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PÓS-GRADUAÇÃO DINÂMICA DOS OCEANOS E DA TERRA UFF

ASSESSMENT OF THE ENVIRONMENTAL CONDITIONS OF THE ELEMENTS OF A RURAL LANDSCAPE USING THE FREE SOFTWARE GOOGLE EARTH PRO

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ABSTRACT

The identification of vulnerabilities in a watershed is, in large part, the result of anthropic interference in rural and urban areas. Sensitivity and common sense in the joint action of the different agents of society can minimize the negative impacts of planned action on a watershed. This study aimed to determine the environmental vulnerabilities of the highest region of the Taquaritinga watershed in SP, Brazil. The research methodology was the observation of satellite images using the free software Google Earth Pro through photo-comparison of images in a sample area of 3581 ha, divided into four quadrants. The results point to the following positives as conservation measures: the presence of straw on the ground and contour lines. However, it is necessary to give special attention to the authorities to properly dispose of urban solid waste and develop projects to re-establish native flora associated with the construction of more containment basins along the access roads to rural producers, which may contribute, in the long term, to improving the flow of water resources in the basin.

Keywords: Watershed; Environmental Impact; Environmental Vulnerability.

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INTRODUCTION

In any watershed, several positive or negative actions constantly occur, which can directly influence the degree of impact to which the watershed may be subjected (Lanna, 2000; Almeida, 2010). A watershed is characterized essentially by the main watercourse, which receives the insertion of its tributaries, and that in the higher parts is bounded by a watershed; within this space occur runoff processes and sediment transport (Sousa, Martins Filho, & Matias, 2012), which impact the quality of water and may induce erosive processes, loss of agricultural productivity, reduction of permanent preservation areas, and silting of waterways (Vischi Filho *et al*., 2016).

Each watershed can be subdivided into smaller watersheds, which means that a watershed is made up of a number of smaller watersheds (Rosa *et al*., 2004). A watershed is an area topographically defined by the drainage area of a river channel or a system of connected river channels, such that all water draining into it has a single direction of outflow, information that is corroborated by the use of geotechnologies (Pereira *et al*., 2017).

The vulnerabilities of a basin are largely the result of anthropic interference in rural and urban spaces (Costa, 2018). Such interference can be aggravated by the geomorphological conditions of a given region and intensified by the characteristics of economic activities carried out by various segments of human activity, especially those that use natural resources (Candido *et al.,* 2010).

Almeida (2010) expands the concept of vulnerability and reports the existence of a very large coincidence between social vulnerability in urban environments and in regions where the population is exposed to greater risks due to factors related to urban expansion (Jatobá, 2011) and soil sealing. It also addresses that the most common risk areas to be impacted are the areas of permanent preservation (APP) in urban environments.

The environmental assessment of a region allows for the identification of its potential use (or non-use) for occupation, vulnerabilities, and the dynamics and complexity of the ecosystem, leading to actions that enable its preservation and conservation (Vischi Filho *et al.*, 2016). The determination of environmental vulnerability enables the evaluation of the risk conditions of the area in question to geoenvironmental processes such as erosion, soil contamination, water resources, and loss of agricultural use (Zonta, 2012; Vischi Filho *et al*., 2016). Through adequate planning, areas of environmental vulnerability can be avoided within the watershed, giving them uses compatible with their current state, in addition to conducting studies to identify the factors that are triggering this picture of environmental vulnerability and then seeking remediation alternatives (Cunha & Borba, 2014; Vischi Filho *et al*., 2016).

Using geotechnologies has allowed conscious studies on the environmental conditions of a watershed (Candido *et al.*, 2010). In this aspect, Candido *et al.* (2010) studied the vulnerabilities of the Uberaba river basin in MG and found that more than half of the basin area presented degrees of severity, ranging from "accentuated to severe." The presence of quite thin vegetation cover was evident in the study basin's vegetation analysis, which denotes one of the study's unique vulnerabilities, and such vulnerabilities are closely associated with negative anthropic actions, the result of soil degradation processes—data that agree with Zonta (2012) and Vischi Filho *et al.* (2016).

Using geotechnology tools allows one to identify and map the geoenvironmental characteristics and the natural and environmental vulnerabilities of a given watershed. One can mitigate the ongoing vulnerability through consistent public policies and orderly watershed management involving the various actors in society (Costa, 2018). Costa (2018) discovered in this study that previously thought to be preserved areas have allowed space for the growth of annual or perennial crops, and even short-cycle crops, so that such anthropic actions, by inappropriate soil use and conservation, have significantly changed the local landscape, which is easily observable by satellite images, even in areas near urban centers, motivated by disorganized urban expansion. This study aims to determine the environmental vulnerabilities of the uppermost region of the Taquaritinga-SP-Brazil watershed using the free software Google Earth Pro.

