SPATIAL AND TEMPORAL ANALYSIS OF CUTANEOUS LEISHMANIASIS INCIDENCE IN SÃO PAULO – BRAZIL

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ABSTRACT

Cutaneous Leishmaniasis transmission occurs in a complex cycle where the environment has a significant influence. Some important parameters related to this cycle can be qualified and quantified with Remote Sensing and Geoprocessing, employed to study 27 cases of CL occurred at Itapira municipality (São Paulo/Brazil), reported between 1992 and 1997. Forest remnants related to these cases were delimited and the distances between dwellings and remnants were calculated. Contact Risk Zones were defined taking the remnants border and expanding it, according to criteria based on the mosquitoes flight range. Also, the influence of vegetation density and deforestation on the CL incidence was analyzed through: 1) a Normalized Difference Vegetation Index (NDVI) and 2) a Multitemporal Principal Component Analysis (PCA). The relative percentages of NDVI classes found around the remnants showed a high Vegetation Index in this region, varying between 0.45 and 1.0 in approximately 50% of remnant surrounding areas. The Second Principal Component derived from PCA was used to determine the areas where deforestation seems to have an important role in CL incidence. The analysis carried out indicate that three types of transmission may be occurring in that region: (i) an intra-forest transmission in locals where a disease focus was localized within a dispersion radius of the mosquito; (ii) an extra-forest transmission probably related to the existence of a high percentage of dense vegetation around remnants where the mosquito can flight and (iii) transmission in human dwellings, possibly caused by a mosquito domestication process.

1 – INTRODUCTION

Remote Sensing and Geoprocessing are becoming very important for Landscape Epidemiology, because it enables the analysis of some environmental variables related to several diseases incidence (Hugh-Jones 1989, Verhasselt 1993, Washino and Wood 1994, Clarke *et al.* 1996, Croner *et al.* 1996, Beck *et al.* 2000). Cutaneous Leishmaniasis (CL) is one of these diseases, in which the transmission profile includes landscape elements.

CL is among the six most important infected-parasitic diseases of the world, and is the second most important caused by protozoan, right below malaria. According to Walsh *et al.* (1993), in South America CL distribution has been influenced by zoofilic vectors because of their ability to adapt themselves to human dwellings and because they use the human blood as source of feed.

In Brazil, where the transmitters (or vectors) are Phebotominae insects in which the main transmitter genus is *Lutzomyia* spp., the transmission profile has been modified along the last decades, and the illness is now considered antropozoonotic (Tolezano, 1994; Gomes, 1992). At São Paulo, a Brazilian state, the etiological agent for CL is *Leishmania braziliensis braziliensis* species (Gomes and Galati 1989). In the study area located in Itapira municipality, in the inlands of São Paulo state, the probable CL transmitters are *Lutzomyia intermedia*, which have strong tendency to invade human dwelling, and *Lu. whitmani*, which is essentially sylvan (Gomes *et al.* 1989; Forattini, 1973). According to previous studies, the Phlebotominae flight range can vary from 200 to 1000 meters, but in most of the cases the range stays between 200 and 300 meters (Forattini 1973; Gomes and Galati 1989; Dourado *et al.* 1989; Gomes *et al.* 1989; Corte *et al.* 1996).

In most of the cases the CL incidence, its prevalence and distribution, are influenced by the human activities related to deforestation, which propitiates the contact between people and environment, more specifically in the neighborhood of vegetation remnants (Forattini 1973; Dourado *et al.* 1989; Gomes *et al.* 1990; Gomes 1994). The Remote Sensing allows the identification of the vegetation cover and amount, along the time. The Geoprocessing techniques allows the user to make maps and quantify the vegetation involved in the life cycle of the CL transmitters mosquitoes (Hugh-Jones13 1989, Verhasselt18 1993, Washino and Wood 1994, Clarke *et al.* 1996, Croner *et al.* 1996, Cross *et al.* 1996, Mbarki1 *et al.* 1995, Miranda *et al.* 1996, Hassan *et al.* 1999, Beck *et al.* 2000, Costa 2001).

