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A LANDSCAPE ECOLOGY APPROACH FOR A NEGLECTED DISEASE IN RURAL AREAS OF ARGENTINA

USANDO ECOLOGIA DE PAISAJE PARA EL ESTUDIO DE ENFERMEDADES DESATENDIDAS EN ÁREAS RURALES DE ARGENTINA

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ABSTRACT

In recent years, there have been problems in controlling the population of the main vector of Chagas disease, *Triatoma infestans* in the Great Chaco region over Paraguay and Argentina. This study was carried out in an area of the Chaco region, La Rioja province (Los Llanos), where almost 50% of the houses in the region have dirt floors, no tap water and/or sanitary infrastructure. The main economic activity on these rural areas is goat breeding where corrals provides one of the best refuges for *T. infestans*. The study aimed to analyze the reciprocal effects between spatial patterns and ecological-human processes in the Los Llanos region. We propose that the landscape patterns can be measured and quantified through satellite images and that this characterization could be used to analyze a possible association between the presence of stockbreeding structures and the peridomestic infestation patterns found in the study area. On the basis of the correlations identified, it would be possible to indirectly relate the vegetation covering with the life quality of the rural inhabitants of Los Llanos region.

RESUMEN

En los recientes años, han existido problemas en el control del principal vector de la enfermedad de Chagas *Triatoma infestans* en la región del Gran Chaco, que incluye parte del territorio de Argentina y Paraguay. El estudio presentado aquí se desarrolla justamente en esta región, específicamente en la provincia de La Rioja (Argentina), donde casi el 50% de las viviendas tienen piso de tierra, no tienen agua potable ni infraestructura sanitaria. La principal actividad económica de estas áreas rurales es la cria de cabras donde sus corrales constituyen un refugio ideal para *Triatoma infestans* . El trabajo apunta a analizar el efecto reciproco entre los patrones espaciales y los procesos productivos/humanos en la región. Nosotros proponemos que los patrones de paisaje que pueden evaluarse y cuantificarse a través de imágenes de satélite pueden ser utilizados para estudiar la asociación entre la presencia de corrales y los patrones de infestación peridomestica encontrados en el área. Sobre la base de las correlaciones encontradas, es posible indirectamente relacionar los patrones de cobertura vegetal y parámetros asociados a la calidad de vida de los habitantes rurales de la zona.

Keywords: landscape ecology, remote sensing, Chagas, rural areas Argentina.

Palabras clave: Ecología del paisaje, sensado remoto, Argentina, Chagas.

INTRODUCTION

In recent years, there have been problems in controlling the population of the main vector of Chagas disease, *Triatoma infestans* in the Great Chaco region over Paraguay and Argentina. The west side of Chaco region is characterized by a low rainfall rate, about 350 mm/year, and has currently a low productivity having been exposed to an over-exploitation of natural forest generating a severe degradation process. Already in 1982, Bucher and Schofield observed that this phenomenon is manifested by a replacement of vegetation and loose of grass cover and they pointed out the negative effect it could have on Chagas disease stressing the need of including rural health care in integral health actions.

This study was carried out in La Rioja province (Los Llanos) located in the arid area of Chaco. In this area the population density is low: according to the national census of 2001, 56208 inhabitants living in a 56585 km^2 area. Of this population, 43.5% is installed in rural settlements with less than 2000 inhabitants while 19.1% lives in dispersed rural houses. Almost 50% of the houses in the region (6175) have dirt floors, no tap water and/or sanitary infrastructure (INDEC 2001, Gorla *et al.*, 2008). The main economic activity on these rural areas is goat breeding where corrals provides one of the best refuges for *T. infestans* (Porcasi *et al.*, 2007). This region in particular, Gral. San Martin Department, showed high rates of house infestation reaching almost the 50% of the peridomiciles before chemical control and almost 30% one year after a single blanked insecticide application. In disperse rural settings, the efforts to maintain active surveillance are restricted by the scarce resources of the provincial Chagas Program.

Based on the concept of landscape ecology, this study aimed to analyze the reciprocal effects between spatial patterns and ecological-human processes in the Los Llanos region. We propose that the landscape patterns can be measured and quantified through satellite images and that this characterization could be used to analyze a possible association with the presence of stockbreeding structures as corrals and with the peridomestic infestation patterns found in the study area.

