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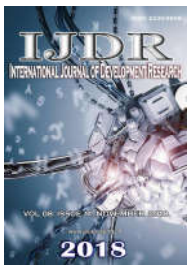

ORIGINAL RESEARCH ARTICLE OPEN ACCESS

INCIDENCE OF LEPROSY IN THE BRAZILIAN AMAZON REGION AND ITS ANALOGY IN RELATION TO BRAZILIAN MUNICIPALITIES: A SOCIODEMOGRAPHIC ANALYSIS USING BAYESIAN NETWORKS

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ABSTRACT

Considering the importance of studying the incidence of leprosy and the scarcity of studies that evaluate the occurrence of this phenomenon in the Brazilian Amazon region in relation to the Brazil, this study aimed to analyse the association between leprosy incidence and the municipal indicators of education, income and domicile population density, comparing municipalities of the Amazon region to those of the whole country. We used data obtained on cases of leprosy in Brazil, availabled by the Information System of Hardship Notifications through the Informatics Department of the National Health Service and the socio-economic indicators found in the last Demographic Census of the Brazilian Institute for Geographical and Statistical Survey, information from the Municipal Human Development Index, regarding education and income, obtained from the website of the Human Development Atlas of Brazil. The methodology combined data mining with the analysis of spatial distribution. We found that municipalities of the Brazilian Amazon region present a high rate of leprosy incidence (65.7%); but this value declines (13.1%) when the analysis contemplated other regions of the country. Using the Bayesian network model, was a significant association between the percentage of homes with more than 2 inhabitants and the rate of incidence of leprosy.

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INTRODUCTION

The Millennium Declaration, elaborated by the United Nations Organization, was based on eight Millennium Development Goals, established by the member states, through a series of assurances to be met within a fixed timescale, in order to improve the future of the human race in this century. The goals, with targets and indicators, were adopted by 164 countries. The sixth goal concerns the combat against diseases that threaten above all the poor and most vulnerable populations, where such countries should strive to reduce poverty through access of the population to information and provide means of prevention and treatment, without neglecting environmental care and nutrition that can stop the spread of these diseases (UN, 2000). In Brazil, in spite of the significant reduction in mortality due to infectious diseases, some diseases are still epidemic such as dengue and other diseases spread by vectorial contamination, and even endemic diseases are persistent, such as tuberculosis and leprosy, which were expected to be under control (Barreto, 2013). The so-called neglected diseases, which include leprosy, are serious hardships that persist in the country and are related to poverty, poor health and social exclusion (Augusto, 2016). Leprosy is a chronic contagious disease caused by the bacterium *Mycobacterium leprae*. It constitutes an enormous social problem in view of its capacity to infect a massive number of individuals, although few become ill. Its incidence is greatest among the economically lowest classes, due to overexposure, low educational level, nutrition and living conditions (Brito *et*

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al. 2014). Indeed, the home is regarded as an important location for the transmission of the disease (Oliveira *et al.* 2014). Leprosy is still a serious problem in public health. Brazil is ranked as the second country with the greatest number of new cases detected in the world, after India. Although the annual detection rate is in decline, in 2010 the global incidence of leprosy was around 212 thousand cases. In Brazil, in 2014, of the 31,064 new cases, 2,341 involved children under 15 and the general detection rate was 15.32 cases per 100 thousand inhabitants. Some municipalities in Brazil have been able to eliminate the disease, however, the north, central-west and northeast regions still record high levels of the disease. In spite of an overall tendency for the detection rate stabilizing in Brazil, there are large regional differences (Gracie *et al.* 2017). Leprosy is still a public health problem in Brazil and requires more effective public policies. Late diagnosis, the refusal to seek services for treatment and negligence with self-care can lead to deformities and physical incapacities that, besides the financial burden for health services, result in poor self-respect and interfere in an individual's perception of the world, culminating in avoiding social relations. The stigma suffered, especially with leprosy, is particularly severe, where men often are the hardest hit and more difficult to cure (Melinski e Girardi, 2014). The establishment of effective public policies for prevention, control and treatment, requires an efficient system for the registration, treatment and recovery of information so that the diagnosis, therapeutics and epidemology may be correctly conducted. The use of computational systems combined with the application of probabilistic models, such as the Bayesian network model could be an effective way to reach efficient solutions as an aid for health administrators in decision making. Considering the importance of studying the incidence of leprosy and the scarcity of studies that evaluate the occurrence of this phenomenon in the Brazilian Amazon region in relation to the whole country, this study aims to analyse the association between leprosy incidence and the municipal indicators of education, income and domicile population density, comparing municipalities of the Amazon region to those of the whole country

