Original Article

Cutaneous leishmaniasis in protected environmental areas in the Eastern Amazon: the case of São Félix do Xingu, Pará, Brazil

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Abstract

Introduction: Cutaneous Leishmaniasis is a disease transmitted to men and animals by infected female phlebotomine sandflies and is considered a great environmental and public health problem in the Amazon region. Thus, the study aimed to analyze the spatial distribution of this disease in São Félix do Xingu, in the state of Pará, Brazil, and its relationship with epidemiological and environmental variables, in the period from 2012 to 2016.

Methodology: The data used were from the Information System of the Pará State Secretariat of Health, the National Institute for Space Research and the Brazilian Institute of Geography and Statistics. The statistical and spatial analysis of the variables were done using non-parametric chi-square statistical test, kernel interpolation technique and the Bivariate Global Moran Index.

Results: The municipality had 183 confirmed cases, non-homogeneously distributed in 5 administrative districts. The individuals most affected were adult males with brown skin, an elementary level of education and rural area residents. In the case series, a direct relationship was observed between the increase of the number of cases and deforestation in the study area. The spatial analysis showed different types of land use and cover related to case clusters in the municipality. Additionally, there was a presence of cases in protected areas and a great epidemiological silence in indigenous lands.

Conclusions: Thus, this disease is a large and complex public health problem in the municipality, related to social and environmental risk factors.

Introduction

Cutaneous Leishmaniasis (CL) is a widespread anthropozoonosis caused by a protozoan of the genus *Leishmania*. It is transmitted through the bite of infected female phlebotomine flies [1].

The World Health Organization has reported 0.7 to 1.3 million new cases of CL registered worldwide each year over the last decade [1]. In Brazil, this disease is widely distributed throughout all regions in the country, notably in the Amazon, especially because of the implementation of development policies that have intensified the process of removing its vegetation cover and have contributed to the production of risk factors for infectious diseases of various etiologies, especially parasitic [2].

The state of Pará in the Amazon region presents different levels of CL endemicity due to various types of environmental degradation such as deforestation that have occurred over the past decades in its municipalities. This fact has contributed to the establishment and maintenance of transmission circuits for the disease in the state [3,4]. In the period from 2007 to 2017, the municipality of São Félix do Xingu, in southeastern of Pará recorded 391 cases of CL [1]. In this territory, high rates of deforestation were also observed, mainly due to the expansion of cattle ranching, agriculture and mining [5].

In this context, protected areas such as Indigenous Lands (IL) and Conservation Units (CU) have been important instruments for ensuring the maintenance of traditional peoples and the biological diversity of natural resources. In that regard, the municipality of São Félix do Xingu has approximately 78% (64.87 km²) of its territory placed in protected areas.

Epidemiological studies based on the spatial distribution of CL in different human populations in the Amazon, and its relationship with environmental risk factors associated with land use and land cover dynamics provide a great challenge for decision-making processes in environmental and epidemiological surveillance of diseases, especially at a local scale [6]. In order to solve this problem, geotechnologies have contributed to construction of epidemiological scenarios for CL that are of great importance for producing spatialized information on its determinants and conditioning factors in different territories [7].

In light of the above, the objective of this study was to analyze the spatial distribution of CL and its relationship with environmental variables in the municipality of São Félix do Xingu, in the state of Pará, from 2012 to 2016. This area and period were chosen due to their ability to represent a critical environmental problem that has impacts on human health and occurs repeatedly in the Amazon region. That justifies the need to study these scenarios at local scales, which is a great challenge for epidemiology.

Methodology

An ecological, analytical and cross-sectional study was carried out with a population of one hundred and eighty-three (183) laboratory-confirmed notified cases of CL, distributed in the five (5) administrative districts of São Félix do Xingu (São Félix do Xingu, Vila Taboca, Ladeira Vermelha, Vila Lindoeste and Vila Nereu), from 2012 to 2016.

Epidemiological data (gender, age group, ethnicity, schooling and housing area) were acquired from the Information System for Notifiable Diseases (SINAN) of the Pará State Secretariat of Health (SESPA) and environmental data (deforestation and land use and cover) were obtained from satellite classifications performed by the PRODES and TerraClass projects, both belonging to the National Institute of Space Research (INPE). The cartographic, demographic, conservation unit and indigenous land databases were obtained from CENSO (2010) of the Brazilian Institute of Geography and Statistics (IBGE). Case records that

presented incompleteness and inconsistency of data were excluded, using Tabwin 36b software.