MATERIALS Y METHODS

Study area and thematic maps. The study area comprises Rosario Vera Peñaloza and Gral. San Martin Departments in La Rioja Province, Argentina. To analyze the environmental characteristics of little rural localities, two Landsat TM images from the study area were used. The images correspond to dry and wet seasons (October 2004 and March 2005) after the insecticide application by the local Chagas Program over the rural area and were geo-referenced on the basis of field points and road mapping and previous Landsat images.

The thematic maps were generated by supervised classification (Maximum likelihood), considering four classes mainly related with the amount of vegetation cover: saline, bare soil, scarce vegetation and dense vegetation. Bare soil class involves local roads, temporary river basins and soil without vegetation cover generated by high transit and grazing pressure called “peladares” which we considered a marker of human activity in the area. The first classification was done over the image with more vegetation cover (March), several inclusion threshold levels were tried until the result which better defined the bare soil class was get. The dry season image was classified with the same training sites, although some changes in land cover were included in the “unclassified class”. To complete the environmental information, elevation data of a SRTM, (Shuttle Radar Topography Mission) obtained by the Maryland University web-page http://glcfapp.umiacs.umd.edu:8080/esdi/index.jsp was used).

Each rural locality was defined by a group of houses separated from another group by more than 2 Km. Following this scale, the area in which landscape metrics were measured was a square of 1850 m. A total of 112 localities were evaluated entomologically and over each one, a centered window of 1850 was used to quantify its landscape. All the image processing was done with ENVI 4.1.

Fourteen general landscape metrics were extract from each locality window and other 14 were measured specifically at bare soil class. These metrics took into account the area, shape and connectivity of different cover classes. Also diversity and evenness indexes (similar to the ecological ones) were included for landscape metrics. All the metrics were made with FragStat 3.3.

Statistical Analysis. The landscape metrics were correlated with the number of coats, the number of goats corrals, cow corrals and henhouse. Besides this approach, as the peridomicile infestation showed an spatial pattern before and after the insecticide application (Porcasi *et al*., 2006), it was carried out a discriminative analysis between groups of houses with high and low infestation level found after the insecticide application.

RESULTS

In the thematic map obtained for humid season in March, the four land cover classes are represented. This map was selected because it delimitates clearly the bare soil (peladares) without a mix with the exposed rock of the hill (Figure 1).