The deforestation is increasing all over the world requiring large scale analyzes, which can be provided by satellite images interpretation. If the vegetation related to CL transmission were identified and the deforestation patterns were discovered it will be possible to understand the relationship between human and vector populations, enabling a correct public health action.

Thus, the objective of this study is to use Remote Sensing and Geoprocessing techniques to analyze the influences of the vegetation density and the deforestation pattern on the presence of CL transmitters in the neighborhood of the human dwellings, using 27 CL cases occurred between 1992 and 1997 in Itapira municipality.

2 – MATERIALS AND METHODS

The 27 CL cases studied were recorded by SUCEN (Endemics-diseases Control Superintendence). The areas where one or more cases occurred were visited, geocoded, and were observed terrestrial targets of interest. It was assumed that all remnants, despite of its size, would be *habitats* of CL transmitters and reservoirs and also that the remnants would be homogeneous regarding the needs to humidity and temperature. From these premises it could be possible to work only with the silvan cycle of CL, since there were no registers of Phlebotominae domiciliation in the reported cases.

There are two analysis perspectives: one from the forest remnants neighborhood and other from the dwelling neighborhood. The first one was carried out using a classified Normalized Difference Vegetation Index (NDVI) image in order to verify if the vegetation density could influence the mosquito fight range. The second perspective was accomplished by a multitemporal Principal Component Analysis (PCA) to investigate the forest cover variation which could determinate the transmitter presence or absence. The software IDRISI (Eastman, 1995) was used for all image processing.

The polygon of the remnants found in a ray of 1000 meters from the location of every point where the disease occurred, were defined considering the dispersion ray of the species that could be acting in the study area. The procedure to define the fragments included: 1) recognition of previously well-known fragments in a False-color Composition of TM-Landsat, from May-1996; 2) location of all the fragments of the study area in a Maximum Likelihood Classification, and 3) refinement of the delimitation through the digitalization of the fragments in a ETM-Landsat image, Pancromatic Band, from August-1999. Contact Risk Zones (CoRZ) between man and the vectors were defined through the expansion of the fragments borders within the distances from 250, 500 and 1000 meters.

The classified NDVI image, derived from the red and near infrared images, was used to assess the vegetation density in each CoRZ. For these purposes, a map with 1000 meters CoRZs, were overlaid with a classified NDVI image, generating new map to quantify the *vegetation density* within each CoRZ. In the NDVI classified image, the minimum value was considered to be the minimum of the vegetation density found in the known remnants (index of 0.23).

In order to investigate the relations between deforestation and the areas involved in CL transmission, an analysis of the deforestation process were evaluated. A multitemporal standard PCA was used to identify the deforestation and re-forestation processes occurred in each CL transmission areas. This analysis was carried out with two red band images of the TM and ETM Landsat satellites (1992 and 1999, respectively). In the red band the more urbanization the higher is the reflectance, and the more chlorophyll concentration the lesser is the reflectance. The second Principal Component (CP2) was classified and analyzed, because it characterizes the variation occurred between dates. In that analysis, the cases 16 and 22 were omitted due to technical problems.

The PC2 image was classified according to Maldonado (2000), because there was a possibility of re-vegetation or deforestation processes could be occurring in larger or smaller intensity from 1992 to 1999. PC2 was divided by five classes, within the limits located in 1 and 2 standard deviations (σ) from the average. The First and Second Classes (1σ e 2σ Re-vegetation *Limit*) are represented by subtraction from the average of 1σ or 2σ respectively. The Fourth and Fifth classes (1σ e 2σ Deforestation *Limit*) are represented by the sum of the average of 1σ or 2σ, respectively (Aparicio 2001). The Second *Limit* classes represent areas where the alteration occurred with larger intensity and the First *Limit* classes are applied to discriminate areas with a lesser intensity alteration. To easier transmission profile interpretation, it was assembled all processed data, except NDVI, which was called *Clippings*.

