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EVALUATION OF LANDSCAPE URBANITY IN AMERICANA, SÃO PAULO, BRAZIL

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ABSTRACT

The constant transformation of space comes as a result of established socio-environmental, economic and cultural relations. In order to understand the relationships between the patterns and processes in the landscape, considering or not the hierarchical organization, the development of methods for the quantification of their structure has been used. This study focuses on analyzing temporal dynamics of landscape and land cover in Americana (SP Brazil in 1994, 2008 and 2016) aiming to diagnose the landscape urbanity through the application of The Urbanity Index (UI). Geographic Information Systems (GIS) were used to map the use and land cover and to visualize the UI. The UIresults evidenced anincrease of the landscape urbanization over time, mainly due to the decrease of forestry in the municipality. The growth of anthropogenic activities and the loss of natural areas can compromise the biodiversity present in Americana, implying the loss of environmental functions and consequently the benefits they provide.

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INTRODUCTION

The constant transformation of space comes as a result of established socio-environmental, economic and cultural relations. Man, through the development of techniques, modifies the organization of the spatial elements, causing environmental impacts in the diverse scales of comprehensiveness (Millennium Ecosystem Assessment 2005; Intergovernmental Panel on Climate Change 2007).Man-occupied terrestrial spaces are changing in nature and composition, requiring a new definition of their boundaries where the dimensions of these anthropized areas undergo a very intense modification process (Santos 2008). ll the processes of occupation by human species managed without planning produced great pressures on natural systems(Vitousek et al. 1997). For instance disappearance of the vegetation cover occurred due to the use of natural resources in an unsustainable way and without taking into account the resilience capacity of ecosystems (Tundisi 2010).

With the rise of anthropogenic–caused pressures on the environment, there is a process of replacing natural landscapes with other land uses. These interferences, convert extensive and continuous areas with forest cover into forest fragments, compromising their environmental functions and consequently the services provided by ecosystems (De Groot 2013). There is a need to analyze the changes suffered by the landscapes over time, caused mainly by the anthropic activities and in this way to verify the main impacts within each unit of the landscape. Identifying and quantifying these changes will allow the assessment of the dimensions of various environmental problems. To overcome this challenge,action programs and public policies are needed for the implementation of international environmental conventions. The analysis of the landscape structure is fundamental to designate the configuration, which corresponds to the spatial structure of its units, subsidizing the understanding of the impacts of anthropic alterations in processes of natural origin (Gardner; O'Neill 1991).

This challenge has been searching to disseminate concepts and techniques of conservation and management that aim to reduce impacts on ecosystems, especially when referring to the recomposition and preservation of landscapes (Momoli 2006). In the last decades, there has been extensive search for new quantitative methods that can analyze patterns, determine the importance of spatial processes and develop models (Turner; Gardner 1991).A prerequisite for understanding of the relationships between patterns and processes in the landscape, considering or not its hierarchical organization, has been the development of methods for the quantification of its structure. In order to quantify the structure of the landscape, it is necessary to gather several indexes, considered as key elements for the elaboration of landscape management strategies, which allow a landscape structure to be obtained in a short time in view of its spatial characteristics (Ritters et al. 1995).Therefore, a new phase of planning is needed, where management plans need to have strong articulations with the management capacity and with effective implementation of the directives established (Moretti 2007).

Turner (1987), O'Neill et al. (1988), Gustafson; Parker (1992), Mcgarigal; Marks (1995) and Trevisan et al. (2016) have developed a large number of indices and descriptive measures of landscape spatial patterns.The modeling is established as an excellent ally for obtaining knowledge and generating hypotheses in landscape ecology and population issues (Trevisan 2015). These measures have been used to compare the composition and structure of different landscapes (O'Neill et al.1988), to identify landscape changes over time (Turner 1987), to explore the effects of different configurations imposed by (Franklin; Forman 1987) and also used as independent variables in explanatory models of species abundance and diversity in terms of aspects of landscape structure such as size, the distance between forest fragments and the composition of landscape structures (Mcgarigal; Mccomb 1995; Metzger 2000).