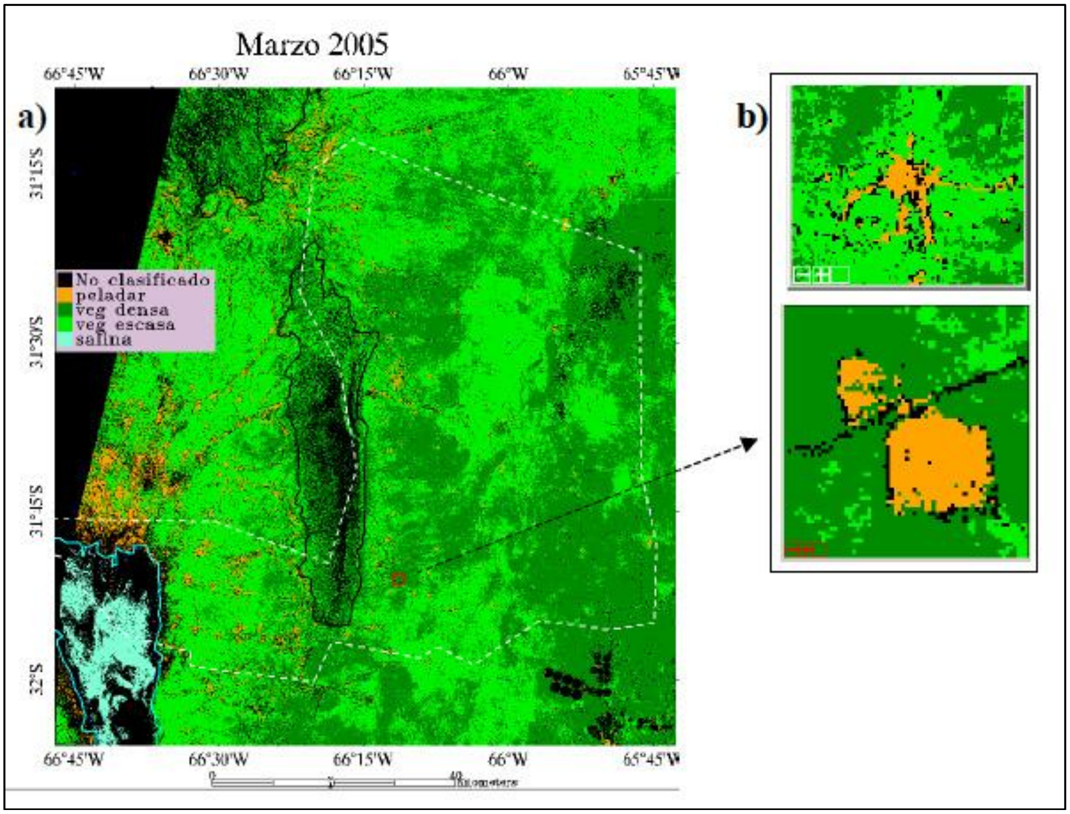

Figure 1. Vegetal cover thematic maps obtained by supervised classification of Landsat images. a) Wet season map (March 2005). b) detail of two localities (among those included in the study with different characteristics in "peladar" shape and evenness of the landscape.

In this map, the scarce vegetation and bare soil are present more frequently in west areas while the vigorous vegetation is more abundant in the east region. Within the 8817 km^2 of the study area, 3.67% of the image obtained in March correspond to bare soil while in the image of October, when the dry season is finishing, the same class reached the 6% of the total area. The comparison of land cover between dry and wet seasons is shown in Table 1 and in Figs. 1a and b.

Table 1. Percent of the study area covered by each of the four classes of vegetation (supervised classification of Landsat TM images). October: dry season, March: wet season.

Class	October 2004	March 2005
Peladar (bare soil)	6	3.67
Scarce Vegetation	36.29	43.28
Dense Vegetation	30.13	30.83
Saline	1.24	1.87
Unclassified	26.33	20.35

The correlation between stock breeding variables and the landscape metrics of the localities was linear and significant but not very strength. The "peladar" metrics correlated better to the number of peridomiciles positives for *T. infestans* one year after insecticide application. On the contrary, landscape general metrics had a better fit with the variables related with stockbreeding-domestics activities. The Pearson correlation values are shown in Table 2.

Considering the metrics took over the "peladar" class only, the best associations were found with the number of peridomiciles positives after insecticide spraying (PD pos 05), and with the total edge length of that class of vegetation (r =0.55, p<0.01). This means that those localities showing more positive peridomiciles have a less compact shape of the "peladar" (with lot of little patches and branches). When the metrics were accounted considering all the landscape, the best correlation was also for the peridomiciles positives after chemical control in 2005, and not with the total edge length but with the total number of patches of any class present in the landscape (r=0.49, p<0.01). The total number of patches had also the best fit with the number of goat corrals and with the number of goat heads (r =0.423 and r =0.421, respectively p<0.01). For all the correlations the association was positive indicating that a high number of patches within landscape or high edge length are associated with a higher number of corrals and goats.

Table 2. Pearson coefficients within "peladar" and general landscape metrics and field measures of infestation and structures related with stockbreeding. All the results are statistically significant p<0.01.

	CA	PLAND	NP	LPI	TE	LSI	*L*NP	*L*E	*L*LSI	*L*AREA	*L*SHDI	*L*SIDI	*L*SHEI	*L*SIEI
Longitud	-0.686	-0.694	-.7256	-.5769	-.7538	-.7501	-0.60	-.5116	-.5116	.4862	-.4951	-.4557	-.5636	-.4899
Sea level			.4580			.4593	.5419	.4852	.4852	-.3898	.4944	.4179	.4771	.4114
Gotas Corrals					.3891	.3839	.4233	.3797	.3797		.3801		.3841	
Tota N goats			.3719		.3859	.3873	.4214	.4041	.4041		.3723		.4281	.3937
ID-PD pos (04)													.3905	.3923
PD pos (05)	.4846	.4935	.5088		.5505	.5489	.4902	.4272	.4272	-.3727	.4055	.3906	.4594	.4172

