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Spatial and temporal study of leprosy in the state of São Paulo (Southeastern Brazil), 2004-2006

ABSTRACT

OBJECTIVE: To assess the temporal and spatial evolution of the leprosy endemy in the state of São Paulo, Southeastern Brazil.

METHODS: This is an ecological-social study that used the number of leprosy cases reported to the Brazilian Ministry of Health from January 2004 to December 2006. Monthly series were generated in each regional health department, and their sequences were adjusted by a Markovian model for the leprosy detection coefficients. The detection coefficient with the number of cases accumulated in the period in each municipality was used to produce the spatial distribution of the endemy; a correlation analysis was carried out with the leprosy detection coefficients and the components of the Social Responsibility Index of the state of São Paulo.

RESULTS: Of the 645 municipalities of the state of São Paulo, 22 did not detect leprosy cases in the period. In the majority of regions, the endemy showed a decreasing trend; the time series presented random fluctuation around expected values. The decline was influenced by a generalized decrease in the detection coefficients at the end of 2005. There was a positive correlation between the detection coefficients and the components "schooling" and "longevity", of the Social Responsibility Index of the state of São Paulo, and a negative correlation with "wealth", another component of the same Index.

CONCLUSIONS: The result of the time series analysis suggests that the endemy is on the decline in the majority of regions of the state of São Paulo, while the spatial analysis shows that the coefficients are high in the northern part of the state.

DESCRIPTORS: Leprosy, epidemiology. Indicators. Temporal Distribution. Time Series Studies. Ecological Studies. Epidemiology, Descriptive.

INTRODUCTION

Leprosy presents high infectiveness and low pathogenicity, and the domicile is the main transmission space.[3] Nowadays, the causality network of the disease includes the molecular biology of the etiological agent, the genetic or immunologic characteristics of the host – which are not fully known yet -, and the social determinants, such as quality of life, sanitation, cultural practices, poverty, among others.[9]

In 2003, Brazil presented the second highest number of cases in the world and the highest number of reported cases in Latin America;[1] the prevalence coefficient of leprosy in Brazil per 10,000 inhabitants was 16.4 in 1985, 6.4

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in 1998 and 4.52 in 2003, suggesting the decline of the endemy.[a] In the state of São Paulo, the detection of cases increased due to education campaigns, personnel training, expansion of coverage and decentralization of services and actions.[14] In 1991, the World Health Organization (WHO) proposed the elimination of or reduction in the incidence of leprosy to less than one case per 10,000 inhabitants in endemic countries, up to the year 2000. This goal has not been achieved by Brazil[9,10,12] and the Ministry of Health has designed a strategy to eliminate leprosy until 2010, in the municipal level, in which the actions are financed by the resources of *Sistema Único de Saúde* (SUS – National Health System). Health services organization is one of the factors that determine leprosy, as it promotes detection, either passive or active, and treatment.[7,9]

Some spatial studies have related the occurrence of leprosy to the tropical zones, where the climatic conditions favor transmission[11] and the wild animals serve as reservoirs for the etiological agent.[b] This strengthens the idea of natural foci of the disease and possible anthropozoonotic transmission networks. Studies on epidemiological landscapes have approached the interactions between natural and social phenomena, discriminating regions which have been essentially created by biotic, evolutionary, and cultural processes, and also by the natural reservoirs – known as *nidality*.[9] Ecological epidemiological studies with ecological-social dimensions admit the use of compound human development indicators to characterize these landscapes from the cultural and socioeconomic point of view. The *Índice Paulista de Responsabilidade Social* (IPRS - Social Responsibility Index of the state of São Paulo) is an indicator that reflects human development in the municipalities of the state of São Paulo, including, beside the Human Development Index (HDI), municipal administrative information updated in years between two demographic censuses.[16] Statistical methods contribute to the evaluation of these epidemiological landscapes: stochastic models of time series analysis[13,15] are used to estimate trend and seasonality parameters, and geostatistical models[5,8,14] generate risk zonings or identify groupings.

The aim of the present study was to assess the temporal evolution of leprosy detection in the state of São Paulo, between 2004 and 2006.

