CSP CADERNOS DE SAÚDE PÚBLICA
REPORTS IN PUBLIC HEALTH

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ARTICLE

Land use, land cover, and prevalence of canine visceral leishmaniasis in Teresina, Piauí State, Brazil: an approach using orbital remote sensing

Uso e cobertura do solo e prevalência de leishmaniose visceral canina em Teresina, Piauí, Brasil: uma abordagem utilizando sensoriamento remoto orbital

Uso y cobertura del suelo y prevalencia de leishmaniosis visceral canina en Teresina, Piauí, Brasil: un enfoque utilizando teledetección

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doi: 10.1590/0102-311X00093516

Abstract

This study examines the association between land use and land cover and the occurrence of canine visceral leishmaniasis (VL). This is a case-control study in which cases were households with seropositive dogs for canine VL and controls were households with seronegative dogs. We used remote sensing images (CBERS: 2/CCD and 2B/HRC) to describe land use and cover in squares of 625m² in the study area. Odds of canine VL were twice as high in households located in squares with an area ≤ 25m² covered by residential structures with little vegetation in comparison to those where the cover reached ≥ 600m². Households located in squares with up to half of the area covered by residential structures with extensive vegetation showed 65% lower odds of canine VL in comparison to those situated in areas almost totally covered by this characteristic. Since canine infection usually precedes the occurrence de human cases, identification of the characteristics of land use and cover associated with canine VL can contribute to the demarcation of risk areas for human VL.

Visceral Leishmaniasis; Dogs; Remote Sensing Technology

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Introduction

Visceral leishmaniasis (VL) is considered one of the world's major public health problems, causing some 200,000 to 400,000 new cases and 20,000 to 40,000 deaths per year [1]. In Latin America, the disease has been reported in at least 11 countries, with 90% of cases occurring in Brazil, which has reported cases in 21 of the 27 states and an incidence rate of 2 cases per 100,000 inhabitants [1].

In the New World, the etiological agent of VL is protozoans of the species *Leishmania infantum* (syn. *Leishmania chagasi*), with the sand fly *Lutzomyia longipalpis* as the principal vector in Brazil [2]. Transmission occurs from bites by female sand flies that have ingested blood from an infected mammal.

Brazil is experiencing a clear process of urbanization of the disease, due to a series of environmental, social, and economic factors, especially poor sanitation and health conditions and deforestation associated with disordered occupation of peripheral areas of cities by large population contingents [3]. In this context, the vector *Lu. longipalpis* plays a central role in maintaining the urban transmission cycle, since it is one of the few sand fly species that has adapted readily to the domiciliary and peridomiciliary environment [4].

Dogs (*Canis familiaris*) have been incriminated as the parasite's principal domestic reservoir in urban areas, providing the basis for culling infected dogs as one of the control strategies for VL in Brazil [5], although the strategy has not produced the desired effect of interrupting spread of the disease, besides the relative lack of studies demonstrating its effectiveness [6,7]. Even given the known importance of dogs as a key source of the infection in urban areas, there are still huge gaps in the knowledge on factors associated with *L. infantum* infection in these animals [8].

Most studies to date on these reservoirs have tended to focus more on the animals' individual characteristics, such as sex, age, breed, size, and others, rather than socio-environmental aspects associated with the infection [8].

Given the above, the current study aimed to examine the role of environmental factors related to urban occupation in the occurrence of infection with *L. infantum* in dogs, using remote sensing (RS) images.