MATERIALS AND METHODS

As a source of data, we used the Research on Homes within the database of the Demographic Census of the Brazilian Institute for Geographical and Statistical Survey – IBGE[1], with regard to the Brazilian municipalities for the year 2010, the latest census carried out. Data were collected from this database for variables concerning the dwelling conditions of the inhabitants. Overall, the sample covered 57,320,474 homes in 5565 municipalities, where 771 were located in the Brazilian Amazon region. Some 42,017 records of leprosy incidence in the municipalities were found in the DATASUS database (Informatics Department of the National Health Service – SUS[2]) of the Information System of Hardship Notifications (SINAN), again regarding Brazilian municipalities for the year 2010. In addition, components of the Municipal Human Development Index (IDHM), regarding education (IDHM-Education) and income (IDHM-Income) were obtained from the website Human Development Atlas of Brazil[3], also for the year 2010. The geospatial database for Brazilian municipalities was obtained from IBGE[4] in *shape file* format, that is operable by the majority of geographic information systems. From these various databases ten variables were selected with regard to the dimensions of leprosy, habitation, income and education, shown in Table 1.

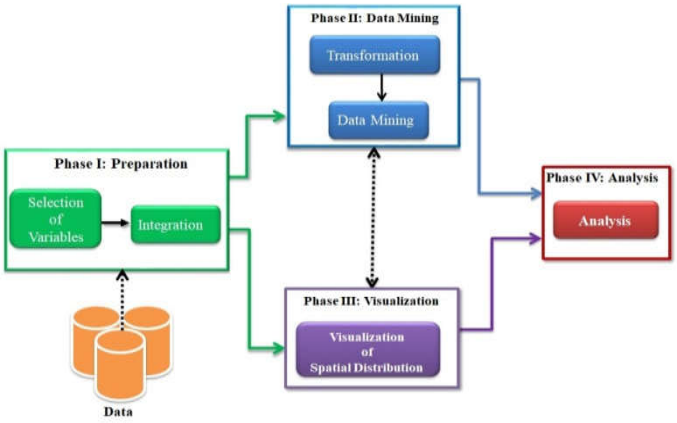

Figure 1. Methodology in phases for data analysis

In phase I (Figure 1), data preparation, the variables were selected and integrated in a single database, resulting in 5565 records of identified municipalities (code and name of municipality) with 10 associated attributes (variables). For integration, pre-processing was necessary, that is, the data were scrutinized so as to eliminate cases of redundancy and inconsistency. In the second phase the two following steps were undertaken: transformation and data mining. For this purpose, only those variables under study were selected, ignoring the identification of the municipality (code and name). This resulted in a matrix of 5565 rows (municipalities) by 10 columns (variables). Transformation involved the application of algorithms of discretization aimed at placing values in intervals such that a limited number of possible states were obtained. This step is important because in a search for association it is not possible to use continuous values since a single variable can be made up of a large quantity of different values, such that it would be impossible to identify relevant associations. The discretization method used was based on frequency, that is, an equilibrium was sought as to the number of records in each range of values, so that ideally each discretization range would contain the same number of records. Thus, all the continuous variables (*Piped Water Supply, Bathroom Piped Water Supply, Rubbish Collection, Electricity Supply, PopDensityAbove2, Leprosy, IDHM-Life Expectancy, IDMH-Income, IDHM-Education*), were put through the process of discretization by frequency. Following this, still in the data-mining phase, the Bayesian network technique was applied in order to measure the association between the studied variables. Bayesian networks permit the construction of models formed by a qualitative structure, defined by directed acyclic graphs, where the dependencies between nodes (variables) and a quantitative structure (conditional probability tables of the nodes) could be represented, enabling these dependencies to be expressed in probabilistic terms (Chen, 2001). These structures offer an efficient representation of the probability distribution of the set of variables under study. Thus, for each node, a distribution of locality probability exists, depending on the status of their parents.