In order to create a Geographic Database (BDGEO), the case records were georeferenced in the field. For this purpose, a Global Positioning System (GPS) receiver was used. In this process, the different types of land use and cover present in the study areas were also observed, as well as the identification of conservation units and indigenous land. Descriptive analyses of the data were performed using the non-parametric chi-square statistical test of expected equal proportions with a significance level of 0.05%. Considering the increase in the number of cases of CL and the increase in deforestation in the administrative districts of the municipality over the study period, an analysis of linear trend between these two variables was performed. Both analyses were made using the Bioestat 5.0 program.

The spatial distribution analysis of the disease was performed by kernel interpolation technique (with a 0.1512º radius) which identified the sites with a higher concentration of cases. The gradient of the extension of land use and cover, which identified the sites with higher deforestation, was done by shapefile quantification with the geometric tools that had been calculated. Both analysis techniques used ArcGis 10.5.1. For construction of the thematic map, the following classes were considered: pasture (clean pasture, pasture with bushy vegetation, regeneration with pasture); mosaic of occupations; urban area; forest; secondary vegetation and deforestation (recent suppression of vegetation without defined activity). The classes for reforestation, mining, annual agriculture was aggregated into "other classes".

To identify the spatial autocorrelation between areas with deforestation and those one with CL cases in the municipality studied, the Bivariated Global Moran geostatistical technique was used, which generated a Moran (I) index of possible spatial autocorrelations between the variables for each administrative district in the municipality. To do that, the following hypotheses were employed: "inverse" ($I < 0$), "randomization" ($I = 0$) and "direct" ($I > 0$), with spatial statistical significance for a value $p < 0.05$. Spatial autocorrelation was considered strong when the index was close to one of the limits (-1,1) and weak when close to zero. The parameters defined for Moran (I) analysis were "high-high" when the relationship between deforestation and the number cases is strong and "low-low" when it is weak.

This study obtained favorable opinion number 3.245.271/2019, from the Research Ethics Committee

of Pará State University, in accordance with the norms of Resolution No. 466/12 of the National Health Council.

Results

We analyzed 183 laboratory-confirmed notified cases of CL located in the different administrative districts of São Félix do Xingu municipality. The analysis of profiles of individuals with the disease showed a higher percentage of occurrence in males (n = 151 - 82.5%), aged 18 to 59 years (n = 148 - 80.9%), with brown skin (n = 109 - 59.6%), schooling up to elementary level (n = 128 - 69.9%) and living in rural areas (n = 128 - 69.9%), all with a statistical significance level (p-value < 0.05), as shown in Table 1.

A non-homogeneous distribution pattern was observed in the spatial analysis of CL cases in the municipality. The Kernel technique revealed a very high density of cases in the districts of the municipal seat and Vila Taboca, high density in the districts of Vila Lindoeste and Vila Nereu and low in Ladeira Vermelha. Thus, it was possible to identify the presence of the disease in both urban and rural areas; however, the greatest number of cases occurred in rural areas that have a high level of deforestation. The presence of an epidemiological corridor was also observed, marked by

a spatial dependence on human settlements along the PA-279 highway and the Xingu and Fresco rivers, as shown in Figure 1.

The municipality of São Félix do Xingu currently presents evidence of major changes in its natural landscape and environmental degradation related to very high percentages of pasture and secondary vegetation in some areas, which can be observed in the land use and cover map generated. Thus, the presence of CL cases in protected categories such as Environmental Protection Areas, Ecological Stations and National Parks that suffered great anthropic pressure was noteworthy. However, the disease was