Methods

Study area

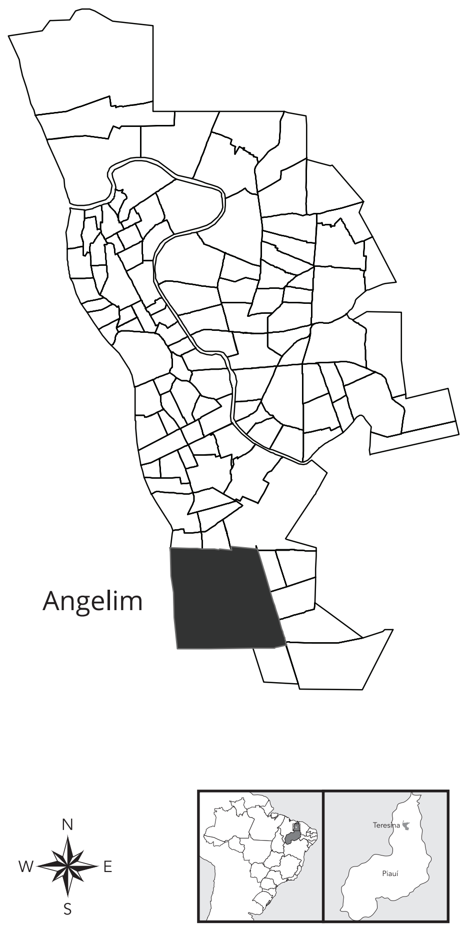
The study was conducted in the neighborhood of Angelim, located in Teresina, capital of Piauí State (Figure 1). Angelim is an area of urban sprawl in Teresina occupying lands that formerly belonged to the ranch called Fazenda Angelim. The area is characterized by rapid, disordered growth. In 1991 there were only 12 inhabitants. By 2000 there were 14,395 inhabitants, increasing to 19,559 in 2010 (Prefeitura de Teresina. Teresina, perfil dos bairros: Angelim. http://semplan.teresina.pi.gov.br/wp-content/uploads/2014/09/ANGELIM.pdf, accessed on 29/Apr/2015). In the first decade of the 21st century, more than 100 autochthonous cases of human VL were reported in the Angelim neighborhood, corresponding to nearly 10% of all cases in the city of Teresina.

Study design

This was a case-control study in which cases (n = 99) were defined as households with at least one dog infected with *L. infantum* and controls (n = 453) were households with uninfected dogs. The study was designed to assess the association between peridomiciliary socioeconomic and environmental factors and canine infection with *Leishmania* [9]. The current article uses data from this study to assess the association between "land use and land cover" characteristics obtained by RS and canine infection.

Figure 1

Angelim neighborhood, Teresina, Piauí State, Brazil.



Data and variables

- **Data source**

Canine data were obtained from the zoonotic disease control service by consulting the standardized forms from the seroepidemiological survey conducted in 2007 in the Angelim neighborhood. These forms contained the animal's name, sex, and age, owner's name, household address, and result of the serological test.

- **Diagnosis of infection**

The forms from the seroepidemiological survey included the results of the canine serological tests, which had used indirect immunofluorescence reaction with the Bio-Manguinhos kit (Oswaldo Cruz Foundation, Rio de Janeiro, Brazil). Samples that displayed fluorescence in dilution starting at 1:40 were considered positive, and those that did not display fluorescence were considered negative.

- **Assessment of covariables**

Interviews were held with the dog owners in the selected households, using a questionnaire with items on socioeconomic conditions, housing structure, presence of dogs and other animals in the household and peridomicile, and presence of animal shelters.

These data were used to generate four indicators potentially associated with the likelihood of *Leishmania* transmission: (1) head-of-household's schooling (incomplete primary versus more schooling); (2) environmental vulnerability index (linear combination of information on adequacy versus inadequacy of sewage disposal, running water, and accumulation of garbage in the peridomicile); (3) household vulnerability index (linear combination of information on household's adequacy versus inadequacy in terms of existence of masonry walls, cement or tile roof, and ceiling materials); (4) presence of domestic animals and related outbuildings and other constructions (linear combination of information on presence or absence of cats, poultry, pigs, horses, sheep, and/or goats, among others, and presence or absence of kennels and chicken coops).

- **Measurement of environmental variables by remote sensing**

a) Images used

Environmental information was gathered from satellite scenes (CBERS 2/CCD) from July 2006, with spatial resolution of 20m and from CBERS 2B (HRC) from October 2008, with spatial resolution of 2.5m, available on the website of the Brazilian National Institute for Space Research (INPE).

b) Image processing

The point of departure was recording of the CBERS 2 image (CCD) from July 2006, through the Landsat satellite image of June 5, 2006, available on the website Global Land Cover Facility (GLCF) of NASA (National Aeronautics and Space Administration). Recording used the image recording routine from the SPRING software package (INPE, São José dos Campos, Brazil) [10].

After the recording, the CBERS 2 (CCD) and CBERS 2B (HRC) images were merged to form a multispectral image with high spatial resolution using the IHS (intensity-hue-saturation) method. IHS fusion consists of performing a combination of images in the red (R), green (G), and blue (B) system to produce the component parts: intensity (I), which represents the total energy involved; hue (H), representing the dominant color or measure of the mean light wavelength reflected or transmitted; and saturation (S), expressing the wavelength interval around the mean wavelength, in which the energy is reflected or transmitted. Having obtained these components, one replaces component I with the panchromatic image with the best spatial resolution in the return procedure to the RGB domain. Thus, the spectral information from the RGB composition is integrated with the spatial information from the panchromatic band [11,12].