GIS has facilitated characterization process of diagnostic analyses and activities. Additionally, it has extensively contributed to urban and environmental planning assisting the simulation of geographic space and its natural processesand the integration of spatial information (Ribeiro 1999). Considering that landscape-transforming cultural processes constitute the integrated manifestation of natural and cultural elements, causing physical or cultural changes on it. The natural environment provides benefits to society in various ways by preserving the structure and function of ecosystems (Balmford et al. 2002). Therefore, balancing environment and development is the main strategy to ensure ecological sustainability, making it essential to consider human needs in relation to the capacity of ecosystems to support the impacts (Sato; Santos 1999). These benefits should motivate the conservation of nature in the face of increasing economic pressures on the natural environment. Having said that, the socioeconomic evaluation of them is a challenging process (Santos et al. 2001) and not incorporated into the conventional economic activity, which are based on the market analysis. This study focuses on analyzing temporal dynamics of landscape and land cover in Americana (SP Brazil in 1994, 2008 and 2016) aiming to diagnose the landscape urbanity through the application of The Urbanity Index (UI).

MATERIAL AND METHODS

Study Area

Americana is located in the administrative region of Campinas in São Paulo state (IGC 2016), between the coordinates 22º 44 '21"South latitude and 47º 19' 53" West longitude, occupying 134,1313 km^2 (Fig. 1).

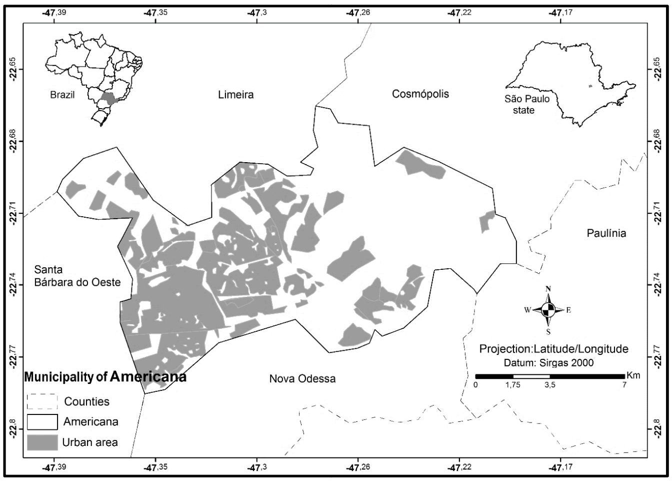

Fig. 1 Geographic location of Americana-SP, Brazil

The municipality has 225,183 inhabitants (population density of 1,681.60 inhabitants per km²), with an urbanization rate of 99.53% and an annual population growth rate of 1.14 (SEADE 2016). The climate is characterized as tropical at altitude, with dry winter, plateau relief and Cerrado biome. The average temperature approaches 21.8°C with a monthly rainfall of 107.65 mm (CEPAGRI 2016).

METHODOLOGY

ArcGIS 10.5 software was used for mapping and visual analysis. To characterize the landscape, georeferenced database of Americana (using geographical Universal Transverse Mercator projection), Zone 23 South, datum SIRGAS 2000 was used to develop the GIS model.Primary data for the geographical limits of Americanawere purchased from digital database IBGE (Geographical Institute of Geography and Statistics), situation 2015 and the plan altimetric'scharts in analog form on the scale 1: 50,000, leaves:

SF-23-Y-A-V-A, SF-23-Y-A-V-1 and SF-23-Y-A-V-3.

Three scenes, related to Landsat satellites were used:

- 220/75 orbit/point, with dates in passing on April 25 1994, July 212008, and April 20 2016.
- For 1994 and 2008, the Landsat satellite 5-sensor TM, bands 5,4,3
- For the 2016 image, the LandSat 8-OLI / TIRS sensor, bands 6,5,4 was used.

It should be noted that satellites in different scenes wereused due to the unavailability of a single satellite image for the study period. Classification of uses and land cover, was based on multi-level classification system proposed by the Land Use Technical Manual (IBGE, 2013), that in the primary hierarchical level (I), included four classes that indicated the principal categories of land cover, analyzed with base on direct interpretation of data from remote sensors on an ample scale.

Secondary hierarchical level (II), explained the types of inserted uses the first level, with a more accurate and precise detailing coverage and land use, on a local level and subsequently the tertiary hierarchical level (III), explained the uses themselves (Table 1).