Figure 1. Case density of Cutaneous Leishmaniasis in the districts of São Félix do Xingu, Pará, Brazil, from 2012 to 2016.
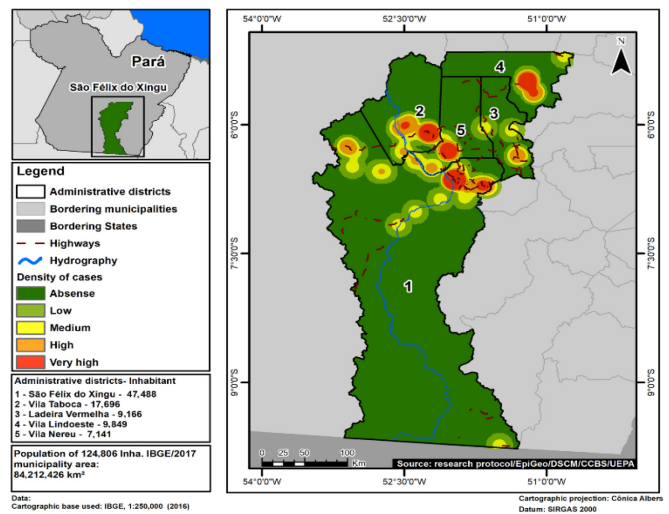

Table 1. Epidemiological profile of cases of American Tegumentary Leishmaniasis, in São Félix do Xingu, from 2012 to 2016.

Variables	n = 183 (%)	* p-value
Sex		
Male	151 (82.51)	< 0.0001
Female	32 (17.49)	
Age group		
Children (<= 12)	16 (8.74)	
Adolescent (13 to 17)	12 (6.56)	< 0.0001
Adult (18 to 59)	148 (80.87)	
Elderly (>= 60)	7 (3.83)	
Skin color		
Brown skin	109 (59.56)	
White skin	46 (25.14)	< 0.0001
Yellow skin	1 (0.55)	
Black skin	27 (14.75)	
Schooling		
Illiterate	10 (5.46)	
Elementary school	128 (69.95)	
High school	29 (15.85)	< 0.0001
Higher school	2 (10.9)	
No schooling application	4 (2.19)	
Ignored	10 (5.46)	
Housing area		
Rural	128 (69.95)	
Urban	49 (26.78)	< 0.0001
Ignored	6 (3.28)	

Source: Research Protocol, 2020; * p < 0.05 (Chi-square, adherence).

Figure 2. Spatial distribution of cases of Cutaneous Leishmaniasis and land use and cover in the districts of São Félix do Xingu, Pará, Brazil, from 2012 to 2016.
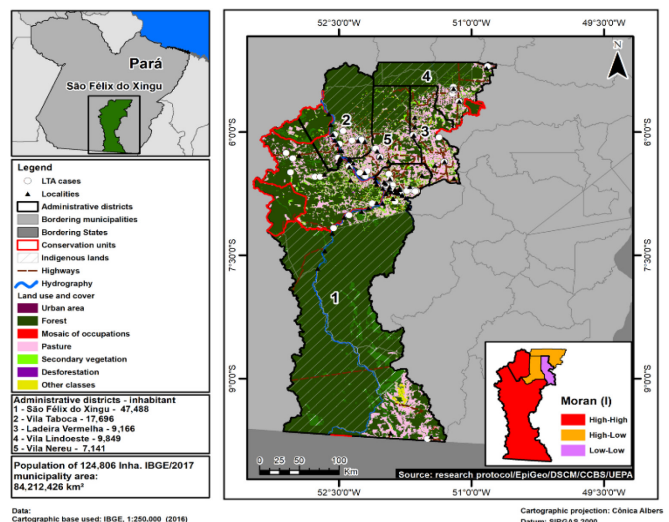
observed to be absent in Indigenous Lands, which are characterized by dense forest cover, although surrounded by areas with large-scale deforestation and the presence of the disease, especially on their borders as shown in Figure 2.

The analysis of the increasing percentage of CL cases (R^2 = 0.392) and environmental degradation (R^2 = 0.3594) showed evidence of a direct relationship between these variables, with an increasing trend due to this relationship occurring in all the municipal administrative districts. It was thus possible to observe that during the study period, the São Félix do Xingu district presented the highest percentage of increases in confirmed CL cases (87/47.5%) and deforestation (555 km²/50.5%). On the other hand, the Vila Ladeira Vermelha district presented one of the lowest percentages of increase in cases (6/3.3%) and deforestation (83 km²/7.5%), as shown in Figure 3.

