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Morphometric Evaluation of the Santana River Basin in Itapuranga, Goiás (Brazil)

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SUMMARY

In view of the importance of morphometric studies for the planning and management of watersheds, this study aimed to carry out the morphometric assessment of the Santana River Basin, located in the municipality of Itapuranga, Goiás. The study area was chosen due to the basin is extremely important for the region, as it is responsible for the irrigation of large areas of cultivation. This fact led to the realization of this study, in order to be able to contribute to the planning and management of the hydrographic basin. The methodology consisted of eight steps, using ArcGis 9.2 software. The results showed the hierarchy of drainage channels in the Santana River basin in four orders. The slope mapping in conjunction with the hypsometric mapping showed areas of steep slopes and interfluves that appear as flattened tops, with considerable elevation. The valley bottoms are at an elevation of 540 to 570 meters. The unevenness of the hydrographic basin was 360 meters, 540 meters at the lowest point and 900 meters from the highest point. The Santana River basin can be fragmented into three distinct landscape units: hills, alluvial plains and top areas. Thus, this study showed basic characteristics of the physical environment that can enable, and support studies aimed at the planning and management of that basin, helping to reduce and mitigate the socioeconomic impacts on water sources.

KEYWORDS: Geoprocessing. Hydrographic basin. Morphometry.

1 INTRODUCTION

The hydrographic basin stands out in the National Water Resources Policy, being a conformity of the management studies, as the adequate planning unit (BRASIL, 1997). The hydrographic basin is understood as the portion of the area that is drained by a watercourse in such a way that all flows of its tributaries are discharged in a single outlet (PANACHUKI, 2003).

With the technological development of Geoprocessing, Geographic Information Systems (GIS) and Digital Elevation Models (DEM), there were significant contributions to the performance of studies in hydrographic basins, as they increased the ease of obtaining and confidence in the results (COELHO, 2014). From that, it became possible to improve the morphometric survey. This survey consists of characterizing a certain area (watershed), through indexes and maps, attributing meaning to the landscape. The data obtained help to analyze the physical environment in different aspects. Among them, it is possible to mention drainage hierarchy, basin shape, region hypsometry, among others. Such analyzes have been presented as important allies in the planning and management of hydrographic basins, as (re)knowing the physical aspects makes it possible to identify, manage and predict processes that affect and/or may affect existing physical and socioeconomic dynamics.

Thus, based on the importance of morphometric studies for the planning and management of hydrographic basins, this study aimed to carry out the morphometric assessment of the Santana River Basin, located in the municipality of Itapuranga, Goiás. This basin is extremely important for the region, as it is responsible for the irrigation of extensive areas of cultivation. This fact led to the realization of this study, in the sense of being able to contribute to the planning and management of the hydrographic basin.

2 LANDSCAPE METRICS APPLIED TO WATER BASIN STUDIES

At the beginning of the 21st century, there were major water crises that threatened humanity and the survival of the entire biosphere. Such crises create obstacles to development, such as: the increase in waterborne diseases and water scarcity, which produce social and economic effects, generating inequality between regions and countries. It is known that water is a strategic resource for the entire population. Water resources "[...] are essential and influence the processes that operate on the Earth's surface, including the development and maintenance of life." (WADT, 2011, p. 19).

With the rapid growth of urban areas and agroforestry activities, there are major environmental impacts, including the hydrological cycle, changing the availability and quality of water resources, generating direct and indirect effects on society. Changes in drainage and changes in the environment cause problems such as: landslides and floods that are caused by hydrological imbalance, where the flow component becomes more intense than the infiltration component (WADT, 2011). In this sense, recognizing the aspects of a given hydrographic basin has become essential in the management of water resources, in which morphometric assessment stands out.

Morphometric parameters play the role of characterizing a given watershed. Surveying morphometric parameters allows identifying areas that present greater environmental vulnerability, that is, those that are more susceptible to the occurrence of processes related to soil erosion and floods, for example, and this allows to guide the more rational and less impactful use to be developed (MILK; ROSE, 2007). Morphometric analyzes can identify geomorphological processes, hydrographic network, perimeter, river hierarchy, extension, among others.

