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ORIGINAL ARTICLE / *ARTIGO ORIGINAL*

Spatial distribution of the human development index, HIV infection and AIDS-Tuberculosis comorbidity: Brazil, 1982 – 2007

Distribuição espacial do índice de desenvolvimento humano, da infecção pelo HIV e da comorbidade AIDS-tuberculose: Brasil, 1982 – 2007

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ABSTRACT: ***Introduction:*** AIDS epidemic has given visibility to the incidence of tuberculosis, for being the most frequent opportunistic infection. It is known that individuals who are socially vulnerable are more susceptible to HIV transmission and tuberculosis as well. ***Objective:*** This study aims to conduct a geoepidemiological study on HIV/AIDS, AIDS-Tuberculosis co-infection and social vulnerability. ***Method:*** This is an ecological study using incidence rates and the human development index to produce thematic maps and a descriptive analysis of epidemiology. The records of reported cases of HIV/AIDS from 1982 to 2007 were used, considering as cases of AIDS-Tuberculosis those records that were positively diagnosed with tuberculosis and those records with unknown diagnosis of tuberculosis, but showing compatible signs and symptoms with tuberculosis (fever, cough, cachexia and asthenia). ***Results:*** The maps allowed the identification of areas with social differences and different patterns of incidence of HIV/AIDS and AIDS-Tuberculosis; regional differences were similar to those found by Josué de Castro, in 1940; regions with higher human development index values also showed higher incidence HIV/AIDS and AIDS-Tuberculosis. ***Conclusion:*** The prevention of HIV infection must be geographically specific, given socioeconomic and cultural differences. Although official records show decline in AIDS-TB co-infection, treatment of cases of HIV/AIDS should observe the occurrence of opportunistic diseases, which should be notified and/or updated.

Keywords: Acquired Immunodeficiency Syndrome. Tuberculosis. Human development. Health information systems. Social determinant. Geoepidemiology.

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RESUMO: ***Introdução:*** A epidemia de AIDS deu visibilidade à incidência de tuberculose, por ter sido a infecção oportunista mais frequente nesses casos. Sabe-se que os indivíduos socialmente vulneráveis são mais suscetíveis à transmissão do HIV e também à tuberculose. ***Objetivo:*** Realizar um estudo geoepidemiológico sobre HIV/AIDS, coinfecção AIDS-tuberculose e vulnerabilidade social. ***Método:*** Trata-se de estudo ecológico com uso de coeficientes de incidência e do índice de desenvolvimento humano para produzir mapas temáticos e uma análise de epidemiologia descritiva. Foram utilizados os registros de notificação de casos de HIV/AIDS de 1982 a 2007. Foram considerados casos de AIDS-tuberculose os registros que tinham o diagnóstico positivo para tuberculose e aqueles que tinham diagnóstico ignorado para tuberculose, mas apresentavam sinais e sintomas compatíveis com a doença (febre, tosse, caquexia e astenia). ***Resultados:*** Os mapas permitiram identificar regiões com diferenças sociais e diferentes padrões de incidência de HIV/AIDS e de AIDS-tuberculose. As diferenças regionais assemelham-se às encontradas por Josué de Castro, em 1940. As regiões com índice de desenvolvimento humano alto apresentaram alta incidência de HIV/AIDS e de AIDS-tuberculose. ***Conclusão:*** A prevenção da infecção pelo HIV deve ser geograficamente específica, dadas as diferenças socioeconômicas e culturais. Apesar de os registros oficiais mostrarem declínio da coinfecção AIDS-tuberculose, o tratamento dos casos de HIV/AIDS deve constatar a ocorrência de doenças oportunistas, que deveriam ser notificadas e/ou atualizadas.

Palavras-chave: Síndrome da imunodeficiência adquirida. Tuberculose. Desenvolvimento humano. Sistemas de informação em saúde. Determinantes sociais. Geoepidemiologia.