METHODS

An ecological and descriptive study was conducted, using information regarding the detection of leprosy cases and human development of the 645 municipalities of the state of São Paulo. The political-administrative division of the state's municipalities was employed as the ecological unit of information; the municipalities were regrouped into 17 *departamentos regionais de saúde* (DRS - regional healthcare departments):[c] Great São Paulo (DRS-1), Araçatuba (DRS-2), Araraquara (DRS-3), Baixada Santista (DRS-4), Barretos (DRS-5), Bauru (DRS-6), Campinas (DRS-7), Franca (DRS-8), Marília (DRS-9), Piracicaba (DRS-10), Presidente Prudente (DRS-11), Registro (DRS-12), Ribeirão Preto (DRS-13), São João da Boa Vista (DRS-14), São José do Rio Preto (DRS-15), Sorocaba (DRS-16) and Taubaté (DRS-17). A geographic information system was constructed with the delimitations of the municipalities and of the DRS, using the software SPRING, in order to conduct the spatial analysis of the endemy in the State.[2]

The number of detected leprosy cases in each municipality in the period from January 2004 to December 2006 was provided by the Ministry of Health, as well as the estimates of the municipal populations' sizes in 2005, in the middle of the studied period. These data were used in the calculation of the leprosy detection coefficients, expressed per 10,000 inhabitants. The spatial analysis of the endemy considered the detection coefficients accumulated in the studied period; the temporal analysis considered 17 time series, created in each DRS, whose values were formed by the detection coefficients of cases accumulated in each month, since January 2004 until December 2006, totaling 36 historically indexed coefficients.

An exploratory analysis was carried out with age group-specific detection coefficients[6] in the DRS, adopting the following stratification: "up to 4 years of age" (pre-school phase), "from 5 to 19 years of age" (basic education phase), "from 20 to 34 years of age" (initial productive phase), "from 35 to 49 years of age" (intermediate productive phase), "from 50 to 64 years of age" (tardy productive phase), and "above 65 years of age" (retirement phase).

The study, characterized by the causal ecological-social model, incorporated socioeconomic dimensions, using the components of the Social Responsibility Index of the state of São Paulo (IPRS). This index expresses human development according to measures related to schooling, longevity and income, and is provided by *Fundação Sistema Estadual de Análise de Dados* (SEADE – State's Data Analysis System Foundation), for each municipality of the state for the year 2004. The average values of the IPRS components (schooling, longevity and income) and the leprosy detection coefficients of each DRS were used in a correlation analysis, using Pearson's statistics.[4]

[a] Ministério da Saúde. Secretaria de Vigilância em Saúde. Departamento de Análise de Situação de Saúde. 2004: hanseníase. Brasília; 2004. p. 311-2.

[b] Fundação Nacional de Saúde. Guia de vigilância epidemiológica. Brasília; 2002. v. 2.

[c] São Paulo (State). Decree no. 51.433, published on December 28, 2006. It creates a unit in Coordenadoria de Regiões de Saúde (Healthcare Regions Coordination) of Secretaria da Saúde (Health Department). Diário Oficial do Estado de São Paulo, 29 dez 2006;Seção 1:1.

The geostatistical analysis of the leprosy endemy was carried out by the conventional kriging interpolation method, using the detection coefficients of the disease of all the 645 municipalities, in the logarithmic scale, to produce the zoning of the epidemiological landscape.[5,8] The kriging interpolation method involves the adjustment of the semivariogram and the estimation of parameters called "nugget", "sill" and "range", besides the identification of the directionality of the spatial correlations of the semivariogram (Lourenço & Landim,[8] 2005). The northwest direction was adopted to model the semivariogram, because it corresponds to the direction in which the historical occupation of the territory occurred: from the coast to the interior of the country in the azimuthal direction 135º. The software SPRING and R were used in this stage of the work.

The temporal evolution of the endemy was conducted with the series of monthly coefficients (*t*) in each DRS. By definition, the values indexed by time (*t*) are not totally independent among themselves; therefore, they are autocorrelated. The process is Markovian when the autocorrelation is based on first order dependence, that is, when the value at instant "*t*" depends only on the value at the immediately preceding instant "*t*-1"; the function called correlogram describes the autocorrelation of the time series.[13,15] The correlograms of each time series allowed us to adopt them as Markovian stochastic processes, following the mathematical model below to verify the presence of trends:

$$Y\ (i,\ t) = \beta_0 + \beta_1 \cdot t + \beta_2\ .\ y(i, t-1)$$

RESULTS

Of the 645 municipalities of the State of São Paulo, 22 did not detect leprosy cases in the period: two municipalities of DRS-2, one of DRS-3, six of DRS-6, one of DRS-8, five of DRS-9, three of DRS-11, two of DRS-15, and two of DRS-17.