[1] http://sidra.ibge.gov.br
[2] http://www2.datasus.gov.br
[3] http://atlasbrasil.org.br
[4] http://downloads.ibge.gov.br/downloads_geociencias.htm

Table 1. Selected variables and data source

Variable	Description	Data source
Piped Water Supply	Percentage of homes with piped water supply. Calculated as the ratio between the number of people living in permanent private homes with water on supply to one or more rooms and the total population resident in permanent private homes, multiplied by 100. The water may be from a general pipe system, a well, a spring or reservoir supplied with rainwater or a tanker.	IBGE
Bathroom Piped Water Supply	Percentage of homes with a bathroom and piped water supply. Calculated as the ratio between the number of people living in a permanent private home with water on supply to one or more rooms and a separate bathroom and the total population resident in permanent private homes, multiplied by 100. The water may be from a general pipe system, a well, a spring or reservoir supplied with rainwater or a tanker. A separate bathroom is defined here as a room with a shower or bath and a toilet bowl.	IBGE
Rubbish Collection	Percentage of homes with rubbish collection. Calculated as the ratio between the number of people living in homes with rubbish collection and the total population resident in permanent private homes, multiplied by 100. This includes situations where rubbish is collected directly by a public or private firm, or rubbish deposited in a dump bucket of any kind outside the residence for posterior collection. Only permanent private homes in an urban area are considered.	IBGE
Electricity Supply	Percentage of homes with electricity supply. Calculated as the ratio between the number of people living in a permanent private home with electricity and the total population resident in permanent private homes, multiplied by 100. Electricity supply is considered whether coming from a general network or not, and with or without a meter.	IBGE
Pop Density Above2	Percentage of homes with a population density above 2 people per bedroom. This is the ratio between the number of people living in a permanent private home with a population density above 2 and the total population resident in permanent private homes, multiplied by 100. The population density of the home is the ratio between the total number of inhabitants of the home and the total number of rooms used as bedrooms.	IBGE
Leprosy	Incidence of leprosy in the municipality. Calculated as being the quotient between the number of cases multiplied by 100,000 habitants and the total population.	DATASUS
IDHM-Life Expectancy	Corresponds to the life expectancy according to IDHM. Calculated from the life expectancy at birth; shows the number of years that a person born in a determined municipality will live, maintaining the same mortality rate.	ATLAS BRAZIL
IDHM-Income	Corresponds to the income component of the IDHM. It is measured as the municipal income *per capita,* or, in other words, the average income of the residents of a determined municipality.	ATLAS BRAZIL
IDHM-Education	Corresponds to the education component of the IDHM. Calculated from the geometric mean of two sub-indexes: the frequency of children and young people in school (weight factor 2/3) and the educational level of the adult population (weight factor 1/3).	ATLAS BRAZIL
Spatial Reference	Indicates whether the municipality is located in the Amazon region or in another region of the country, assigned values as "Amazon" or "Other", respectively.	IBGE

In order to test the Bayesian network structure, an algorithm for a K2 heuristic search (Cooper e Herskovits, 1992) was applied, based on a matrix of 5565 rows x 10 columns. The K2 algorithm learns the structure of the Bayesian network from the matrix applied using a method that selects the structure with maximum true similarity, through a repetitive search that initiates with a very simple network structure where all the variables are dependent on one another. Then, an evaluation is made of marginal true similarities of each network resulting from possible changes (such as, the addition of a new link between two nodes of the network) followed by the application of the best alterations before starting a new repeat process. This procedure continues until the algorithm is no longer able to find any single alteration that increases the maximum similarity. The resulting network may contain a number of dependent variables lower than the number of variables in the matrix. This algorithm, classified as a search tool, was selected according to its performance in terms of computational complexity and precision, obtained from an adequate sorting of variables. In this study, the target variable (leprosy) was placed in the last column of the matrix. Once the Bayesian network was established, statistical analysis was used to estimate the posterior distribution of the parameters. The basic task of analysis consisted in computing the conditional probability distribution using quantitative information of the Bayesian network, that is, for any set of consultation variables (*Consult*), given the values of the observed event (*Evidences*), the system computes P (*Consult*| *Evidences*). In order to evaluate the relevance of the association rules produced, the model support-confidence (Agrawal *et al.,* 1993) was used that permits evaluation of the quality of the association found. In the third phase, the software Qgis[5] was employed and the 5565 municipalities integrated in the *shap efile* file, that contains the georeferenced information of the municipalities, in order to present the spatial distribution of leprosy incidence in Brazil. The maps obtained in this phase, together with the results of data mining, were analyzed in phase IV.

