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American tegumentary leishmaniasis: spatial analysis to identify high-risk areas in the state of Mato Grosso

Leishmaniasis tegumentaria americana: análisis espacial de áreas de alto riesgo en el estado de Mato Grosso

Leishmaniose tegumentar americana: análise espacial de áreas de alto risco no estado de Mato Grosso

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ABSTRACT

Objective: to identify areas of high risk for the occurrence of ATL and to investigate the determinants associated with this phenomenon in the state of Mato Grosso-Legal Amazon. **Method:** this is an ecological study carried out in the state of Mato Grosso, Legal Amazon, Brazil, with ATL cases reported between 2010 and 2019. High-risk areas were identified using the Scan statistic, and the associated determinants were identified using a binary logistic regression model. **Results:** a total of 23,698 ATL cases and 17 ATL infection risk clusters in the period, with the highest relative risk (RR) of 5.52 ($p<0.001$). The determinants cattle herd, largest harvest area and rainfall volume showed a positive association with high-risk areas. The municipal human development index showed a

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negative association. **Conclusion:** the results show the existence of high-risk areas for ATL in the state and suggest that there are determinants that may be influencing the occurrence and maintenance of these risk regions.
Descriptors: Leishmaniasis; Neglected Tropical Disease; Risk Map; Spatial Analysis; Environment and Public Health.

RESUMEN
Objetivo*: identificar áreas de alto riesgo para la ocurrencia de ATL e investigar los determinantes asociados a este fenómeno en el estado de Mato Grosso-Amazonia Legal.* ***Método****: este es un estudio ecológico realizado en el estado de Mato Grosso, Amazonía Legal, Brasil, con casos de ATL reportados entre 2010 y 2019. Las áreas de alto riesgo se identificaron mediante estadísticas Scan y los determinantes asociados se identificaron mediante una logística binaria. modelo de regresión.* ***Resultados****: un total de 23.698 casos de ATL y 17 grupos de riesgo de infección por ATL en el período, con el riesgo relativo (RR) más alto de 5,52 (p<0,001). Los determinantes hato bovino, mayor área de cosecha, área de cosecha y volumen de precipitación mostraron una asociación positiva con las áreas de alto riesgo. El índice de desarrollo humano municipal mostró una asociación negativa.* ***Conclusión****: los resultados mostraron la existencia de áreas de alto riesgo para ATL en el estado y sugieren que existen determinantes que pueden estar influyendo en la ocurrencia y mantenimiento de estas regiones de riesgo.*
Descriptores*: Leishmaniasis; Enfermedades Tropicales Desatendidas; Mapa de Riesgos; Análisis Espacial; Medio Ambiente y Salud Pública.*

RESUMO
Objetivo*: identificar áreas de alto risco para a ocorrência da LTA e investigar os determinantes associados a este fenômeno no estado de Mato Grosso-Amazônia Legal.* ***Método****: estudo ecológico realizado no estado do Mato Grosso, Amazônia Legal, Brasil, com casos de LTA notificados entre 2010 e 2019. Áreas de alto risco foram identificadas usando a estatística Scan, e os determinantes associados foram identificados por meio de um modelo de regressão logística binária.* ***Resultados****: um total de 23.698 casos de LTA e 17 aglomerados de risco de infecção por LTA no período, com o risco relativo (RR) mais elevado de 5,52 (p<0,001). Os determinantes do rebanho bovino, maior área de colheita e volume de precipitação apresentaram associação positiva com as áreas de alto risco. O índice de desenvolvimento humano municipal apresentou associação negativa.* ***Conclusão****: os resultados mostraram a existência de áreas de alto risco para LTA no estado e sugerem que existem determinantes que podem estar influenciando a ocorrência e a manutenção dessas regiões de risco.*
Descritores*: Leishmaniose; Doenças Tropicais Negligenciadas; Mapa de Risco; Análise Espacial; Meio Ambiente e Saúde Pública.*

INTRODUCTION

American Tegumentary Leishmaniasis (ATL) is a cosmopolitan, neglected disease, being endemic in several regions of the globe, and especially affecting developing countries. The World Health Organization (WHO) estimates that more than 350 million people live in areas at risk for ATL infection worldwide, focusing on regions with precarious basic

sanitation, low socioeconomic conditions, increasing deforestation, agricultural growth and migration processes[1].