The thematic map resulting from the application of the geostatistical method presents the magnitude of the leprosy endemy in the DRS (Figure 1). High detection coefficients were observed in DRS-2, DRS-5, DRS-11 and DRS-15, in the interior of the state, and DRS-17, in the state's coast, whose values varied between 18.13 and 32.14 cases per 10,000 inhabitants. On the other hand, DRS-1, DRS-16, DRS-7, DRS-14 and DRS-6 showed relatively low detection coefficients, whose values varied between 3.25 and 5.77 cases per 10,000 inhabitants, in the studied period.

Table 1 shows the results of the exploratory analysis of the ecological-social model per DRS. It contains information on the IPRS components in relation to the leprosy detection coefficient, population size and sex ratio. The correlation coefficient of the leprosy detection coefficients with the average scores of the "longevity" component resulted in 0.5101 (p=0.0364); with the average scores of the "schooling" component resulted in 0.5572 (p=0.0201); with the average scores of the "wealth" component resulted in –0.5307 (p=0.0284); with populations' sizes resulted in –0.4246 (p=0.0893); and with the sex ratios resulted in –0.1444 (p=0.5803). The sex ratios showed the predominance of cases of the male sex.

Table 2 presents the distribution per age group of the proportional coefficients in each DRS, showing that the disease was mainly detected in adults who are in the economically productive phase, in a similar way in all the administrative regions.

The results obtained by the mathematical models adjusted to the series, in the study of the endemy's trends in the DRS, with diverse temporal patterns, can be seen in Figures 2 and 3: (1) pattern with an increasing trend and with great variability (white noise), observed in DRS-2 and DRS-8; (2) pattern with a decreasing trend and with homogenous evolution, observed in DRS-3, DRS-9, DRS-10, DRS-11 and DRS-12; (3) pattern with a decreasing trend and with a sharp decline between October 2005 and February 2006, observed in DRS-1, DRS-4, DRS-5, DRS-6, DRS-7, DRS-13, DRS-14, DRS-15, DRS-16 and DRS-17. The pattern observed for the state of São Paulo (resulting from the sum of the cases detected in the DRS) showed a decreasing trend, influenced by the sharp decline between the months of October 2005 and February 2006.

DISCUSSION

The present study identified a spatial distribution pattern of the detection of leprosy cases in the state of São Paulo, with zones of high detection coefficients located in DRS-2, DRS-5, DRS-11 and DRS-15. On the other hand, the zones identified by low detection coefficients were located in DRS-1, DRS-4, DRS-16, DRS-7 and DRS-14, as well as other zones located in DRS-3 and DRS-6.

There was positive correlation between the leprosy detection coefficients and the average scores of the "schooling" and "longevity" IPRS components, and negative correlation between the leprosy detection coefficients and the average scores of the "wealth" component of IPRS. The detection of leprosy cases is related to the diagnosis capacity of the health services in each municipality, according to the health programs of each DRS, either by active search or by stimulated demand. The "schooling" component of IPRS reflects the production of teaching activities and the inclusion of individuals in citizenship networks, collaborating with the construction of perception and discernment concerning health problems, besides influencing the access to the services. The "longevity" component reflects the quality of life and the lifestyle of populations,

resulting from the promotion of individual and collective well being and from disease prevention. The "wealth" component is related to economic productive activities, which generate municipal revenues and which allegedly return as public health services. The results of the correlation study establish ecological-level relations that may induce to the ecological fallacy if the interpretations of the correlations between the variables are extended to the individual level. However, these results reveal important information in the regional level, which may influence the elaboration of public policies in the governmental level.