The analysis using the Bivariated Global Moran Index (I) showed significant spatial relationships between certain areas with CL cases and deforestation in the administrative districts of the municipality. Thus, a direct autocorrelation between these two variables was observed in the administrative districts of São Félix do Xingu (municipal seat), Vila Taboca, Vila Lindoeste and Vila Nereu. In the Vila Ladeira district, the autocorrelation was considered inverse, with a negative index (I < 0). The autocorrelations were strong for São Félix do Xingu district (I = 0.86 / high-high) and weak in Vila Taboca (I = 0.40 / high-high), Vila Lindoeste (I = 0.08 / high-low), Vila Nereu (I = 0.07 / high-low) and Vila Ladeira Vermelha (I = - 0.27 / low-low).

Discussion

The analysis of the epidemiological profile revealed a situation that has been repeatedly observed in several places in the Amazon region. It was seen that the disease affected adult males in a more significant manner. This fact may be related to their work activities that imply a higher degree of exposure to CL, such as subsistence agriculture with vegetable growing, fruit trees and cassava flour production. In those types of work activities, the productive unit becomes confused with the family unit itself and exposes all its members, especially adult males, due to the lack of individual and collective protection used in these activities, according to Veiga *et al*. (2019) [8].

In addition to the previous activities, unhealthy practices that are considered risk factors for several infectious diseases were also observed, such as ranching and legal or non-legal logging. This type of profile indicates that the cases are predominantly rural

Figure 3. Cases of Cutaneous Leishmaniasis and increasing deforestation in the districts of São Félix do Xingu, Pará, Brazil, from 2012 to 2016. Source: Research Protocol, 2020.
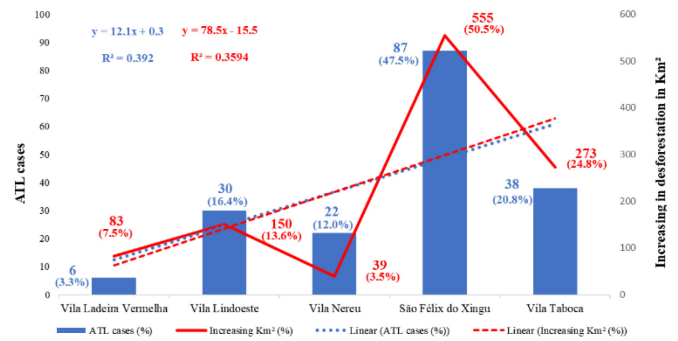
and reflects a recurring pattern of CL transmission in the State of Pará [9,10].

The low level of education among individuals affected by the disease points to their socio-economic vulnerability and constitutes a risk factor for the disease, since, given their low level of formal education, this population is not aware of situations that may condition the occurrence of the disease, as well as forms for preventing it. Therefore, the issue of health education should be expanded in the basic education curriculum, especially in rural areas. This fact has been observed in several Brazilian municipalities, taking into consideration their socioeconomic and environmental characteristic [11].

The observation that the highest number CL cases occurred in persons with brown skin may be due to the ethnic formation of the Amazon, which consists mostly of this ethnic group [9]. This fact may be related to the historical process of multiethnic unions between indigenous peoples with Europeans and Africans which occurred in the northern region and which determined the quantitative significance of this ethnic group in the state of Pará, where approximately 70% of the population self-declares as having brown skin [12].

The occurrence of most CL cases in rural areas of all the districts in São Félix do Xingu is related to the disorderly process of occupation that has occurred there in recent decades. Thus, this municipality presented one of the highest demographic growth rates in Brazil, as a result of the development of intense processes of non-sustainable economic activities such as settlements with agglomeration of people that led to major changes in the natural environment in certain areas of the municipality [13].

In certain portions of the administrative districts, important transmission circuits for the disease have thus been established involving humans, synanthropic animals and phlebotomine sandflies contaminated with

the pathogen and adapted to rural and urban environments, enabling the occurrence of disease cases [14].

The use of the kernel technique showed that the higher densities of CL followed the spatial direction of environmental degradation, with a non-homogeneous distribution of cases as a function of the spatial vectorization of those two variables related to land use in the municipality during study period. This fact was strongly evidenced by the gradual process of vegetation suppression that has historically occurred in the municipality, with construction of the PA-274 state highway that links São Félix do Xingu to neighboring municipalities [15].

The construction of this highway has caused a great migratory flux to the region, with transformation of the local landscape due to the intensification of non-sustainable economic practices such as logging and cattle ranching that may occur in a legal or non-legal form. These activities put pressure on the protected territories such as conservation units and indigenous lands, weakening their human populations through the establishment of risk factors for infectious and parasitic diseases, with the result being a significant number of CL cases [16].