From this perspective, IHS fusion allows merging the best spatial resolution of the panchromatic band with the best spectral resolution of the other bands, producing a colored image that combines both characteristics.

Image classification aimed to extract variables referring to "land use and land cover". Land use and land cover are interrelated but intrinsically different concepts: land cover results from the land's use [13,14]. Land cover includes the land surface's biophysical characterization and can involve, for example, type and amount of vegetation, water bodies, buildings, and paving. Meanwhile, land use refers to the forms and purposes for which humans use the land and its resources, including agriculture, conservation and preservation of areas, and built-up structures for commercial or residential purposes, among others [14,15].

There are major difficulties in producing separate maps for "land use" and "land cover", especially based on a single RS image, since the two have different temporal characteristics. For example, since "land cover" can vary rapidly, it tends to be defined at a specific moment in time, while "land use" needs to be evaluated over longer time periods [13,14]. Despite these differences, land cover maps allow capturing characteristics of land use at specific moments in time. Therefore, since this study is based on a single RS image, the assumption was that the proposed classification presents "land use" and "land cover" characteristics simultaneously, and that there is no practical way to distinguish between the two in this context.

Table 1 describes the eight target classes of "land use and land cover", as well as the epidemiological rationale for the use of each in this study's context [2,4,16,17,18,19]. To obtain these classes of "land use and land cover", we conducted an object-based image analysis (OBIA) with five stages: characterization of the classes, segmentation of the image, elaboration of the semantic network, classification, and evaluation of the results.

The image classification procedure, performed with the Definiens 7.0 package (http://www.definiens.com/), included basically two steps: multiresolution segmentation and algorithmic classification with fuzzy and Boolean logic. This approach uses combinations of spectral, textural, and contextual/topological information. In segmentation, objects are created on different scales according to criteria of shape, color, and homogeneity, interconnected. In classification, the objects relate with each other by means of the definition of a hierarchical network (legacy of the attributes describing the class) and semantic network (logical structure of the relationship between the classes). Thus, object-based analysis is performed through analysis of segments of the image (objects), and not only of the pixels. Objects with common characteristics are grouped in classes, and the classes are organized as a hierarchical and semantic network. OBIA uses spatial information in its processing and has thus proven more efficient in applications in urban areas [16].

Figure 2 shows the semantic network and levels of segmentation and classification used in the classification process. Level 1 aimed to discriminate between the super-classes "Water" and "Non-water" in the study area. Level 2 separated the superclass "Non-water" into "Vegetation" and