Morphometric analyzes reveal the geomorphological processes that are physical indicators of the basin. These morphometric analyzes of basins are differentiated into linear, real, hypsometric and topological analysis. This means that the metrics are mathematical models of the watershed surface. For example, hypsometry is the joining of all points on the ground at the same altitude in relation to sea level, forming isolines of the altimetric dimensions.

The hydrographic network assumes the entire drainage of a basin that places it on a sample in fluvial channel arrangements reflecting on a geological structure and on the morphogenetic evolution of a given region. The area of a basin can be identified as a drainage area corresponding to the area of contribution in sets of river areas. This area can be a basic element to calculate physical characteristics, in horizontal projections which are included in topographic dividers.

The perimeter (P) of a hydrographic basin is the delimitation of the watersheds. These dividers are responsible for dividing rainfall between different basins. In many cases, these dividers arise from an intercity and interstate limitation, which can be marked as aerial references and plan altimetric charts. The fluvial hierarchy, on the other hand, is a process that establishes and classifies a particular watercourse, or drained areas, belonging to a hydrographic basin. This is done to facilitate and make morphometric studies of hydrographic basins more objective.

The measurement of the length of a river can be done by curvimeter or by geoprocessing techniques. The main river is the one that drains a larger area inside a hydrographic basin, it can be called the collector of all its tributaries. The density of a drainage informs the length of river channels being available to drain each unit of each basin area and informs if there is availability of surface water runoff (SANTOS ,2004). Drainage density is important to portray relief and sediment removal capacity. Although it does not directly portray slopes and erosion processes, it is estimated that their susceptibility is related, the greater the drainage density, the more developed the channel networks will be, therefore, the greater the output of sediments from the basin.

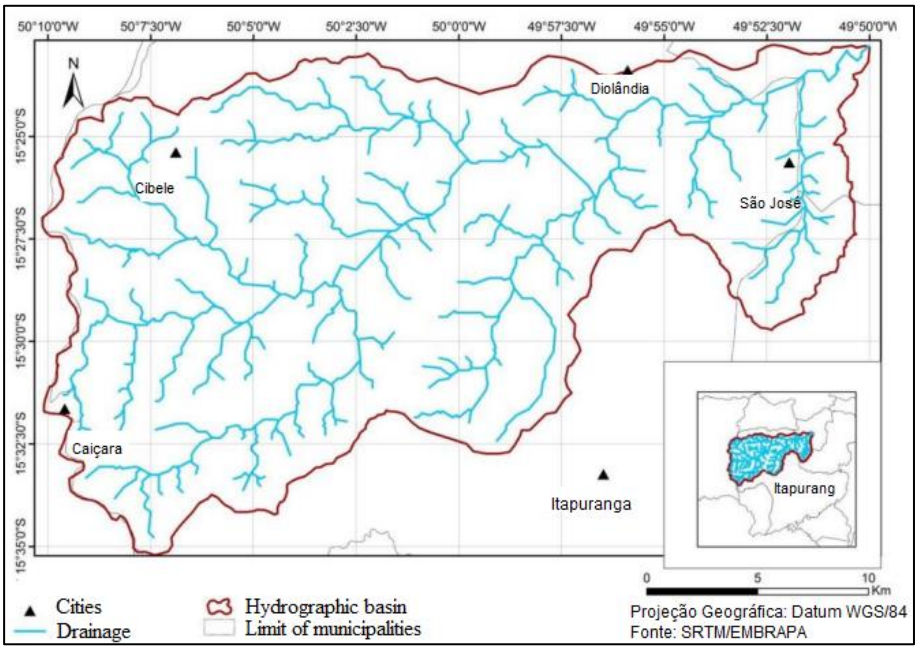
In general, the hydrographic basins of large rivers are shaped like a fan or a pear fruit. The smaller ones, on the other hand, vary a lot in their format, this is because it depends on several factors, mainly on the geological structures of each terrain. The infiltration process, in many cases, establishes a water balance in the root zone, being responsible for the phenomenon of erosion at a certain point in rainfall. The analysis of water infiltration in the soil can be done by simple methods to represent the conditions in which the soil is found. Precipitation and runoff affect the detachment of differentiated particles that influence erosion.