RESULTS

The data were selected and compiled in a single database, as described in the Methods section for the first phase. In the second phase, all the continuous variables were subjected to discretization, where intervals of the same frequency were considered for distribution of each value in the created categories. In the case of the variable *Leprosy*, due to the elevated number of municipalities (2,193) without any recorded cases of the disease, it was necessary to first classify these municipalities as "NoCases" and then apply the method of discretization by frequency for the remaining municipalities (3,372). Thus, the municipalities with cases of the disease were classified in three ranges of values, of equal frequency (Table 2), that is, 1,124 municipalities in each category of disease incidence ("low", "medium", "high") Other variables were discretized in four range of values (Table3). The means for the rate of incidence of leprosy for the municipalities of the Amazon and other regions are presented in Table 4 and include a list of the top ten Brazilian municipalities with the highest incidence of the disease. Although the average for the Amazon region is greater than for other regions of the country, the top ten list contains only five municipalities of the Amazon. The others are three from the state of Mato Grosso (MT), one from the state of Tocantins (TO) and one from the state of Pará (PA). In the Amazon, the municipality with the greatest incidence is Araguaiana (state of MT), with 563.03 and second is Jacareacanga (state of PA) with 354.53.

[5] http://qgis.org

Table 2. Classification of incidence rates

Rate of Incidence Category	Number of Municipalities	(%) municipalities in each category	Interval of the category
NoCases	2,193	39.40%	[0]
Low	1,124	20.20%	(0 – 14.09]
Medium	1,124	20.20%	(14.09 – 37.46]
High	1,124	20.20%	(37.46– 840.97]

Table 3. Classification of *IDHM-Income, IDHM-Education, Bathroom Piped Water Supply* and *Pop Density Above2*

Variable	Category	(%) municipalities in category	Interval of category
IDHM-Income	Very Low	24.9%	[0.400 – 0.572]
	Low	25.0%	(0.572 – 0.654]
	Medium	24.9%	(0.654 – 0.707]
	High	25.2%	(0.707 – 0.891]
IDHM-Education	Very Low	24.9%	[0.207 – 0.490]
	Low	24.9%	(0.490 – 0.560]
	Medium	25.2%	(0.560 – 0.631]
	High	25.0%	(0. 631– 0.825]
BathroomPipedWaterSupply	Very Low	24.6%	[3.26 – 67.78]
	Low	25.6%	(67.78 – 91.25]
	Medium	25.2%	(91.25 – 98.00]
	High	24.6%	(98.00 – 100.0]
PopDensityAbove2	Very Low	24.7%	[0.65 – 15.41]
	Low	25.2%	(15.41 – 23.07]
	Medium	25.5%	(23.07 – 32.58]
	High	24.7%	(32.58 – 88.64]

Table 4. Leprosy, as the Rate of Incidence - mean (Amazon, Other) and selected municipalities

Region	Municipality	Rate of Incidence
Amazon	(mean)	73.23
Other regions	(mean)	16.98
MS	Pedro Gomes	840.97
GO	Campos Verdes	697.21
MT	Araguaiana	563.03
SE	Amparo de São Francisco	483.52
GO	Padre Bernardo	458.96
TO	Novo Jardim	366.30
PA	Jacareacanga	354.53
MT	Itaúba	349.73
MT	Nova Nazaré	330.14
GO	Jussara	313.27

