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## GEOSPATIAL ANALYSIS OF AMERICAN TEGUMENTARY LEISHMANIASIS IN ALAGOAS, 2007-2021

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### ABSTRACT

American tegumentary leishmaniasis (ATL) is an infectious disease transmitted by vectors and caused by several protozoa of the genus *Leishmania*. In Brazil, it is considered a serious public health problem due to its endemicity throughout the national territory. The aim of this study is to analyze the spatial distribution of cases of ATL infection in the municipalities from the State of Alagoas, Brazil, and to identify related social determinants during the period of 2007 to 2021. This is an ecological, retrospective, and quantitative study. We use descriptive and spatial statistics. Data about the disease and social conditions were obtained in the Department of Informatics of the Brazilian National Health System (DATASUS) and Atlas Brasil platform. During this period, 1,033 cases of leishmaniasis were recorded, of which 41% corresponded to the age group of 15-39 years old; men (67%) and black individuals (76%) were the most affected by the disease. The predominant clinical form was cutaneous (95%). The spatial correlations indicate a lack of dependence of the disease, both alone and when compared to the human development index. The findings highlight the need for further investigations to better understand the underlying factors contributing to the disproportionate distribution of the disease and its association with demographic characteristics.

**KEY WORDS:** American tegumentary leishmaniasis; cutaneous leishmaniasis; environmental health; social conditions.

### INTRODUCTION

American Tegumentary Leishmaniasis (ATL) is a neglected and endemic disease in several parts of the world, including Brazil, where it is considered a public health problem (Basano & Camargo, 2004; Brasil, 2017). Moreover, ATL is a notifiable disease in the country, and its incidence has significantly increased in the recent decades (Pignatti et al., 1995; Rocha et al., 2015; Vita et al., 2016; Gosch et al., 2017; Teles et al., 2019; Pinto et al., 2020).

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Several factors are related to the incidence of ATL, including the presence of the vector (mainly *Phlebotominae*, belonging to the order Diptera, family *Psychodidae*, subfamily *Phlebotominae*, genus *Lutzomyia*), environmental conditions favorable to the vector such as high temperature and humidity, and the presence of parasite reservoirs – in the urban environment they are dogs (*Canis familiaris*) and in the wild environment are foxes (*Dusicyon vetulus* and *Cerdocyon thous*), rodents (*Bolomys lasiurus*, *Rattus rattus*, and *Nectomys squamipes*) and marsupials (*Didelphis albiventris*) (Gomes et al., 1990; Brasil, 2017). Furthermore, the disease has been associated with socioeconomic factors such as low human development index, poor housing, sanitation, and education conditions (Santos et al., 2000; Peixoto, 2020).

In this sense, geospatial analysis of ATL may contribute to identifying areas of higher risk and supporting public health policies aimed at controlling the disease (Ursine et al., 2021). Additionally, the relationship between ATL and the human development index can be useful for understanding the factors that influence the incidence of the disease.

Therefore, this study aims to perform a geospatial analysis of ATL cases in the State of Alagoas, Brazil, and to investigate the relationship between the disease incidence and the human development index of its municipalities, considering that the State is one of the poorest and least socially developed in the country.

## MATERIALS AND METHODS

### *Study coverage area*

Alagoas is a State located in the Northeast region of Brazil, with a territory of 27,768 km<sup>2</sup> and a population of 3,120,494 inhabitants in 2010, according to the latest census conducted by the Brazilian Institute of Geography and Statistics (IBGE, 2023). The State has 102 municipalities.

### *Study design*

This study is a descriptive, cross-sectional, retrospective work with a quantitative approach. Data for this research were obtained from the Department of Informatics of the Brazilian National Health System (DATASUS), using the systems of Surveillance of Diseases and Notification Information (SINAN; Brasil, 2023) and resident population (DATASUS, 2023), and Atlas Brasil platform (Atlas Brasil, 2023).

### *Data analysis*

The variables analyzed in this study were the cases of ATL, gender, clinical form, age group, educational level, municipality of residence, and Human

Development Index (HDI) of municipalities in Alagoas. The inclusion criteria used were notification data from 2007 to 2021, and the exclusion criteria were cases notified before the study period.