More than 90% of the cases registered in the world in 2020 are concentrated in seven countries, namely: Afghanistan, Algeria, Brazil, Colombia, Iraq, Pakistan and the Syrian Arab Republic[2,3]. In Latin America, Brazil is the country with the highest number of people infected with ATL, with about 90% of all cases registered among all countries in the block, with regions where the disease is endemic and has the status of a chronic disease[4].

Brazil has registered cases of ATL in all states of the federation, with a greater focus on the states that are part of the so-called Legal Amazon, an endemic region for ATL and where the state of Mato Grosso is located. Among the state's economic activities are agriculture and extractivism, which occur with great intensity and are related to the degradation of natural environments, which consequently may influence the occurrence of risk areas for ATL infection[5].

Mato Grosso is the second state with the highest deforestation rates since 2006. The state also has two predominant biomes, the Cerrado and the Amazon, and between the two there is a transition area (ecotone) that is considered one of the last agricultural frontiers in Brazil and therefore, being the perfect scenario for ATL outbreaks, due to the intense agricultural activity[6]. The Brazilian territory, despite the general reductions in ATL infections, still ranks first among the countries with the highest number of people infected with ATL in the Americas[7,8].

WHO has established goals aimed at eradicating ATL and other important Neglected Tropical Diseases (NTDs), which are part of the process of perpetuating poverty in developing countries[2].

The 2030 agenda, as it became known worldwide, indicates the NTDs that need greater attention in terms of public health in the world and has established specific targets that include a reduction of more than 75% in the number of deaths from neglected diseases transmitted by vectors, like leishmaniasis. Based on these assumptions, this study proposes to investigate, through a spatial approach, the behavior pattern of ATL in one of the regions most affected by the disease in Brazil[8].

Recognizing the priority areas that are most vulnerable to the

occurrence of the disease and the factors that are influencing the emergence of these cases may be the key to achieving the ATL elimination targets proposed by the WHO. Thus, this study aims to identify high-risk areas for the occurrence of ATL and investigate the determinants associated with this phenomenon in the state of Mato Grosso-Legal Amazon.

METHOD

This is an ecological study that was carried out in the state of Mato Grosso, which has 141 municipalities and is located in the central-west region of Brazil that belongs to the legal Amazon in Figure 1. The state has a territorial area of 903,207.019 km2, with a population density of 3.36 inhabitants/km2 and an estimated population of 3,484,466 inhabitants. The Human Development Index (HDI) of the region is 0.725, geographically it is located at 12.6819° S, 56.9211° W[9].

The study population consisted of positive cases for ATL registered in the state of Mato Grosso from 2010 to 2019. Cases residing in other states, cases that presented a change in diagnosis and duplicate data were excluded from this study.

The sources of information used for data collection included public databases made available by the government of the State of Mato Grosso, the Unified Health System, the Notifiable Diseases Information System (SINAN), the Brazilian Institute of Geography and Statistics (IBGE) and data from the National Institute for Space Research (INPE).

The sociodemographic and clinical-operational variables of the reported cases of ATL that were analyzed included: clinical form, presence of skin scars, results of histopathological tests, results of Montenegro intradermal reaction tests, results of direct parasitological tests, evolution of cases, schooling, gender, age and race/color.

The collected data were further categorized into three dimensions of determinants related to the studied phenomenon, dimension one socioeconomic and health determinants of municipalities, dimension two determinants of health care and care network and dimension three environmental determinants in Chart 1. It is noteworthy that the determinants included in the analysis were selected based on the theoretical framework that explores the biological and

developmental characteristics of ATL[10,11].

Descriptive analysis was performed by calculating absolute and relative frequencies for sociodemographic and clinical-operational variables. For gender, age, race/color and schooling (without schooling) data, incidence rates were also calculated according to the population provided by the Brazilian Institute of Geography and Statistics[9]. As análises foram realizadas por meio do software SPSS versão 20.0.

