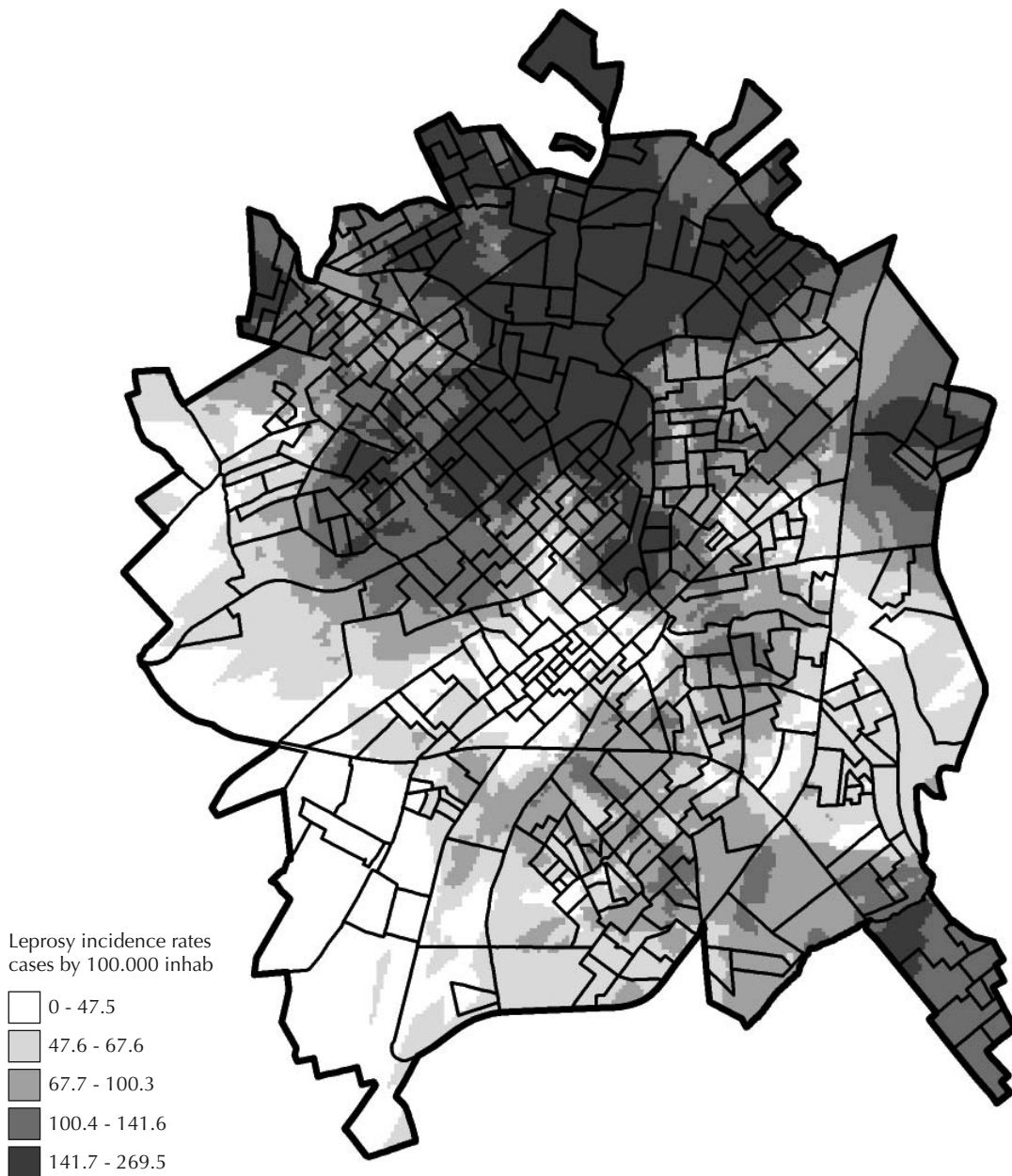


Figure 2. Spatial distribution of leprosy incidence rates (per 100,000 inhabitants) in the urban area. São José do Rio Preto, Southeastern Brazil, 1998-2007.

(large houses and green areas) and the latter, a high density (high concentration of residential apartment blocks) (Figures 2, 3, 4).