The incidence rate was calculated using the proportion of cases in the total population, and the incidence rate per municipality was analyzed by dividing the number of confirmed cases by the exposed population aggregate in the period, expressed per 100,000 inhabitants, as expressed in the following equation: incidence rate = (total cases / population) × 100,000

In this paper, it was applied a spatial correlation model to evaluate the patterns of spatial variation. In other words, it measures the extent to which neighboring locations have similar values of ATL prevalence and Municipal Human Development Index (MHDI). For this, we estimate Moran's I uni and bivariate (Moran, 1950). Values with  $p < 0.05$  are considered statistically significant.

### *Computational tools*

Data manipulation was performed using Microsoft Excel 2019<sup>®</sup>, while statistical analysis was performed using RStudio software. Geoda was also used to perform the geospatial analyses. Materials for replication are publicly available on: <https://osf.io/3qrex/>.

### *Ethical guidelines*

As this study was conducted using secondary data obtained from public access information systems, it was not necessary to submit it to the Research Ethics Committee for its execution, nor is it necessary to use the Informed Consent Form.

## RESULTS

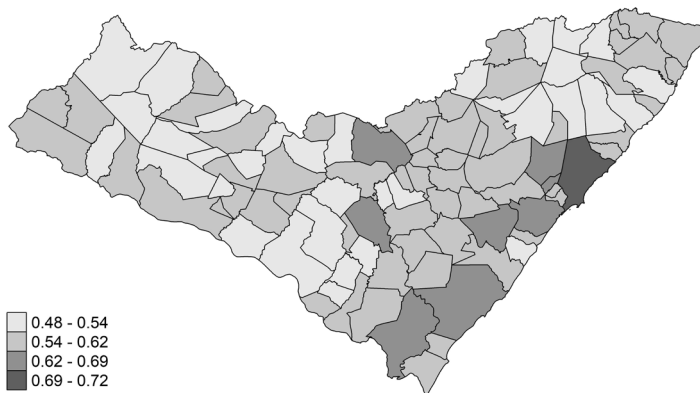
From 2007 to 2021, a total of 1,033 cases of ATL were reported in the State of Alagoas, which corresponds to an incidence rate of 30 cases per 100,000 inhabitants. Table 1 presents the sociodemographic characteristics of ATL cases in Alagoas during the observed period. In general, males were more affected, accounting for 67% of the cases. About 76% of infected people were black, while 17% were white. In the analysis by age group, the highest percentage occurred in individuals aged 15 to 39 years old (41%), and the lowest percentage occurred in those older than 60 years old (13%). The most predominant clinical form of ATL was the cutaneous form, accounting for 95%, while the mucosal form corresponded to only 5%. Regarding the area of residence, 15% of ATL cases lived in urban areas and 70% in rural areas.

*Table 1.* Sociodemographic characteristics of ATL cases in Alagoas, from 2007 to 2021.

Variable	Cases	
	n	%
Sex		
Male	670	
Female	333	
Race		
Black	761	6
White	174	4
Indian	21	
Not applicable/Unknown	45	
Residence		
Rural	706	
Urban	146	
Periurban	3	
Not applicable/Unknown	148	
Age		
<15	218	
15 – 39	415	
40 – 59	242	
>= 60	127	
Not applicable/Unknown	2	1
Education level		
Illiterate	157	
Elementary School	542	
High School	71	
Higher Education	20	
Not applicable/ Unknown	213	
Clinical Form		
Cutaneous	955	
Mucosal	48	
Total	1003	100

Table 2 presents the average prevalence of ATL cases in the municipalities from Alagoas during the analyzed period. Pindoba reported the highest prevalence rate (238.1), followed by Novo Lino (81.1) and Jundiá (75.6). On the other hand, Maceió, the capital of the State, exhibited the lowest prevalence rate (0.3), followed by Arapiraca (0.5), which is the second most developed city in the State. It is worth noting that 32 municipalities did not register any ATL cases.

Nonetheless, when analyzing the MHDI, the pattern is reversed. Maceió has the highest value (0.721), followed by Satuba (0.660), Arapiraca (0.649), Rio Largo (0.643), and Marechal Deodoro (0.642). Of these, the only one that is not part of the metropolitan region of Maceió is Arapiraca, in the Agreste region of the State. From the other end, Inhapi (0.484), Olivença (0.493), and Olho D'Água Grande (0.503), located in the extreme hinterland, register the lowest levels of development. Figure 1 illustrates the pattern, where the darker the color is, the higher is the MHDI.