INTRODUCTION

It is estimated that 50 million people are carriers of *Mycobacterium tuberculosis* (Mt), and that 129,000 new cases of tuberculosis (TB) are diagnosed every year[1]. Tuberculosis is the most common death-causing communicable disease in developing countries. In the early 21st century, Brazil ranked 15th among the 22 countries that showed 80% of reported cases on the planet[2]. In 2002, there were 36,227 reported cases in the Southeast region (15,885 cases in the state of São Paulo and 13,152 in the State of Rio de Janeiro), 22,244 cases in the Northeast (6,351 cases in the state of Bahia), 8,790 cases in the South, 7,122 cases in the North and 3,453 cases in the Midwest region. Considering the population size of each state, the State of Rio de Janeiro had the highest coefficient, followed by the states of Bahia and Rio Grande do Norte[3]. Tuberculosis occurs more easily in environments with high population density, in conditions of malnutrition and poverty[4,5].

HIV infection weakens the immune system of individuals, making them up to 50 times more vulnerable to tuberculosis when compared to uninfected individuals[6]. Karpati et al.[7] found an association between the incidence of tuberculosis, behavioral factors, socioeconomic conditions and poverty. The economic development of the South American continent has

increased commercial activities, by multilateral trade agreements such as Mercosur, which enhances human contacts[8], promoting the transmission of HIV and M.tuberculosis (MTb)[9].

Epidemiology studies the patterns of incidence of diseases, focusing on demographic, spatial and temporal characteristics; geoepidemiology has contributed to the geographical assessment of HIV infection[10,11]. Eco-epidemiological studies consider the division of municipalities as a criterion for aggregation of information from case reporting, generating a sociopolitical diathesis. The Human Development Index (HDI)[12] is a useful tool to study the correlation between socioeconomic factors and the incidence of disease.

This study aims to evaluate the spatial relationship between the incidence of AIDS and AIDS-tuberculosis comorbidity in relation to the HDI, in Brazilian municipalities, seeking to contribute with the knowledge on social determinants in Brazil.

METHOD

Three levels of aggregation were considered: data aggregated by macroregion (North, Northeast, Southeast, South and Midwest), used in the descriptive epidemiology of reported cases of infection by HIV and AIDS and by AIDS-tuberculosis comorbidity; data aggregated by microregions, used in the geostatistical analysis of the incidence of HIV infection and of AIDS-tuberculosis comorbidity, as a strategy to circumvent the bias of small areas, which produces overdispersion in the Poisson random variable[13]; data aggregated by municipalities were used in geostatistical analysis of the HDI, which is available from the Institute of Applied Economic Research (IPEA) in this format. Such divisions were defined according to the Brazilian Institute of Geography and Statistics (IBGE).

In the study, the total cases of HIV/AIDS reported to the Department of Sexually Transmitted Diseases, AIDS and Viral Hepatitis, linked to the Department of Health Surveillance of the Brazilian Ministry of Health, from January 1st, 1980 to December 31st, 2007, were obtained; this time frame was adopted because the Rio de Janeiro/Caracas criteria, which adopted tuberculosis as an opportunistic infection indicative of AIDS, and was gradually replaced by laboratory testing criteria, making the notification form an incomplete source for the study of focused comorbidity. Cases selected presented diagnostic made by the Rio de Janeiro/Caracas criteria, adapted CDC and investigation of death, besides cases of HIV infection identified by laboratory tests. Among the cases of HIV/AIDS, the following were considered as evidence of comorbidity AIDS-tuberculosis: (1) when there was a positive and confirmed diagnosis of tuberculosis, and (2) when the diagnosis of tuberculosis was ignored, but the signs/symptoms of fever, cough, asthenia and cachexia had been registered, making them suspected cases of AIDS-tuberculosis comorbidity[14]. Two variables were generated: count of the incidence of HIV/AIDS and of the incidence of AIDS-tuberculosis comorbidity, which were aggregated by microregion, and their incidence rates were calculated on base 5, using the population sizes of the 2000 Population Census by IBGE. HDI values from the 2000 Census were used, being the nearest estimative from the half of the study period, considering that

the status of human development does not change substantially in a few years, especially in a country of continental dimensions and marked social differences like Brazil.