The temporal assessment showed that DRS-2 and DRS-8 presented increasing detection trends, above the WHO's goal for the year 2000, probably associated with the capacity to detect the endemy showed by the health services of these regional departments. In the majority of regions the endemy's trend was, mathematically speaking, a decreasing one; the temporal series presented random fluctuation around expected values, which could denote a probable reduction in the endemy. In some of these evolutional patterns, the time series proved to be intriguing, as they presented a sharp decline, simultaneously in the DRS, between the months of October 2005 and February 2006, in DRS-1, DRS-4, DRS-5, DRS-6, DRS-7, DRS-13, DRS-14, DRS-15, DRS-16 and DRS-17. This is not a casual coincidence; it derives from the political changes that influenced the capacity to detect the cases, of ten among 17 DRS. The majority of these regions presented an increasing detection trend up to the middle of October 2005; however, the sharp declines after October 2005 changed the variation level of the detection coefficients. The parameters of the mathematical model were estimated in each series and the majority resulted in a negative trend, suggesting the decline in the endemy, influenced by the described falls. These behaviors are illustrated by the dotted lines in Figures 2 and 3.

Despite the fact that the transmission between individuals can be controlled through public policies to improve the life condition and the access to the health services, the intervention on the anthropozoonotic transmission mechanisms demands a change in cultural practices and in practices of human contact with wild animals. There is no doubt that home conviviality represents the main contagion form of the disease and the active detection of leprosy cases represents the most efficient means to achieve the goals for the elimination of the endemy. Therefore, the supervised domiciliary treatment represents an important strategy to eradicate or reduce leprosy cases.

Table 1. Descriptive values of the average scores of the components of the Social Responsibility Index of the State of São Paulo (IPRS), of the leprosy detection coefficient per 10,000 inhabitants, of population size and of sex ratio, according to the regional healthcare department (DRS). State of São Paulo, Southeastern Brazil, 2004-2006.

DRS	IPRS Component			CDH	Population	Sex ratio
	Schooling	Longevity	Wealth			
1	50.79	68.05	48.64	12.87	19,403,480	1.31
2	61.55	70.55	33.08	59.67	693,474	1.27
3	55.80	71.96	37.12	20.88	928,663	1.57
4	49.11	62.44	55.67	26.99	1,637,565	1.08
5	55.55	73.55	37.15	61.87	421,228	1.43
6	54.20	68.24	32.58	20.56	1,615,465	1.47
7	52.95	70.64	44.81	23.82	3,809,996	1.44
8	50.14	67.68	37.77	29.17	646,990	1.66
9	59.44	68.80	32.27	38.61	1,053,980	1.21
10	54.84	70.72	42.32	33.67	1,369,828	1.40
11	60.33	72.47	28.98	82.12	717,130	1.28
12	44.47	67.67	29.20	41.98	294,927	1.97
13	51.16	73.40	38.32	38.43	1,214,710	1.56
14	52.57	67.86	39.19	20.34	799,402	1.43
15	59.86	72.82	32.80	51.31	1,427,507	1.16
16	48.67	66.92	33.88	26.75	2,203,002	1.33
17	49.62	64.41	37.62	31.46	2,205,448	1.34

Source: Datasus
DRS: Regional Healthcare Department
IPRS: Social Responsibility Index of the State of São Paulo
CDH: leprosy detection coefficient

Table 2. Distribution of the age group-specific coefficients, of the number of detected leprosy cases per 10,000 inhabitants, according to the regional healthcare department (DRS). State of São Paulo, Southeastern Brazil, 2004-2006.

DRS	Leprosy cases	Age group-specific incidence coefficient (%)					
		< 4 years	5-19 years	20-34 years	35-49 years	50-65 years	> 65 years
1	24,981	0.32	10.75	33.43	28.39	17.95	11.20
2	4,138	0.05	5.24	18.44	31.68	27.11	17.40
3	1,939	0.31	6.55	20.99	31.77	26.56	16.97
4	4,419	0.18	9.05	26.70	29.08	22.86	12.08
5	2,606	0.08	6.10	21.18	30.31	26.75	14.93
6	3,321	0.27	7.56	22.58	30.47	23.58	19.96
7	9,077	0.12	7.61	25.33	31.25	21.52	19.04
8	1,887	0.42	4.29	23.95	33.44	24.32	13.57
9	4,069	0.22	5.43	17.67	30.87	27.80	17.77
10	4,612	0.07	6.35	21.73	33.59	25.00	13.27
11	5,889	0.15	5.48	16.32	33.35	25.71	19.53
12	1,238	0.73	5.57	19.71	31.66	24.47	17.85
13	4,668	0.15	6.62	22.34	31.13	24.59	14.91
14	1,626	1.11	6.03	22.69	31.92	22.08	14.70
15	7,324	0.16	5.52	15.47	30.60	28.14	16.64
16	5,892	0.31	10.01	25.81	32.62	19.23	13.97
17	6,938	0.30	8.82	24.75	30.96	23.18	11.86