The eastern region of the city is characterized by a combination of low, medium, and high socioeconomic levels and, respectively, high, intermediate, and low leprosy incidence rates (Figures 2, 3). The demographic density also varied, but without any apparent relationship to socioeconomic levels or leprosy cases. The areas of low demographic density in the eastern region are sparse due to the municipal reservoir, the lake that supplies water to part of the population (Figures 4, 5).

After transforming the incidence rate and the socioeconomic factor into categorical variables, the chi-squared test showed an association between disease and the SF ($\chi^2 = 180.7$; $p < 0.0001$).

Figures 3 and 5 show that the northern, northeastern, and southeastern regions, which have low socioeconomic levels, have the highest number of government schools, daycare facilities, and government healthcare clinics and are close to the city trash dump. Almost all hospitals (all private) and most of the private schools and daycare facilities are located in the southwestern and central regions, regions with high socioeconomic

levels. The reference centers for leprosy are also located in areas with a low incidence of the disease (Figure 2) and high socioeconomic levels (Figure 3).

DISCUSSION

This study confirms the decrease in leprosy prevalence and incidence and found heterogeneous leprosy incidence rates in São José do Rio Preto census tracts. Clusters of high leprosy occurrence were associated with the lowest socioeconomic level areas and it was revealed that locations where ill people live lack healthcare services. Additionally, there is no association

between leprosy incidence and demographic density. The decrease in leprosy prevalence, which was less than 10 cases per 100,000 inhabitants in 2006 and 2007, and in the detection of new cases point to a possible elimination of the disease in the city.

The possibility of the occurrence of ecological fallacy, an important consideration in ecological studies, was minimized by the use of census tracts as the units of analysis, which, according to the IBGE, are continuous areas comprising an average of 300 buildings with homogeneous demographic and socioeconomic characteristics. The adequacy of the socioeconomic factor as a representation of the socioeconomic levels is confirmed



Figure 3. Spatial distribution of the socioeconomic factor. São José do Rio Preto, Southeastern Brazil, 2000.