The surface runoff begins when a large proportion of precipitation increases the infiltration of water into the soil, or when the capacity for surface water accumulation is exceeded.

3. ENVIRONMENTAL CHARACTERIZATION OF THE SANTANA RIVER BASIN

The Santana River Basin (figure 1) is located in the municipality of Itapuranga, Microregion of Ceres, in the northern portion of the state of Goiás (Brazil). It is an important source that supplies four districts – Caiçara, Cibele, Diolândia, São José. Furthermore, it is used to capture water for irrigation of extensive agricultural areas.

Figure 1: Location of the Santana River Hydrographic Basin



Source: Reis, 2017.

The Santana River Basin area comprises the paleo-mesoheoproterozoic geological framework. The region is located in the Brasilia folding band. The geological structure of Central Brazil is largely inherited from the Brazilian orogeny, which established a network of folding bands separated by cratons. The bands correspond to Mesoproterozoic and Neoproterozoic sedimentary basins that have experienced tectonic inversion processes, while the cratons are stable areas, not affected by the Brazilian orogenetic processes. The Brasília Belt comprises a belt of Neoproterozoic folds that occur on the western edge of the São Francisco Craton, covering parts of the States of Tocantins, Goiás and Minas Gerais. (SCHIAVETTI; CAMARGO, 2002).

In the Santana River basin, it is possible to find a mixture of metamorphic rocks (quartzite) with sedimentary ones (sandstones). The soils find and present an abundance of primary minerals (quartz) from the serra da mesa/dorada group. The table saw is presented by marine continuations mixed by sediments applied to a marine platform. “[...] The serra da mesa group presents metamorphism in the amphibolite facies and tight to asymmetric folding[...]” (MARQUES, 2009, p. 2).

The hydrographic basin is inserted in the morphoclimatic domain of the Cerrados, characterized by the occurrence of savanna, forest and countryside formations (COUTINHO, 2006). According to Ab’Saber (2003), it is characterized as a mosaic of various types of plant formations, climate, topography and a great diversity of soils.

The climate is tropical savannah, with dry winter (Aw), with strong influence from the South Atlantic Convergence Zone (ZCAS), characterized by the large amount of moisture transported from the ocean to the interior of this region - from east to west - from the coast. Other events that directly influence the climate of the region are the occurrence of the so-called Intertropical Convergence Zone (Amazon convection), originating in the northern portion of the country, and the Upper Bolivia, originating in the West, forming a continuous band of nebulosity in the northwest- southeast, which extends from the Amazon region to the South Atlantic, where large blocks are formed, with long periods occurring with high rainfall (SILVA et al., 2008).

4 METHODOLOGY

The methodological procedures were carried out according to the eight steps mentioned below:

i) Drainage extraction using SRTM: All procedures were performed using ArcGis 9.2 software. The SRTM image was added, then transformed to GRID format. Then, the next step was too open Arc Toolbox and proceed to the path Spatial Analyst Tools > Hydrology > Fill. The next step was to generate a raster with the flow direction. In Arc Toolbox followed the destination Spatial Analyst Tools > Hydrology > Flow Direction > Flow Accumulation. Then the Input Flow direction raster was applied. Then, the image generated from the processing of Flow direction > Conditional was added. The formula value > 100 was used for Expression.

ii) Transformation of drainage from raster format to shapefile: The next step was to generate the shapefile of the drainages. In Arc Toolbox we placed Spatial Analyst Tools >Hydrology > Stream to Feature. In Input stream raster, the file with the one generated in the previous step was placed. In Input Flow direction raster, the volume direction file was inserted. In Output polyline features, the generated shapefile was named.

iii) Delimitation of the watershed using the SRTM: The next step to determine the watershed is from a collection or point. For this, a point shapefile was created and added to