The incidence rates for ATL were calculated according to the municipalities of the state of Mato Grosso, according to the recommendations of the Pan American Health Organization[12].

After calculating the incidence, the spatial distribution of this indicator was carried out according to the municipalities of Mato Grosso, which were the units of analysis in this study. A thematic map was prepared to present the most critical regions in relation to the incidence of ATL cases.

Spatial risk clusters were detected by the Scan statistics[13].The spatial scanning technique is carried out by controlling the occurrence of cases of the disease by the size of the population of the municipalities in an attempt to detect clusters of high and low relative risk. To carry out this analysis, the following criteria were used: discrete Poisson model, no geographic overlapping of the clusters, maximum cluster size equal to 50% of the exposed population, cluster with circular shape and 999 replications.

A null hypothesis is considered if there is no cluster of high or low risk, that is, the entire population has the same probability of being infected with ATL, regardless of its location. While the alternative hypothesis predicts the existence of clusters, which are areas where the population would be more or less likely to become infected[13].

With the identification of the spatial clusters by the scanning technique, thematic maps were constructed with an indication of the relative risk (RR) of the respective clusters. Relative risk allows comparing different regions, standardizing and removing the effect of different populations, in this way the RR shows the intensity of occurrence of a certain phenomenon in relation to the total study region[14].

Software SaTScan™ version 9.7 was used for this analysis and thematic

maps were developed in Software ArcGis 10.7.

Binary logistic regression was performed to identify the determinants that could be related to high-risk areas for the occurrence of ATL cases.

The areas at risk for illness from ATL that were identified through the scan statistics were considered as a dependent variable. These areas were dichotomized into 0 (non-cluster) and 1 (cluster). As independent variables, the determinants listed in Chart 1 were considered.

These variables underwent a careful process of collinearity diagnosis, and the variables not being collinear was a prerequisite for the models to be performed. For this verification, the Variance Inflation Factor (VIF) tests were used, which must have a value <10, and the Tolerance test, which must have a value >0.1.

The logistic model was elaborated using the method Backward Stepwise (Likelihood Ratio), which analyzes the data by including the variables within the model, where the weight of the variable is measured at each variable insertion step. The value of the pseudo (R^2) of Nagelkerke, was used to show the percentage of explanation of the generated model[15]. The Hosmer and Lemeshow and Omnibus tests were applied to estimate the goodness of fit of the model. Additionally, the Receiver Operating Characteristic Curve (ROC) was constructed to verify the explanatory capacity of the variables inserted in the final model. Odds Ratio (OR) values were indicated with a confidence interval (CI) of 95% and the type I error was set at 5% ($p<0.05$) as statistically significant. These analyzes were performed using the SPSS Software version 20.0.

This study complied with the requirements of Resolution nº 466/2012 of the National Health Council and has approval from the Ethics Committee under number32128820.3.0000.5587.

RESULTS

In total, 23.698 cases of ATL were registered in the state of Mato Grosso. It was observed that males had a higher number of cases (79.9%; n=18,939) and the most affected age groups were 20 to 39 years (41.0%; n=9.718) and 40 to 59 years (30.1%; n=7.125). Regarding race, most cases occurred in brown (47.9%; n=11.356) and white (33.7%; n=7.987) people. Regarding schooling, it is observed that most of those infected have less than 11

years of schooling, with 51.3% (n=12.578) having 8 years or less of schooling. When analyzing the population groups, a higher incidence was observed among men (122.2/100000 inhabitants), indigenous people (407.2/100000 inhabitants) and blacks (81/100000 inhabitants), the incidence among the non-schooled population was (270.4/100000) inhabitants.

Figure 1 - Geographic location of the study setting. Mato Grosso - Legal Amazon, 2022.