3 – RESULTS

Figure 1 illustrates the descriptive numbers of the CL cases, from 1 to 27, the 1000 meters dispersion radios, and the CoRZ. The NDVI classes in each CoRZ are represented in **Figure 2**. On that figure, the more the value of the NDVI approaches to 1, darker the green tone, and denser the vegetation are. The NDVI classes were: **1:** -1.0 to 0; **2:** 0 to 0.23; **3:** 0.23 to 0.34; **4:** 0.34 to 0.44; **5:** 0.44 to 0.54; **6:** 0.54 to 0.64; **7:** 0.64 to 1.0. Classes 1 and 2 represent absence or low vegetation density; from class 3 to 7 the vegetation density is increasing, whose classes 5 the 7 represent the forests, eucaliptals and perennial plantations. The NDVI values resulted in each class were summed in the CoRZs areas, resulting the following values: **1:** 2.4; **2:** 8.2; **3:** 15.0; **4:** 26.2; **5:** 27.1; **6:** 17.3; **7:** 3.8. Adding the denser vegetation classes (4, 5, 6 and 7), it is possible to observe that approximately 50% of the areas of each CoRZ present a very dense green area, with NDVI varying from 0.45 to 1.

Figure 3 shows the *Clippings* originated from PC2. They are defined by the set 1000 meters radius polygon (black lines) plus remnants (green lines) associated to one or more cases, and indicate the behavior of PC2 inside the possible maximum mosquito flight range (1000 meters). For each *Clipping*, including one or more cases, and associated to one or more remnants, the percentage areas related to each class of PC2 were calculated.

The *Clippings* are described on **Table 1**. It registers the cases numbers (**Figure 1**) and occurrence year, the distance between the dwellings and from the next remnant border, and the absolute percentage of the sum of PC2 classes that present deforestation or re-vegetation. The Second Deforestation limit could be considered that with larger probability of indication forest areas, since in this case the difference between target reflectance from 1992 to 1999 would be larger.

In an overview it was noted that the re-vegetation areas concentrate on Itapira West region, where there are the lesser altitudes and great eucalyptus replants. Deforestation areas are concentrated, in spite of few exceptions (D and E C*lippings*), in the East and part of the Central region, where the highest altitudes of the city are. Between 1992 and 1999 it was observed little or no alteration (Class 3) on the limits of the remnants.

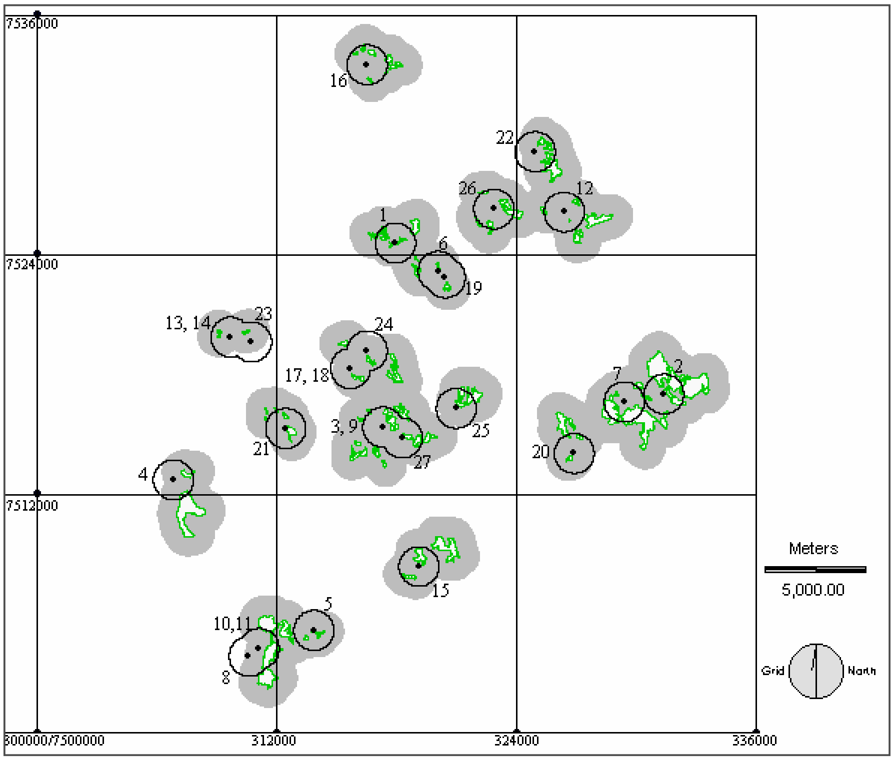

Figure 1: Contact Risk Zones: 1000 meter expansion of the remnants borders (green line), obtained from digitalization in a Pan-Chromatic image, and related to CL cases in Itapira between 1992 and 1997. It was possible to observe the locals where it there were one or more CL cases, numbered from 1 to 27, and the 1000 meters dispersion radios (black line).