ArcGis, placed in the shapefile editing (point) and choosing the location to determine the basin. Then followed the steps Spatial Analyst Tools > Hydrology > Watershed.

iv) Extraction of contour curves, slope and hypsometry: The contour curves were extracted from a Digital Elevation Model (DEM). For this, the triangular grid was created, interpolation every 5 meters was performed for the study area.

v) Hydrographic basin compactness index: The compactness coefficient (Kc) is the relationship between the basin's perimeter and the perimeter of a circle with the same area as the basin. The following equation was used: $c = 0.8\, P/\sqrt{A}$. The Kc is always a value > 1. The smaller the Kc (closer to unity), the more circular the basin, the smaller the Tc and the greater the tendency for there to be flood peaks.

vi) Watershed shape index: To obtain the shape index of the watershed, the following equation was used: $Ff = A/L^2$, where: Ff is the shape factor; A is the basin area in km²; and La is the axial length of the basin in km.

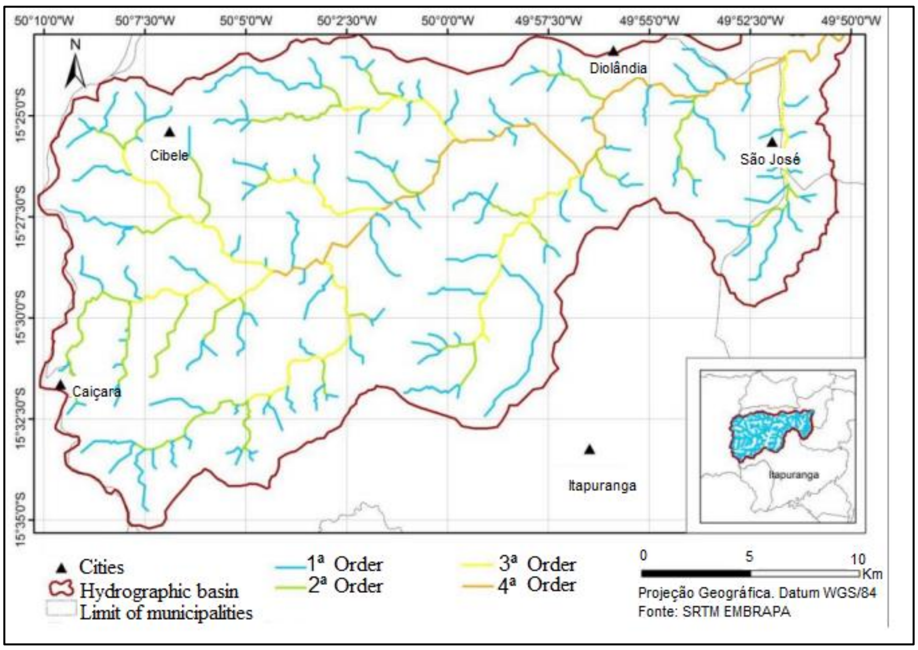
vii) Hierarchy of drainage channels: The method of STRAHLER (1952) was used.

viii) Field performance, in August 2020, to identify the analyzes carried out in the landscape, mainly the existing landscape units.

