REVISTA HYGEIA
https://seer.ufu.br/index.php/hygeia

ISSN: 1980-1726
DOI: https://doi.org/10.14393/Hygeia2069916

TYPOLOGIES OF LAND USE AND LAND COVER ASSOCIATED WITH CASES OF CUTANEOUS LEISHMANIASIS IN A METROPOLITAN REGION IN THE BRAZILIAN AMAZON

TIPOLOGIAS DE USO E COBERTURA DA TERRA ASSOCIADOS A CASOS DE LEISHMANIOSE CUTÂNEA EM UM REGIÃO METROPOLITANA NA AMAZÔNIA BRASILEIRA

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ABSTRACT

Characterizing the probable site of infection of cutaneous leishmaniasis (CL) in face of anthropic changes in the Amazon makes it possible to understand the distribution of this disease in order to adopt control measures. The objective of this study is to identify landscape typologies resulting from changes in land use and land cover in the Metropolitan Region of Santarém regarding the occurrence of CL cases in 2012 and 2014. Landscape typologies were developed from TerraClass project data using regular 1 km² cells. Landscape presence and dominance metrics were used to generate cells with a single class and cells with more than one class, called mosaics. For cases of leishmaniasis, the metric was the presence of the disease. Association analyses were extracted from a 2x2 contingency table. The primary forest typology (PP04) had the highest number of cells in both years analyzed. However, changes in land use and land cover were evidenced by the growth in the number of cells with mosaics of agriculture (PP11 and PP12), urbanized areas (PP03 and PP10), and pastures (PP13). The presence of at least one case of CL in each year occurred in ten typologies, particularly in compositions with urbanized areas, pastures, and secondary vegetation. Typologies with the agriculture class, although the number of cells increased, did not follow the same growth logic regarding the presence of the disease. This study makes it possible to identify and characterize the places where CL occurs and provides further information for health surveillance agencies.

Keywords: Land use and land cover. Landscape typology. Cutaneous leishmaniasis. Amazon.

RESUMO

Caracterizar o local provável de infecção da leishmaniose cutânea (LC) diante de mudanças antrópicas na Amazônia possibilita a compreensão da distribuição da doença para adoção de medidas de controle. O objetivo deste estudo foi identificar tipologias de paisagem decorrentes das mudanças no uso e cobertura da terra na Região Metropolitana de Santarém em relação às ocorrências de casos de LC nos anos de 2012 e 2014. Tipologias de paisagem foram desenvolvidas a partir dos dados do projeto TerraClass utilizando células regulares de 1 km². Utilizou-se as métricas de paisagem presença e dominância para gerar células com uma única classe e células com mais de uma classe chamadas mosaicos. Para os casos de leishmaniose a métrica foi a presença do agravo. Análises de associação foram extraídas de uma tabela de contingência 2x2. A tipologia de floresta primária (PP04) esteve em maior número de células nos dois anos analisados, contudo mudanças no uso e cobertura da terra foram evidenciadas pelo crescimento da

Recebido em: 04/07/2023.
Aceito para publicação em: 19/01/2024.

quantidade de células com mosaicos com agricultura (PP11 e PP12), área urbanizada (PP03 e PP10) e pastagem (PP13). A presença de pelo menos um caso de LC em cada ano ocorreram em 10 tipologias, particularmente nas composições com áreas urbanizada, pastagem e vegetação secundária. Tipologias com a classe agricultura embora tenha aumentado a quantidade de célula não seguiu a mesma lógica de crescimento para a presença da doença. O estudo possibilitou identificar e caracterizar os locais de ocorrência de LC proporcionando mais informações para órgãos de vigilância em saúde.

Palavras-chave: Uso e cobertura da terra. Tipologia de paisagem. Leishmaniose cutânea. Amazônia.

INTRODUCTION

Fast and significant environmental changes are taking place in the Amazon. Multiple evidence suggests that habitat disturbance due to land cover changes is likely to be the single largest global environmental cause of infectious disease risks (PATZ et al., 2008; MCFARLANE et al., 2013; GOTTDENKER et al., 2014). Cutaneous leishmaniasis (CL) is one of these diseases that is associated with anthropogenic changes (BUZANOVSKY et al., 2020).

CL is a vector-borne disease classified by the World Health Organization as a neglected tropical disease (PORTELLA; KRAENKEL, 2021). It is caused by an obligate parasite of the genus Leishmania and transmitted to humans through the bite of infected female sandflies (BUZANOVSKY et al., 2020). The Amazon region is endemic for leishmaniasis. It concentrates most cases in Brazil: 80% of cases occur in only 10% of the municipalities that belong to the Brazilian Legal Amazon (PORTELLA; KRAENKEL, 2021). Cases of CL are important causes of illnesses in the region. There are outbreaks related to disturbed environments mainly due to the disorderly occupation of new areas, which results in a greater contact between humans and vectors of Leishmania (CONFALONIERI; MARGONARI; QUINTÃO 2014).

CL is linked to environmental factors, among which landscape composition is part of the ecological complexity that involves the elements of the epidemiological chain (FONSECA; D’ANDREA, 2014; DA COSTA et al., 2018; BUZANOVSKY et al., 2020). A diversity of parasitic species, vectors, and reservoirs coexist in certain environments, and this relationship is crucial for disease transmission processes. Epidemiological patterns of occurrence and dispersion are related to certain types and attributes of the landscape (DA COSTA et al., 2018). Land use and land cover (LULC) are proxies to determine areas at high risk of Leishmania transmission (OCAMPO et al., 2012, PÉREZ-FLÓREZ et al., 2016, DE OLIVEIRA et al., 2016; MELCHIOR et al., 2017; GUTIERREZ et al., 2018; VALERO et al., 2021).