Table 1. Description of use and land cover classes

Class (I)	Type (II)	Description (III)
Area anthropic and don't agricultural	Urban areas	Urban density area and areas with rural facilities (industrial and household)
Area anthropic-agricultural	Sugar cane	Cultivation area of *Saccharum officinarum L.*
	Citrus	Cultivation area of *CitrusSinensis*.
	Pastures	Area with a predominance of herbaceous vegetation (native or exotic), used for extensive livestock farming.
	Silviculture	Cultivation area of *Eucalyptus spp* or *Pinus spp*.
	Exposed soil	Soil fallow area for *Saccharum officinarum L.* cultivation
Natural vegetation	Natural vegetation	Area with a predominance of shrub/tree vegetation, with vegetation types of semideciduous forest and Cerradão.
Water	Water corpses	Large rivers, lakes, ponds and reservoirs.

For landscape pattern description, arising from the influence of anthropogenic processes (uses and land cover), UIwas used (O'Neill et al. 1988; Wrbka et al 2004), using information obtained in the dynamics of use and land cover for 1994, 2008 and 2016, through the expression (Equation 1):

$$IB = \log_{10} \frac{(U + A)}{(F + W)} \qquad (1)$$

Where: U: urban area expansion;*A*: agriculture expansion;*F*: natural vegetation area expansion;*W*: water bodies. The information (or variables) collected for integrated environmental analysis have different natures. The spatial mapping of UI was produced in ArcGIS 10.5 and wasscaled using fuzzy logic (FUZZY), straight type [y = f (x)], with values from zero to one. The fuzzy technique has been used in spatial inference machine (Tanscheit 2006)as an extension of Boolean logic that allows intermediate logical values between the false (0) and true (1). For example, the average value 'maybe' (0.5). This means that a fuzzy logic value is any value within a range of values between 0 and 1, allowing intermediate states can be treated by control devices (Marro et al. 2013). It was considered UI = 0, the maximum degree of ease and UI = 1, a minimum degree of naturalness, corresponding to predominantly altered by human systems, where larger naturalistic correlate with less impacted and lower naturality systems with more impacted systems.

RESULTS AND DISCUSSION

The uses of sugarcane, exposed soil, water bodies, pasture, urbanized areas and native vegetation were classified, with an expansion of urban areas by 10.87% from 1994 to 2016, representing an increase of 1,458.26 hectares (ha).In 1994, approximately 43% of the area had the predominance of agricultural activities, with 2,938.34 ha occupied by sugarcane, 2,049.00ha for pastures and 907.55ha for exposed soil.

The practices of sugarcane cultivation are associated with the exposed soil that they refer to the fallow period and soil preparation for the next harvest (Table 2).

Table 2 Land use and coverage values from 1994, 2008 and 2016.

Land uses	1994		2008		2016	
	Area (ha)	(%)	Areaha)	(%)	Area(ha)	(%)
Urban área	3,508.94	26.16	3,818.98	28.47	4,967.20	37.03
Natural Vegetation	3,109.30	23.18	3,100.26	23.11	2,949.05	22.00
Sugar cane	2,938.34	21.91	1,902.26	14.18	2,126.64	15.84
Pasture	2,049.00	15.28	1,129.40	08.42	1,696.62	12.65
Exposed soil	907.55	06.77	2,562.23	19.10	773.62	05.77
Water	900.00	06.71	900.00	06.71	900.00	06.71
TOTAL	13,413.13	100.00	13,413.13	100.00	13,413.13	100.00

Figure 2 presents the Americana's use and land cover mapping. The urban area, over the years (grey area in Figure 2), mainly in the period of 2008 to 2016, has had a growth of 10 % (Figs. 2, 3 and 4) from) from 3,818.98 ha to 4,967.20 ha. This growth has emerged as a transition from residential to commercial use with an expansion of the central area, growing around the municipality and in different directions over time according to trends of local urban growth. Industrial development increased due to urbanization.