MATERIAL AND METHODS

The study was carried out in the region of latitude 21°22'12.94 "S and longitude 48°26'29.97 "W of the highest region of the Taquaritinga watershed, which belongs to the Tietê-Batalha Watershed Council (CBH-TB). For the study, a sample area of approximately 3581 ha was designated (**Figure 1**), made with the "line" tool in the "circle" tab of the free software Google Earth Pro (2021). From this sample area of 3581 ha, it was divided into four quadrants using the Google Earth Pro tools, according to Rodrigues, Bovério, and Ferrarezi (2020). **Figure 1** shows the main study area and the elements of Quadrant 1 in colored highlights.

The elements of the rural landscape, which are the sugarcane carriers (SC), impermeable area (IA)—represented by the asphalt grid—, area of permanent preservation (APP), construction areas (CA), woody crop areas (WC), and water table areas (WT), were quantified in the four quadrants using the "polygon" tool, which includes information on the perimeter and area of each element in each quadrant. The

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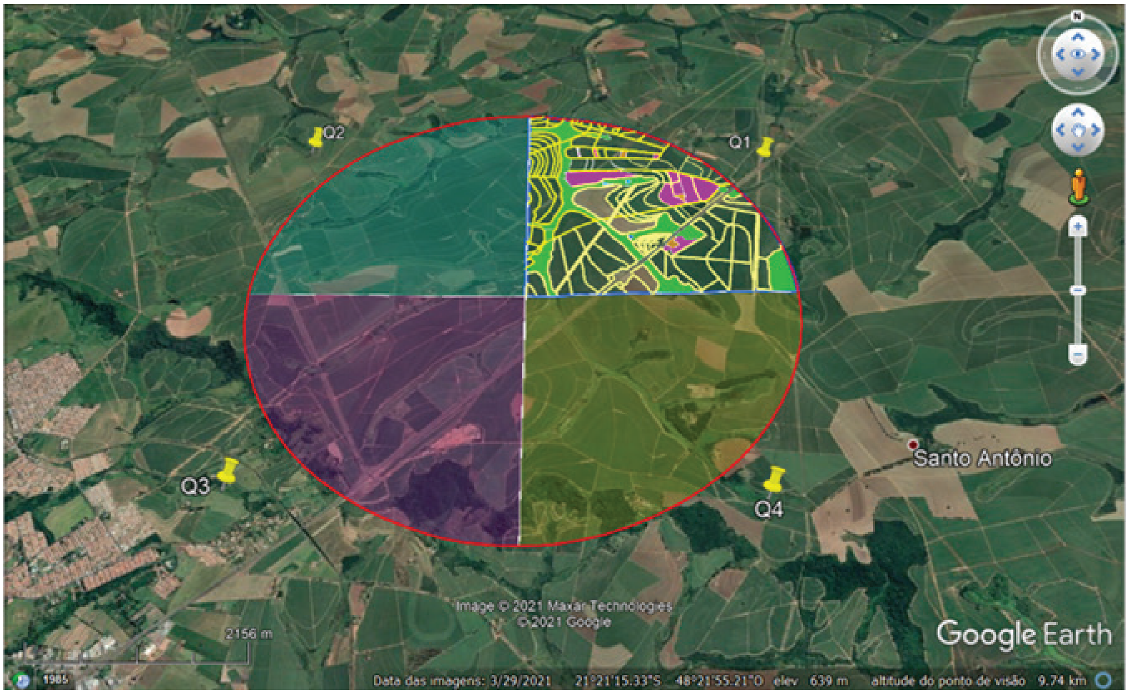

Figure 1. Sample area of the uppermost region of the Taquaritinga watershed, SP.
Source: Google Earth Pro (March 2021); Q1, Q2, Q3, and Q4: Quadrants of the sample area of 3581 ha.

measurement of semi-perennial crops (SPC) represented by sugarcane was performed by subtracting the total area of each quadrant from the landscape elements present in the respective quadrant. The "path" tool was used specifically to measure the lengths of the conveyor elements and the impervious area, which corresponds to the domain area of the paved road in the four quadrants (**Figure 2**). To calculate the area of footpaths (bare ground), the various types of footpaths in the quadrant, which vary in width, were considered. For this, ten random widths of the footpaths present in each quadrant were sampled to obtain an average width of the footpaths, and, using the total length of the footpaths multiplied by the average width of the footpaths, it was possible to estimate the probable area without soil. The asphalt areas followed the same logic. Once the lengths of all paved areas in the quadrant were determined, the area resulted from multiplying the length by the asphalt sidewalk's width.