The Metropolitan Region of Santarém (MRS) temporarily belongs to a hotspot area of CL incidence in the western region of the State of Pará (PORTELLA e KRAENKEL, 2021). However, this region has undergone transformation processes in land use and cover since the late 1990s due to the introduction of intensive soybean monoculture (COELHO et al., 2021). This new logic of territorial occupation results in new and different landscape patterns due to intense transformations that have occurred in the area (DE PAULA et al., 2022). Although approaches analyzing the landscape as a potential means of disease transmission have been developed for several regions (LINARD, 2009; VANWAMBEKE et al., 2011), in the Amazon few analyses (BECKER, 2018) have been carried out studying the current spatial configurations resulting from changes in LULC in recent decades. This is because, among others, of limitations in scaling landscape data to a scale compatible with the transmission of the disease.

Innovative and intensified surveillance practices are encouraged by the Pan-American Health Organization (PAHO) as priorities in the "Plan of Action 2016-2022" (PAHO, 2016), which aims to strengthen the generation and dissemination of information for surveillance and control of neglected infectious diseases. In this context, the characterization of the probable site of infection (PSI) of CL is of fundamental importance for the investigation process and to adopt control measures. Thus, the identification of LULC patterns becomes a useful analysis tool that may help prevention and monitoring strategies in territorial units of epidemiological relevance. For this, changes in land cover and the resulting patterns need to be determined in order to be related to the occurrence of the disease.

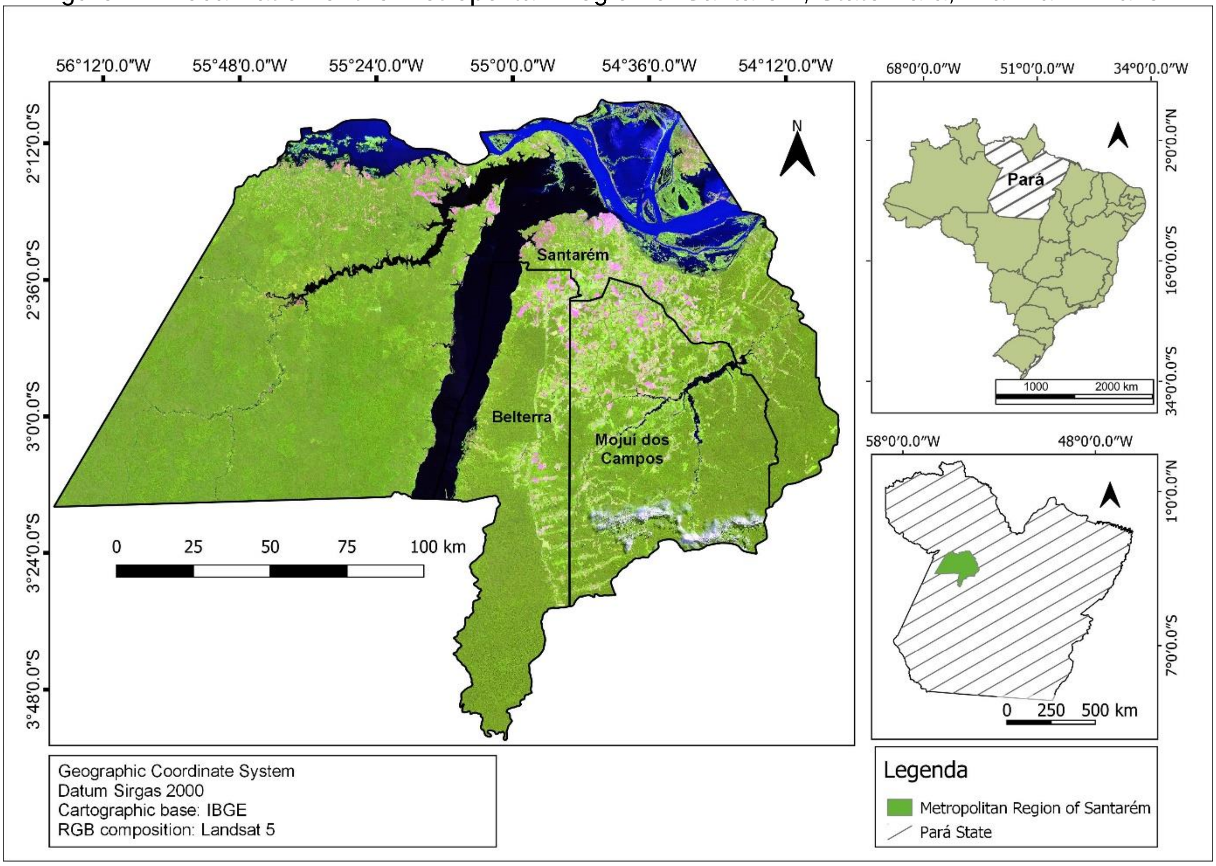
Thus, the objective of this study is to identify landscape typologies resulting from changes in LULC in the Metropolitan Region of Santarém regarding the occurrence of CL cases in 2012 and 2014.

MATERIALS AND METHODS

Study Area

Situated in the Amazon region, MRS in State of Pará (Figure 1) has a surface area of 27,285.043 km², corresponding to territory of municipalities Belterra, Mojuí dos Campos and Santarém. The estimated population in 2021 for the three municipalities is 342,565 with Santarém being the third most populous municipality in the state of Pará (IBGE, 2022).

Figure 1 – Localization of the Metropolitan Region of Santarém, State Pará, Brazilian Amazon



Source: The authors.

The landscape, climate and population together are relevant for the presence of disease-carrying vectors. The region presents a heterogeneous mosaic of landscapes, with natural and anthropized areas. The region's predominant climate is hot and humid.

