

Spatial analysis of areas likely to harbor American cutaneous leishmaniasis in Seropédica, Rio de Janeiro State, Brazil

Análise espacial das áreas de favorabilidade para ocorrência de leishmaniose tegumentar americana no município de Seropédica, Estado do Rio de Janeiro, Brasil

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Abstract

The goal of the present study was to evaluate the spatial distribution of American cutaneous leishmaniasis (ACL) in Seropédica, Rio de Janeiro State, Brazil according to the favorability of occurrence. The Vista-SAGA Geo-environmental Analysis System (*Sistema de Análise Geoambiental Vista-SAGA*) was used to create a database (theme maps) and perform environmental analyses, signatures and combinations. The degrees of likelihood were obtained by evaluating soil use and plant cover; soil type and geomorphology (geo-environmental factors); and altitude and slope (topographic factors). The factors used in the analyses were selected based on results from the literature and according to the technical feasibility of their inclusion in the databases. Weights and grades were attributed to the factors and their categories, respectively, according to their relevance to the life cycle of parasites from genus *Leishmania* and parasite vectors. Based on the results of the environmental analyses, areas were classified and grouped to represent the spatial distribution of favorability. Areas were classified as very unfavorable, unfavorable, somewhat favorable, favorable and very favorable for ACL occurrence. The results of the signature analyses showed that the municipality included 6.81% very favorable areas, 65.14% favorable areas, 17.98% somewhat favorable areas, 2.39% unfavorable areas and 0.07% very unfavorable areas for ACL occurrence. The signature analyses of the results and theme maps were able to locate and characterize the ecosystem profiles in terms of risk of ACL occurrence, indicating that rural, peri-urban and urban areas of the municipality of Seropédica may be classified as favorable for the occurrence of this disease. The results of the present study may be used to support management decisions made by authorities responsible for ACL control and prevention in Seropédica. In addition, geoprocessing was found to be a low-cost alternative for data integration in areas where it is difficult to perform surveys.

Key words: Geoprocessing, GIS, *Leishmania braziliensis*

Resumo

O objetivo deste estudo foi avaliar a distribuição espacial de leishmaniose tegumentar americana (LTA) no município de Seropédica, segundo grau de favorabilidade para sua ocorrência. O Sistema de

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Análise Geoambiental Vista-SAGA foi utilizado na preparação das bases de dados (mapas temáticos), análise ambiental, assinaturas e combinação. Os graus de favorabilidade foram obtidos por avaliações procedidas sobre os fatores uso do solo e cobertura vegetal, tipo de solo e geomorfologia (fatores geoambientais) e altitude e declividade (fatores topográficos). Os fatores utilizados nas análises foram selecionados com base na literatura e na viabilidade técnica para a preparação das bases de dados. Pesos e notas foram atribuídos aos fatores e suas categorias, respectivamente, conforme a relevância para o ciclo de vida de parasitos do gênero *Leishmania* e de seus vetores. Os resultados das análises ambientais foram categorizados para representarem a distribuição espacial da favorabilidade, classificada como áreas pouquíssimo favorável, pouco favorável, favorável, muito favorável e muitíssimo favorável para ocorrência de LTA. Os resultados das assinaturas evidenciam que o município apresenta 6,81% da área classificada muitíssimo favorável, 65,14% muito favorável, 17,98 % favorável, 2,39% pouco favorável e 0,07% pouquíssimo favorável. As assinaturas sobre os mapas de resultados e temáticos permitiram não só localizar, mas também caracterizar o perfil dos ecossistemas quanto ao risco para a ocorrência de LTA, indicando que o município de Seropédica pode ser classificado como muito favorável para ocorrência desta doença tanto em áreas rurais quanto peri-urbanas e urbanas. Estes resultados poderão subsidiar a tomada de decisões dos órgãos responsáveis pelo controle e prevenção da LTA em Seropédica. Além disso, o geoprocessamento como ferramenta de integração de dados se mostrou uma alternativa de baixo custo para áreas onde haja dificuldade para realização de inquéritos.