The maximum value for this indicator (840.97) belongs to the municipality of Pedro Gomes (state of MS). On expanding Table 4 for the first fifty municipalities with the highest incidence, all are municipalities small in size (up to 50 thousand inhabitants) and 31 of these are located in the Amazon region. Of the total municipalities of the Amazon (771), 498 municipalities have a high incidence rate of leprosy (above 37.46), which represents 64.59% of the Amazonian municipalities; when considering other regions of Brazil only 13.06% of the municipalities fall into this category. When the spatial reference refers to the Brazilian states, the ten states with the most cases of leprosy are headed by Maranhão and Pará, which, together, present mare than 7000 cases (Figure 2). The high and mean leprosy incidence rate for the state of Pará are found, respectively, in 60.84% and 29.37% of the municipalities. In the state of Maranhão the high incidence rate of the disease is found in 58.06% of the municipalities and the mean in 22.58%. The Bayesian network technique was then used in order to measure the association between the studied variables. Applying the algorithm K2, relevant associations were found for the following variables: *Spatial Reference, IDHM-Income, IDHM-Education, Bathroom Piped Water Supply, PopDensityAbove2.* At this stage the remaining variables were discarded from the association study. The resulting Bayesian network (Figure 3) revealed that the variable *Leprosy* is directly dependent on the variables *Pop Density Above2* and *Spatial Reference*.

The inferences presented as follows were obtained from the results of the propagational algorithms. When the data concern a municipality belonging to the Amazon region, the probability of presenting a high rate of leprosy incidence is 65.7%; this value falls to 13.1% when the location is for other regions of the country. When the data show a municipality with a lower *PopDensityAbove2* (<15.41%), the probability that this municipality has no recorded disease is 60%; on the other hand when the highest range is presented (above 32.58%) this probability drops to 22.7%. When looking at the two variables (*Spatial Reference* = Amazon and *PopDensityAbove2* <15.41), this probability becomes 56.1% (Figure 4); otherwise, when considering other regions of the country, this value is reduced to 17.9%. The presence of a bathroom with a piped water supply, according to the Census data, is a typical problem in the Amazon region: for such municipalities, the probability of lower percent values for the presence of such a bathroom is 56.1%; this percentage drops to 19.6% for other regions. Indeed, the case where the incidence of *Leprosy* is high, the *PopDensityAbove2* is also high and the *Bathroom Piped Water Supply* incidence range is low, is a typical scenario for the Amazon region (probability of 73% against 27% for other regions). The variables *IDHM-Income* and *IDHM-Education* did not show a direct association with *Leprosy*. However, *IDHM-Income* was directly associated with *Bathroom Piped Water Supply*: in the lowest range for *IDHM-Income*, the probability of a municipality having the lowest incidence of

Bathroom Piped Water Supply was 74.2%; on the other hand, for the high range of *IDHM-Income* this probability drops to zero. The variables *IDHM-Income* and *IDHM-Education* were related to the population density of the home: when the indicators of income and education were in the lowest range, the probability that the municipality would have the highest range of *PopDensityAbove2* was 54.2%; this probability decreases to 4.7% when the indicators of income and education are in the highest range. In order to illustrate, as a percentage, the incidence of Leprosy in Brazilian municipalities, a map showing the geographical distribution of this disease is presented in Figure 5, according to the classification ranges defined by the process of discretization. For example, for the different value ranges used in the *Incidence Rate*, 60.6% of the Brazilian municipalities present a classification for the disease in the ranges low, medium and high. The geographical distribution revealed that a pattern for high incidence of the disease predominated in the states of Pará, Mato Grosso, Goiás, Pernambuco and Bahia and that, above all, there was a relationship of contiguity among the municipalities with high incidence rates for the disease.

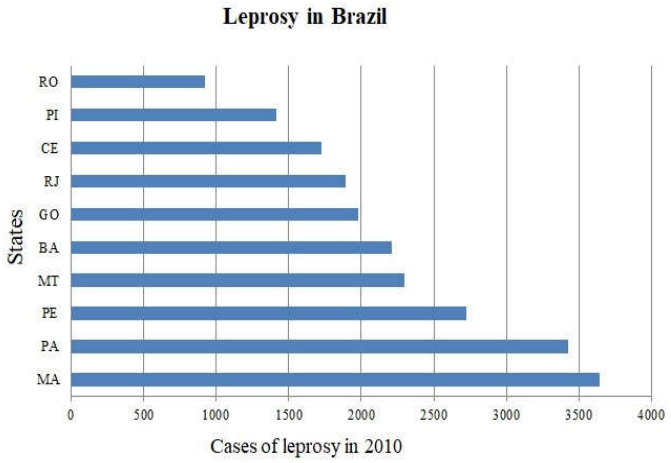

Figure 2. Cases of leprosy in Brazilian states.