LUCL classes and classification rules

To determine the association between LULC patterns and cases of CL in the MRS, a landscape pattern typology was developed based on land cover maps from TerraClass project for the Legal Amazon (EMBRAPA/INPE). The classes considered were Pasture (shrubby cultivated pasture plus herbaceous cultivated pasture), Other (Non-observed area plus the existing class Other), Agriculture (temporary agricultural culture class), and urbanized area (Urban class). The other classes present in the analyzed period remained as in the original captions: Primary Forest, Secondary vegetation, Non-forest, Annual deforestation, and Water bodies.

The methodology of regular grids was adopted in order to homogenize the spatial unit, thus making the cell the unit of analysis. The most consistent cell size for this study was 1 km x 1 km, considering the parameter mean distance of flight range of disease-transmitting species of the genus *Lutzomyia* (up to 960 m) (ALEXANDER; YOUNG, 1992). In addition, the database of cases of the disease does not have an exact location, but a probable location of infection. Therefore, the established size covers a representative area of influence of landscape attributes on the vectors that transmit the disease.

A total of 27,841 cells were established for the entire length of the MRS. For typology operationalization, the land use and land cover attribute (element that will be applied to the landscape metric) was inserted in the cellular space using the class percentage operator of the FillCell Plugin (TerraME), while confirmed cases were inserted through the presence operator, in which the value 1 represents at least one case (or more) and the value zero represents no occurrence of the disease in the analyzed year.

Rule-based classification for landscape typology

The typology was defined from cells that contain a single class and cells with more than one class of land use and cover, called mosaics. Presence and dominance were the metrics established from the attribute of class percentage of nine classes (Agriculture- “AGR”, Urbanized area - “URB”, Other – “OUT”, Primary Forest – “FLO”, Annual deforestation – “DEF”, Secondary vegetation – “VEGSEC”, pastures – “PAST”, Water bodies – “HYDRO,” and Non-forest – “NFLO”). A class with a percentage different from 0 characterizes the presence of the class; the opposite means absence. Dominance represents the class in terms of percentage of area greater than the other classes present in the cell. This model was adapted from the proposal developed by Becker (2018).

Single Class Presence (SP) is for a class that dominates 100% of the area, existing only in the cell. This typology represents a total of eight patterns, designated from PP01 to PP08, defined according to the total land use and land cover classes, with the exception of deforestation class in a year because it presents small patches in terms of area to the detriment of an intrinsic particularity of this type of use. As for mosaics, 13 landscape compositions, designated from PP09 to PP21, were established based on the primary obligatory presence (PP) or predominant primary obligatory presence (PPD) of the class. PP means that the existence of a primary class in the composition is enough to represent the group regardless of the size of the strip, while PPD quantifies the class as greater than the presence of other classes in percentage. The other classes of composition are characterized only by presence: secondary presence (PA) and optional presence (PF).

Frame 1 shows the rules established for generating the typology. For systematization, a rule-based model was used in which the "IF x THEN y" format is used, where x represents the mandatory (PP) or predominant presence (PPD) of land use and cover class and y is the type of established pattern. The Boolean logical operators AND and OR were used for the presence of other classes in the cells.

Land use and land cover data of 2010 were used as a test for model creation and later applied to 2012 and 2014. If the model did not apply to any cell, the acceptable error would be lower than 0.1% (30 cells) of all cells in the area (27,841 cells). Thus, it would analyze each unadjusted cell individually and verify the possible adjustment in one of the categories already used according to the composition of the cell and its nearest neighbors.

Frame 1 – Classification rules for landscape typology

			Classification rules								
Class			AGR	OUT	URB	DEF	FLO	HIDRO	NFLO	PAST	VEGSEC	Typology
Typology order	Random	Single Class Presence	SP	-	-	-	-	-	-	-	-	PP01
			-	SP	-	-	-	-	-	-	-	PP02
			-	-	SP	-	-	-	-	-	-	PP03
			-	-	-	-	SP	-	-	-	-	PP04
			-	-	-	-	-	SP	-	-	-	PP05
			-	-	-	-	-	-	SP	-	-	PP06
			-	-	-	-	-	-	-	SP	-	PP07
			-	-	-	-	-	-	-	-	SP	PP08
	Mandatory increasing	Mosaics	-	PF	PP	-	PA$^+$	PF	PF	-	PA$^+$	PP09
			PA$^+$	PF	PP	PF	PF	PF	PF	PA$^+$	PF	PP10
			PPD	PF	-	-	-	PF	-	PA$^+$	PA$^+$	PP11
			PP	PF	-	PF	PA$^+$	PF	-	PF	PA$^+$	PP12
			-	PF	-	PF	PA$^+$	PF	PF	PPD	PA$^+$	PP13
			-	PF	-	PF	PPD	PF	-	PA$^+$	PA$^+$	PP14
			-	PF	-	PA$^+$	PP	PA+	-	-	-	PP15
			-	PF	-	PF	PA$^+$	PF	-	PA$^+$	PPD	PP16
			-	PA$^+$	-	-	-	PA+	-	-	PP	PP17
			-	PF	-	PF	PA$^+$	PF	PP	PA$^+$	PF	PP18
			-	PF	-	-	-	PF	PP	-	PF	PP19
			-	PF	-	PF	PF	PP	-	PA$^+$	PA$^+$	PP20
			-	PP	-	-	PA$^+$	-	-	PF	PA$^+$	PP21

SP= Single Class Presence; PP = Primary Mandatory Presence; PPD= Predominant Primary Mandatory Presence (class with dominance in terms of percentage of area over the other classes present in the cell); PA+ = Secondary Mandatory Presence of at least one class; PF = Optional Presence (may or may not be present); and (-) = Absence.
Source: The authors.