Table 1

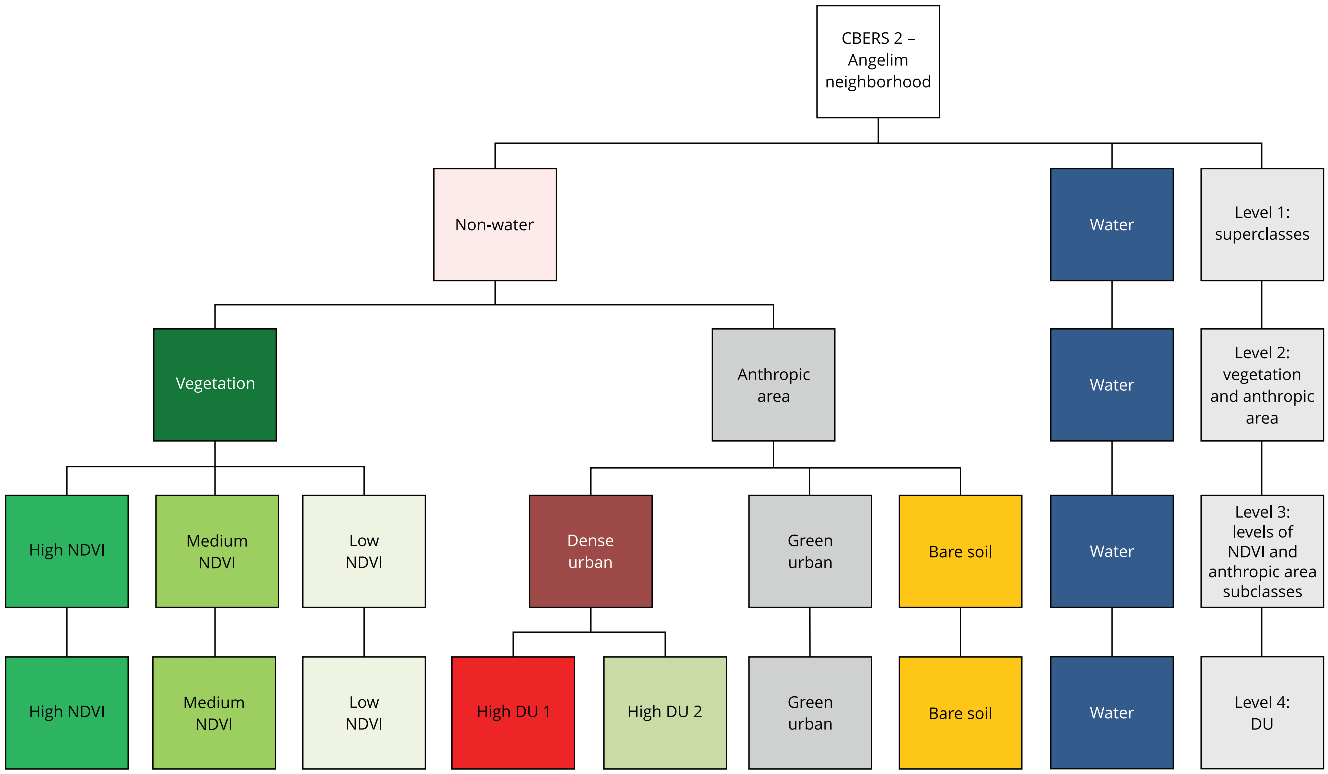
Description of environmental variables used in the study on canine visceral leishmaniasis and epidemiological rationale for their use.

Environmental variables (classes)	Description	Epidemiological rationale
High NDVI	% of area in squares with high density of green vegetation	
Medium NDVI	% of area in squares with medium density of green vegetation	Greater density of vegetation is associated with presence of vectors for VL and higher incidence of human VL [2,18,19]
Low NDVI	% of area in squares with low density of green vegetation	
Bare soil	% of area in squares with bare soil	Bare soil in a city undergoing expansion, like Teresina, represents intermediate-stage urbanization: environmental destruction for subsequent occupation with large housing projects on the city's periphery. Described as an element of the landscape associated with increased incidence of human VL [16]
High DU 1	% of area in squares covered by residential structures with little vegetation	Urbanization process has been associated with increased incidence of VL due to the high adaptability of the principal vector, Lutzomyia longipalpis, to peridomiciliary conditions, exploiting the accumulated organic matter generated by domestic animals and poor sanitation [2,4,18]
High DU 2	% of area in squares covered by residential structures with extensive vegetation	
Green urban	% of area in squares covered by sparse residential structures with extensive vegetation	Abundant vegetation close to households represents typical environment for transmission of VL, intersecting the sylvatic and peridomiciliary transmission cycles [17]
Water	% of area in squares covered by water	Not used in the analyses, since water bodies are not a preferential habitat for sand flies [2]

DU: dense urban; NDVI: Normalized Difference Vegetation Index; VL: visceral leishmaniasis.

Figure 2

Semantic network between classes and levels of segmentation and classification.



DU: dense urban; NDVI: Normalized Difference Vegetation Index.

"Anthropic area". In Level 3, the levels of the Normalized Difference Vegetation Index (NDVI) were used to divide the superclass "Vegetation" into the classes "High NDVI", "Medium NDVI", and "Low NDVI" according to the vegetation cover's conditions and density. The "Anthropic area" superclass was also subdivided into the classes "Bare soil" and "Green urban" area; a superclass was also created to represent "Dense urban" area. In Level 4, the superclass "Dense urban" was subdivided into classes "High DU 1" and "High DU 2", thus reaching the final level of classification.

In order to assess the errors associated with the classification process, five reference points were identified for each class, for subsequent comparison with classes obtained through Google Earth (http://www.google.com/earth), in this case considered the gold standard for land use and land cover characteristics. This comparison is shown by means of an error matrix [20]. The error matrix, with 90% overall accuracy, indicated good classification performance, with few diverging situations between the classification as performed and the gold standard (Google Earth), that is, there are few situations of classification outside the diagonal of the error matrix (Table 2).

c) Definition of environmental variables

The study area was divided into 25m-by-25m squares (area, 625m^2). The "land use and cover" characteristics in each square (in m^2) were assigned to the households included in it. For households located at the intersection of squares, we averaged the squares' characteristics and assigned this mean to these households.