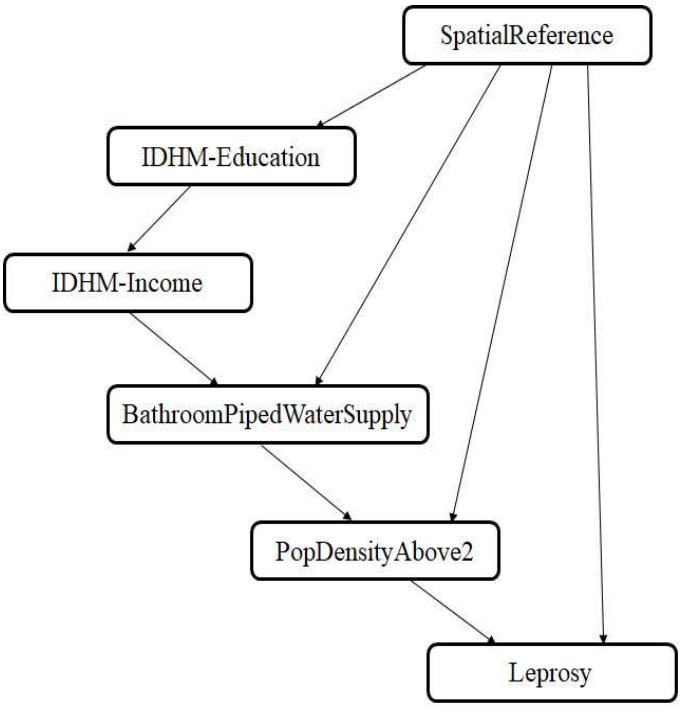

Figure 3. Structure of the selected Bayesian network

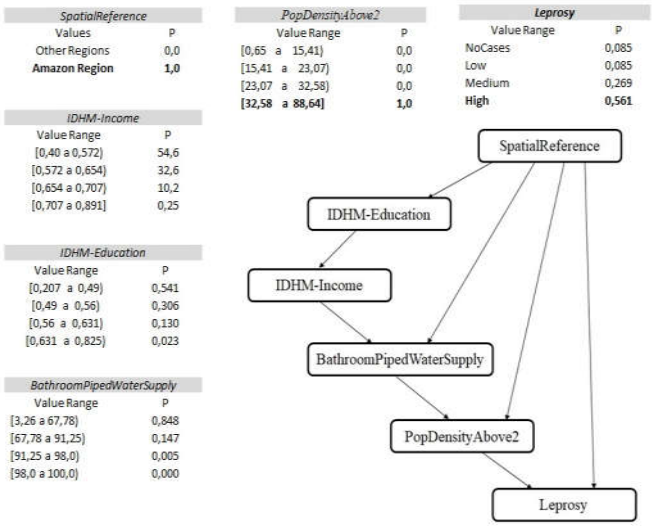

Figure 4. Bayesian network (data: *SpatialReference*="Amazon" and *PopDensityAbove2* >32.58).

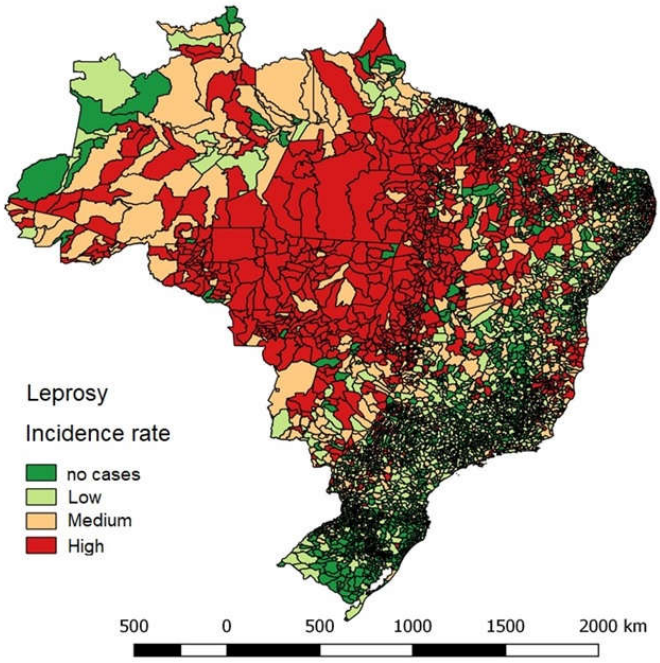

Figure 5. Map of leprosy cases in Brazilian municipalities.