Palavras-chave: Geoprocessamento, SIG, *Leishmania braziliensis*

Introduction

Leishmaniasis is considered a neglected disease (WORLD HEALTH ORGANIZATION, 2010), and its risk increases with poverty, which contributes to the maintenance of inequality and developmental impairment of affected countries (MINISTÉRIO DA SAÚDE, 2010). Until recently, *Leishmania (Viannia) braziliensis* was considered to be the only species responsible for ACL cases occurring in the state of Rio de Janeiro. However, *Leishmania (Leishmania) amazonensis* has been isolated from an ACL case in Paraty, Rio de Janeiro State (AZEREDO-COUTINHO et al., 2007).

Leishmania (V.) braziliensis is present in all endemic regions of the country in areas that have been recently or historically colonized (MINISTÉRIO DA SAÚDE, 2007). Natural cases of infection have been observed in wild and synanthropic rodents, marsupials (BRANDÃO-FILHO et al., 2003; QUARESMA et al., 2011), cats (SCHUBACH et al., 2004), dogs (MADEIRA et al., 2006) and horses (AGUILAR et al., 1986). The role of animals in the transmission cycle is not fully understood; however, there is evidence that only wild rodents are reservoirs of *L. (V.) brasiliensis* (DANTAS-TORRES, 2007; MINISTÉRIO DA

SAÚDE, 2007). Its vectors are sandflies (Diptera: Phlebotominae) from genus *Lutzomyia*, and which are more frequently represented in the state of Rio de Janeiro by *Lu. Intermedia* (primary species), *Lu. migonei*, *Lu. fischeri* and *Lu. whitmani* (AGUIAR et al., 1996; SOUZA et al., 2009, 2002, 2001). In Seropédica, *Lu. intermedia*, *Lu. whitmani*, *Lu. migonei* and *Lu. oswaldoi* are the main sandfly species in areas where ACL infections in humans and dogs have been reported (CARDOSO et al., 2009).

The geographical distribution of ACL reflects the distribution of vectors, which are influenced by the presence and abundance of plant cover and relief (CAMARGO-NEVES et al., 2002). Several factors are involved in the transmission of ACL in Brazil (PEDROSA; XIMENES, 2009), including altitude, vegetation, proximity to water reservoirs or sources, and climate (AGUIAR et al., 1996; CAMARGO-NEVES et al., 2002; SOUZA et al., 2002; TOLEZANO, 1994). The ecoepidemiology of ACL caused by *L. (V.) braziliensis* presents spatial and temporal variations in the different biomes of Brazil; therefore, each area of occurrence should be analyzed separately (MINISTÉRIO DA SAÚDE, 2007). Geographical information systems (GIS)

have been used as important tools in the assessment of leishmaniasis epidemiology (APARÍCIO; BITENCOURT, 2004; SHIMABUKURO et al., 2010) and can be used to produce risk maps that can predict event probability in locations that are not covered by surveys and allow for planning and resource allocation for more effective decision making and management (WORLD HEALTH ORGANIZATION, 2010). Because of the difficulty of performing surveys, the goal of the present study was to use geoprocessing to identify risk areas for ACL occurrence in Seropédica.