5 MORPHOMETRY OF THE RIVER SANTANA HYDROGRAPHIC BASIN

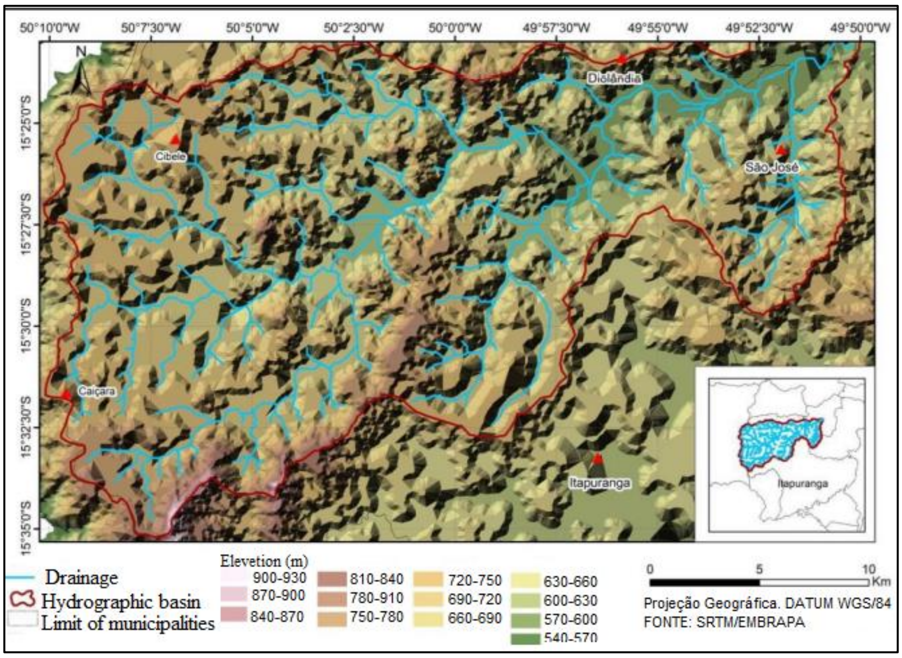
From the analysis of the hierarchy of drainage channels in the Santana River Basin, channels of lower order (1st and 2nd order) and higher channels (3rd and 4th order) were identified, with the basin showing maximum hierarchy. 4th order level (figure 2). The drainage pattern of the basin showed the relationship between the availability of sediments and the relief dissection, being a consequence of the hypsometry and the slope of the area (figures 3 and 4, respectively).

Figure 2: Hierarchy of drainage channels in the Santana River Basin



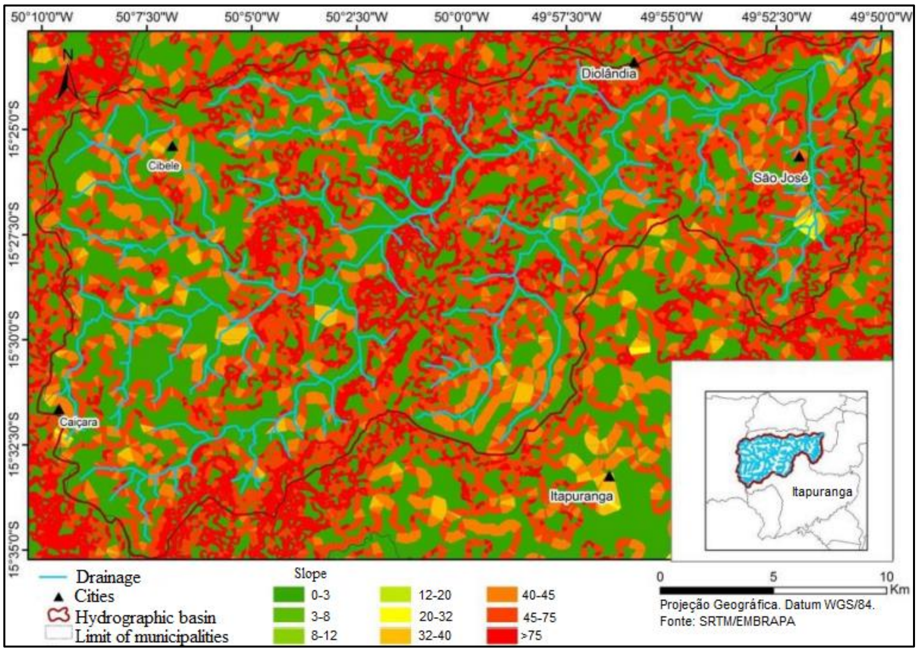
Source: Reis, 2017.

Figure 3: Hypsometric map of the Santana River Basin



Source: Reis, 2017.

Figure 4: Slope map of the Santana River Basin



Source: Reis, 2017.