Table 2

Error matrix of image fusion classification (CBERS 2/CCD 2006 and CBERS 2B/HRC 2008) in the Angelim neighborhood, Teresina, Piauí State, Brazil.

Classes	High NDVI	Medium NDVI	Low NDVI	Bare soil	High DU 1	High DU 2	Green urban	Water	Not classified	Total pixels
High NDVI	**27**	3	0	0	0	0	0	0	0	30
Medium NDVI	0	**31**	2	0	0	0	2	0	0	35
Low NDVI	0	3	**25**	0	0	0	2	0	0	30
Bare soil	0	0	0	**35**	2	1	0	0	0	38
High DU 1	0	0	0	0	**27**	3	0	0	0	30
High DU 2	0	0	0	2	2	**32**	0	0	0	36
Green urban	0	0	0	0	1	2	33	0	0	36
Water	0	0	0	0	0	0	0	**20**	0	20
Not classified	0	0	0	0	0	0	0	0	0	0
Total pixels	27	37	27	37	32	38	37	20	0	255
Overall accuracy *	**0.90**									

DU: dense urban; NDVI: Normalized Difference Vegetation Index.

* Obtained by dividing the total correct classifications (230, the sum of the principal diagonal) by the total number of pixels in the error matrix (255).

The environmental variables were categorized in four classes according to the area covered by each of the "land use and land cover" characteristics (≤ 25m²; 26m² to 312m²; 313m² to 599m²; ≥ 600m²), so as to situate in the extreme classes those situations in which a given "land use and land cover" characteristic was present (lower class ≤ 25m²) or absent (upper class ≥ 600m²) in only 25m² (up to 4%) of the square's area.

Data analysis

For the analysis, only the following "land use and land cover" characteristics were used: "dense urban with little vegetation (High DU 1)", "dense urban with extensive vegetation (High DU 2)", and "green urban", since they were the ones that presented sufficient variability in the study area. The "High NDVI" and "Low NDVI" characteristics did not occur in any of the squares evaluated. The characteristic "Medium NDVI" only occurred in six squares, and the "Bare soil" characteristic in only one square.

Logistic regression was used with correction for the effect of household aggregation within the same square, to estimate odds ratio (OR) as the measure of association between environmental variables and canine infection, as well as the respective 95% confidence intervals (95%CI).

For each of the target environmental variables, we first estimated crude OR and then adjusted OR according to the co-variables "head-of-household's schooling", "environmental vulnerability index", "household vulnerability index", and "presence of domestic animal and related outbuildings". Multivariate analysis used each environmental variable separately in order to avoid colinearity. The analyses used Stata 11 (StataCorp LP, College Station, USA).

Ethical aspects

This study used data from a routine seroepidemiological survey conducted in the Angelim neighborhood in 2007 by the Center for the Control of Zoonotic Diseases (CCZ) of the City of Teresina Municipal Health Secretariat. The use of these data for this study (without identifying the dogs' owners and with the guarantee of confidentialiy) was granted by the director of the Department of Healthcare under the Teresina Municipal Health Secretariat.