Materials and Methods

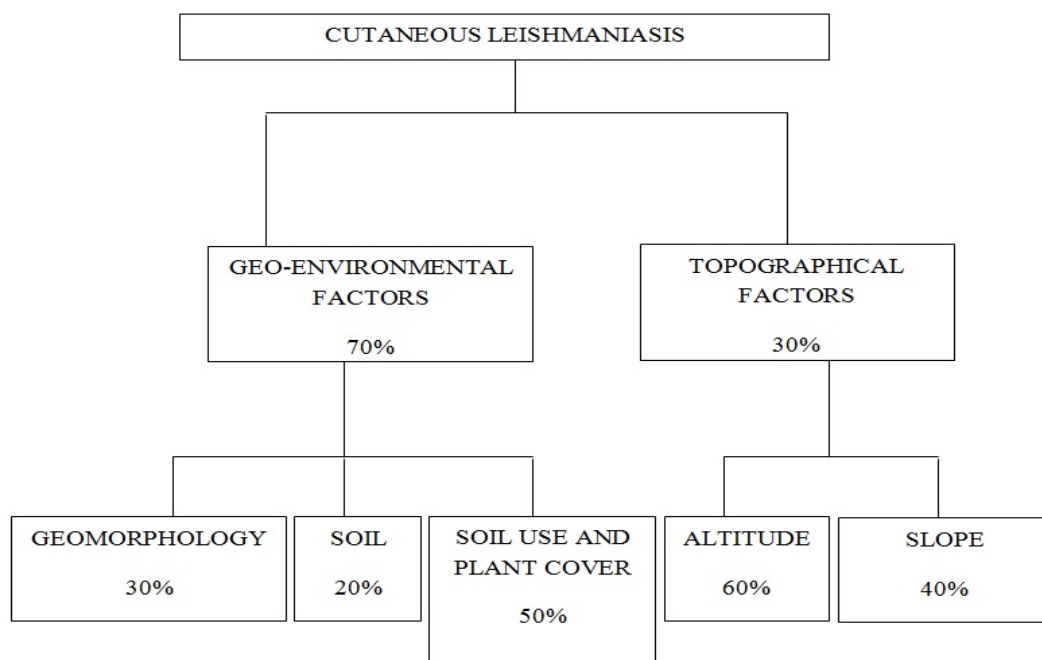
Seropédica, Rio de Janeiro State (RJ) is located at 22° 44' 38" S and 43° 42' 27" W and bordered by the municipalities Rio de Janeiro, Nova Iguaçu, Itaguaí, Queimados, Japeri, and Paracambi, and its main access roads are BR 116 (Via Dutra), BR 465 (former Rio- São Paulo), BR 493/RJ-109 (Rio de Janeiro metropolitan arch), and RJ 099.

A geoprocessing analysis of the environment was performed using the Geo-environmental Analysis System Vista Saga 2007 software (Sistema de Análise Geo-Ambiental Vista Saga 2007) (LABORATÓRIO DE GEOPROCESSAMENTO, 2007). Environmental variables were analyzed in terms of land area and possible causal associations based on their occurrence in space (by territorial expression) by applying an integrating and classifying ordinal scale structure.

The spatial distribution of leishmaniasis was obtained through evaluations of soil use, plant cover, soil type, altitude, slope and geomorphology. Each factor was represented on a theme map, and factor combinations formed the environmental inventory. The selected factors were grouped into geo-environmental (geomorphology, soil type, soil use and vegetation) and topographical (altitude and slope) factors and subjected to environmental, signature and combination analyses.

The percentage weights (Figure 1) and grades (Tables 1 and 2) were assigned to the information plans and respective categories, and the information was applied to construct a decision tree (Figure 1) using the Delphi method, which consists of a multidisciplinary evaluation of the relevance of each factor for ACL occurrence based on the professional experience of the team members and the literature on ACL, its vectors and potential reservoirs (XAVIER-DA-SILVA, 2001). The grades attributed to the geo-environmental and topographical factors were recategorized to produce two maps; these maps were evaluated, and a classification map was produced that indicates areas with different grades of ACL favorability. Favorability was assessed as follows: grades 1 and 2 were considered very unfavorable; grades 3 and 4 were considered unfavorable; grades 5 and 6 were considered somewhat favorable; grades 7 and 8 were considered favorable; and grades 9 and 10 were considered very favorable.

The percentage areas per degree of favorability for each category were obtained using the combine module of the software.

Figure 1. Decision tree integrating geo-environmental and topographical factors relevant to the epidemiology of American cutaneous leishmaniasis.**Table 1.** Grades attributed to categories of geo-environmental factors.

Geomorphology		Soil		Soil use and plant cover	
Categories	Grades	Categories	Grades	Categories	Grades
Dissected border of structural plateau	2	Podzol-1	4	Cloud forest	8
Plateau dissected in structural hills and valleys	5	Podzol-2	4	Grassland and rural sites	5
Talus slopes	4	Cambisol-1	2	Herbaceous hygrophyte vegetation	9
Piedmont structural hills	3	Cambisol-2	2	Reforestation	4
Flattened hills/silted depressions	7	Planosol	9	Pasture	2
Isolated hills/structural islands	2	Humic Gley	10	Crops	1
Colluvial slopes	6	Indiscriminate Gley	7	Urban or industrial site	1
Colluvial-alluvial plain	8	Low-humic Gley	8	Mineral extractivism	1
Cover alluvial plain	9	Alluvial soil	9	Rock outcrop	0
Deltaic fluvio-lacustrine plain	10	Semi-organic Lithosol	9	Institutional area	1
			1	Urban expansion	8
				Municipal dump	9
				Exposed soil	1
				Flona	9
				Recreation	2

Table 2. Grades attributed to categories of topographic factors.