Association between landscape typologies and CL cases

Cases confirmed by probable site of infection of cutaneous leishmaniasis were considered. They are in the database of the Technical Nucleus in Health Surveillance (NTVS) and the National Information System of Notifiable Diseases (SINAN) of the municipality for 2012 and 2014. The coordinates of the communities where the cases occurred were obtained from the Santarém Municipal Environment Department (SEMMA).

As it is an analysis with dichotomized variables, the Odds Ratio (OR) (Equation 1) was used considering a 2 x 2 contingency table. The contingency table consists of the case and control study between the typology (individualized) and the cases of each disease. The total number of cells for the analyzed typology, with the presence and absence of the disease and the other cells, consist of the difference between the total of the analyzed pattern and the total of cells in the area, called control, which also verified the presence and absence of the disease (SANTOS et al., 2016).

$$\frac{\frac{p}{(1-p)}}{\frac{q}{(1-q)}} = \frac{p(1-q)}{q(1-p)} \qquad (1)$$

OR identifies and quantifies the strength of associations between two dichotomous variables. An odds ratio greater than 1 indicates that there is an association, the higher the number being stronger. While an odds ratio less than 1 indicates that the event is unlikely to occur. OR = 1 indicating that there is no association between both variables.

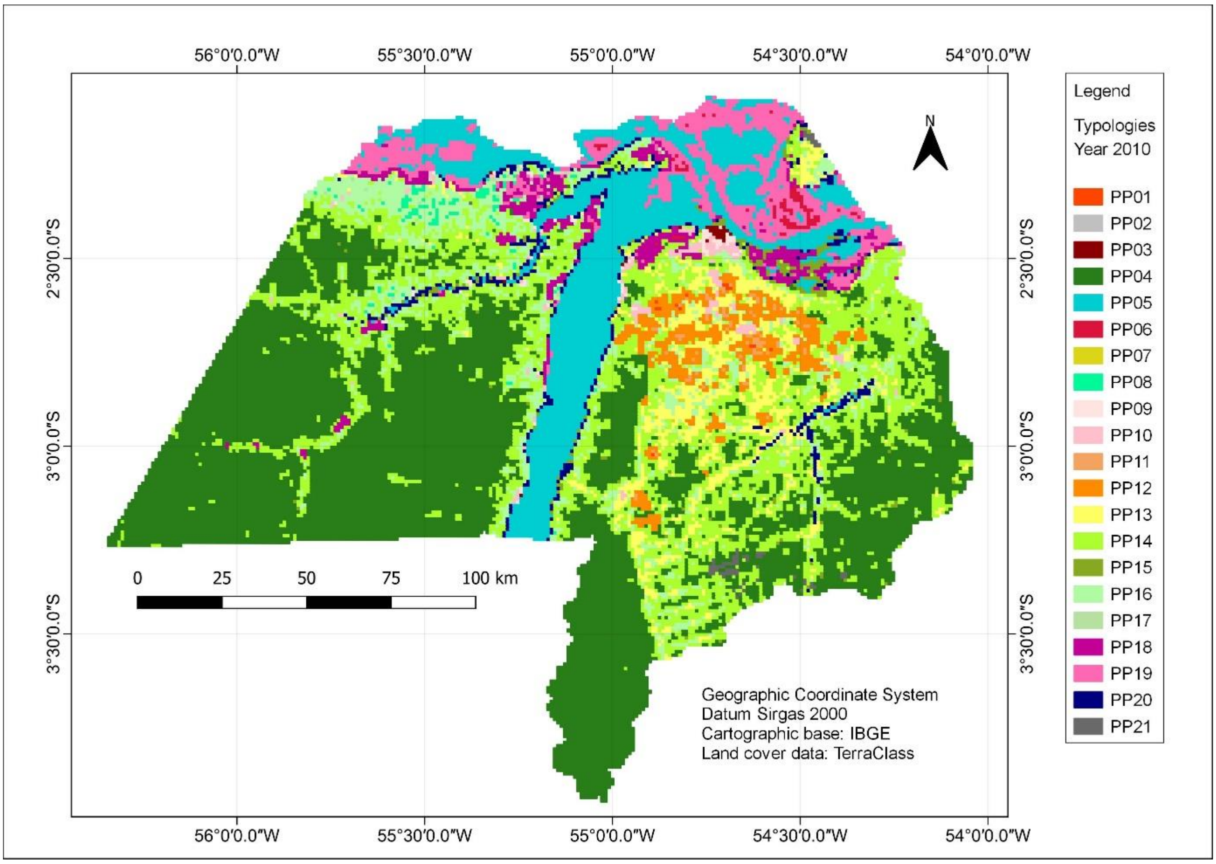
RESULTS

Landscape pattern in the Metropolitan Region of Santarém

In the model used as reference (2010) (Figure 2), it is possible to observe, in a visual analysis, the predominance of primary forests (PP04) mostly located inside Conservation Units (Tapajós-Arapiuns Extractive Reserve and Tapajós National Forest). Cells with the presence of the agriculture classes PP01, PP11, and PP12 are concentrated mainly in the region known as the Santarem plateau, while the pattern with urban classes PP03, PP09, and PP10 are located in urban centers and small population centers in the municipalities. Another characteristic pattern of the area is located in the lowland areas of the Amazon River. The typologies PP06 and PP19 predominate: they are areas of natural grassland, herbaceous, and shrubby vegetation referring to the non-forest class mapped by the TerraClass project.