Thematic maps were produced with the study variables, using the geostatistical technique known as kriging[15,16]. Incidence rates of HIV/AIDS and AIDS-tuberculosis received the logarithmic transformation, because that is the binding function of random variables with Poisson distribution in the theory of generalized linear models[13]. As part of the kriging method, semivariograms were adjusted for each measure of incidence and for HDI, adopting the exponential function as describer of the relations of spatial dependence. The initial parameters of the stochastic process, such as nugget, sill and range effects, were visually defined[14-16]. The I-Moran estimator was used to study the existence of spatial dependence of the incidence rates, making the geostatistical model feasible[11,17]. The descriptive analysis included stratification by sex, age, HIV transmission category, macroregion of residence and year of diagnosis. The STATA® software and free software "R", with "geoR" package, were used.

RESULTS

Table 1 presents the characteristics of the pattern of incidence of HIV/AIDS and AIDS-tuberculosis comorbidity, according to age, gender and HIV transmission category, in the country's macroregions. The burden of epidemic HIV/AIDS in the Southeast, which is the most populated and the one with the highest intensity of human contacts; there is a higher incidence in people in the 20-49 years age groups, classified as "young adults". The transmission of HIV through sex is noteworthy as the most important in all geographical regions, in addition to the transmission by use of injectable drugs in the South and Southeast. The large number of cases reported in the unknown category of HIV transmission reveals the quality of the collection instrument of the information system. Table 1 also shows the incidence of AIDS-tuberculosis comorbidity as a fraction of the reported cases, with an underestimation of the actual dimensions, because of the non-monitoring of HIV/AIDS cases after diagnosis and/or notification.

Temporal trends in the incidence of AIDS-TB (Figure 1) shows the sharp increase in the detection of tuberculosis among reported cases of HIV/AIDS by 1992, mainly in Southeast macroregion, which stabilized between 1992 and 1997, and declined after 1998. The strong growth until 1992 can be explained by the size of the population in the Southeast, which, being larger, produces more case reports; the subsequent decline may be due to the infrastructure and organization of diagnostic services, which perform the detection of HIV through laboratory tests, even before the onset of opportunistic diseases such as tuberculosis. A consequence of this is that the presence of AIDS-tuberculosis co-infection is not important for the diagnosis of AIDS.

Among the reported cases of HIV/AIDS that had a confirmed diagnosis of tuberculosis, the incidence was higher in subjects of the 20 – 49 years age range. Among the reported

Table 1. Distribution of diagnosed cases of AIDS/HIV and of AIDS-tuberculosis by macroregion, age, gender and HIV transmission category, Brazil, 1980 – 2007.

Variable	HIV/AIDS cases					AIDS-tuberculosis cases				
	N	NE	SE	S	MW	N	NE	SE	S	MW
Age range (years)										
Up to 12	576	1,698	9,252	4,078	851	–	–	–	–	–
13 – 19	432	984	6,005	2,243	673	8	9	103	13	5
20 – 34	8,198	25,957	137,504	42,285	13,452	82	239	2,100	315	201
35 – 49	5,593	19,845	108,987	32,275	9,596	47	168	1,364	172	107
≥ 50	1,304	4,605	27,325	8,369	2,185	14	36	309	31	24
Gender										
Female	5,703	17,322	94,059	33,600	9,288	60	151	1,026	143	104
Male	10,400	35,767	195,010	55,649	17,468	91	301	2,850	388	233
HIV transmission category										
Homosexual	1,685	7,449	36,188	7,441	2,703	11	61	586	39	22
Bisexual	1,238	5,253	17,666	4,143	1,697	10	51	275	16	21
Heterosexual	6,996	21,094	113,787	39,834	12,041	98	240	1,489	236	144
Drug user	568	2,156	43,668	15,335	2,740	16	18	1,067	185	89
Blood transfusion	74	364	2,412	312	249	–	6	39	2	3
Vertical	328	1,027	6,328	2,777	566	–	–	–	–	–
Unknown	1,087	4,836	34,380	6,056	2,732	16	76	419	53	58