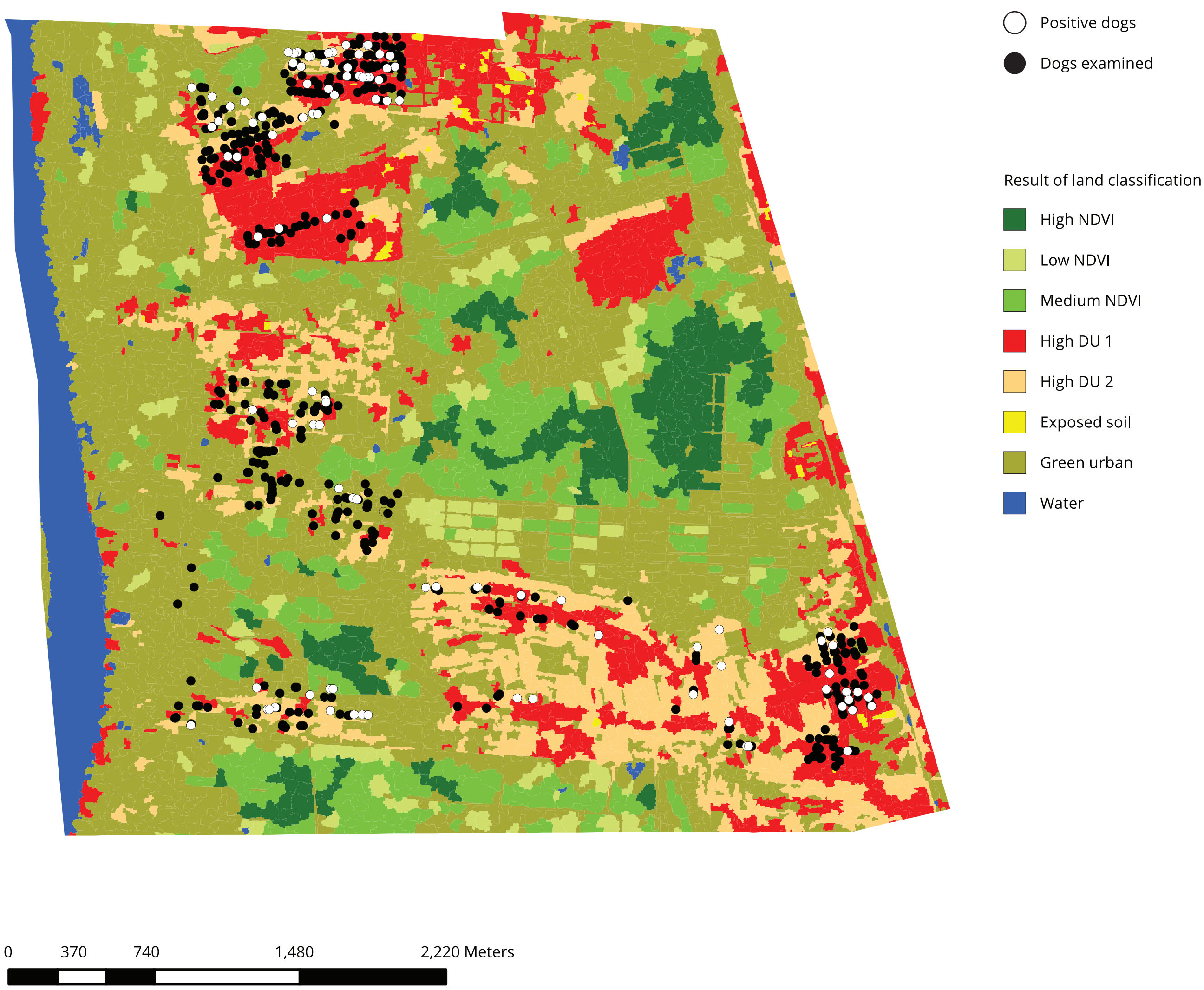
Results

Figure 3 shows the result of the classification of satellite images. In the more urbanized areas, where the households investigated for canine VL are located, the land use and cover characteristics of "High NDVI" and "Low NDVI" are absent, and the characteristics "Medium NDVI" and "Bare soil" are present in only six and one of the 446 squares evaluated, respectively.

Table 3 shows the association between environmental characteristics and canine *Leishmania* infection. The odds of infection were twice as high for households located in squares in which the area covered by residential structures with little vegetation ("High DU 1") was ≤ 25m², when compared with those in which such cover reached ≥ 600m², even after adjusting for head-of-household's schooling, presence of animals or animal shelters in the peridomicile, and indicators of environmental

Figure 3

Land use and land cover classes and location of seropositive and seronegative dogs, Angelim neighborhood, Teresina, Piauí State, Brazil, 2007.



DU: dense urban; NDVI: Normalized Difference Vegetation Index.

Table 3

Odds ratios (OR) and 95% confidence intervals (95%CI) for canine infection with *Leishmania infantum* associated with environmental characteristics of the Angelim neighborhood, Teresina, Piauí State, Brazil, 2007.