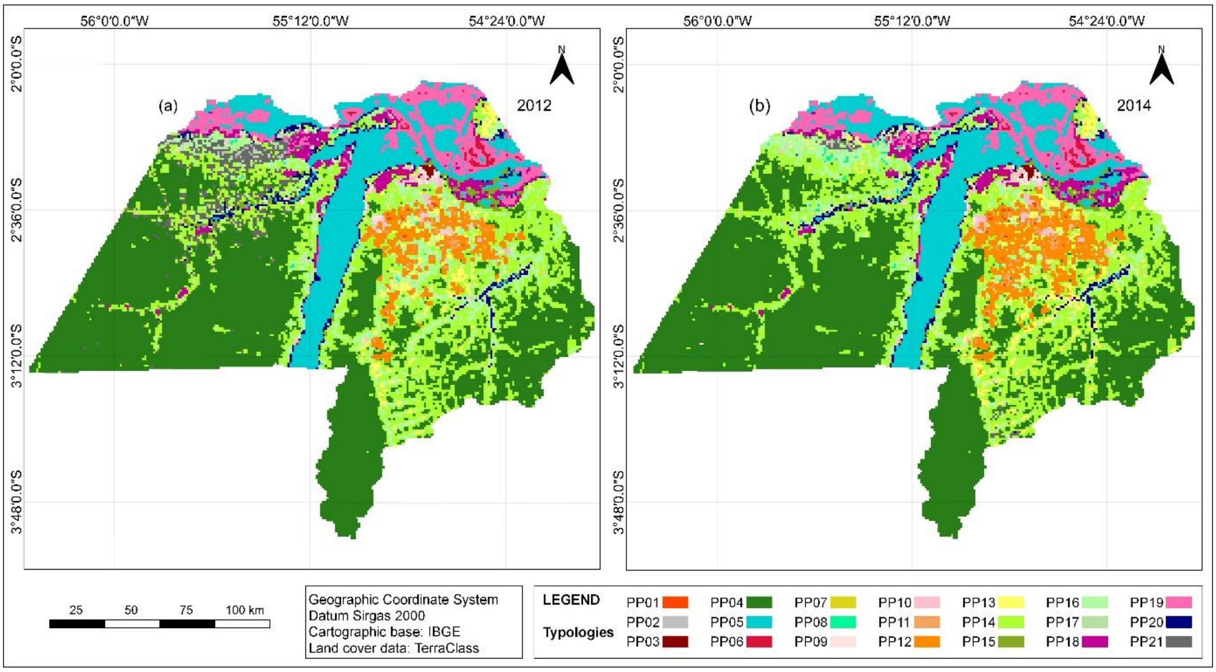
For 2012, the model presented an error of 0.025% (seven cells), while for 2014 the error was 0.043% (12 cells). In 2012, there was a strong presence of clouds in the northwest region of the MRS, where there is the presence of the PP02 and PP21 typologies (Figure 3a). However, in 2014, there is a decrease in the number of cells of these typologies (Figure 3b). The presence of agriculture (PP11 and PP12) and pasture (PP13) gained expression in 2014 (Figure 3b). Furthermore, the pattern with urban cells (PP03 and PP10) increased, mainly in the urban area of Santarém and in population centers with a higher population density.

Figure 2 – Landscape typology for the year 2010



Source: The authors.

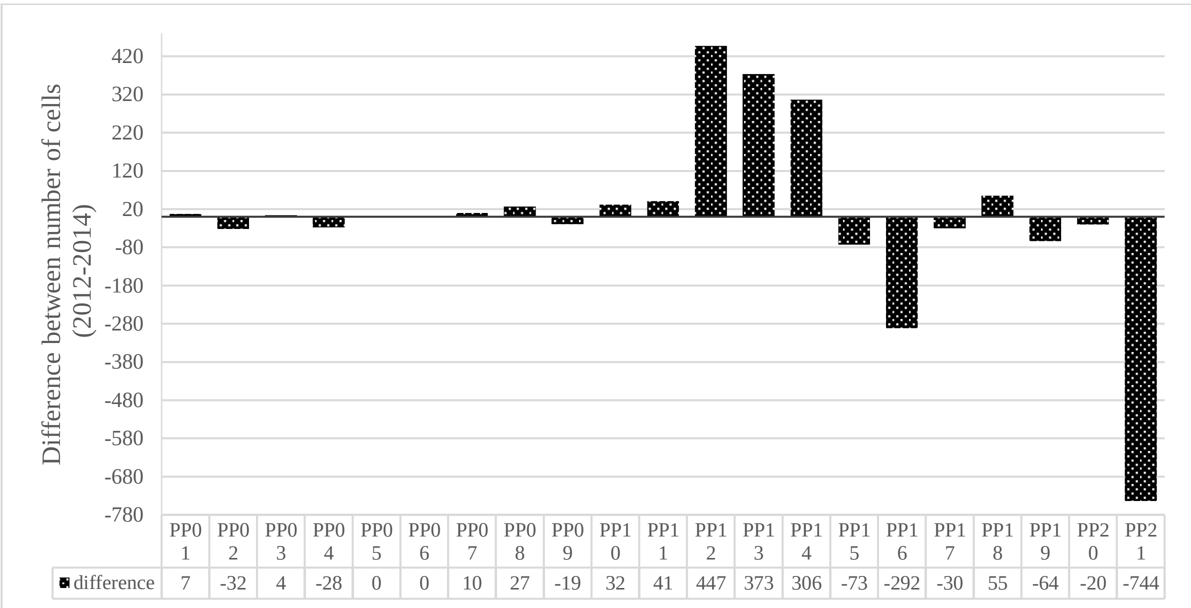
Figure 3 – Landscape typology (a) 2012 and (b) 2014



Source: The authors.

Figure 4 shows the changes in the number of cells of the typologies between 2012 and 2014. There was a loss of primary forest in 28 cells, while there was an increase in the compositions PP10, PP11, PP12, PP11, PP13 and PP14. PP12 had the greatest increase in cells with 447.