L before the names indicate Landscape metrics. Ca: Total class area, *P*land: percent of landscape cover by this class, LPI: Largest Patch index, NP: Number of Patches, LSI: Landscape Shape Index, *P*SHDI: Shanon diversity index, *P*SIDI:Simpson diversity index, *P*SHEI: Shanon evenness index, *P*SIEI: Simpson evenness index, Area: mean area of landscape patches, TE: Total edge length.

If the space variation in a broad scale is considered, the relationship between the landscape metrics and the position of each locality in "longitude" (east-west sense) is also significant. This association is tighter with "peladar" metrics than within Landscape metrics. A discriminative model based on the three groups identified by spatial analysis (low, high and standard infestation level) was significant and included 6 variables (Wilks-lambda = 0.231, F(12,138) = 12.138, p<0.01). The height over the sea and the number of patches of "peladar" class had the best discriminative power. The model had an 83% of agreement in the classification matrix, with the major errors corresponding to the localities with standard level of infestation. The scatter plot in Figure 2 shows that the first root of the analysis discriminates the high and low level groups of localities while the second root differentiates the middle level of infestation.

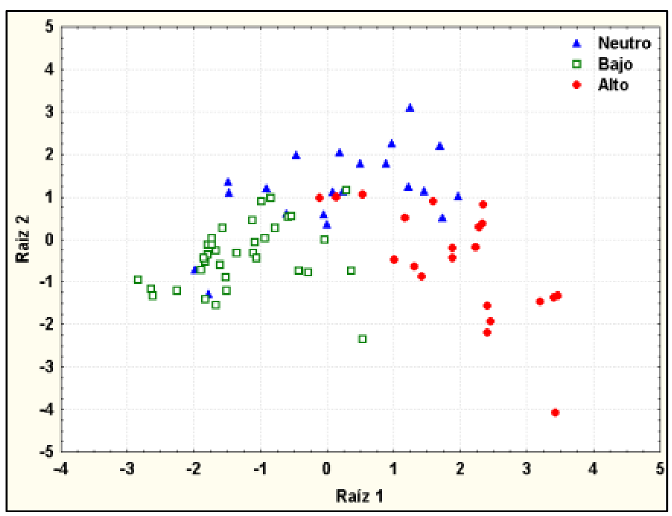

Figure 2. Scatter plot for the canonic roots obtained in the discriminative analysis with three infestation level groups obtained by spatial analysis in Gral. San Martin Department.

When only the high and low infestation levels groups are considered for a discriminative analysis, the model included 8 variables (Wilks-lambda = 0.166 F(8,47) = 29.463, p<0.01). The height, two metrics of diversity at landscape level and the mean area of “peladar” patches were significant. The model classified correctly 98.2% of the localities.

When we analyze the characteristic of the localities with high and low level of infestation for these variables, we found that the group of high level of infestation is placed at a major altitude and the localities have bigger “peladares” (showed as Area-Mn in Figure 3). The diversity indexes are also higher in the localities with high level of infestation and they have a more even distribution of classes and patches within the landscape.

The variability in landscape features was bigger in Standard localities (those ones not included neither in high nor low infestation groups): for example, the height over the sea, the most important variable in the discrimination, didn’t allow the clear identification of this group due to its wide variation (Figure 3a).

DISCUSSION

Despite the landscape modification in the Chaco biogeographic region has being detected during the more recent decades, the first quantification of the vegetal community changes using satellite images have been reported in 2004 (Zak *et al.*, 2004) in the north of the Cordoba province. This study had revealed a great loss and fragmentation of native vegetation in the Cordoba environment. However, in our study area, the environmental changes due to human activity differs from those identified in Cordoba and corresponding to the classic geometric landscape pattern generated by agricultural activities (Forman, 1995). On the contrary, in San Martin Departments (and in the neighbors places in La Rioja), the alterations generated by human activity resulted in an irregular pattern with bare exposed soil showing a “star shaped” aspect where the houses and corrals are located. The environmental degradation on the Chaco region was proposed already in 1981 by Bucher and Schofield as a factor related to Chagas disease prevalence.