Altitude		Slope	
Categories	Grades	Categories	Grades
0-40 m	10	0-2.5%	10
40-80 m	9	2.5%-5%	10
80-120 m	9	5%-10%	9
120-160 m	9	10%-20%	7
160-200 m	8	20%-40%	5
200-320 m	8	>40%	2
320-400 m	8		
400-520 m	7		

Results and Discussion

A classification map in ordinal scale was obtained (Figure 2), and it included the geographical locations, spatial correlations and spatial expressions.

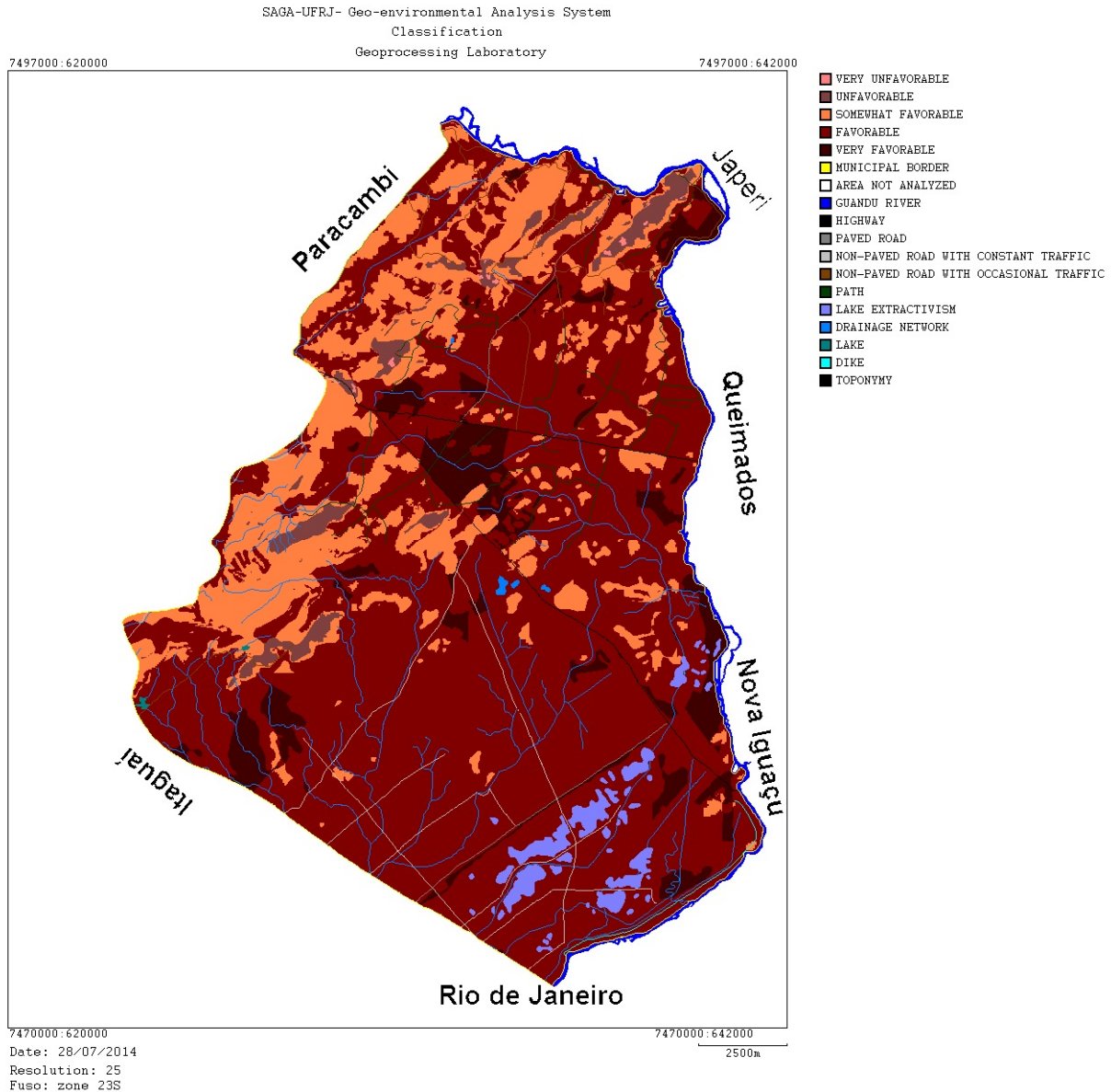
The areas classified as very favorable totaled approximately 1,855.5625 ha (6.81% of the municipality area), primarily occurred at altitudes of 0-40 m and slopes of 0-2.5% and were distributed in planosol soil (Albaquarf), primarily in colluvial-alluvial planes, with a predominance of urban expansion. Favorable areas totaled approximately 17,7496.250 ha (65.14% of the municipality area), primarily occurred at altitudes of 0-40 m and slopes of 0-2.5%, were distributed in planosol soil, primarily in colluvial-alluvial planes, with predominance of pastures.