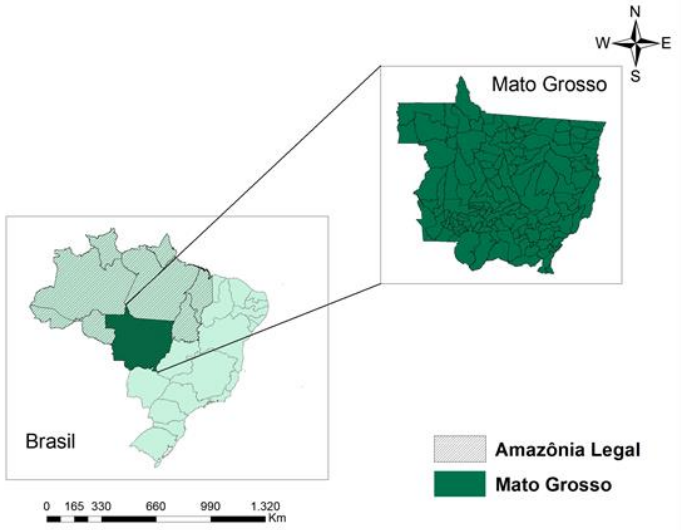

Chart 1: Dimensions of the ATL-related determinants that were investigated in the study. Mato Grosso, Legal Amazon.

Dimension 1	Dimension 2	Dimension 3
Socioeconomic and health determinants of municipalities	**Determinants of health care and care network**	**Environmental determinants**
Municipal Human Development Index (HDIM)	Number of health professionals	Deforestation data (Km^2)
Gini index	Population coverage estimated by primary care teams	Average point precipitation (rain)
Per capita household income	Proportion of population registered by the family health strategy	Forest area (Km^2)
Sanitation situation	Total health expenditure value per Inhabitant	Bovine herd (Number of heads)
Urbanization rate	Percentage of Investment expenditure in relation to total realth expenditure	Total harvest area in the state
	Amounts expense with own resources in health	Land use data (Productive areas)
	Amounts revenue transfer from SUS	Income from agriculture
	Number of doctors and nurses	

Source: Developed by the authors.

The most prevalent clinical form of ATL in the state of Mato Grosso was the cutaneous one, representing 92.7% (n=21.973) of all cases registered in the period. Regarding the evolution of these cases, most evolved to cure (83.2%; n=19.722), with abandonment being (2.3%; n=537). The presence of scars was not recorded in the notification forms in most cases (93.2%; n=22.082).

Direct parasitological examination was the diagnostic method most used, displaying positive results in 78.9% (n=18.708) of cases. Histopathological examination showed the presence of the parasite in 12.5% (n=2.966) of cases and was not performed in 80.3% (n=19.038) of patients. Regarding the Monte Negro intradermal test, the result was positive for 13% (n=3.077) of those tested and the test was not performed in 82.8% (n=19.038) of the patients.

As for the spatial distribution of the incidence rate, the results showed values that ranged from zero to 578.87 cases (per 100000 inhabitants). The highest rates occurred in the southeast and central-north regions of Mato Grosso, while in the southern region of the state we observed a lower incidence during the investigated period (Figure 2).

In the scan analysis, 17 clusters (RR>1) were identified for the occurrence of ATL cases in the state of Mato Grosso, covering 69 municipalities, with 858835 people residing in these high-risk areas. The clusters were located in the southeast and north-central regions of Mato Grosso (Figure 3).

The clusters with the highest RR for ATL infection were cluster 1 (Santa Rita do Trivelato) with RR=5.52 (p=<0.001); 2 (Itaúba) with RR=5.13 (p=<0.001); and 3 (Alto Boa Vista, Bom Jesus do Araguaia, Canabrava do Norte, Novo Santo Antônio, Ribeirão Cascalheira and Serra Nova Dourada) with RR=4.54 (*p*=<0.001).

Then, the logistic regression analysis was performed, which made it possible to identify the determinants related to the ATL risk areas within the state. Four statistically significant variables (p< 0.05) were identified.

A positive relationship was obtained with high-risk areas for the variables: the presence of cattle herd, harvested area and rainfall. Indicating that the higher the values of these variables in the municipality, the greater the chances of this municipality

belonging to a high-risk cluster for ATL infection in Table 2.

Figure 2 - Spatial distribution of average incidence rates of ATL cases according to the municipalities of Mato Grosso – Legal Amazon (2010-2019).