Figure 4 – Cell gains and losses from 2012 to 2014



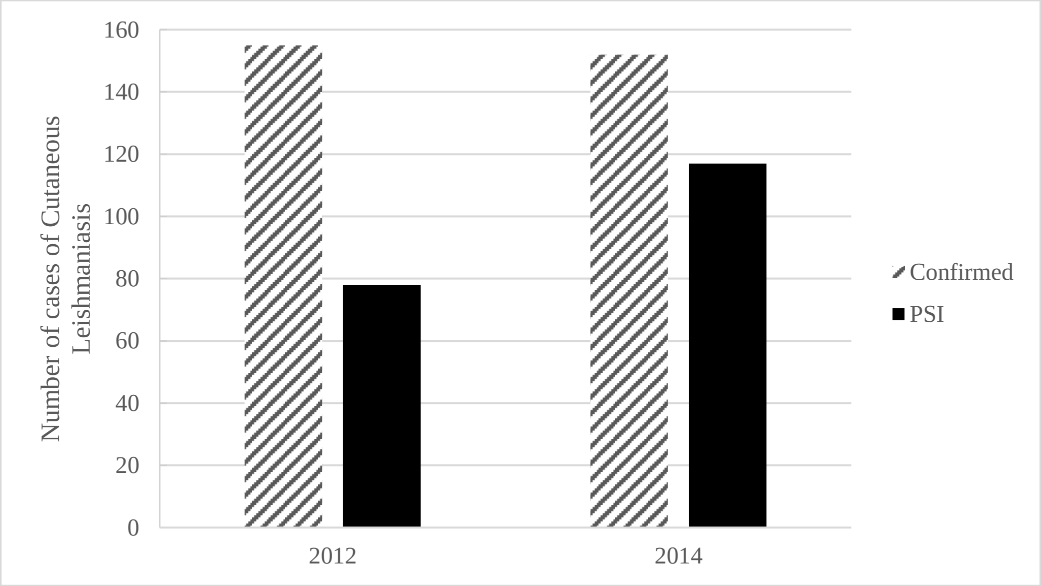
Source: The authors.

Cutaneous leishmaniasis cases in the Metropolitan Region of Santarém

In the MRS, 155 cases of leishmaniasis were confirmed in 2012 and 152 in 2014. However, from the total number of notified cases, it was possible to identify an PSI of 50.32% and 76.97% in 2012 and 2014 (Figure 5).

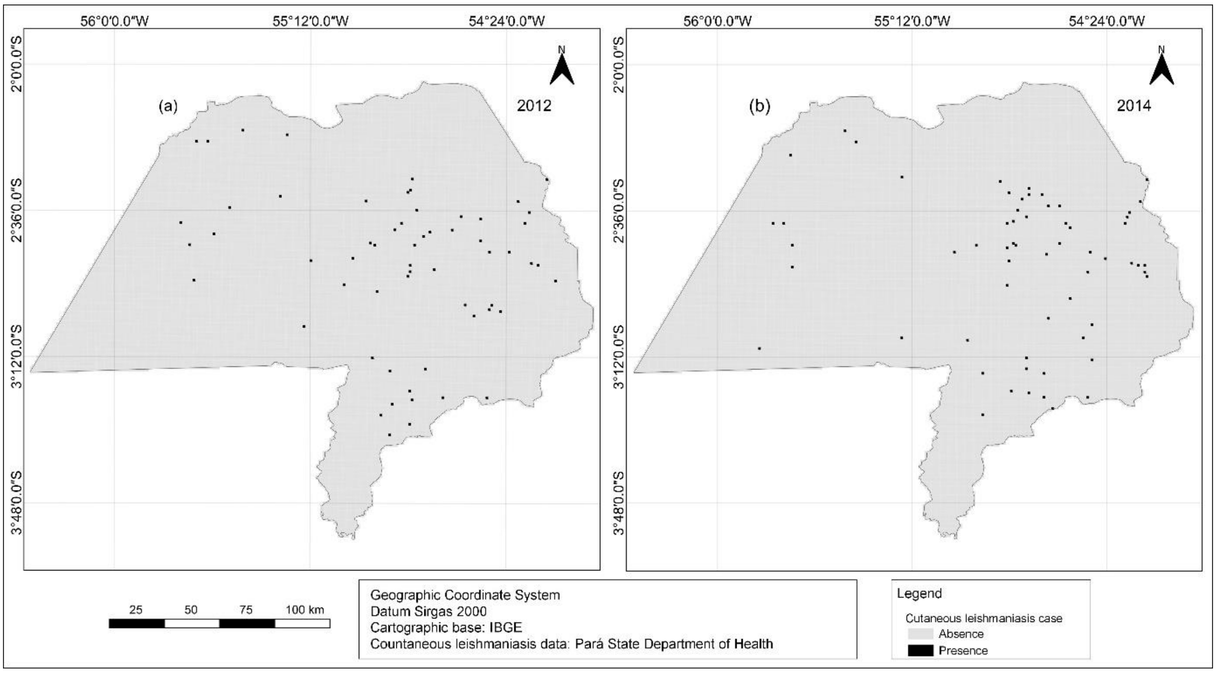
Cells with the presence of at least one confirmed case of CL are distributed in different points of the MRS, with a mean of 61 cells in both years analyzed. Due to spatial distribution (Figures 6a and 6b), places designated as rural, especially communities in Conservation Units and rural settlement projects in the Santarem plateau, were the places that presented the most cases.

Figure 5 – LC cases in MRS in 2012 and 2014



Source: The authors.

Figure 6 – Presence and absence of LC cases in MRS (a) 2012 and (b) 2014



Source: The authors.