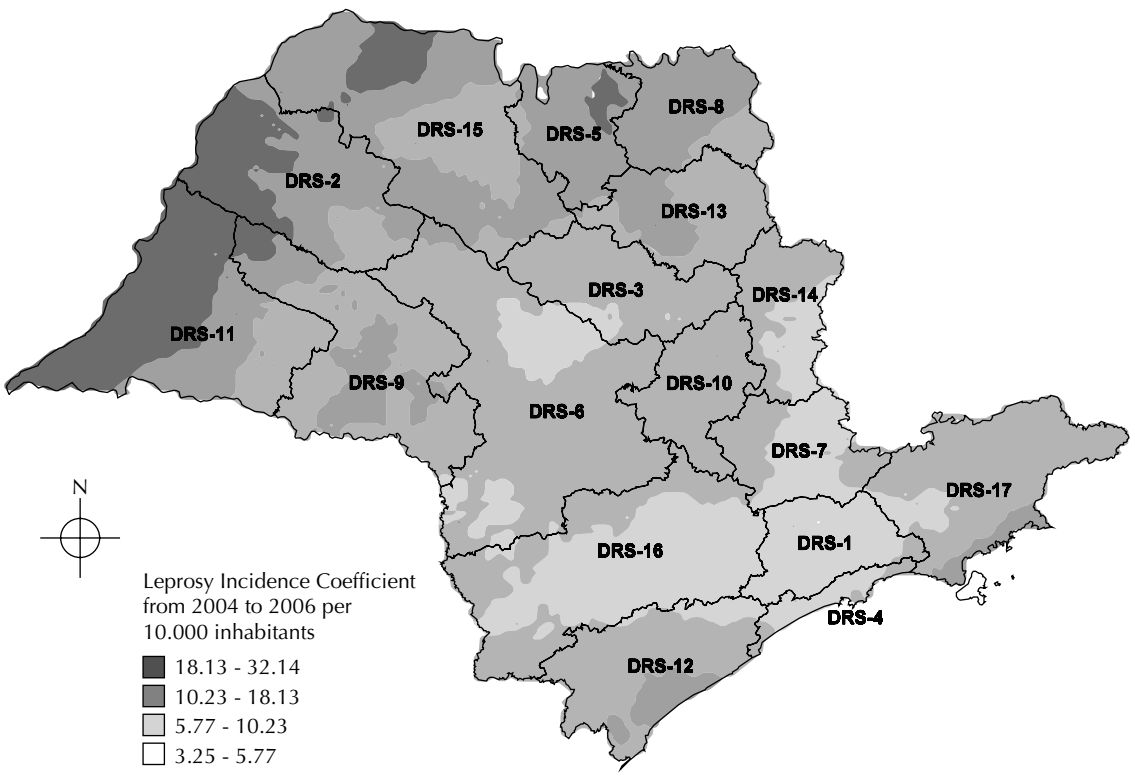

Figure 1. Thematic map of the geographic distribution of the leprosy detection coefficient per 10,000 inhabitants, according to the regional healthcare department (DRS). State of São Paulo, Southeastern Brazil, 2004-2006.

The integration of *Programa de Agentes Comunitários* (Community-Based Health Agents Program) and of *Programa Saúde da Família* (Family Health Program) is based on actions of educational measures, campaigns to detect suspects, social and community mobilization and adequate register of the cases in the information system of SUS. In addition, it offers technical and financial support to feed the database of *Sistema de Informação de Agravos de Notificação* (Accident and Disease Reports Information System), whose resources were transferred to the municipal health funds. This strategy aimed to meet the goals established by WHO until 2005,[12] focusing on important determinants of the endemy related to the offer of health services, mainly through the strategy "Incentive to Expand the Detection of the Hidden Prevalence of Leprosy", which provided resources per detected and reported case as a way of stimulating productivity. The results of the present study showed that, in many regions, there was an increase in the detection rate up to the end of 2005, while this strategy was executable; the sharp decreases in the detection coefficients that occurred in the turn of 2005 to 2006 may be due to changes in the funding of the procedures.