Characteristics	Crude OR	95%CI	Adjusted OR *	95%CI *
High DU 1 (m^2)				
≤ 25	2.23	1.34-3.73	2.17	1.24-3.80
26-312	0.73	0.29-1.81	0.89	0.36-2.17
313-599	1.49	0.67-3.32	1.42	0.61-3.29
≥ 600	1.00		1.00	
High DU 2 (m^2)				
≤ 25	0.44	0.22-0.86	0.35	0.17-0.72
26-312	0.44	0.11-1.03	0.36	0.14-0.88
313-599	0.56	0.24-1.36	0.53	0.21-1.32
≥ 600	1.00		1.00	
Green urban (m^2)				
≤ 25	0.69	0.38-1.27	0.86	0.45-1.62
26-312	1.12	0.52-2.42	1.28	0.58-2.83
313-599	0.63	0.28-1.39	0.72	0.32-1.63
≥ 600	1.00		1.00	

DU: dense urban.

* Adjusted by head-of-household's schooling, presence of animals or animal shelters in the peridomicile, and environmental and household vulnerability indices.

and household vulnerability. Analogously, households located in squares with up to half of the area covered by residential structures with extensive vegetation ("High DU 2") showed 65% lower odds of canine infection when compared to households located in areas almost totally covered by this type of land cover. The "green urban" variable did not show a statistically significant association with the outcome.

Discussion

The study's results demonstrate that given characteristics of the environment related to land use and land cover are associated with canine infection with *Leishmania*. In general, human dwellings located in areas with more vegetation cover harbored more seropositive dogs.

This result is consistent with other studies that have pointed to higher canine seropositivity for *Leishmania* in dwellings close to forest areas [21,22,23,24,25,26]. The proximity to areas with more dense vegetation favors interaction between the sylvatic and peridomiciliary cycles of the disease and favors conditions for maintenance of sand fly populations [2].

The importance of environmental transformations in the process of urbanization of VL in Brazil has been highlighted by various authors [3,4,27,28], but there are still few studies specifically designed to evaluate the role of land use and land cover characteristics in the occurrence of VL in the urban environment, and especially studies focusing on the canine population.

In this context, geographic information systems (GIS) and RS are tools that provide a new perspective on this subject. The development of studies in this field is important, among other reasons to assess the actual potential of these tools in studies on factors related to patterns of occurrence and dissemination of transmissible diseases and definition of priority areas for implementation of control measures [29].

Spatial approaches to study the epidemiology of infectious diseases using GIS and RS to define high-risk areas for transmission have been used for quite some time [30,31], mainly in studies on malaria [30,32]. However, their use in the study of VL is much more recent and relatively infrequent, particularly in Brazil, where VL transmission is zoonotic [33].

Consulting the MEDLINE (PubMed) and LILACS databases on 31/Dec/2015, only 12 studies were identified that used RS to assess the relationship between land use and land cover characteristics and spatial distribution of VL in the Brazilian context [16,18,19,29,34,35,36,37,38,39,40,41].

Only two of these studies addressed the association between environmental features extracted from satellite images and canine VL [34,38]. An ecological study in 33 municipalities in Bahia State, by Bavia et al. [38], found an inverse association between vegetation cover and cases of canine VL. In the study, vegetation cover was assessed by the NDVI, obtained by satellite images from the AVHRR sensor, with resolution $64km^2$. Meanwhile the study by Machado da Silva et al. [37] in Barra de Guaratiba in the city of Rio de Janeiro found higher serological titers for canine infection with *Leishmania* in areas with preserved vegetation. In the study, characterization of vegetation cover was obtained by aerial photographs.

In the other ten studies that did not assess canine VL, seven focused on VL incidence in humans and three on the presence of sand flies. Nine of the ten studies used Landsat satellite images with resolution of 15 to 30 meters [16,18,19,29,34,35,39,40,41] and only one used IKONOS images with resolution of 1 to 4 meters [36]. As for environmental aspects, seven studies evaluated vegetation cover, mainly using NDVI, and three evaluated land use and land cover characteristics. Six studies on human VL found a direct association between vegetation cover and risk of VL [16,18,19,29,39,40], while only one found an inverse association [41]. In the studies on vectors, two found higher vector density in areas with little vegetation cover [34,35] and one found a direct relationship between vegetation cover and presence of vectors [36].

The current study offers a series of new contributions to the study of relations between the environment and VL. First, it is one of the few studies addressing zoonotic canine VL using satellite images, and is the one with the largest sample size. Second, except for a vector study that used IKONOS images [36], the current study is the one that used images with the highest resolution (2.5 meters) in Brazil, which has been identified as an important characteristic to be considered in the study of VL, particularly in the urban setting [29,42]. Third, it uses OBIA, which combines spectral information with texture and context attributes, allowing greater flexibility for evaluating land use and land cover characteristics in the urban environment [16].