*Figure 1.* Variation of the HDI in the municipalities of Alagoas (2010).

Figure 2 depicts the spatial autocorrelation pattern of the average prevalence of ATL cases in Alagoas. Overall, a positive but statistically insignificant association was found (Moran's I 0.088, p-value > 0.05, 999 permutations; Figure 2A). However, some clusters with association patterns among territories were identified (Figure 2B). The first cluster is formed by the municipality of Mar Vermelho, characterized by the high-high pattern, where cities with high rates are clustered together. The second cluster consists of the municipalities of Arapiraca, Lagoa da Canoa, São Sebastião, Penedo, Piaçabuçu, and Satuba, forming the low-low pattern, where cities with low rates are clustered together.

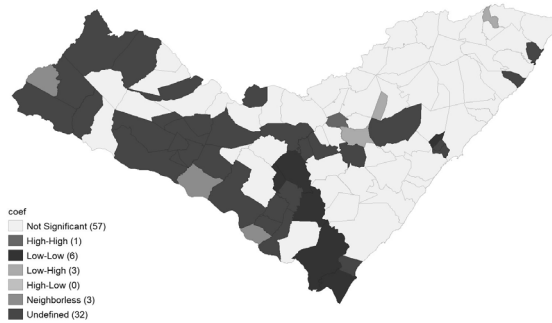


Figure 2. Spatial autocorrelation of the average prevalence of ATL cases in Alagoas (2007-2021).

Finally, Figure 3 describes the association pattern between HDI and the prevalence of leishmaniasis. Overall, there is a negative and statistically insignificant correlation (Moran’s I  $-0.028$ ,  $p\text{-value} > 0.05$ , 999 permutations; Figure 3A). Clusters with association patterns between the two variables are also formed here (Figure 3B). The first cluster is formed by municipalities in the metropolitan region: Maceió, Pilar, Paripueira, Marechal Deodoro, and Satuba, and characterized by the low-high pattern, i.e., low prevalence and high HDI. The second cluster is formed by the municipalities of Maravilha and Joaquim Gomes, with the high-low pattern, high prevalence and low social development. The only municipality belonging to the low-low category, i.e., low HDI and cases of the disease, was Piranhas.

In both Figure 2 and Figure 3, 32 municipalities were categorized as undefined since they did not report information in the analyzed period.

Table 2. Average prevalence of ATL cases in the municipalities of Alagoas, from 2007 to 2021.

Order	City	Average prevalence	Order	City	Average prevalence
1	Pindoba	238.1	36	Pariconha	9.5
2	Novo Lino	81.1	37	Cacimbinhas	9.4
3	Jundiá	75.6	38	Paripueira	9.3
4	Jacuípe	74	39	Ouro branco	9.0

5	Tanque d'Arca	63.1	40	Dois riachos	8.9
6	Colônia Leopoldina	55.3	41	Cajueiro	8.5
7	Chã Preta	50.2	42	Maribondo	7.4
8	Mar Vermelho	39.8	43	Barra de santo Antônio	6.3
9	Joaquim Gomes	27.1	44	Matriz de Camaragibe	5.8
10	Quebrangulo	22.9	45	Porto calvo	5.7
11	Belém	21.3	46	Piaçabuçu	5.7
12	Santana do Mundaú	20.8	47	Messias	5.6
13	Maravilha	18.2	48	Estrela de alagoas	5.6
14	Jaramataia	17.3	49	Inhapi	5.4
15	Viçosa	16.8	50	Lagoa da canoa	5.3
16	Jequiá da Praia	16.7	51	Palmeira dos Índios	5.2
17	Campo Alegre	15.8	52	São Sebastião	4.5
18	Branquinha	15.6	53	Craibas	4.2
19	Murici	15.4	54	Igreja nova	4.1
20	Roteiro	15	55	Piranhas	4.1
21	União dos Palmares	14.9	56	Junqueiro	4.0
22	Belo Monte	14.9	57	Limoeiro de Anadia	3.7
23	Satuba	14.8	58	Boca da mata	3.7
24	Campestre	14.8	59	Maragogi	3.2
25	São Brás	14.5	60	Pilar	2.8
26	Senador Rui Palmeira	14.4	61	Girau do Ponciano	2.6
27	Paulo Jacinto	13.2	62	Teotonio Vilela	2.3
28	Capela	12.5	63	Santana do Ipanema	2.2
29	Porto de Pedras	12.1	64	Marechal Deodoro	2.7
30	Barra de São Miguel	12.1	65	Rio largo	2
31	São Jose da Laje	12	66	São Miguel dos campos	1.8
32	Flexeiras	11.8	67	Coruripe	1.7
33	São Luís do Quitunde	10.3	68	Penedo	1.6
34	Passo de Camaragibe	9.9	69	Arapiraca	0.5
35	Ibateguara	9.6	70	Maceió	0.3