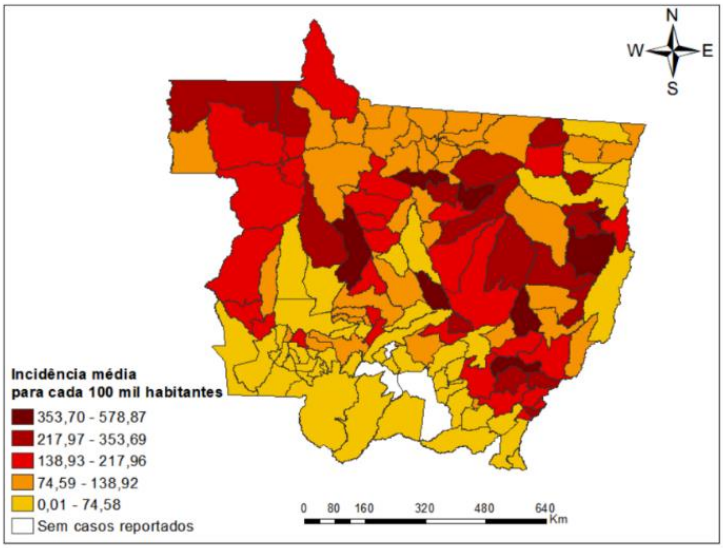

Figure 3 - Map of risk clusters (Cl) for the occurrence of ATL cases in the state of Mato Grosso – Legal Amazon (2010-2019).

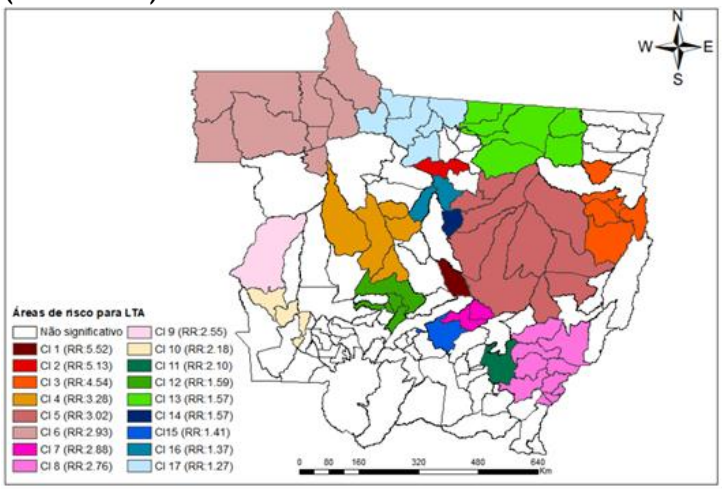

Table1 - Characteristics of high-risk clusters for the occurrence of ATL cases in Mato Grosso - Legal Amazon (2010-2019).

Risk Cluster	Cities	Population at risk	Log-likelihood ratio	p-valor	RR	IC 95%
1	Santa Rita do Trivelato	2.491	95.058.303	<0.001	5.52	4.58-6.65
2	Itaúba	4.575	150.536.425	<0.001	5.13	4.45-5.92
3	Alto Boa Vista Bom Jesus do Araguaia Canabrava do Norte Novo Santo Antônio Ribeirão Cascalheira Serra Nova Dourada	27.598	683.559.564	<0.001	4.54	4.26-4.84

Continuation (Table 1)

4	Brasnorte Itanhangá São José do Rio Claro Tapurah Nova Maringá	54.739	645.181.234	<0.001	3.28	3.11-3.46
5	Água Boa Campinápolis Canarana Feliz Natal Gaúcha do Norte Nova Ubiratã Paranatinga Querência Santa Carmem União do Sul	120.527	1.080.711.808	<0.001	3.02	2.90-3.14
6	Apiacás Aripuanã Castanheira Colniza Cotriguaçu Juruena Nova Bandeirantes Rondolândia	103.266	878.437.769	<0.001	2.93	2.81-3.06
7	Nova Brasilândia Planalto da Serra	7.313	62.197.693	<0.001	2.81	2.41-3.28
8	Araguainha Barra do Garças General Carneiro Guiratinga Novo São Joaquim Pontal do Araguaia Ponte Branca Ribeirãozinho Tesouro Torixoréu	99.510	728.578.719	<0.001	2.76	2.64-2.89
9	Comodoro	18.178	117.105.115	<0.001	2.55	2.30-2.83
10	Conquista D'Oeste Nova Lacerda Vale de São Domingos	11.873	47.519.764	<0,001	2.18	1.90-2.50
11	Poxoréu	17.599	62.282.452	<0.001	2.10	1.87-2.36
12	Alto Paraguai Arenápolis Diamantino Nortelândia Santo Afonso	50.150	55.783.559	<0.001	1.59	1.47-1.72
13	Guarantã do Norte Marcelândia	96.348	96.987.088	<0.001	1.57	1.45-1.70