Association between Landscape Typology and CL

The presence of CL occurred in ten of the 21 typologies in both years. The highest number of records was in PP10 (seven cells in 2012 and ten cells in 2014), PP12 (ten cells in 2012 and ten cells in 2014), PP13 (four cells in 2012 and ten cells in 2014), PP14 (nine cells in 2012 and ten cells in 2014), PP16 (20 cells in 2012 and 14 cells in 2014) (Table 1). In these typologies, the chance of presence of statistically significant CL was observed in eight typologies in 2012 and six in 2014. The greatest difference in the presence of cases based on landscape pattern typologies for 2012 were in the cells of PP10 (OR, 19.38; 95% CI, [8.71-43.19]), followed by PP03 (OR, 14.25; 95% CI, [1.92-105.91]), PP11 (OR, 10.16; 95% CI, [2.44-42.19]), PP09 (OR , 8.84; 95% CI, [2.13-36.64]), PP16 (OR, 6.22; 95% CI, [3.63-10.66], PP12 (OR, 5.37; 95% CI, [2.72-10.63]), PP20 (OR, 3.77; 95% CI, [1.361-10.43], and PP13 (OR, 3.35; CI of 95 %, [1.21-9.27]). There were no differences in the other records. For cells of typologies in 2014, PP10 (OR, 24.43; 95% CI, [12.25-48.69]), PP03 (OR, 12.29; 95% CI, [1. 66-91.02]), PP09 (OR, 10.37; 95% CI, [2.49-43.08]), PP13 (OR, 5.45; 95% CI, [2.76-10.75]), PP16 (OR, 4.26; 95% CI, [2.34-7.74]), and PP12 (OR, 3.51; 95% CI, [1.78-6.915]) (Table 2). These results show that in these typologies, the chances of CL cases are higher. Only PP04 in 2014 was significantly protective (OR, 0.023; 95% CI, [0.003204-0.1668]).

Table 1 – Number of cells of landscape typologies with presence of CL

	2012		2014	
Typology	**No. of Cells**	**presence of CL**	**No. of Cells**	**presence of CL**
PP01	14	-	21	-
PP02	37	-	5	-
PP03	34	1	38	1
PP04	11555	-	11527	1
PP05	3073	-	3073	-
PP06	90	-	90	-
PP07	4	-	14	-
PP08	31	-	58	-
PP09	110	2	91	2
PP10	195	7	227	10
PP11	96	2	137	1
PP12	1007	10	1454	10
PP13	584	4	957	10
PP14	5147	9	5453	11
PP15	256	-	183	-
PP16	2087	20	1795	14
PP17	78	-	48	-
PP18	670	1	725	-
PP19	1388	-	1324	-
PP20	521	4	501	2
PP21	864	-	120	-
Total	27.841	60	27.841	62

Source: The authors.

DISCUSSION

The present study identifies landscape typologies of occurrence of Cutaneous Leishmaniasis in a metropolitan region in the Amazon. In the characterization of the landscape, the presence of primary forest (pattern PP04) is the typology with the highest number of cells in the MRS. However, there is a growth of compositions with the presence of agriculture, pointing to changes to a commoditized landscape in the analyzed period. The increase in this type of land use arises from the incipient mechanized agriculture in the region. Soybeans have been the main temporary crop from 2003 onwards and have intensified in current periods (COELHO et al., 2021; DE PAULA et al., 2022). Agricultural activities predominate in these areas, which allows for a dynamic transition between the classes of land use and land cover agriculture, pasture, and secondary vegetation, represented by the typologies PP10, PP11, PP12, and PP13.

Table 2 – Landscape typologies associated with LC presence in 2012 and 2014

Typology	Cells with presence of LC	control	OR	95% CI	p-value
2012					
PP03	1	27807	14,25	[1,92-105,91]	0,009
PP09	2	27731	8,84	[2,13-36,64]	0,002
PP10	7	27646	19,38	[8,71-43,19]	<.001
PP11	2	27745	10,16	[2,44-42,19]	0,001
PP12	10	26834	5,37	[2,72-10,63]	<.001
PP13	4	27257	3,35	[1,21-9,27]	0,019
PP14	9	22694	0,78	[0,38-1,58]	0,487
PP16	20	25754	6,22	[3,63-10,66]	<.001
PP18	1	27171	0,69	[0,095-4,965]	0,709
PP20	4	27320	3,77	[1,361-10,43]	0,010
2014					
PP03	1	27803	12,29	[1,66-91,02]	0,0140
PP04	1	16314	0,023	[0,003204-0,1668]	0,0001
PP09	2	27750	10,37	[2,49-43,08]	<.001
PP10	10	27614	24,43	[12,25-48,69]	<.001
PP11	1	27704	3,33	[0,46-24,21]	0,234
PP12	10	26387	3,51	[1,78-6,915]	0,0003
PP13	10	26884	5,45	[2,76-10,75]	<.001
PP14	11	22388	0,88	[0,46-1,7]	0,714
PP16	14	26046	4,26	[2,34-7,74]	<.001
PP20	2	27340	1,82	[0,44-7,48]	0,405

Source: The authors.

The number of cells with the presence of at least one case of CL were in the Santarem plateau in greater numbers. This is a region formed by nucleus of rural settlements and communities in Conservation Units. In this region, landscape compositions produce several possibilities for the disease by allowing contact and exposure to the transmitting hosts and vectors. In these areas, transmission may initially occur accidentally due to the entry of hosts into the habitat of vectors transmitting parasites of the genus Leishmania (LAINSON; SHAW, 1978), which are found in areas of vegetation cover, such as primary forests and secondary forests, especially in areas of plant extractivism. In the State of Acre, populations from the Brasiléia and Sena Madureira microregions belong to high-risk regions for leishmaniasis. They are territorially located largely in the Chico Mendes Extractive Reserve region (MELCHIOR et al., 2017). The population of these locations is more likely to come into contact with wild reservoirs and the vector, mainly in agro-extractive activities. In the countryside of Amazonas, in Rio Preto da Eva, cases of CL come from endemic foci in infected rural areas along the AM-010 highway or in branches distributed along its length (FIGUEIRA et al., 2014). Thus is the rural behavior of CL cases as it occurs in other parts of the Amazon.