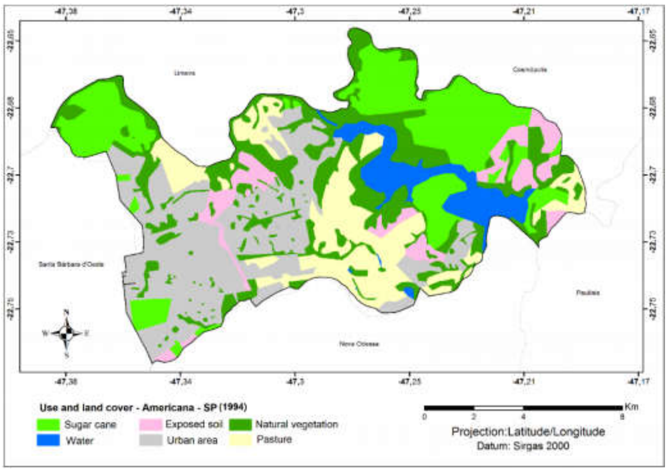

Fig. 2 Land use in 1994 to Americana-SP, Brazil

This characteristic in Americana coincides with the São Paulo state scenario, the largest producer of sugarcane in Brazil. Due to the growth of the domestic market and conditions favorable to its cultivation such as being the state with more fertile land, which allows the average productivity higher than in other regions and the fact that it has a developed sector of production assets for the sugarcane crop (Natale Netto 2007). Large industries (especially in the 1970s, 1980s, and 1990s) as a result of São Paulo's deconcentrationand the migratory flow as a result of that causing population causing population growth in several regions. As well as in Americana, due to the attractiveness of the industrial sector, especially textiles, which in turn demanded urban infrastructure (Trentin; Freitas 2010; Trentin 2008). The areas of native vegetation are fragmented, with a loss of 1.18%, representing 160.25ha. These fragments are immersed in the urban matrix and are mostly associated with water bodies. This suppression of natural vegetation is similar to studies carried out with this theme in other regions (Rudorff et al. 2010; Fisher 2008; Coelho et al. 2007; Criuscuolo et al. 2006, Trevisan et al. 2011) which also showed the expansion of anthropogenic activities, either by urban expansion or agriculture, which resulted in the fragmentation of areas of native vegetation