N: North, NE: Northeast, SE: Southeast, S: South, MW: Midwest.

cases in the heterosexual HIV / AIDS transmission category (47.6% of records), 41.3% cases with AIDS-tuberculosis comorbidity were confirmed in the country. In the injectable drug use transmission category, 4.7% of notifications were observed in the North, 5.1% in the Northeast, 17.2% in the Southeast, 20.2% in the South and 12.1% in the Midwest, which confirmed the diagnosis of tuberculosis in 10,6%, 4.0%, 27.5%, 34.8% and 26.4% of cases, respectively. In the homosexual and bisexual transmission category, 24.4% of notifications were observed in the North, 30.1% in the Northeast, 21.2% in the Southeast, 15.3% in the South and 19.4% were found in the Midwest, with confirmed diagnosis of tuberculosis in

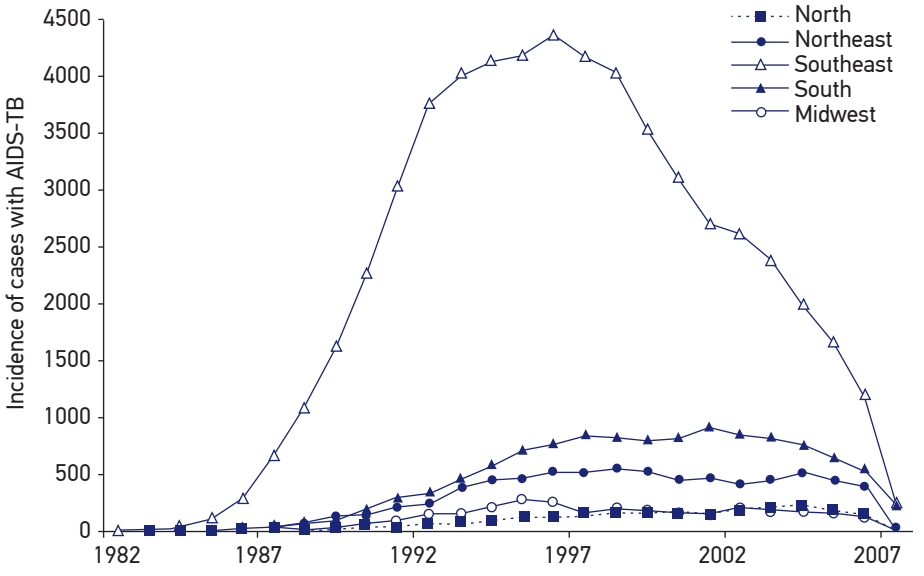

Figure 1. Temporal trends of incidence of AIDS-tuberculosis by macroregion: Department of Sexually Transmitted Diseases, AIDS and Viral Hepatitis of the Ministry of Health, Brazil, 1982 – 2007.

13.9%, 24.8%, 22.2%, 10.4% and 12.8%, respectively, of these cases. A total of 5,347 cases were admitted with AIDS-tuberculosis comorbidity in the cases recorded with diagnosis of HIV/AIDS, 151 in the North, 452 in the Northeast, 3,876 in the Southeast, 531 in the South and 337 in the Midwest; of the total, 2,586 were residents of the State of São Paulo, 869 in the State of Rio de Janeiro, 370 in Minas Gerais and 51 in Espírito Santo. A total of 81,590 AIDS cases with tuberculosis were found, considering reported and suspected cases, with 57,068 cases in the Southeast (38.611 in the State of São Paulo and 13,168 in the State of Rio de Janeiro), 11,613 in the South, 7,497 in the Northeast, 3,052 in the Midwest and 2,360 in the North.

The study of spatial correlation showed statistical significance of the existence of spatial correlation of the distribution of the incidence of HIV/AIDS (I = 0.22, Z-score = 60.76), the incidence of AIDS-tuberculosis (I = 0.19, Z-score = 54.03), and HDI (I = 0.78, Z-score = 791.44). These results support the idea that there is a spatially correlated behavior, making the use of the geostatistical model feasible, using proximity criteria (distance as a determinant of correlation), that is, the Kriging method can be used to produce zoning — thematic maps.