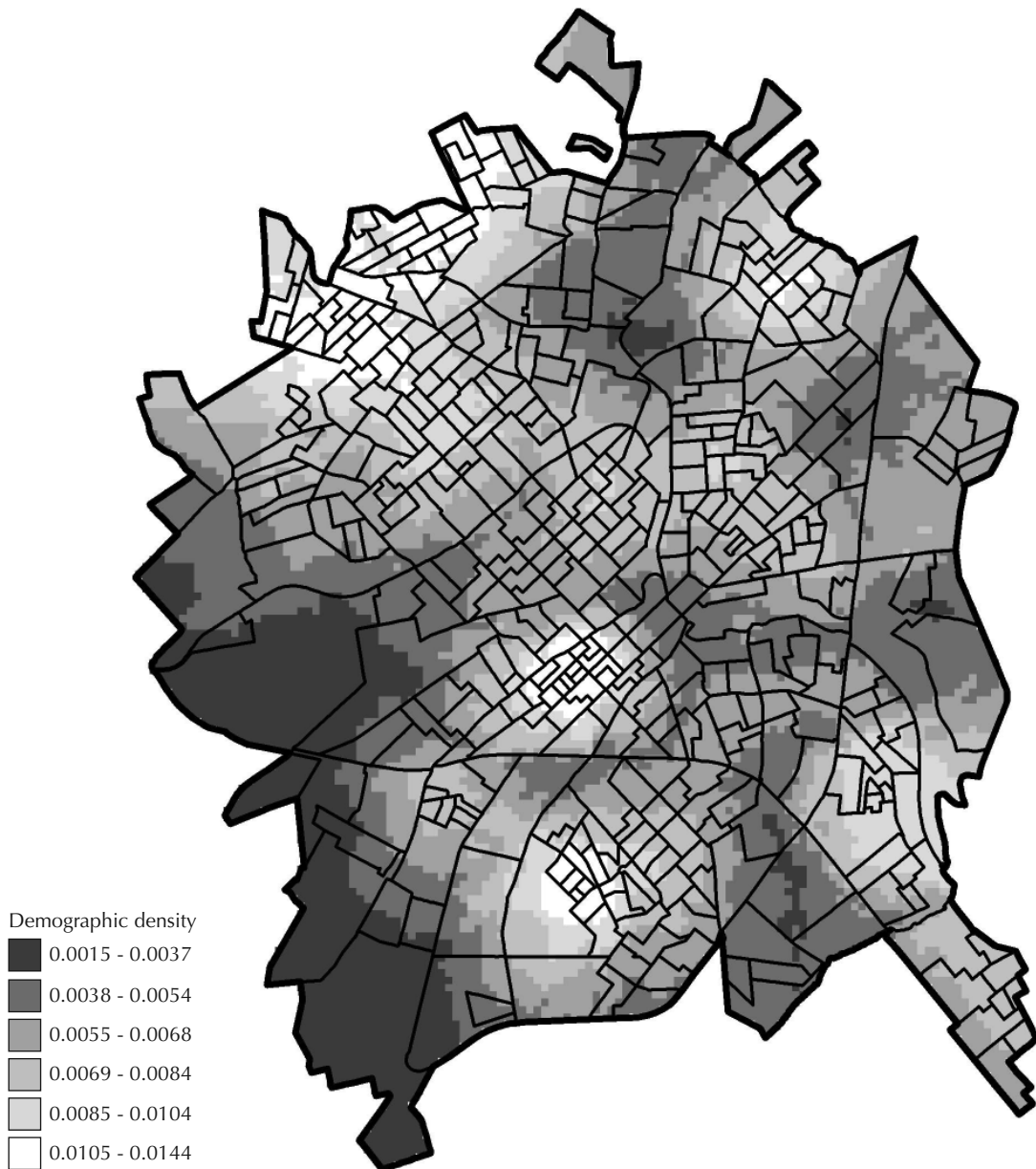


Figure 4. Spatial distribution of demographic density (inhabitants per km²). São José do Rio Preto, Southeastern Brazil, 2000.

by the greater concentrations of public schools, daycare facilities and healthcare clinics in the areas identified as having lower socioeconomic levels. On the other hand, areas identified as having higher socioeconomic levels possessed greater concentrations of private schools and daycare facilities, and almost all the hospitals are located in areas with higher socioeconomic levels.

The association of areas of low socioeconomic levels and high leprosy incidence rates found in this study are in agreement with the results of Bechelli⁵ (1936). Additionally, it has been reported that patients with

unfavorable social conditions have lower chances of receiving treatment⁶ and, in their residences' locations, obstacles are in place to make access to healthcare services difficult.¹² According to Sampaio et al¹⁷ (1987), apart from the favorable climatic conditions in tropical regions, other factors such as nutritional deficiencies, promiscuity, and low socioeconomic levels predispose individuals to leprosy.

The identification of areas with different levels of leprosy incidence and of clusters with the highest incidence rates provides information that can be useful to

⁶ Pinheiro RS. Estudos sobre variações no uso de serviços de saúde: abordagens metodológicas e a utilização de grandes bases de dados nacionais [doctorate thesis]. Rio de Janeiro: Fundação Oswaldo Cruz, Escola Nacional de Saúde Pública; 1999.