Historically, cutaneous leishmaniasis has occurred in areas of native forest (VALDERRAMA-ARDILA et al., 2010; OCAMPO et al., 2012). However, the disturbance of the environment makes the vectors adapt to areas of human interaction, such as in settlement or peri-urban areas (MARZOCHI; MARZOCHI, 1997). In this study, the presence of patterns of human activities associated with the occurrence of CL, specifically typologies with urbanized areas, pastures, and agriculture.

The new spatial configurations in the Amazon have increased in urban areas close to forest areas, a fact observed in this study's area with the increase in the typologies PP03, PP09, PP10. Notably, population centers, particularly those located in the interstices between the municipalities of the MRS, have increased the presence of built-up, more urbanized areas, including the mayor offices of municipalities that are in the process of urban expansion.

The proximity between urban areas and vegetation cover is permissive for the transmission chain in residential areas around forests, especially in cities where urban areas advance into forest regions. In urban areas, for example the city of Manaus, AM, patients with urban CL usually live near residual forest areas within the city limits (BENÍCIO et al., 2015). In the metropolitan region of Belém, PA, in forest fragments inside the urban area, six species belonging to the genus Lutzomyia were found. They are considered relevant for their proven and/or putative implications in the transmission of CL agents in the Brazilian Amazon, among them *Lu. (Tho.) ubiquitalis* and *Lu. (Psy.) davisi* (FERREIRA et al., 2014), implying a possible risk of transmission.

Regarding the compositions with pastures, PP13 showed a significant chance of occurrence of CL. There is an increase in the power of magnitude, reflecting the greater number of cells of this typology and an increase in the number of cells with the presence of CL. The proximity of pastures and secondary vegetation to population centers in the Santarem plateau region in communities such as Corta Corda, Piranha, Vista Alegre do Moju, among others, allows the proximity or contact of hosts with transmitting vectors (VALDERRAMA-ARDILA et al., 2010).

The typologies with composition of classes that alternate, differing only by percentage of a class or another, as is the case of PP13, PP14 and PP16, may become one of the limitations of this study, as they are all composed by the presence of forest primary, secondary vegetation and pastures, thus making no distinction as to which land use and land cover affect the most the disease production. These classes are dynamic because they are transitions of land use and land cover changes, and presented the highest amounts of cells with the presence of CL.

The number of cells with agriculture increased (PP11, PP112); however, the presence of CL did not follow this growth. For each year, respectively, the magnitude of the association decreased or was not significant. In this study, agriculture represents mechanized agriculture. It is classified as such for containing only one plant species - soy, increasingly decreasing the human presence in the fields. In a study in Latin America, Maia-Elkhoury et al. (2021) found no association between agriculture and cases of CL in regions of expansion of the agricultural frontier, even though these are places with significant records of CL. On the other hand, other agricultural types such as coffee, bananas, and others related to family farming can be considered risk factors for transmission of CL due to the facilitation of conditions for the presence or situation of contact with the vectors (VALDERRAMA-ARDILA et al., 2010). In this sense, we need data with distinct classifications of the types of agriculture in the study area that reflect the local reality since the MRS is also a region of family and extractive agricultural production that supplies the entire region with production of cassava, bananas, rice, corn, annatto, chestnut, açaí, among others.

Cells that are composed of only one type of land cover use did not present cases of CL, with the exception of the 100% urban cell. In the health database, many patient records store the residential address of the place of treatment of the disease and not the place of infection. These incompatibilities in the records of health departments end up hiding the exact place where transmission occurs. Differentiating endemicity or typical rural outbreak from a probable atypical urban outbreak might be crucial for decision making, especially in endemic clusters (PORTELLA; KRAENKEL, 2021), as is the case of MRS, which presents anthropic environmental changes.

Local changes and the scale at which the disease occurs may potentially increase the risk of transmission; therefore, they need to be continuously monitored and characterized to understand their impacts on the spatial and temporal pattern of CL. Therefore, it is necessary that the endemic database have the exact location of occurrence recorded so that it is possible to make associations on a compatible scale between the phenomena. In this sense, this study has made these associations, in which the main typologies of land use and land cover where the disease occurred were identified.

FINAL CONSIDERATIONS

In this study, we create typologies of land use and land cover patterns to characterize the place of occurrence of cases of Cutaneous Leishmaniasis in the Metropolitan Region of Santarém. The results show changes towards an anthropized landscape resulting from the new dynamics of land use and land cover in the region. However, there is a pattern in disease occurrences in typologies already established, such as those with the presence of secondary vegetation. The typologies that had an increase in the number of cells, only those with composition with the urbanized and pasture class, had an increase in the number of cells with the presence of CL. Typologies with the agriculture class, although the number of cells increased, did not follow the same growth logic regarding the presence of CL between 2012 and 2014.

In view of the lack of data with the location of occurrences of the disease in a precise way, the methodology identifies locations characterizing the transmission patterns in 2012 and 2014. In view of this, the patterns identified may be analyzed by municipal surveillance agencies in the control of leishmaniasis, especially in carrying out campaigns on the importance of early diagnosis and treatment of LTA in affected populations.

ACKNOWLEDGMENTS

This research was supported by Fundação Amazônia de Amparo a Estudos e Pesquisa (FAPESPA) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES, Finance Code 001).

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