The thematic map of the incidence rate of HIV/AIDS is presented in Figure 2. On the map, areas with high incidences, especially the coastal towns of the South, Southeast and North, bordering Guyana, Venezuela, Colombia, Bolivia, Paraguay, Argentina and Uruguay, can be seen. There is a major route of dissemination of the HIV/AIDS epidemic that connects the coastal areas of the Southeast, in the State of São Paulo, and go toward

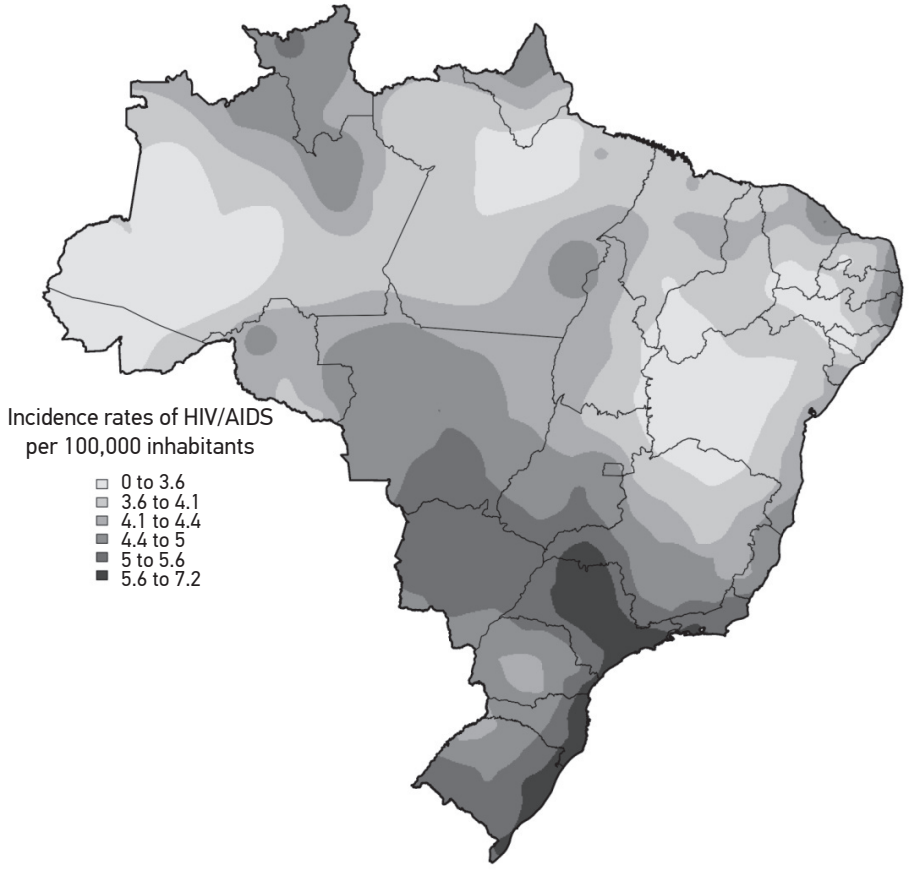

Figure 2. Thematic map of the distribution of the incidence rate of HIV/AIDS per 100,000 inhabitants per microregion: Department of Sexually Transmitted Diseases, AIDS and Viral Hepatitis of the Ministry of Health, Brazil, 1982 – 2007.

the towns of Ponta Porã, Bela Vista and Corumbá, in the triple border with Paraguay and Bolivia. Cases of HIV / AIDS were found almost entirely in Brazilian territory, except in regions of the Amazon forest and the central region of the North. The thematic map of the incidence rate of AIDS-tuberculosis is shown in Figure 3, which shows a similar pattern to the HIV / AIDS, but presents more ramified areas toward several regional / local cores. The HDI thematic map is shown in Figure 4, which shows the greatest concentration of human development (HDI > 0.80) in the Southeast and South, especially, as well as some areas in the Midwest. Noteworthy regions are those with low HDI (HDI < 0.60) in the Northeast, especially in the backcountry and the in Amazon, where indigenous reserves are found.