Thus, the majority of the very favorable and favorable areas did not differ in terms of altitude, slope, geomorphology or soil type. However, very favorable areas were predominantly areas of urban expansion, and favorable areas were predominantly pastures. Pastures present a flat relief (EMBRAPA, 2006); in association with a low slope, such reliefs result in the accumulation of water and organic matter. Decomposing organic matter and small organisms are food sources for sandfly larvae (HANSON, 1968). Humidity is one of the determining factors for sandfly density (DIAS-LIMA et al., 2002). In addition, these areas present favorable altitudes for the development of *Lu. intermedia* (FERREIRA et al., 2001), which was identified as the species with the highest prevalence

at 100 m.a.s.l. in domiciles and peridomiciles. The second-most prevalent species was *Lu. migonei*, which had the highest prevalence at 300 m.a.s.l. in drier areas and banana plantations of the municipality of Itaguaí (AGUIAR et al., 1996), bordering Seropédica. In Seropédica, areas where human and dog cases were registered, Cardoso et al. (2009) reported a predominance of *Lu. intermedia* followed by *Lu. whitmani*, *Lu. migonei* and *Lu. oswaldoi* in peridomiciles of peri-urban and rural areas. It should be noted that this region has a flat landscape with a predominance of pastures and less than 10% secondary vegetation. These geographic characteristic are consistent with the results of the present study obtained using geoprocessing because the distribution of ACL reflects the distribution of vector species (CAMARGO-NEVES et al., 2002).

The observed predominance of urban expansion areas in the very favorable category is consistent with previous reports. These areas generally possess secondary vegetation, and the houses are built close to the vegetation, which is known to harbor sandflies (AGUIAR et al., 1996; CONDINO et al., 1998). In Seropédica, urban expansion areas are contiguous with areas of herbaceous vegetation, rural sites and a forest preservation site, the Mario Xavier National Forest (*Floresta Nacional Mario Xavier* – FLONA). Areas of demographic expansion, where urbanization occurs close to the boundaries of forests and preservation areas are found within the cities, are considered determining factors for ACL risk (GOMES; CAMARGO-NEVES, 1998; NEGRÃO; FERREIRA, 2013), which is supported by the present study.

Figure 2. Classification map of the spatial distribution of degrees of favorability of cutaneous leishmaniasis occurrence in the municipality of Saranópolis



For the areas classified as favorable, the pastures are contiguous with herbaceous vegetation areas, rural, reforestation, cultivation and extractivism sites, and FLONA.

Water reservoirs are observed in areas that practice extractivism (Figure 2), which is consistent with the results of Tolezano (1994), who reported an

association between ACL and the rivers traversing the state of São Paulo. Cultivation practices and areas with domestic animal shelters are also favorable to sandfly development (SOUZA et al., 2002, 2001).

The predominance of very favorable and favorable areas (Figure 2) that are contiguous with urban sites confirms that human populations and anthropic actions are conditioning factors for

ACL occurrence, whose transmission continues to occur after decades of forest destruction in these areas because of adaptations in *Lu. intermedia* (TOLEZANO, 1994). *Lu. intermedia* presented a high rate of capture inside houses located 240 m from the forest (CONDINO et al., 1998). Spatial modeling of ACL risk zones revealed that 50% of the houses where ACL cases occurred were less than 200 m from the border of a forest fragment with a landscape characteristic of ACL occurrence (APARÍCIO; BITENCOURT, 2004).