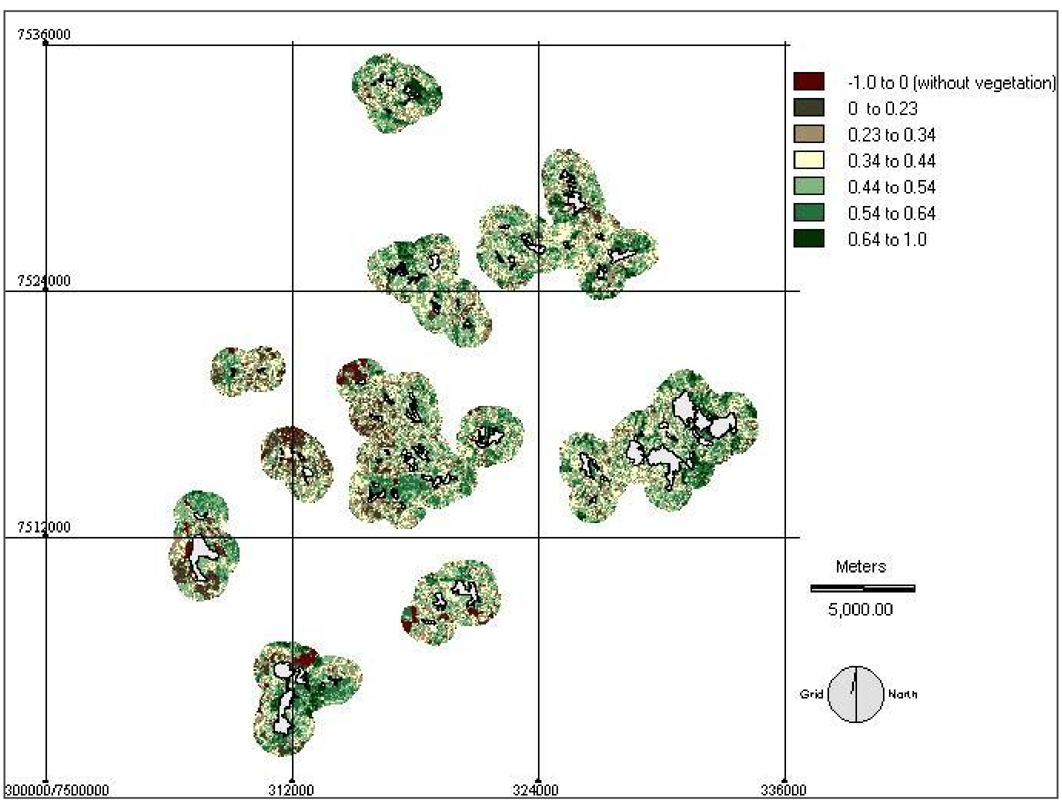

Figure 2: NDVI classes found in up to 1000 meters from the remnants borders (here in black line).