New goals were established and a strategy was proposed by the Ministry of Health, to be developed between 2006 and 2010. Up to the present moment, because of the uncertainty concerning the achievement of the objectives stipulated by the WHO, leprosy

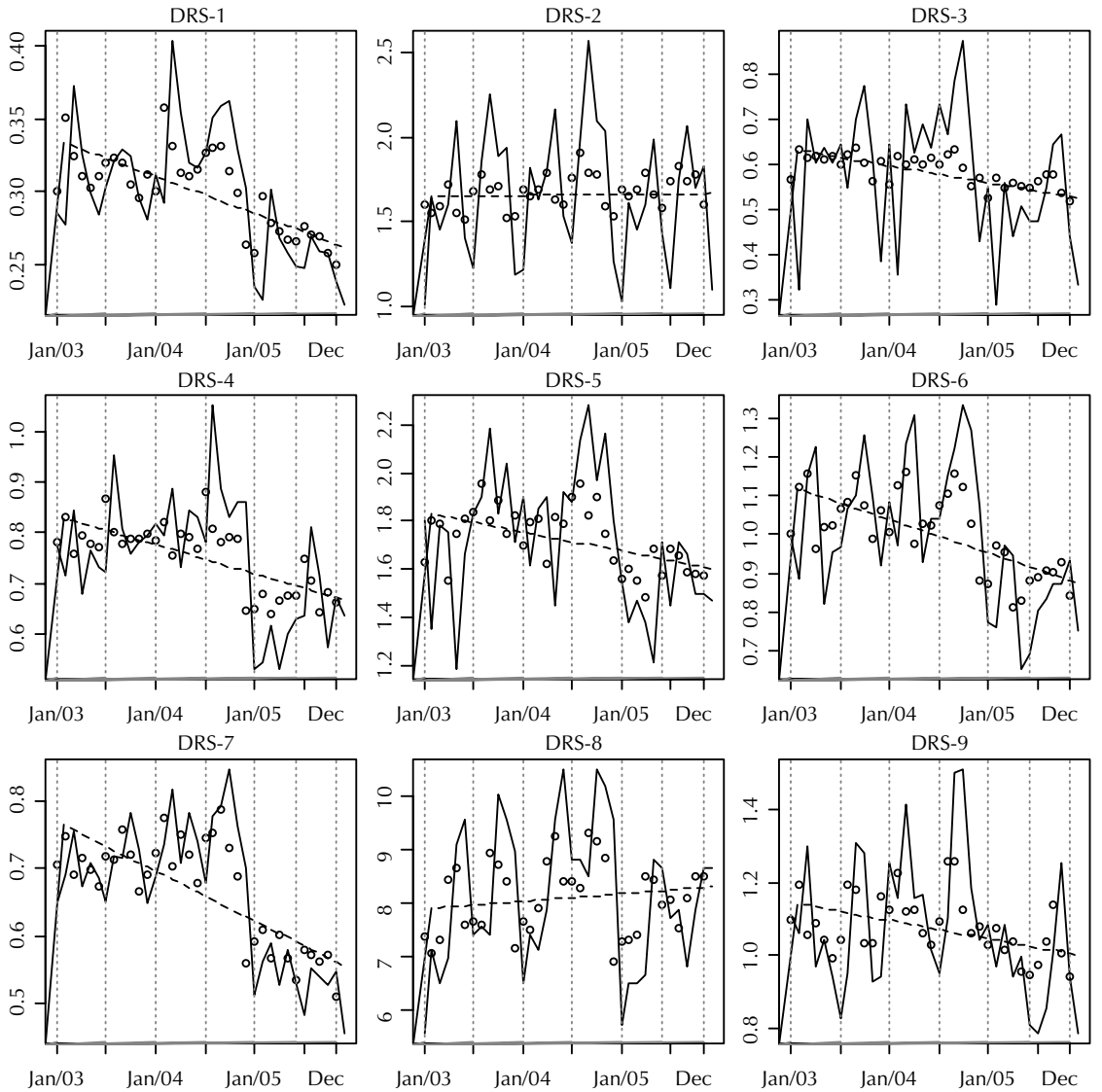

Figure 2. Monthly series of the leprosy detection coefficient per 10,000 inhabitants, in the regional healthcare departments (DRS) 1 to 9, showing the observed values (connected by a line), the adjusted values (dots) and the estimated trend (dotted line). State of São Paulo, Southeastern Brazil, 2004-2006.