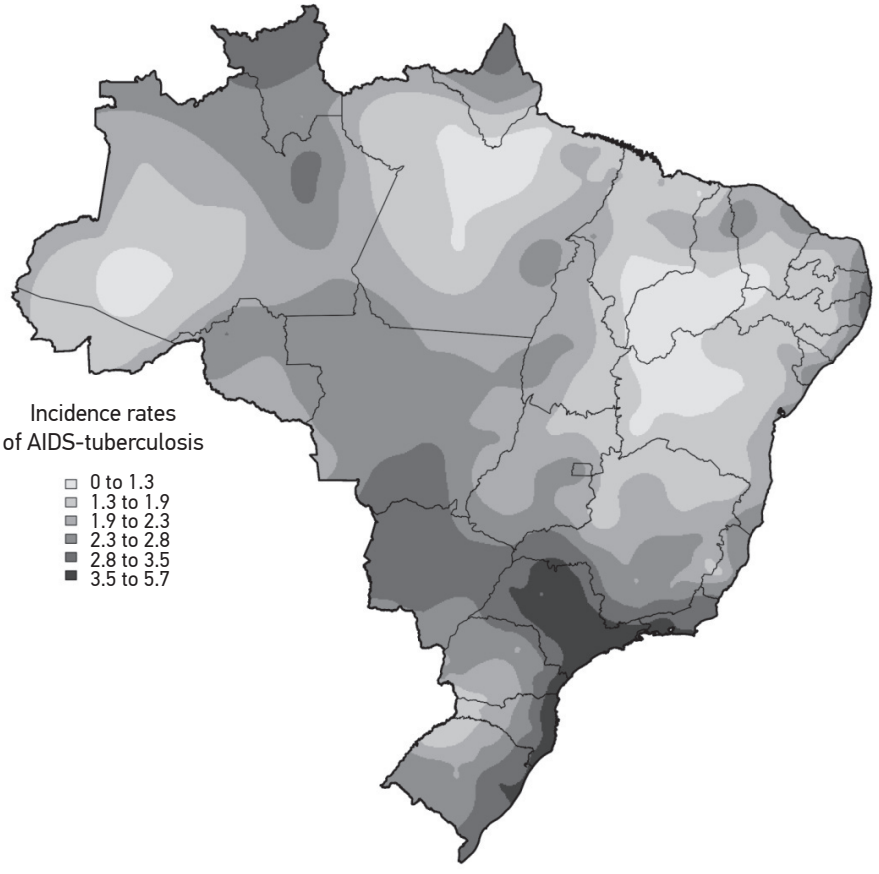

Figure 3. Thematic map of the distribution of the incidence rate of AIDS-tuberculosis in percentiles per 100,000 inhabitants per microregion: Department of Sexually Transmitted Diseases, AIDS and Viral Hepatitis of the Ministry of Health, Brazil, 1982 – 2007.

DISCUSSION

The geostatistical model adjusted for the rate of incidence of HIV/AIDS showed, highlighting areas where residents are more exposed not only because they reside in these areas, but because, in some manner or dynamic, they are more susceptible to HIV infection. In Figure 2, the area stretching from the coast of the states of São Paulo and Rio de Janeiro, where the epidemic began in the 1980s, toward the triple border with Bolivia and Paraguay, which runs through the state of Mato Grosso to the states of Pará and Rondônia, is stressed. There is also a coastal extension starting from the states of São Paulo and Rio de Janeiro towards the South; there are areas of susceptibility in the coastal Northeast and regional