In the Areas of Permanent Preservation (APP), Construction Areas (CA), Woody Crop Areas (WC), and Water Table Areas (WT), the perimeter and area were directly determined when using the "polygon" tool. The semi-perennial crops (SPC) represented by the sugarcane crop were determined by subtracting the total area of the quadrangle and all rural landscape elements. The construction sites were clear images of houses or masonry sheds and part of a contour, sometimes composed of pastures, sometimes composed of various fruit trees or native species, and finally, the degraded areas.

The data were organized in Excel for the data measured in hectares corresponding to the area and for the percentages of each landscape element related to the total quadrant area. For the statistical analysis of the data, the quadrants were considered blocks, and only the data repeated more than or equal to four evaluations in each quadrant were considered a treatment. In this case, only the APP areas, the carriers (paths), and the area of sugarcane crops (fields) could be statistically analyzed. The other elements could only be verified. The randomized block design with four repetitions was applied for the analysis of variance by the Fisher-Snedecor F-test. For the Scott Knott test of means, both at 11% probability, Ferreira's (2008) free software Sisvar, version 5.6, was used.

RESULTS AND DISCUSSION

The results of the analysis of variance of the landscape elements most prominent in the visualizations during the study showed that there were no significant effects regarding the size of the sugarcane fields (CSP), the length of the sugarcane tracks, and the areas of permanent preservation (APP) at the 11% probability level (**Table 1**). The test of means

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showed that there was a significant difference (P<0.11) only regarding the size of the sugarcane fields. The quantification results of the rural landscape elements that are possible to quantify or visually identify are shown in **Graph 1**. The four most expressive elements in the landscape correspond to the sugarcane crop (75%), followed by Areas of Permanent Preservation (APP = 15.1%), Woody Crops (3.1%), Carriers (CA = 3.96%), Construction Areas (CA = 1.12%), Paved Areas (impermeable) (PA = 0.76%), Institutional Areas (IA = 0.42%), and Water Blades (0.06%), for a total of 3581 ha. Since the total area of this study corresponds to 3581 ha, according to the new Forest Code, the areas destined for the Legal Reserve (LR) should correspond to approximately 20% of the quadrant area, i.e., 716.2 ha.

Due to the layout of the sample area, which included part of the hillside area of the Jaboticabal Mountains, it was not identified the existence of significant areas of legal reserve (LR) in the four quadrants, occurring in part in the southern region of quadrants 3 and 4. Observing the study area, it appears that the areas of sufficient environmental fragility correspond to the areas surrounding the controlled landfill in quadrant 3 (**Figure 3**), which has significant potential for groundwater contamination (Gouveia & Prado, 2010; Giacomazzo & Almeida, 2020) in the short term and more in the long term of the Bauru aquifer due to leachate percolation.

Graph 1. Rural landscape elements in the uppermost region of the Taquaritinga Watershed

Legend: Paved Areas; Woody crops; Carriers; Sugarcane areas; Institutional areas; APP areas; Degraded areas; Water bodies; Construction areas; Total area

Source: Google Earth Pro (May 2021)

It is also noted that the impermeable area is present in the four quadrants, represented by the asphalt of two highways, one that connects Taquaritinga to Jaboticabal, SP, and another that connects Taquaritinga to Monte Alto, SP. The edges of the highway connecting Taquaritinga to Jaboticabal are formed by a double lane and endowed with proper slope conservation and internal channels for rainwater runoff between the two lanes. It is easily visible that stormwater containment basins (**Figure 4**) were constructed at the edges of one of the lanes, which is a positive measure of water resource conservation. The study area is still well endowed with contour lines and the presence of straw on the soil due