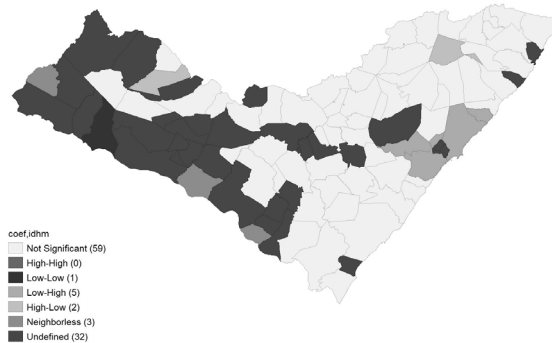


Figure 3. Spatial correlation of the average prevalence of ATL cases in Alagoas (2007-2021)  $\times$  MDHI (2010).

## DISCUSSION

During the analyzed period, some considerations may be made regarding the cases of ATL in Alagoas. The first point to be highlighted concerns the pattern of infection occurred mostly in young adults, which is consistent with the literature (Costa, 2005). Ethnicity is an important variable and recent studies indicate that the black population (including mixed-race individuals) is the most affected group (Gosch et al., 2017; Teles et al., 2019; Pinto et al., 2020). However, it is important to note that the racial variable in question may serve as a confounding factor concerning both risk and work exposure habits, as well as marginal areas of residence, within certain racial groups (Benmarhnia et al., 2021).

Similarly, regarding the clinical form, the cutaneous form is the most prevalent, while the mucosal form is a secondary form to the cutaneous form, and it is more frequently present in individuals who do not adhere adequately to the treatment (Brasil, 2017).

A higher number of ATL cases among men and young adults suggests transmission outside the household in the economically active population. The men are more exposed to ATL, as they go to work in forested areas, in addition to their habit of not wearing shirts or sleeping on the porches of their homes. On the other hand, women have more preventive habits, such as using insect repellent, clothing that protects them, and even using protective screens against insects (Chagas et al., 2006; Guerra et al., 2015). The occurrence among women, children, and non-agricultural workers happens due to intra and/ or peridomiciliary transmission (Passos et al., 1993).



Overall, the study points to a positive global autocorrelation coefficient, indicating that areas with high leishmaniasis rates tend to be closer to others in the same situation. Nevertheless, the findings are not consistently significant. Another point concerns the spatial correlation between the disease and socioeconomic conditions. The global association is negative, indicating that more developed areas tend to be closer to areas with low disease incidence. However, there is also no statistical support for this.

The study presented important limitations regarding its population and sample. The size of the affected municipalities, as there were municipalities with minimal numbers of cases, generating an insignificant p-value in the statistical tests, showing that the distribution did not follow a normal distribution pattern. This is because ATL has a microfocal transmission pattern, and risk factors on meso or macro scales may tend to compensate for opposite values. Finally, the presence of population-unweighted parameters may introduce some biases in the analyses.

ATL is a disease directly related to socio-environmental factors in the State of Alagoas. The findings highlight the need for further investigations to better understand the underlying factors contributing to the disproportionate distribution of the disease and its association with demographic characteristics. Such insights will be valuable for implementing targeted preventive and control measures to effectively mitigate the burden of leishmaniasis within the affected population.

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#### CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest to disclose.

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