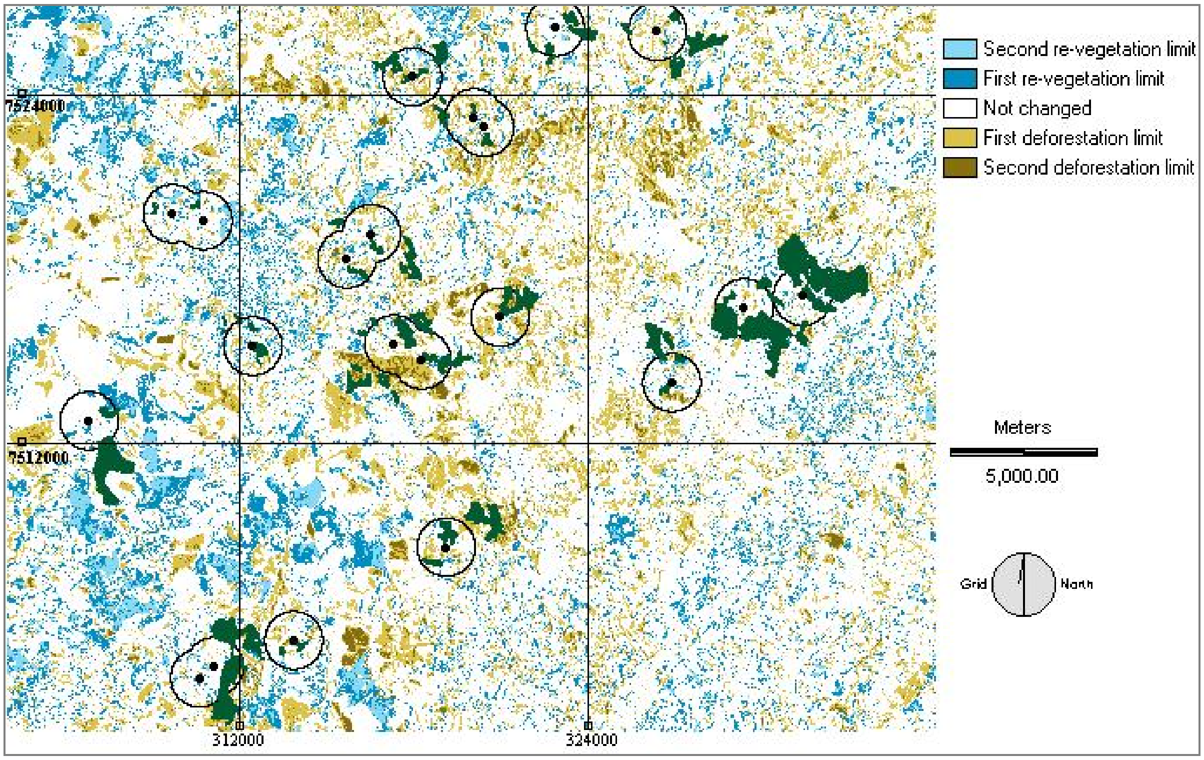

Figure 3: Second Principal Component classified, with the polygons of 1000 meters radius (black line), and with remnants (green) found inside or on the edge of these polygons.

Table 1: *Clippings* description, according to the year of the CL cases report, and distance between the dwellings and the border of the next remnant. The percentage areas related to sum of 1+2 and 4+5 PCA classes are also described, and the *Clippings* of the lower altitudes are in bold characters. The G+H and K+L *Clippings* were added because of the proximity of their cases to the same remnants.

Clipping	Case number	Reporting year	Distance (meters) from dwellings	Classes 1+2 (Re-vegetation)	Classes 4+5 (Deforestation)
***Clipping* A**	4	1993	510	13.72	1.31
***Clipping* B**	13, 14 e 23	1994 (2 cases) and 1996 (1 case)	545 e 474	18.13	6.99
***Clipping* C**	21	1995	75	16.32	13.35
***Clipping* D**	17, 18 e 24	1995 (2 cases) and 1996(1case)	276 e 210	12.90	18.00
***Clipping* E**	3, 9 e 27	1992, 1993 and 1994	340 e 94	4.26	35.18
Clipping F	25	1997	187	4.91	33.15
***Clipping* G+H**	5, 8, 10 e 11	1993 (4 cases)	15; 0 e 313	8.10	11.30
Clipping I	15	1994	90	5.76	17.01
Clipping J	20	1995	33	11.44	17.00
Clipping K+L	2 e 7	1993 (2 cases)	150 e 368	6.86	6.69
Clipping M	1	1992	33	13.87	19.89
Clipping N	6 e 19	1993 and 1995	54 e 260	9.38	25.83
Clipping O	26	1997	424	8.11	10.77
Clipping P	12	1994	441	8.47	19.09

Some of the *Clippings* (A, B, C, D, E, G e H) inserted in re-vegetation area presented also some of the higher deforestation index (**Table 1**). The average of total deforested area (4 and 5 PC2 classes) percentage among these *Clippings* was 14.35%, while the average of the total re-vegetation area percentage among them was 12.24%.