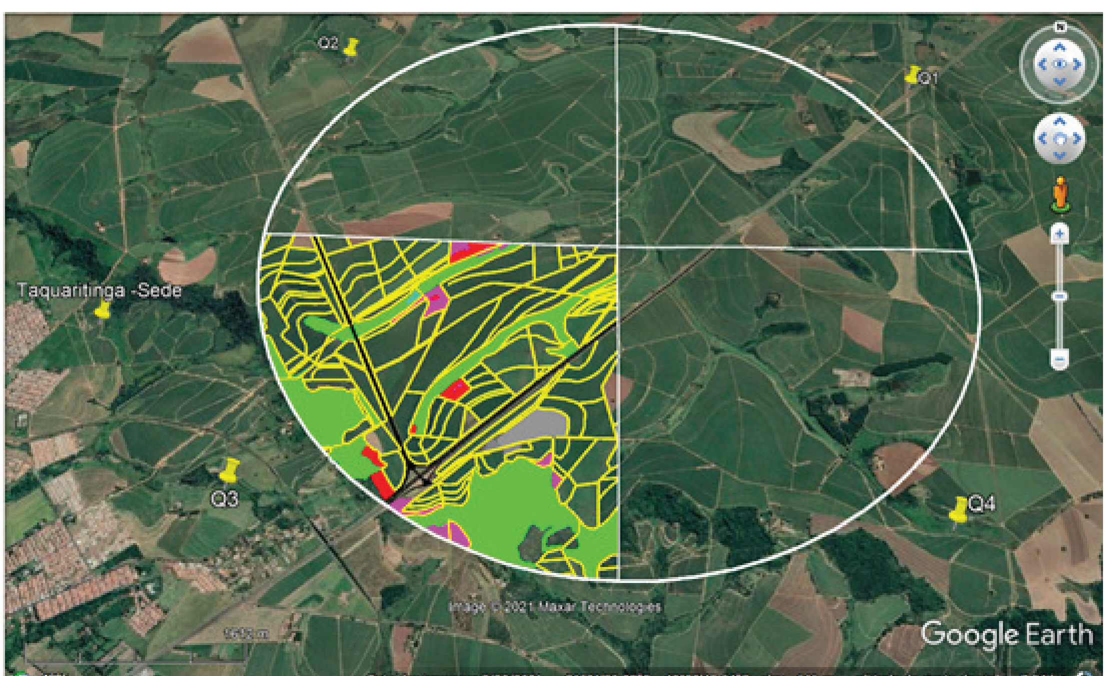

Figure 2. Sample area of the uppermost region of the Taquaritinga watershed, SP (Quadrant 3), highlighting the main landscape elements: Areas of Permanent Preservation (APP, light green), Areas of Woody Crops (pink), Areas of Rural Construction (red), Carriers (yellow), Institutional Area (gray), Impervious Area (black), and Areas of Sugarcane Cultivation (dark green).
Source: Google Earth Pro (May 2021).

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Table 1. Summary of the analysis of variance of the plot size effects, length of tracks, and size of Permanent Preservation Areas of the sample area of the uppermost region of the Taquaritinga watershed, SP

Analysis of variance concerning size among sugarcane fields					
FV	GL	QM	Fc	Pr > Fc	
Treatment	3	105.601	2.776	0.103*	
Residue	3	47.959	1.261	0.345	
Residue	9	38.04			
CV (%)	Testing the means of the sugarcane fields				General Average
32.55	Q1**	Q2	Q3	Q4	18.95 ha
	14.06b	19.55b	16.30b	25.ª7a	
Analysis of variance of the length of sugarcane carriers					
FV	GL	QM	Fc	Pr > Fc	
Treatment	3	0.295	0.343	0.79ns	
Residue	3	2.394	2.776	0.10	
Residue	9	2.587			
CV (%)	Test of means of the sugarcane carriers				General Average
40.71	Q1**	Q2	Q3	Q4	1.31 km
	1.ª8a	1.ª9a	1.ª8a	1.º0a	
Analysis of variance referring to the Areas of Permanent Preservation					
FV	GL	QM	Fc	Pr > Fc	
Treatment	3	151.08	0.548	0.661ns	
Residue	3	2234.60	8.110	0.006	
CV (%)	Test of Means of the Areas of Permanent Preservation				General Average
50.33	Q1**	Q2	Q3	Q4	32.98ha
	24.ª2a	33.ª5a	36.º0a	37.ª5a	

*It indicates that the test was significant at the 11% probability level; ns: indicates that the test was not significant.
**Similar lower case letters in the same row indicate that the test was not significant at the 11% probability level.