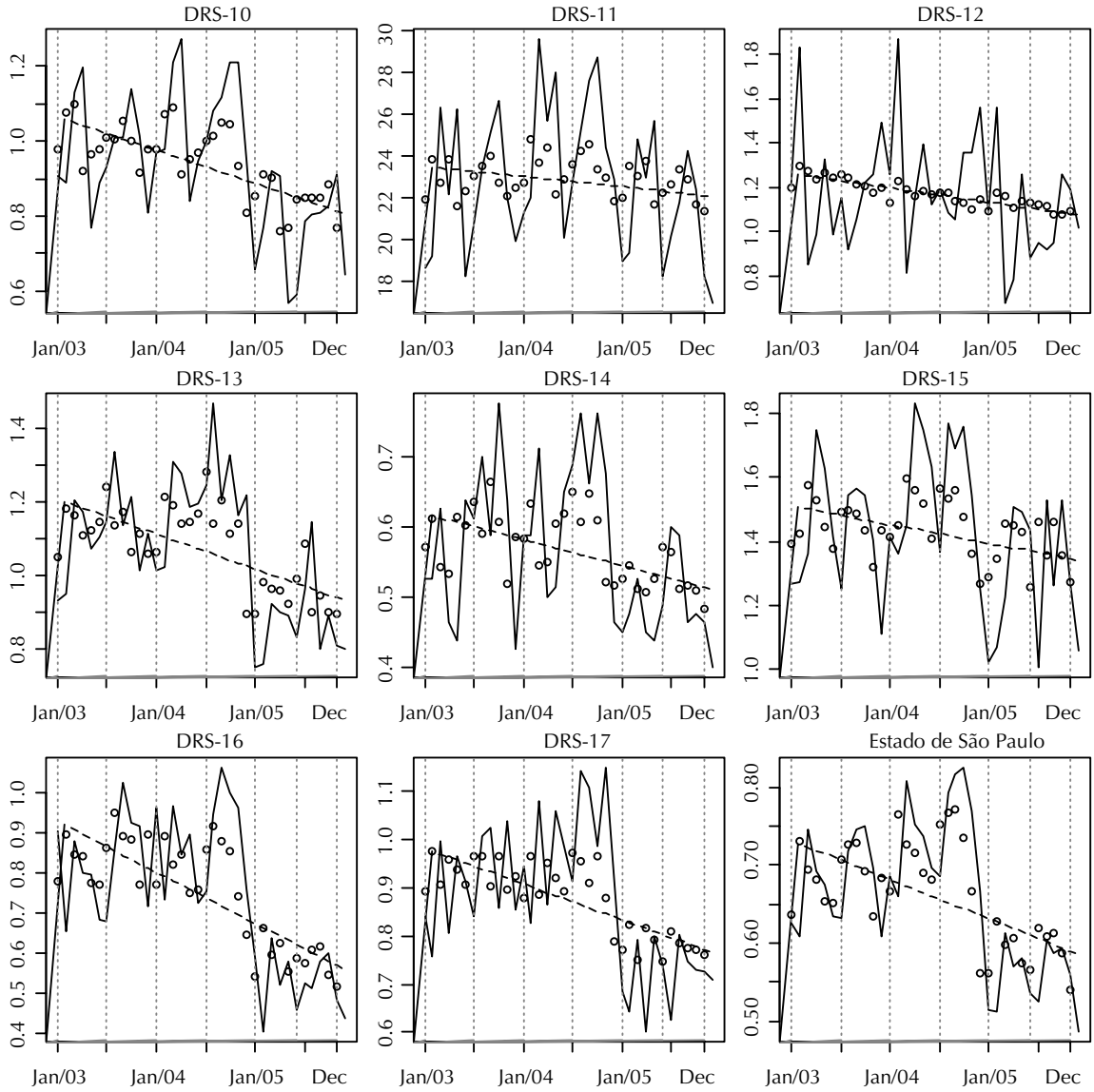

Figure 3. Monthly series of the leprosy detection coefficient per 10,000 inhabitants, in the regional healthcare departments (DRS) 10 to 17 and in the State of São Paulo, showing the observed values (connected by a line), the adjusted values (dots) and the estimated trend (dotted straight line). State of São Paulo, Southeastern Brazil, 2004-2006.