The vegetal cover change between seasons in this area could be described as an overcome of “scarce vegetation” class over “bare soil” class in the humid period. When the localities were analyzed considering each one as a landscape, the metrics related to bare soil class as well as those corresponding to the complete environment, showed a relationship with the infestation registered one year after chemical disinfestations. The variables related with goat stockbreeding also demonstrated to be associated with landscape metrics. The increase of peladar complexity (length of its edges and number of patches) was directly associated with the number of goats and corrals. The “star shapes” (Figure 1b) could be related with the roads generated by the goats in their way from the corral to the source of feeding. The size of the “peladar” patches could be affected by a number of factors such as the total number of houses in the locality, the grazing pressure and the vegetal community resilience capacity.

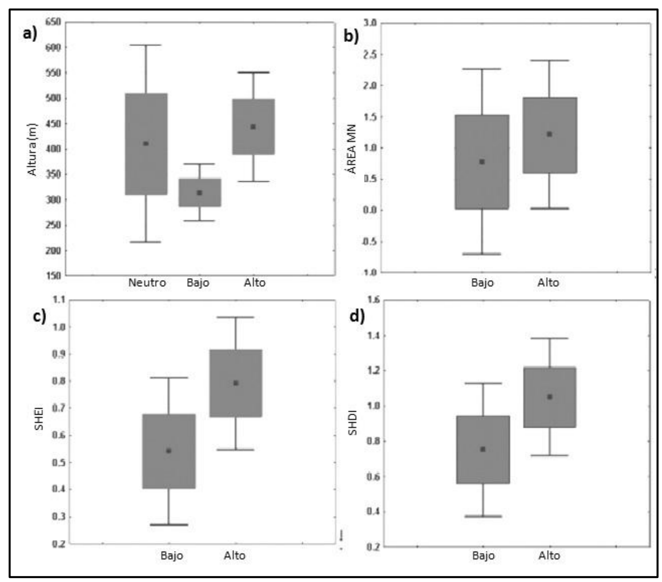

Figure 3. Box plot comparison of variables with major weight on discriminative analysis between groups of localities with different levels of peridomicile infestation. a) Sea level, b) “Peladar” class mean area, c) Shanon eveness index at landscape level, d) Shanon diversity index at landscape level. Alto: High infestation group, Bajo: low infestation, Neutro: Standard infestation localities.

At the landscape level, the heterogeneity and diversity indexes increase in a direct relationship with the goat stockbreeding variables, and are very useful to discriminate between high and low infestation localities. In localities with high level of infestation, the mean area of “peladar” patches as well as the heterogeneity and evenness indexes increases. The opposite features should indicate a landscape with better community conditions. The landscape matrix (major cover class within the landscape) should be composed by scarce or vigorous vegetation at the locality scale selected in this study (almost 4 Km^2, Figure 1b). A higher covering of the area with vegetation of those classes is associated with better grazing sources and with a main economic activity consisting in stockbreeding. For these reasons, it is possible to indirectly relate the vegetation covering with the life quality of the rural inhabitants of Los Llanos region.

The increase in spatial heterogeneity and in the diversity of patches are features linked to landscape fragmentation. Fragmentation generates changes in emergent ecosystems properties like stability, resilience and succession (Forman, 1995; Ojima *et al.*, 1994). The analysis at different scales provides different levels of landscape description and enable the identification and quantification of the patterns related to stockbreeding both at class and at landscape level. This would reveal the environment in which the inhabitants lives and the constrains imposed by the locality ecosystem (O´Neil *et al*., 1989).

In a region suffering for several decades of landscape change and exploitation, the characteristics of the localities with higher peridomicile infestation levels correlate with the idea that the ecosystem degradation represents a risk for neglected diseases as proposed by Bucher and Schofield (1982). The description (metrics) of a region, especially at a locality level, confirms the need to encourage Chagas integrate programs with actions oriented not only to the vector control but also aimed to provide better life conditions to rural communities of the Chaco region.

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