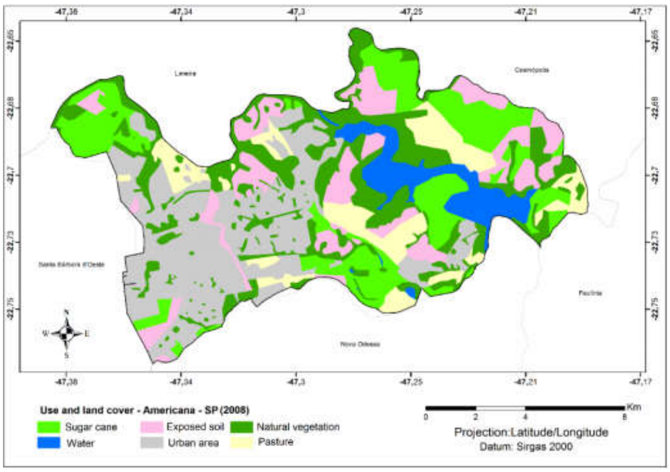

Fig. 3. Land use in 2008 to Americana-SP, Brazil

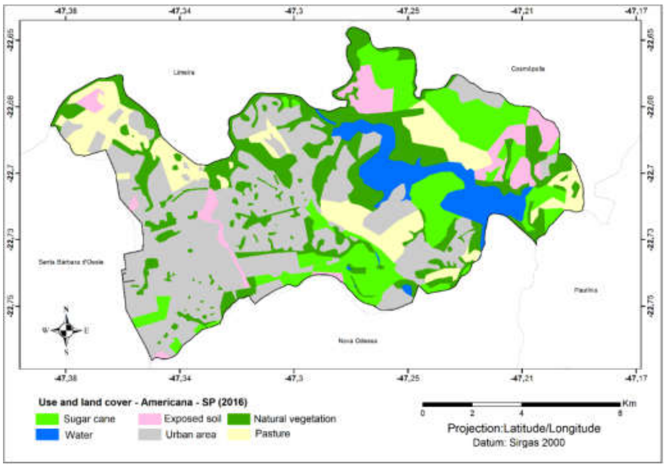

Fig 4 Land use in2016 to Americana-SP, Brazil

Studies by Mello (2014); Moschini (2005) and Cintra (2004), analyzed the phyto physiognomies of Cerrado and Seasonal Semideciduous Forest, vegetation types present in the study area. The Atlantic Forest and the Cerrado are two hotspots of biodiversity, requiring immediate intervention in the process of fragmentation of the landscape, mostly due to the advance of the agricultural frontier, more specifically by the cultivation of sugarcane, which implies severe changes. The biological patterns of the landscape and the conservation of fauna and flora present in these habitats (Moraes et al. 2013). Through the analysis of the temporal dynamics of use and land cover, theUI analysis was elaborated and the spatial distribution of the its intervals was presented in Table 3.(for 1994, 2008 and 2016). UI index values in Table 3 show continuous and increasing process of landscape alteration over these years. This is the contributing factorto the expansion of anthropic activities, mainly associated with urban areas.

Table 3. UI values from 1994, 2008 and 2016

Breaks	1994		2008		2016	
	Área (ha)	(%)	Área (ha)	(%)	Área (ha)	(%)
0.0– 0.2	0.00	0.00	0.00	0.00	0.00	0.00
0.2– 0.4	0.00	0.00	0.00	0.00	0.00	0.00
0.4– 0.6	612.33	4.60	459.91	3.40	421.82	3.10
0.6– 0.8	3,600.80	26.80	3,677.77	27.40	3,495.13	26.10
0.8– 1.0	9,200.00	68.60	9,275.45	69.20	9,496.18	70.80
TOTAL	13,413.13	100.00	13,413.13	100.00	13,413.13	100.00

According to the Brazilian Institute of Geography and Statistics - IBGE (2016) in 1994, the population of the municipality was 153,840, increased to 200,000 in 2008 and 225,183 in 2016, with a growth of approximately 146%. This implies that the population density has contributed to the growth of UI and the loss of natural landscape and is proportionally correlated to the expansion of urbanization. Figure 5, Figure 6 and Figure 7 demonstrate the UI mapping in 1994, 2008 and 2016 respectively.

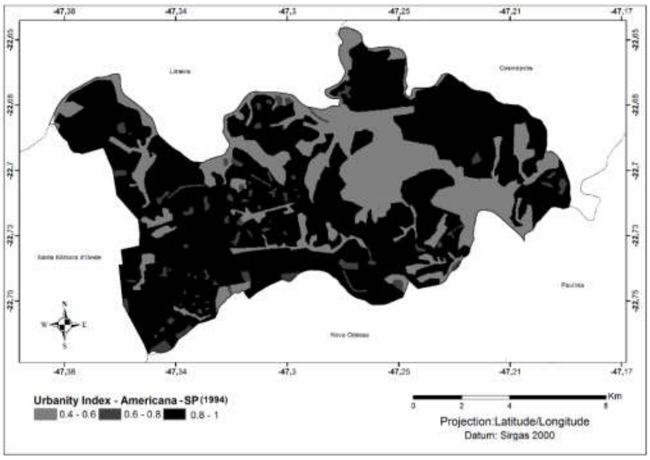

Fig. 5. UI mappingin1994 to Americana-SP, Brazil

The observation of natural landscape conditions in these figures clearly reflect the compromise of goods and services provided by the ecosystem with rapid rate of urban growth. In the three scenarios analyzed, the presence of fragments of native vegetation cannot be captured for low UI (UI = 0 to 0.2 and UI = 0.2 to 0.4). These issues arises from the lack of landscape parameters such as connectivity between the fragments, area, perimeter, shape and border.