Thus, a major determinant of environmental degradation in the municipality is the large number of deforested areas associated to a process of disorganized human occupations, which generate risk factors for the establishment of active circuits of CL transmission. The spatial dependence between those variables points to the formation of the epidemiological corridors observed, especially along the PA-274 and the Xingu and Fresco river basins [17,18].

In these areas the field work also found secondary vegetation with ecological successions, marked by the presence of different types of secondary growth *capoeira* (young, adult and old). Those kinds of vegetation are associated with the development of the disease vector ecotopes that proliferate in these environments, increasing their population density and genetic variability. This fact was also observed in a study conducted by Andrade *et al.* [19].

The occurrence of the greatest number of cases mainly in areas degraded by deforestation and located in rural areas presented in the TerraClass classified as "Secondary Vegetation" and "Pasture", also points to the fact that the causes of CL are economic and social. In this context, despite the clear identification of risk factors for the disease and the exposure of the human populations, the municipality of São Félix do Xingu

was considered in the year 2015 as the largest cattle producer in Brazil [20].

Therefore, establishing pastures was the main factor responsible for the suppression of natural vegetation in the municipality. This fact points to the inefficiency of public policies for sustainable use of the forest as a natural resource which end up enabling the occurrence of human impacts related to active disease transmission circuits in São Felix do Xingu, given that it was considered one of the most deforested municipalities in the state of Pará during the study period [21].

The occurrence of CL cases in some conservation units may be related to the anthropic pressure they have suffered due to their geographic characteristics and their economic potential, such as mining and timber harvesting, which may lead to different illegal anthropic relationships in these areas [22]. Thus, although the absence of cases in the indigenous lands belonging to the Kayapó, Menkranotire, Apyterewa, Arawete and Trincheira Bacajá tribes has been noted, these areas have also suffered from human impacts coming from outside their areas, mainly on their northern and southern borders, with high degradation of the natural environment and production of risk factors for CL. Those conditions point to a potential epidemiological silence in the area.

Therefore, the low number of cases in indigenous land may be related to insufficient coverage by the National Policy for the Health Care of Indigenous Peoples associated with difficulties for access such as distance and logistical conditions for carrying out the work. With that in mind, this epidemiological silence observed should be better investigated as a possibility for mitigating the social, environmental and sanitary liabilities historically established in the indigenous lands in the Amazon region. This epidemiological silence reflects the fragility of these human populations and entails tragic outcomes related to their health conditions.

The observation that contiguous areas with high deforestation rates and occurrence of CL cases formed an epidemiological corridor with strong direct spatial autocorrelation between those two variables, such as the municipal seat and its adjacent district, points to the continuous and procedural production of health inequities in the municipality. This fact has also been observed in studies about disease and degradation processes in other states of the Amazon, such as Acre, Mato Grosso, Manaus and Roraima [22-26].

Conclusions

Considering the analyses performed, it became evident that the occurrence of CL in São Félix do Xingu constitutes a large and complex public health problem. This is reflective of a recurrent epidemiological scenario in the Amazon region, due to its systematic relationship with socioeconomic and environmental risk factors generated and conditioned by insufficient public environmental and health policies.

The epidemiological profile of individuals affected by the disease in the municipality was male, adult, brown skin, with low schooling and living in rural areas. A non-homogeneous distribution pattern of the disease was observed, with clusters of cases in rural areas, especially along roads and river basins. The occurrence of CL was vectored by environmental degradation. The areas with indicators of human impact, such as "pasture" and "secondary vegetation" were the ones that presented the highest number of cases due to their association with deforestation processes.

The use of geoprocessing tools in spatial analysis of the disease distribution was satisfactory for the construction of its epidemiological scenario, in the area studied. They thus have great potential for providing health managers with information for continuous and systematic surveillance of CL.

Considering the relationships between the variables analyzed in this study, the development of other studies at local scales is necessary to mitigate the disease and environmental impacts in the municipality, despite structural difficulties such as great distances and access.

Based on the results obtained, throughout the development of this work, we have highlighted the need to strengthen epidemiological and environmental surveillance as public policies, in order to avoid health inequities in all areas of the municipality, especially in protected areas.

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