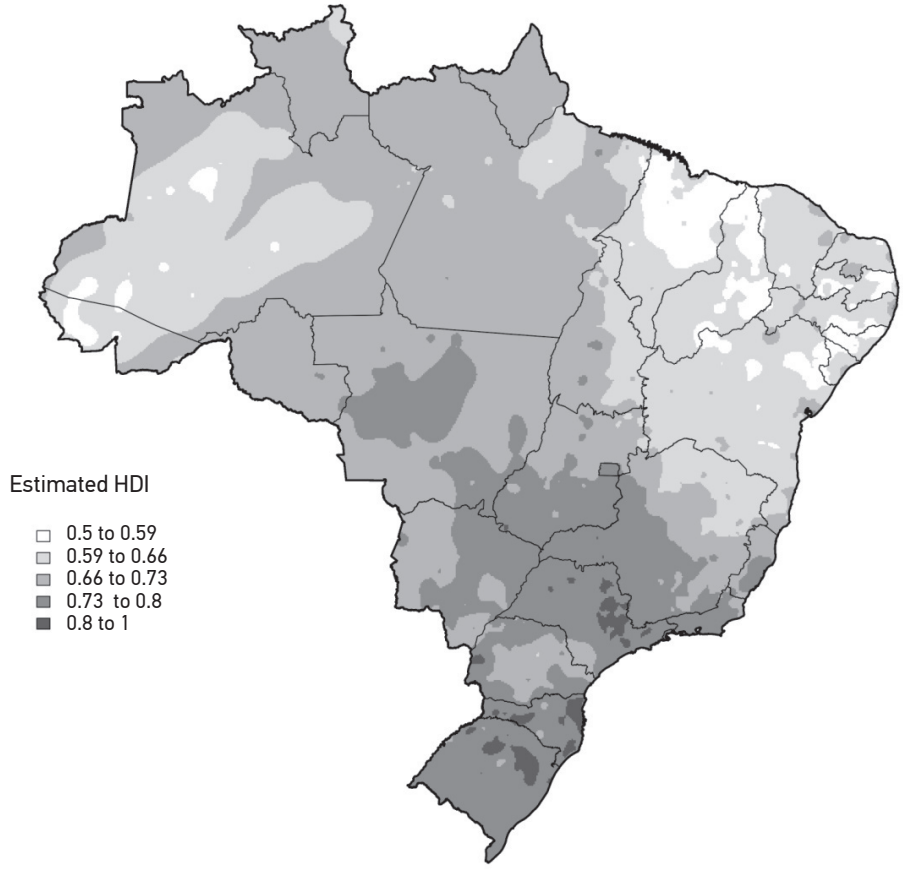

Figure 4. Thematic map of the distribution of Human Development Index by municipality: the limits of class intervals were manually identified for a better visualization of the magnitude of the Human Development Index, UNDP, 2000.

centers near Manaus, in State of Amazonas, which extends towards the state of Rondônia and to the border with Colombia and Venezuela; there are areas in the Oiapoque region, near the border with French Guiana.

The State of São Paulo has an epidemiological landscape that has the highest rates of HIV transmission in the country. Starting from the city of São Paulo, which is the center of economic production of the country, there is an axis of diffusion of the HIV/AIDS epidemic towards the countryside, until it reaches the triple border with Bolivia and Paraguay, where there is a flow of production and distribution of raw materials and consumer goods in both directions, both from the interior to the coast for export occurs, as well as from the state capital to the inlands, for the distribution of products. This economic infrastructure facilitates contact between people, the spread of HIV and serves as a platform for the traffic

of illegal drugs. It is known that the strategy used to enable the "passage" of shipments of illicit drugs through municipalities towards the coast and from there to locations abroad is the cheapness of the drug, which generates users along the route[18]. This explains the transmission of HIV to injectable drug users in the State of São Paulo.