DISCUSSION

The present study demonstrates an association between the incidence rate of leprosy and variables that represent the dimensions of income, education, bathrooms with a piped water supply and homes with a population density greater than 2, using data for Brazilian municipalities for the year 2010. The percentages of the *Leprosy Incidence Rate* were greater for the municipalities of the Amazon region than for the whole country (Table 4). Furthermore, this phenomenon was observed to be typical of municipalities with the lowest populations, although the greatest number of cases are recorded in the largest municipalities and metropolises (Table 5). The five states with the greatest *leprosy incidence rates* are respectively: Goiás, Mato Grosso, Tocantins, Maranhão and Pará, and of these, four are located in the Amazon region forming an area, together with Rondônia, where the disease is endemic in Brazil (Freitas *et al.* 2017). In the Bayesian network model a significant association exists between the percentage of homes with a population density above 2 and the incidence of leprosy.

Table 5. Cases and incidence rate of leprosy according to the size classification of the municipality

Size of Municipality	Nº Cases		Incidence rate	
	Minimum	Maximum	Minimum	Maximum
Metropolis	737	988	72.62	64.25
Large	45	703	43.73	86.34
Medium	21	140	40.66	189.08
Small 1	1	67	37.55	840.97
Small 2	8	127	38.75	458.96

Although the relationship between the incidence rate and socio-economic factors (no water supply, bathroom in the home, poverty and the agglomeration of people in the home), low educational indexes and income have been reported in several studies (Ponnighaus *et al.* 1994; Kerr-Pontes *et al.* 2006; Queiroz *et al.* 2009; Sales et al.2011; Suzuki *et al.* 2012; Moura *et al.* 2013), the inclusion of the variable that considers homes with a population density greater than 2 adds a further element to the problem without conflicting with the conclusion of those studies. Indeed, the municipalities whose homes have the greatest population density tend to be the ones that also concentrate the worst level of family income (and vice versa), and, equally, the worst level of education (and vice versa). As carried out in the study of Freitas *et al.* 2017, our study investigated the association between the incidence of leprosy in a collective sense (municipalities) and not individual, that is, an association observed for the municipality not necessarily occurs for individuals, which could lead to errors of ecological fallacy. Ecological fallacy can arise when considering that relationships for groups are maintained for individuals (Freedman, 1999). In our study, the inferences obtained are supported by the aggregated data and, therefore, cannot be extended to the level of the individual. In spite of this limitation, the association rules found here support the studies carried out whose arguments relate this phenomenon to the environment in which the individuals, afflicted with leprosy, are interposed. Knowledge of the vulnerability of people to transmittable diseases helps decision making with regard to aspects of health needs, due to social exclusion and fear. Identification of the variables and factors involved can lead to the development of strategies that may diminish the advance of diseases such as leprosy. Although the incidence rate of leprosy involves social factors related to vulnerability, for its prevention it is fundamental to provide information and adequate orientation, intensify actions to combat leprosy, including early diagnosis, prevention, treatment, physical and social rehabilitation, as well as promoting access to diagnosis and treatment in the municipalities with the higher levels of endemism. The scenario found after the analysis of the data reveals the peripheralization of Brazil, which represents a barrier to guarantee equality for the access to health services and information. Três Arrois (state of Rio Grande do Sul), for example, is a municipality that has 0.65% of a habitational density above 2; while at the other extreme, Uiramutã (state of Roraima) 88.64%, Santa Isabel do Rio Negro (state of Amazonas) 87.59%, Melgaço (state of Pará) 86.43% and Maraã (state of Amazonas) 82.75%, all in the Amazon region.

REFERENCES

Agrawal, R., Imielinski, T. and Swami, A. 1993. Mining association rules between sets of items in large databases. IBM Almaden Research Center 650 Harry Road. San Jose, CA 95120.