Continuation (Table 1)

	Matupá Peixoto de Azevedo São José do Xingu Santa Cruz do Xingu					
14	Vera	10.235	10.883.075	<0.001	1.57	1.32-1.87
15	Chapada dos Guimarães	17.821	10.370.138	<0.0011	1.41	1.23-1.62
16	Ipiranga do Norte Sinop	118.222	53.830.140	<0.001	1.37	1.29-1.45
17	Alta Floresta Carlinda Nova Canaã do Norte Novo Mundo Paranaíta Nova Monte Verde	98.390	28.343.213	<0.001	1.29	1.21-1.37

Source: Developed by the authors.

It was also found that the municipal human development index (MHDI) has a negative association, indicating that the lower the value of this variable, the greater the chances of a given area being part of a high-risk cluster for ATL infection in Table 2.

Nagelkerke's pseudo (R^2) value showed that the generated regression model explains 34.6% of the risk areas in the state of Mato Grosso. The value of the Omnibus test was p > 0.005 while the Hosmer and Lemeshow test showed a value of p=0.398, the ROC curve returned a value of 0.789.

Table 2 - Logistic regression analysis for high-risk areas for ATL in the state of Mato Grosso - Legal Amazon (2010-2019).

Variáveis	ß	Wald	p		OR	IC95%
	Forest area	0.026	2,816	0,093	1,026	0,996-1,058
	Herd of cattle	0,000	4,618	0,032	1,000	1,000-1,000
	MHDI	-0,023	7,319	0,007	0,978	0,962-0,994
	Harvest (area)	0,000	4,860	0,027	1,000	1,000-1,000
	Rain precipitation	0,003	8,701	0,003	1,003	1,001-1,006

MHDI: Municipal human development index
Source: Developed by the authors.

DISCUSSION

This study aimed to identify high-risk areas for the occurrence of ATL and investigate the determinants associated with this phenomenon in the state of Mato Grosso, a state belonging to the Legal Amazon, from 2010 to 2019 and the identification of environmental, social and environmental variables of

health related to risk areas existing in the state.

The results showed high incidence rates and high-risk areas for the occurrence of ATL in this region of the Legal Amazon, which was associated with socioeconomic and environmental determinants present in the municipalities.

It was possible to observe that the highest incidence rates are found in the southeast and central-north regions of the state, which are regions that have a strong influence on livestock and agriculture, with high rates of deforestation, commonly linked to the expansion and creation of new areas for agriculture exploration. This fact may explain the high incidence of ATL in the state, since the increase in cases is linked to the increase in deforestation, especially in formerly natural areas with recent anthropization. This relationship was also established for cases of visceral leishmaniasis[16].

The pattern of ATL infection in this region of the Legal Amazon is very similar to that of other neglected diseases that exist throughout the world, and it was shown in this research that the disease affects mainly men, with low education and an economically active age, which is characteristic in NTDs. Regions where precarious socioeconomic conditions are maintained are places that should be considered a priority when it comes to NTDs, such as ATL, given that poverty perpetuates the conditions that favor the spread of these diseases[17].

Another issue that must be considered is that low economic power prevents affected people from obtaining adequate access to prevention and care. In addition, the inhabitants of these regions also do not have a voice or political strength, which limits the empowerment of the population in relation to their own health and reinforces the stigma generated by NTDs[18,19].