There is evidence in the literature that HIV transmission at the border of the Amazon region is related to migration processes of individuals and families — mainly farmers — who evade the areas where there are narcoguerilla activities heading to the Brazilian territory, moving primarily to the towns of Tabatinga and Manaus. These migrants often have little or no education, making them socially vulnerable subjects, unemployed in urban environments[9,10,19]; poor women are the most vulnerable to prostitution, being more exposed to unprotected sex due to their little bargaining power as sex workers in poor regions

The areas with higher HIV exposure located near the coast, in the Northeast and in the South, are related to transmission through sex; in the Northeast, there is little impact of HIV transmission through injectable drug use, but in the Southeast and South, the impact is great. In the Northeast, there is evidence of the existence of "sex tourism" and its causality in the transmission of HIV, which, in turn, is closely associated with poverty and social exclusion[19]. Josué de Castro, in the 1940s, described areas with different types of hunger in Brazil, noting: areas of epidemic famine, caused by long periods of drought, as a cyclic natural disaster, especially in the Northeastern backlands area, affecting people as an epidemic; areas of endemic famine, which exposed communities to incomplete nutritional standards, particularly in the Amazon region, in spite of the region's biodiversity, and in the North; areas of poor nutrition and obesity located in the South, Southeast and Midwest, where there was economic output in agriculture and livestock, and where food consumption was based on the combination of starch and fat[20].

The work of Josué de Castro represented an important contribution to social epidemiology and, with the existence of a correlation between "hunger" and "social determinants", his findings do not appear to have changed substantially over time, when looking at the thematic map of the distribution of the HDI, for example: the areas of endemic famine and areas of epidemic famine coincide with areas of low HDI and, similarly, the areas of obesity and malnutrition coincide with areas of high HDI. The distribution map of the HDI shows the conditions of inequality in the country, suggesting that there was little change in the last 60 – 70 years.

In this study, epidemiological measures with different geographical scales or levels of aggregation were admitted, in order to produce credible evidence to the analysis of social determinants of the HIV / AIDS epidemic and the AIDS-tuberculosis comorbidity, assuming that the measurement of HDI is adequate. The adjusted geostatistical model for the three measures was able to recreate coherent epidemiological landscapes with the theoretical background of the issues involved, noting that the microregional scale downplayed the problem of overdispersion of the Poisson variable. It cannot be stated that the geostatistical technique rebuilt a virtual reality, by abstraction, producing

evidence that corroborate the accumulated knowledge; thematic maps represent a credible approximation of the data.

The information system of the Department of Technology of the Brazilian Unified Health System (DATASUS) is an important source of public information (open-source), which has enabled reviews from the point of view of public health policies, particularly with regards to the AIDS epidemic. The cases of HIV/AIDS have been recorded since the 1980s, and information production cycles (collection, processing, analysis and distribution) have been improved, aiming at minimizing the delay of notification and reducing underreporting, to increase the quality of information; however, in the evolution of the informational processes of the epidemic, technical procedures of AIDS diagnosis were improved. Prior to 1997, diagnosis of AIDS was based on finding a set of opportunistic diseases, with tuberculosis being the most prevalent, of signs and symptoms (Rio de Janeiro/Caracas and adapted CDC criteria) and of posthumous investigation. The diagnosis is now done by serology, in reference centers, detecting HIV infection before the onset of opportunistic diseases and immunodeficiency. This change in technical procedures produced an underreporting of opportunistic diseases, because there was no record of confirmation of tuberculosis, for example, after the notification of cases of HIV/AIDS. Figure 1 shows the decline in tuberculosis notification, after 1997, clearly visible in the Southeast, which should not be understood as a result of opportunistic disease control, but the lack of follow-up of cases infected by HIV. The notification system of HIV/AIDS cases has served to enroll the user for the distribution of the treatment, but has not been valued as a strategic tool for the prevention and confrontation of diseases.

CONCLUSION

The information produced in this study were consistent with the existing body of knowledge, clearly showing the regions of the country with highest and lowest human development indices, which showed a relation to the areas of famine of Josué de Castro, corroborating the claim that social and economic changes do not occur over short periods of time, but take decades. The study showed spatial correlation of aggregate measures, making geostatistical technique an important tool for the construction of epidemiological knowledge. Maps of incidence of HIV/AIDS and the incidence of AIDS-tuberculosis revealed priority areas for action by the State and society, considering that those with the lowest incidence rates coincide with areas of low values of the human development index, and whose infrastructure and the provision of health services can be improved.

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