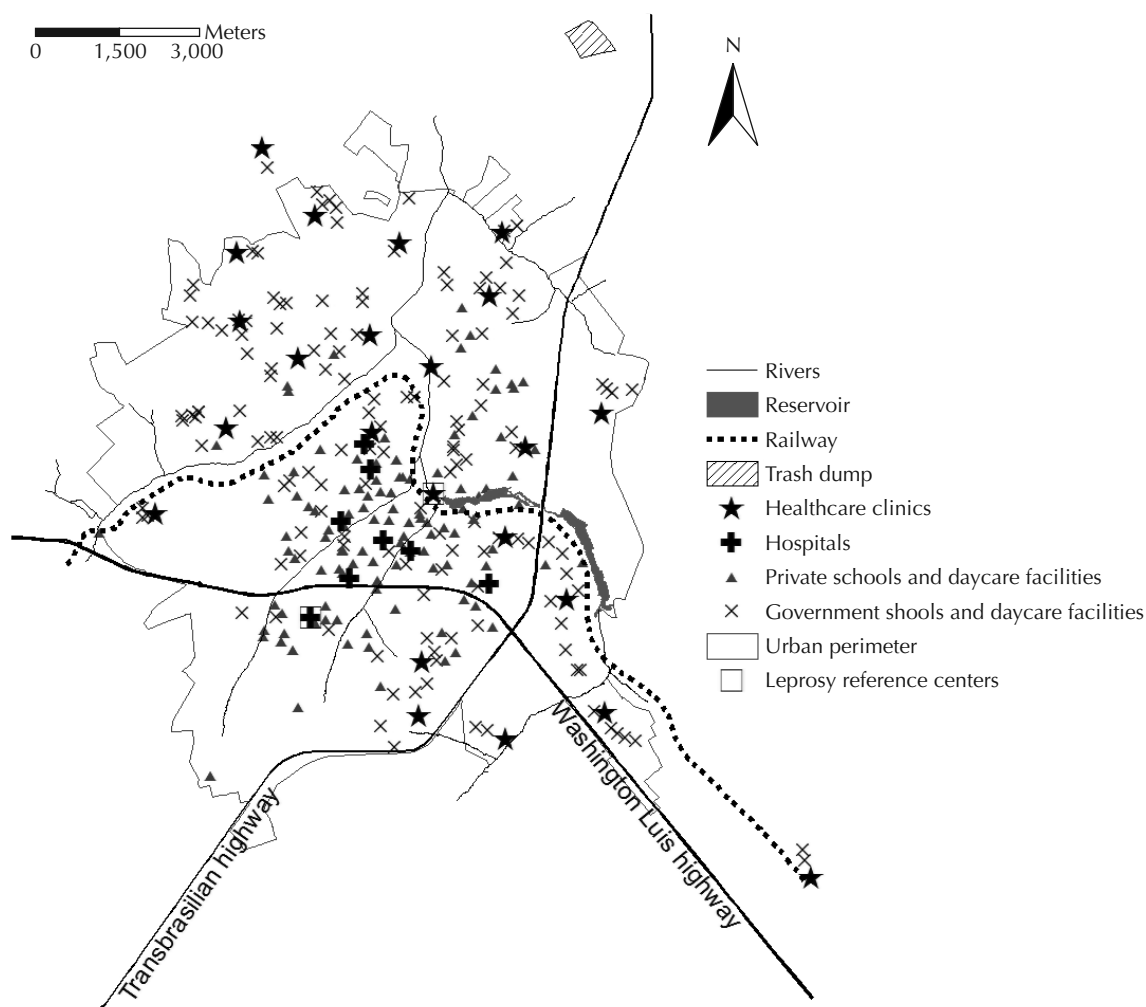


Figure 5. Urban perimeter of São José do Rio Preto, rivers, reservoir, railway, highways, government and private schools and daycare facilities, healthcare clinics and hospitals.

help surmount administrative challenges and facilitate decentralized assistance and monitoring with the aim of eliminating leprosy. The heterogeneous occurrence of leprosy indicates that analyses designed to determine whether the disease is being eliminated cannot be made by treating the municipality as an indivisible unit.

The implementation of control measures and disease treatment are centralized in São José do Rio Preto, which is in conflict with the Brazilian Ministry of Health directives.^f Centralization hinders access to treatment and is further exacerbated by the fact that the two leprosy reference centers are located in areas with high socioeconomic levels and low incidence rates of the disease. Decentralization of leprosy control measures would provide better conditions for the assistance of patients and their contacts, allowing diagnosis and treatment close to their homes, and improving acceptance, understanding, and knowledge

among the public about the disease. This may also help to reduce the stigma attached to leprosy and improve disease control.

The use of GIS and spatial analysis techniques have shown to be important tools in planning disease surveillance and control measures, and in evaluating and monitoring the effectiveness of healthcare services.^{3,8} The features and techniques utilized in this study, apart from providing important information for planning surveillance and control measures for leprosy, identified clusters at the highest risk for leprosy in the poorest areas of the city. Investment in the schools, culture, healthcare, basic sanitation, housing, work opportunities, and leisure activities, in areas with higher incidences of leprosy can help to minimize the effects of social inequality and increase the standard of living, hygiene, and education of the population thereby reducing the magnitude of the disease burden.^{18,19}

^f Ministério da Saúde (BR). Guia para o controle da hanseníase. Brasília (DF): Departamento de Atenção Básica, Secretaria de Políticas de Saúde; 2002.

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