The most affected age groups are among the economically active population ranging from 20 to 64 years. It was also possible to perceive a high incidence in the population aged 65 years or more, this characteristic of those infected with ATL in the state of Mato Grosso may be related to the aging of rural populations[20,21]. Of importance, the Brazilian Agricultural Research Corporation, recorded an accelerated aging process within the rural population in Brazil was identified in the last agricultural censuses[22].

The high incidence of ATL in indigenous populations was recorded in several studies, corroborating our findings, which may be mainly related to cultural aspects of these peoples, such as the way of life, rituals and places where they live[23]. Black and brown populations also have a high incidence, corroborating other research, such as those performed in Tocantins and Acre, areas also belonging to the Brazilian Legal Amazon[20,24].

Regarding the clinical characteristics, the predominant form of ATL in the region was the cutaneous one, which corroborates with other studies carried out in Brazil[8,10,25]. Most registered cases evolved to cure, being above the percentage observed in the Americas (70%), but below those found in other states of Brazil, which places Mato Grosso as one of the most critical states in terms of coping with ATL.

Regarding parasitological tests used to ALT diagnosis, the most used in the state was the direct parasitological test, in which the parasite is sought in the biological sample under analysis. This exam is the most performed because it is cheaper, easier to perform and because it offers reliable results in relation to positive results, but it can present false negatives in the case of samples without the presence of the parasite, having 50% to 70% of sensitivity[4].

The most effective diagnostic test was the Montenegro intradermal resection and the histopathological examination, as they have a greater sensitivity, 84% to 100% and 70 to 100%, respectively[4].

The high number of infected men may also be related to the main economic activities in the state, which has great agricultural and extractive influence, considered activities mostly performed by men. These activities are strictly related to natural environments, favoring infection by the parasite due to the proximity of regions with the presence of the vector and parasite, as well as the feeding times of the Leishmaniasis vector that coincide with work hours, favoring the infection process[11,26].

Through the spatial analyzes carried out, it was possible to verify that the municipalities with the highest incidence rates of ATL and which are also part of the high-risk clusters are regions where extractive and agricultural activities and expansion are more intense[27].

Another aspect that reinforces the robustness of the results found in

this research is that the southern region of the state, where the incidence rates are lower and there are fewer risk clusters, coincide with areas where, due to unfavorable climatic conditions, there is low deforestation and low agricultural activity, which suggests that these environmental factors may be possible protective factors for the occurrence of the disease[5,25,28,29].

A relevant aspect presented in the spatial analysis was the existence of municipalities and microregions that did not include reported cases of ATL in the period from 2010 to 2019. These territories, located mostly in the southern part of the state of Mato Grosso, coincide with areas of less agricultural activity and lower deforestation rates, in addition to presenting less developed environmental and climatic conditions for the protection of the leishmaniasis vector.

This absence of cases may be related to a combination of protective factors, such as less anthropization of the territory, greater preserved vegetation cover and, possibly, better socioeconomic indicators. However, it is also necessary to consider the possibility of underreporting in areas with low health service coverage, which reinforces the importance of strengthening active surveillance even in regions with an apparent absence of the disease[27,28].

Binary logistic regression analysis strengthens these assumptions, since of the four significant variables that made up the model, three refer to environmental determinants, even overlapping determinants related to health care, which were also investigated. The results of this analysis showed that the existence of a cattle herd, the MHDI, harvest area and rainfall are associated with high risk areas for ATL. These variables suggest a relationship between the occurrence of ATL and economic activities and social and environmental characteristics in Mato Grosso.

The agricultural advances present in the state increase human activity in risk regions, close to forests, bringing an increase in incidence mainly in regions of recent anthropization, making it possible to perceive the influence of agricultural variables on the incidence of ATL, mainly in brown and black populations as well as seen in other research in the legal Amazon region[20,24].

Another important point, in relation to agricultural activities, is the proximity of homes to forest regions,

research shows that sandflies can fly from 250 to up to 1000 meters from forest edge regions, indicating that people are not infected only in forest regions, but also in nearby locations[10]. The characteristics observed for non-traditional populations differ from factors related to the high incidence in indigenous peoples, where cultural aspects and habits favor the ATL infection process because they are strictly related to natural environments[23].