The ACL investigation forms from the National Disease Notification System of autochthonous human cases occurring in Seropédica in 2006, 2008 and 2010 describe the presence of banana plantations, forests and sandflies around the patients' homes in villages where human cases of ACL occurred. In the present study, only the forest was directly included in the evaluation, and the interaction of all factors was considered a determining factor for the presence of sandflies. Despite this restriction, the evaluation was efficient because these villages are located in areas very favorable to ACL. The presence of banana plants and other fruit trees was also described in the peridomiciles of patients in several municipalities of the ACL endemic region of RJ (BUSTAMANTE et al., 2009). In addition, the abundance of *L. intermedia* was related to the cultivation of banana trees in Uberlândia, Minas Gerais State (LE MOS; LIMA, 2005). Souza et al. (2002) reported *Lu. whitmani* to be the second-most captured species in areas close to banana plants.

Peri-urban areas with high population density and vegetation growth around houses and water bodies, which are characteristics favorable to the development and maintenance of sandflies, were located in areas classified as very favorable and favorable for ACL. This result is consistent with that of Cardoso et al. (2009), who observed a high prevalence of *Lu. intermedia*, which is anthropophilic and adapted to disturbed environments (AGUIAR et al., 1996; TOLEZANO, 1994), in two villages located in these areas. Thus, greater attention

should be dedicated to areas that have dense human populations and have experienced urban expansion.

The FLONA is an environmental conservation area open to the public, and Seropédica residents use this area for morning walks, which coincides with the time that sandflies are more active (CONDINO et al., 1998). The FLONA was indicated in the present study as very favorable to ACL occurrence because it provides opportunities for human-vector contact. However, stray, semi-domiciled and community dogs within the urban sites surrounding FLONA are also observed within this preservation area, which increases the probability of infection of these animals. For the Itaguaí microregion, Silva et al. (2013) reported higher seropositivity for *Leishmania* spp. in dogs in Seropédica [59.46% (88/148)] followed by Itaguaí [29.05% (43/148)] and Mangaratiba [11.49% (17/148)], and higher relative frequencies were observed in animals with access to the forest, streams and pastures.

Areas classified as somewhat favorable totaled approximately 4,898.6875 ha (17.98% of the municipality area), primarily occurred at altitudes of 40-80 m and slopes of 20-40% and were distributed in podzol-1 soil primarily at dissected borders of structural plateaus with a predominance of herbaceous vegetation, rural sites, and pasture-like areas. The altitude of these areas was compatible with the development of vector species (AGUIAR et al., 1996, FERREIRA et al., 2001). However, the higher slope, geomorphology, soil use, soil type (podzols possess lower concentrations of organic matter than planosols) and plant cover resulted in lower favorability for ACL occurrence compared with the geo-environmental and topographical factors of areas classified as very favorable and favorable.

The unfavorable areas totaled approximately 652.5625 ha (2.39% of the municipality area), primarily occurred at altitudes of 80-120 m and slopes of 20-40% and were distributed in cambisol2 soil primarily at dissected borders of structural plateaus with a predominance of rock outcrops. Very

unfavorable areas totaled approximately 19.3125 ha (0.07% of the municipality area), primarily occurred at altitudes of 120-160 m and slopes >40% and were distributed in cambisol-2 soil at dissected borders of structural plateaus in areas with rock outcrops.

In unfavorable and very unfavorable areas, although the altitude was compatible with the presence of vector species (AGUIAR et al., 1996), the sandy loam or more clayey soil texture (EMBRAPA, 2006) associated with their slope and geomorphology reduced the compatibility of these areas for the development of the ACL cycle.

The signature analyses conducted for the results and theme maps were used to locate and characterize the ecosystem profiles for the risk of ACL occurrence. The analyzed geo-environmental and topographical characteristics indicate that Seropédica may be classified as favorable for ACL occurrence in rural, periurban and urban areas.

Conclusion

The use of geoprocessing as a data integration tool was able to determine the predisposition for ACL occurrence in the studied area. Therefore, the results of the present study may be used to support decision making for planning and resource allocation, and may result in more efficient ACL control actions. In addition because this method has a lower cost than other techniques used in epidemiology, it can be used as an alternative in areas where it is difficult to conduct survey .

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