Augusto, DS. 2016. Neglected Diseases: Study of the knowledge and practices of teachers of primary education in the municipality of Jaboatão dos Guararapes/state of Pernambuco. Recife [Masters Dissertation] (*in portuguese*) FIOCRUZ

Barreto, M L. 2013. Outline of a scenario of health conditions of the Brazilian population in 2022/2030. *In* Cruz, F.O. (Ed.). Health in Brazil in 2030: strategic prospection of the Brazilian health system – population and sanitary profile (*in portuguese*). Rio de Janeiro: Fiocruz / Ipea / Ministério da Saúde, p.97-120.

Brito KKG, Araújo DAL, Uchôa REMN, Ferreira, JDL, Soares, MJGO, Lima, JO. 2014, Epidemiology of leprosy in a state of the northeast of Brazil (*in portuguese*). *Rev. Enferm*, UFPE. 8(8): 2686-93.

Chen, Z. 2001. Data Mining and Uncertain Reasoning: An Integrated Approach. New York: John Wiley & Sons Inc,

Cooper, GF. and Herskovits, E. 1992. A Bayesian method for the induction of probabilistic networks from data. *Machine Learning,* 9(4): 309-347.

Freedman, DA. 1999 Ecological inference and the ecological fallacy. *International encyclopedia of the social & behavioral sciences*, (6): 4027-4030.

Freitas LRS, Duarte, and EC Garcia, LP. 2017. Analysis of the epidemiological situation of leprosy in an endemic area of Brazil: spatial distribution for the periods 2001-2003 and 2010-2012 (*in portuguese*). *Rev. Bras. Epidemiol*, 20(4): 702-713.

Gracie, RP, JNB, Soares FBR, and Hacker MAVB. 2017. Analysis of the geographic distribution of leprosy cases in Rio de Janeiro 2001 to 2012 (*in portuguese*). *Ciência & Saúde Coletiva,* 22(5):1695-1704.

Kerr-Pontes**,** LRS., Barreto, ML**.**, Evangelista, CMN., Rodrigues, LC**.**, Heukel bach, J. and Feldmeier H. 2006. Socio-economic, environmental and behavioural risk factors for leprosy in the northeast of Brazil: results of a case-control study (*in portuguese*)**.** *Intern Jour of Epidemio***,** 35 (4): 994–1000.

Melinski, MC and Girardi, DR. 2014. Diabetes and Leprosy: stigma, cure, analysis using Bayesian Networks (*in portuguese*). FAE - Centro Universitário | Núcleo de Pesquisa Acadêmica. PUC-PR.

Moura, LTR., Luna, ICF. and Vieira, MCA. 2013 Clinical-epidemiological profile of leprosy in children under 15 years of age in the municipality of Juazeiro, Bahia state (in portuguese). Rev. Bras. *Promoc Saude*, 26(2): 208-215.

Oliveira, JCF., Leão, AMM. and Britto, FVS. 2014.Analysis of the epidemiological profile of leprosy in Maricá, Rio de Janeiro: a contribution of nursing (in portuguese). *Rev Enferm.* UERJ, 22(6):815-21.

Pönnighaus, JM. *et al*. 1994. Rate of leprosy incidence in the Karonga district, north of Malauí: profiles by age, sex, status and BCG classification (in portuguese). *Int. J. of Leprosy and Other Mycobact. Diseases*. 62 (1): 10-23.

Queiróz, ML. and Scatena, JHG.2009. Spatial and temporal distribution of leprosy in Mato Grosso state, for the period 1996 to 2007 (in portuguese). *Cad . Saúde Colet,* 17 (1): 145 – 161.

Sales, AM *et al*. 2011. Leprosy and patient contact: a multilevel study of risk factors (*in portuguese*)**.** *PLOS Neglected Tropical Diseases,* 5 (8): 10.137.

Suzuki, K., Takeshi, A., Kawashima, A., Yoshihara, A., Yotsu, RR. and Norihisa, ISHII. 2017. Present state of leprosy: epidemiology, basic science and clinical perspectives (in portuguese). *The Jourl of dermatol, Fev,* 39 (2): 121–9.

UN. United Nations Millenium Declaration. 2000.

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