Nevertheless, the results presented here should be viewed with caution. For example, information bias may have occurred in relation to the questions asked in the interview. However, since dog owners were unaware of whether their animals were infected, we believe that if an information bias was present, it was not influenced by diagnosis of canine infection, thus suggesting non-differential error [43]. Likewise, the low sensitivity and specificity of the serological test used here could lead to outcome classification errors, but would also tend not to be differential. The definition of "case" as the existence of at least one positive dog in the household is also a question to be considered when interpreting the results. Based on this criterion, different types of households are included as "cases", ranging from those with only one positive dog to those with multiple dogs, of which only one or several dogs might be positive. This heterogeneity in the population of "cases" may disguise differences in the strength of association between land use and land cover characteristics and *Leishmania* infection in relation to the number of dogs in the household. This aspect may be important, since households with only one positive dog may be less relevant for transmission than households with two or more infected dogs.

Despite these limitations, the study's results support the hypothesis that the identification of environmental factors associated with canine VL can be useful for demarcating areas at increased risk for human VL, since canine infection usually precedes the occurrence of human cases [44].

Contributors

A. B. F. Figueiredo, G. L. Werneck and A. S. Almeida participated in the study conception and design, data analysis and interpretation, and writing and approval of the final version, and takes full responsibility for all aspects of the work in terms of its precision and integrity. M. S. P. Cruz and J. P. Silva participated in the data collection, analysis, and interpretation and writing and approval of the final version, and takes full responsibility for all aspects of the work in terms of its precision and integrity.

Acknowledgments

The authors wish to thank the director of the Department of Healthcare Action under the Teresina Municipal Health Secretariat at the time the study was conducted for authorizing use of the data. We also wish to thank community health workers Ricardo, Marilene, Marcos, Edson, and Assis for their assistance during the data collection.

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Resumo

Este estudo examina a associação entre uso e cobertura do solo e a ocorrência de leishmaniose visceral (LV) canina. Estudo caso-controle em que casos foram residências com cães soropositivos para LV canina e controles, as residências com cães soronegativos. Utilizaram-se imagens de sensoriamento remoto (CBERS: 2/CCD e 2B/HRC) para descrever o uso e cobertura do solo em quadrículas de 625m² na região do estudo. A chance da LV canina foi duas vezes maior em domicílios localizados em quadrículas com área ≤ 25m² coberta por estruturas residenciais com pouca vegetação em comparação com aquelas em que essa cobertura alcançou ≥ 600m². Domicílios localizados em quadrículas com até metade da área coberta por estruturas residenciais com muita vegetação tiveram chances 65% menores de LV canina em comparação com aquelas situadas em áreas quase totalmente cobertas por essa característica. Como a infecção canina costuma preceder a ocorrência de casos humanos, a identificação de características de uso e cobertura do solo associadas à LV canina pode contribuir para a delimitação de áreas de risco para LV humana.

Leishmaniose Visceral; Cães; Tecnologia de Sensoriamento Remoto

Resumen

Este estudio examina la asociación entre uso y cobertura del suelo y la ocurrencia de leishmaniosis visceral (LV) canina. Es un estudio de caso-control, donde los casos fueron analizados en residencias con perros seropositivos para LV canina y controles, además de residencias con perros seronegativos. Se utilizaron imágenes de teledetección (CBERS: 2/CCD e 2B/HRC) para describir el uso y cobertura del suelo en cuadrículas de 625m² en la región del estudio. La oportunidad de la LV canina fue dos veces mayor en domicilios localizados en cuadrículas con un área ≤ 25m², cubierta por estructuras residenciales con poca vegetación, en comparación con aquellas donde esa cobertura alcanzó ≥ 600m². Los domicilios localizados en cuadrículas con hasta la mitad del área cubierta por estructuras residenciales con mucha vegetación tuvieron oportunidades un 65% menores de LV canina, en comparación con aquellas situadas en áreas casi totalmente cubiertas por esa característica. Como la infección canina acostumbra preceder la ocurrencia de casos humanos, la identificación de las características de uso y cobertura del suelo, asociadas a la LV canina, puede contribuir a la delimitación de áreas de riesgo para LV humana.

Leishmaniasis Visceral; Perros; Tecnología de Sensores Remotos

Submitted on 31/May/2016
Final version resubmitted on 28/Dec/2016
Approved on 06/Jan/2017