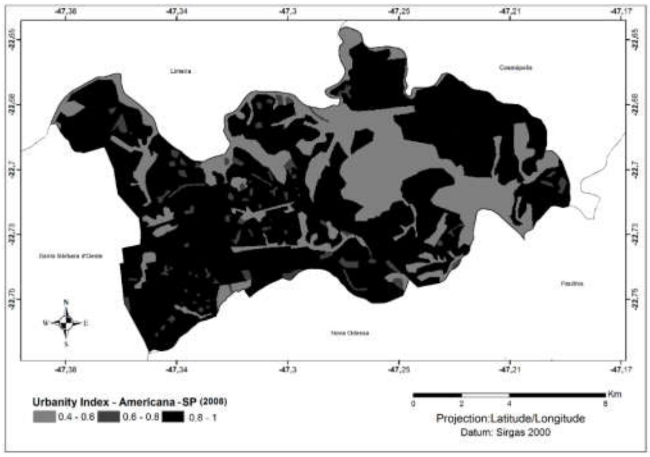

Fig.6 .UImapping in 2008 to Americana-SP, Brazil

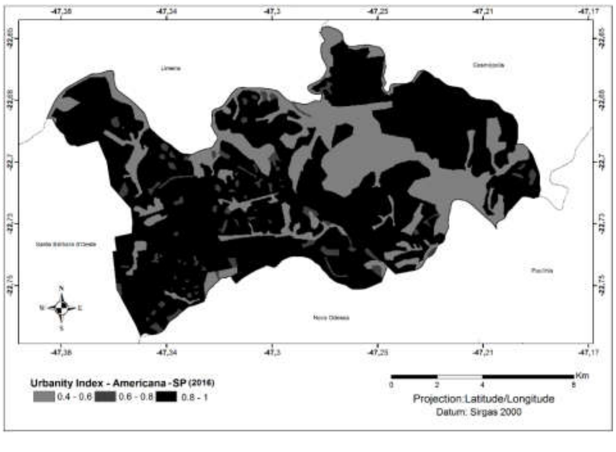

Fig. 7. UI mappingin2016 to Americana-SP, Brazil

UI values in the range of 0.4 - 0.6represents an intermediate scenario of natural landscape and onlycould be identified in regions of the municipality. These regions are associated with fragments of native vegetation that are still conserved and/or restored, but which continue to be influenced by strong pressures due to their proximity to anthropic activities and thus becoming susceptible to loss of naturalness. Also, the results indicate that most of the landscape fragments are within the intervals of UI = 0.6 to 0.8 and mainly in the interval of UI = 0.8 to 1.From an environmental perspective, this shows the native vegetation loss since 1994 andthe critical condition of municipality due to the pressures exerted by the anthropic activities causing isolation and restriction of the fragments.

In spite of this extremely fragmented landscape in small areas of native vegetation, they preserve an important role in relation to the environmental services provided by these areas, in particular, the regulation, production, and support, which are essences for maintenance and development of anthropic activities in the municipality. This scenario observed in Americana, which corresponds to the loss of the environmental quality of the landscape and consequently your naturalness, is similar but with greater impacts than the studies done by Moschini (2008), Dos Santos (2011) and Trevisan et al. (2016). These authors also evidenced the loss of areas of natural vegetation and the consequent increase of impacts on the landscapes studied, but in these regions, there are still fragments that have their natural characteristics, different from what occurs in Americana.

Corroborating with the ideas and need of development geared to urban planning and consequently focused on the conservation of natural resources, where zoning strategies are necessary for relation to the disposition of the types of use and occupation of the soil along the diverse natural landscapes. The process of the landscape urbanization in Americana has been occurring in an intense manner, necessitating urgent actions to maintain and recover areas of native vegetation, so that the ecosystem can continue to provide the services to the population, good quality of life, in addition to meeting socioeconomic needs.

Conclusion

- The Urbanity Index, when expressing the state of conservation and naturalness of the landscapes, was presented as an important tool in the landscape diagnosis aimed at the conservation of the ecosystems, allowing a precise analysis of the elements that compose the landscape.
- The growth of anthropic activities and the loss of natural areas can compromise the biodiversity present in Americana, implying the loss of environmental functions and consequently the benefits they provide.
- This concern is not only about the current condition of the municipality, but also about the trends that have solidified over the years, such as the loss of natural areas as a result of the consolidated expansion of the anthropic activities, which were evidenced in the analyses of vegetation remnants native of the municipality.
- The strengthening of participation spaces, through the mobilization of the population and its representative bodies, should be a premise of the municipal administration, for the formulation, execution and follow-up of urban development plans, programs and projects, adapting to the local reality and thus fulfilling its objectives, proposing, then, an integrated management between government and civil society.

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