and several other diseases can be labeled as "tropical diseases" because they are endemic in countries with vulnerable economies. Programs based on secondary prevention, on active detection and on supervised treatment represent realistic, efficient, and lower cost strategies to face the leprosy endemy and meet the established goals. However, other equally important strategies demand high investments and have high costs, such as those based on technology, like molecular biology and the development of vaccines (primary prevention). It should be considered that the state of São Paulo is part of a country of vulnerable economy and that its population is subject to several epidemics and endemies. Controlling and combating them depend on the harmony between public policies and on the development of science and technology.

To conclude, although the evolution of the leprosy endemy was influenced by the Ministry of Health's strategies in the period between 2004 and 2006, they were not enough to achieve the goals established by the WHO to eliminate the disease.

REFERENCES

1. Araújo MG. Hanseníase no Brasil. *Rev Soc Bras Med Trop*. 2003;36(3):373-82.
2. Camara G, Souza RCM, Freitas UM, Garrido J. Spring: Integrating remote sensing and GIS by object-oriented data modeling. *Computers Graphics*.1996;20(3):395-403. DOI: 10.1016/0097-8493(96)00008-8
3. Chin J. Lepra. In: Manual de controle das doenças transmissíveis. 17. ed. Porto Alegre: Armed; 2002. p. 308-11.
4. Dawson B, Trapp RG. Bioestatística: básica e clínica. 3. ed. Rio de Janeiro: McGraw Hill Interamericana do Brasil; 2003.
5. Diggle PJ, Ribeiro JR, PJ. Model based geostatistics. New York: Springer; 2007.
6. Figueiredo IA, Silva AAM. Aumento na detecção de casos de hanseníase em São Luis, Maranhão, Brasil, de 1993 a 1998. A epidemia está em expansão? *Cad Saude Publica*. 2003;19(2):439-45. DOI: 10.1590/S0102-311X2003000200010
7. Lapa TM, Albuquerque MFPM, Carvalho MS, Silveira Júnior JC. Análise da demanda de casos de hanseníase aos serviços de saúde através do uso de técnicas de análise espacial. *Cad Saude Publica*. 2006;22(12):2575-83. DOI: 10.1590/S0102-311X2006001200008
8. Lourenço RW, Landim PMB. Mapeamento de áreas de risco à saúde pública por meio de métodos geoestatísticos. *Cad Saude Publica*. 2005;21(1):150-60.
9. Magalhães MCC, Rojas LI. Diferenciação territorial da hanseníase no Brasil. *Epidemiol Serv Saude*. 2007;16(2):75-84.
10. Martelli CMT, Stefani MMA, Penna GO, Andrade ALSS. Endemias e epidemias brasileiras, desafios e perspectivas de investigação científica: hanseníase. *Rev Bras Epidemiol*. 2002;5(3):273-85. DOI: 10.1590/S1415-790X2002000300006
11. Meade M, Earickson A. Medical geography. 2. ed. New York: The Guilford; 2000.
12. Moreira TA. Panorama sobre a hanseníase: quadro atual e perspectivas. *Hist, Cien Saude Manguinhos.* 2003;10(supp 1):291-307. DOI: 10.1590/S0104-59702003000400014
13. Moretin PA, Toloi CMC. Análise de séries temporais. 2. ed. São Paulo: Edgarg Blucher; 2004.
14. Opromolla PA, Dalben I, Cardim M. Análise da distribuição espacial da hanseníase no Estado de São Paulo, 1991-2002. *Rev Bras Epidemiol.* 2005;8(4):356-64. DOI: 10.1590/S1415-790X2005000400004
15. Sumway RH, Stoffer DS. Time series analysis and its applications with R examples. New York: Springer; 2006.
16. Torres HG, Ferreira MP, Dini NP. Indicadores sociais: por que construir novos indicadores como o IPRS. *Sao Paulo Perspec*. 2003;17(3-4):80-90. DOI: 10.1590/S0102-88392003000300009