The other *Clippings* are found in the region where the altitudes are higher. In this case the average of the total deforested area percentage was 18.67% and the average of the total re-vegetation area percentage was 8.60%. D, E and F *Clippings* seem to be associated to a greater deforestation occurred in the area where they are found. The same thing probably occurs with M, N, O and P *Clippings*.

4 – CONCLUSIONS

The results initially demonstrated that the transmission has not occurred only inside the normal flight range of Phlebotominae mosquitoes (about 250 meters). The high NDVI indices found around the fragments could be indicating that it is necessary to have enough green density around the fragments in order to the mosquito be able to reach human dwellings, amplifying its average flight range. This makes it possible to suggest a landscape pattern where the incidence of the disease would be related not only to the presence of woods, but also to the presence of other kinds of vegetation spread around the fragments, as long as it is dense enough.

The reason why the areas with larger deforestation indices are concentrated on Center-East region of Itapira could be linked to the fact that a great portion of wood areas had already been deforested before 1992 in lower altitudes, remaining the areas of restricted access, in higher altitudes, in the Center-East region, that is now deforested. It could be possible to assume that, if the influence of the vegetation density in the presence of the mosquito was to be considered, and the Second Deforestation Limit is indicator that there was denser vegetation in 1992, the relative areas to this limit also can be directly related to the alterations in CL incidence. Therefore, the fact of the *Clippings* sets {D, E, F} and {M, N, O, P} being associated to the areas where the biggest rates of the Second Deforestation Limit occurred, it seems to indicate a relation between these cases and the deforestation.

PCA analysis showed that in some of the areas where there was CL transmission it was possible to relate the deforestation to the incidence of the disease. The very high deforestation rates can represent the disappearance, from the beginning of the study period, of remnants related to the disease. In some areas, it was possible to identify deforested remnants that could have influenced the appearance of the disease, and which can be observed in Central region. In the *Clippings* of this region (D, E, F, M, N), the incidence of the disease could have been affected not only as a function of the high indices found for Second and First Deforestation Limits, but also due to the fact that the relative areas to the Second Deforestation Limit are near to the First limit, and near to the fragments of permanent woods. Thus, the relative areas of the Second Deforestation Limit should be acting as indicators that they would be composing, with the First Deforestation Limit areas associated to them, a wood area in 1992 which would have been deforested (Aparicio 2001).

According to these analyses, it could be possible to consider four possibilities to indicate transmission profile in the studied cases: 1) the transmitters became adapted to the domestic environment and/or the CL reservoirs may be circulating between woods and dwellings; (2) the mosquito is getting the houses through sufficiently dense vegetation spread around of the wood borders; (3) the remnants that could be considered the habitats of the vectors would have been deforested; (4) the person who got sick frequented the woods at night when caught CL.

The first possibility seems to be feasible, once it explains the cases that were more than 250 meters distant from forest remnants, and the cases that the deforestation did not collaborate for CL Incidence as well. If the complete domestication has not occurred yet, a transitory process, suggested by the second possibility, could be occurring. In this case, the mosquitoes could be reaching the human dwellings since the NDVI values, registered around the remnants, was elevated.

The third hypothesis is also valid for the *Clippings* D, E, and N, whose distances from houses to the border of the remnants are respectively of 276, 340 and 260 meters, and where the association with the Second and the First Deforestation Limit is observed. Finally, the last hypothesis seems to be an unviable confirmation, since it involves personal information, such as if the sick person has been frequented or not in the woods or in its proximities during night.

The analysis carried out indicates that three types of transmission may be occurring in that region: (i) an intra-forest transmission in areas where a disease focus was found within a dispersion radius of the mosquito; (ii) an extra-forest transmission probably related to the existence of a high percentage of dense vegetation around remnants where the mosquito could flight and (iii) transmission in human dwellings, possibly caused by a mosquito domestication process, in which the CL transmitters could develop its complete cycle in the houses neighborhood and where it could be possible to the CL reservoir circulate from remnant to house.

5 – REFERENCES

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