Despite these observations, other researchers also reported important numbers of ATL cases in urban areas, which raises the question of the synanthropic process, which can be an important point, especially in chronically endemic areas such as Mato Grosso[30].

Rainfall was also an important variable in the infectious process of ATL, since increased rainfall increases the risk of contamination. The increased risk of contamination in areas of higher rainfall is highly related to the vector's life cycle. Soils rich in organic matter and with high humidity are favorable for sandfly reproduction, increasing the number of vectors, we end up having an increased probability of infection, explaining the positive beta value within the regression model for rainfall[15].

The MHDI showed a negative association in the logistic model, which indicates that the lower the MHDI of the municipality, the greater the chance of belonging to a high-risk cluster, showing that quality of life is strongly related to cases of ATL in the state. The MHDI is an index composed of three dimensions, among which is the education of the local population. This becomes even more relevant when considering that in this study, low education was also evidenced in more than half of the reported cases of ATL.

The level of education is crucial for understanding the infectious process, and this variable may be related to the increase or decrease in the incidence of diseases in different geographic territories. This relationship can be observed at the national level on the patterns of infection by ATL, and with other diseases, such as visceral leishmaniasis, which also affects the most vulnerable populations, with lower education in peripheral regions and with brown skin color[20,24,31].

The same negative association found in our research for MHDI was also observed by Monachesi (2020)[32] for Mucosal Leishmaniasis, this research also reported a negative correlation with per

capita income and life expectancy at birth[32].

Regarding the stigma of the disease, which is linked to the deformities and scars caused by the parasite, in most cases in this study, data about the presence of scars was not reported, making it difficult for the processes of conducting scientific research aimed at the most vulnerable populations to develop these deformities, which is a limitation of the study. Another limitation of this research is linked to the secondary databases used in this study, which may present incomplete data.

Although there is a WHO perspective to control ATL, the efforts made so far are reactive and late. Disease control is difficult and becomes more complex with the specificities of territories and more vulnerable populations. In this research it was evident that the fight against ATL in Mato Grosso is an even more worrying challenge, since in addition to the precarious living conditions that are inherent to the individuals themselves, it involves determinants linked to the main economic segment of the state, agriculture. In addition, another issue that should be highlighted is that almost 1/3 of the state's population lives in areas at risk for the occurrence of ATL, which reinforces the urgency in adopting effective strategies and tools for health surveillance of this disease.

Even in this context, if control strategies are targeted at areas of potential risk, as evidenced in this study, it is likely that the impacts of ATL will be mitigated and deaths will be avoided. This research advances in scientific knowledge on the subject of ATL because, in addition to targeting the Legal Amazon, an admittedly vulnerable region, it uses spatial analysis techniques that have proven to be useful tools for the management of specific public policies to face several diseases.

CONCLUSION

The results of this study showed that there are risk areas for the occurrence of the ATL spread throughout the state of Mato Grosso – Legal Amazon and that the emergence of these areas is associated with the socioeconomic condition of the municipalities, and mainly with environmental determinants. The study also made it possible to know the sociodemographic and clinical-operational profile of the reported ATL cases.

The maps and analyzes presented highlight the importance of space for understanding ATL dynamics and constitute a robust tool for understanding epidemiological data, but which is still little explored for ATL control. The results obtained here are valuable for public managers, given that they provide subsidies for the elaboration of integrated policies, which take into account the individual characteristics and each location, including the degradation processes present in each region.

In addition to identifying critical areas for the occurrence of ATL, this study also revealed municipalities and microregions with no reported cases during the analyzed period, which should be prioritized for preventive actions to avoid the introduction or reemergence of the disease. At the same time, territories with higher incidence and belonging to high-risk clusters require integrated interventions in surveillance, diagnosis, and treatment, addressing persistent challenges such as reactive surveillance, limited access to more sensitive diagnostic tests, poor treatment adherence, and underreporting, especially among vulnerable populations. Therefore, strengthening active surveillance, training healthcare teams, expanding access to accurate diagnostic methods, and investing in community-based health education are essential strategies both to preserve disease-free areas and to control its spread in already affected territories.

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