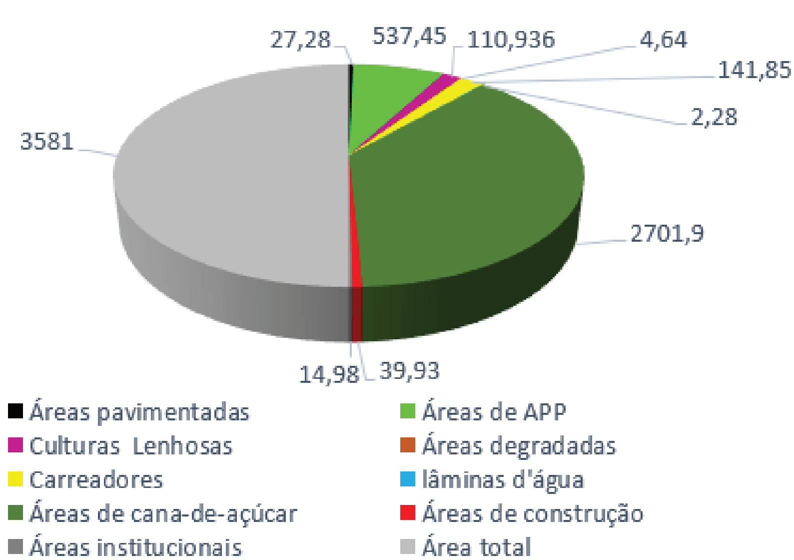

Gráfico 1. Elementos da paisagem rural na região mais alta da Bacia hidrográfica de Taquaritinga
Fonte: Google Earth Pro (maio de 2021)

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Figure 3. The highlight of the main landscape elements in quadrant 3 (larger red outline) represents the controlled landfill in Taquaritinga, SP. In a smaller red outline are the stormwater containment basins.

Legend: Containment Basins; Controlled Landfill.
Source: Google Earth Pro (May 2021)

to the mechanized sugarcane harvest, mainly in quadrants 3 and 4, which is a highly recommended practice that can mitigate the eventual degree of erodibility of a given region or even prevent erosivity by rainfall, which can place the watershed in a state of environmental fragility (Santiago *et al*., 2019). In this study, the straw shown by the satellite images can infer that the presence of straw on the soil exerts a positive aspect to mitigate eventual losses of soil and organic matter, contributing to the sustainability of the agricultural production system (Sousa, Martins Filho, & Matias, 2012).

In the APPs of the studied area, it is noted that the existence of artificial and natural water slides is rare. Such landscape elements have their natural ecosystem conservation function, as they enrich habitats that wild animals can better exploit for watering, but their margins and interiors present grass contamination. In addition, it is perfectly observable that there are native plants, but they are very sparse, which denotes a source of food and shelter for wild animals in precarious conditions. Such vulnerabilities are in agreement with the vulnerabilities of a watershed reported by Candido *et al*. (2010) in the region of Uberaba, MG, and in the studies of Almeida (2010).

The factors triggering environmental vulnerability in the studied basin may be reversed in the medium and long term by seeking remediation alternatives (Cunha, Ritter, & Borba, 2014). According to Costa (2018), through consistent public policies and the orderly management of watersheds, the ongoing vulnerability process can be mitigated, provided that several agents are involved (Castro, 2012), including farmers, public extension agents or not, members of the watershed committee, the municipal government, and the sugar and ethanol segments operating in the watershed. As a result, using geotechnologies becomes increasingly important to respond to the ever-increasing and diverse demands of public policies with greater speed and quality (Guia *et al*., 2016).

The soil and water conservation management practices cited by Tucci (2005), if implemented in a given watershed, would allow positive changes in the landscape and positively influence the yield of agricultural activities. Satellite images can prove different landscape changes through photocomparison, a fully possible methodology for monitoring and even agro-environmental rehabilitation for managing micro-basins (Vichi Filho *et al*., 2016).

CONCLUSION

The main vulnerabilities detected in the region under study are environmental protection and the legal reserve, which disagree with the legislation. The permanent pres-

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Figure 4. The highlighted landscape element in quadrant 4 (red outline) represents a single degraded area in the sample.
Source: Google Earth Pro (May 2021)

ervation areas feature contamination with diverse forage grasses; there are few native woody plants, and the surface water courses are not apparent. The study area also risks contamination of the water table and the Bauru aquifer due to a controlled landfill. The excessive clipping of the sugarcane areas divided by pathways results in a considerable area of bare soil. The area in question presents the presence of straw on the ground, contour lines, and containment basins as positive points but few as conservation measures. However, the area under study indicates a need to develop projects for re-establishing native plants associated with constructing more containment basins, which can contribute, in the long term, to improving the flow of water resources in the basin.

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