The hypsometric mapping together with the slope mapping showed areas of accentuated slopes. The interfluves appear as flattened tops, with considerable elevation. The valley bottoms are found at an elevation of 540 to 570 meters. The difference in elevation in the basin was equal to 360 meters - 540 from the lowest point and 900 from the highest point.

Tables 1 and 2 show the metrics obtained from the Santana River basin.

Table 1: Metrics of the Santana River Basin

Data obtained	Results in the basin
Perimeter	89,2 km
Drainage area	118,98 km²
Bowl axis	40,3 km
Length of main channel	48,8 km
Form factor	2,291
Compactness index	0,002
Number of channels	148
Number of springs	111
Order of the basin	4ª

Source: Authors, 2017.

Table 2: Metrics of drainage channels in the Santana River Basin

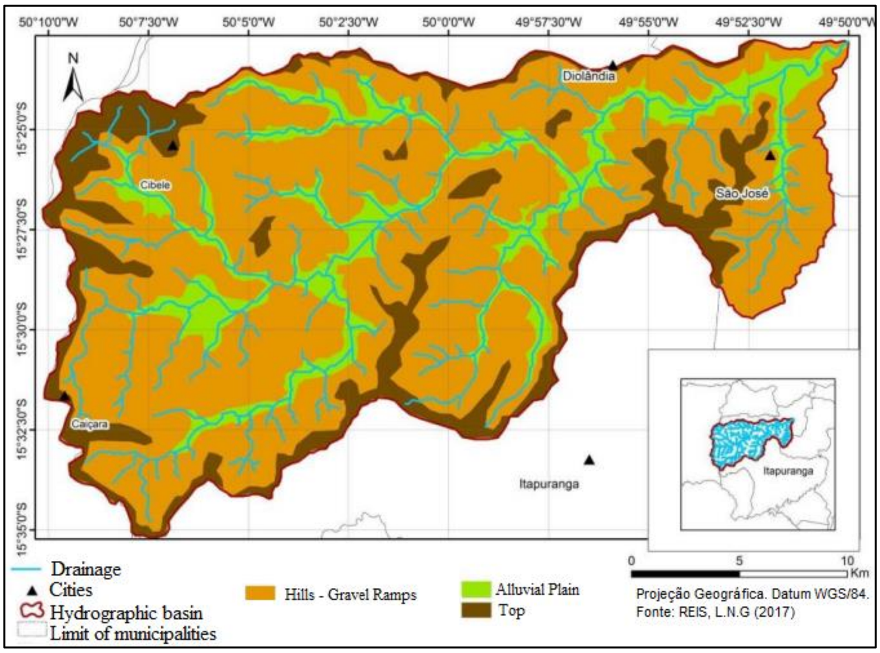
Ordem dos canais	Número de canais	Extensão (em Km)
1ª	111	102,6
2ª	29	52,7
3ª	7	32,1
4ª	1	17,6

Source: Authors, 2017.

The shape factor of the basin presented a value of 2.29, that is, it is explained by the elongation characteristic of the drainage. Values close to 1.0 show the circularity of the basin. This index revealed that the basin presents little risk of flash flooding during the flood period. The drainage density of the Santana River basin presented a value close to 0.58, indicating that the area presents good drainage per km², also indicating an intense dissection process and a good infiltration capacity of the soils in the study area. Regarding the number and extension of the channels, we have that the majority is composed of first order channels, which implies that the drainage network is formed by 111 springs that form a dendritic drainage system.

Figure 5 shows a proposal for segmenting the Santana River basin into Landscape Units.

Figure 5: Landscape units for the Santana River Basin



Source: Reis, 2017.

The top relief areas in the Santana River basin show a relief with low slope (flat relief), with the predominant use of pasture, with some remnants of Cerrado, as can be seen in figure 6.

Figure 6: Top areas, with predominance of pastures in the Santana River Watershed

Source: Sousa, 2018.

In the field, it was also possible to observe the low variation in the slope in contrast to the embedding of the drainage, the carving of channels, called ravines that formed the tributaries, sources of tributaries of the Santana River. In this unit of the landscape, the management of prepared soils for the crop was also observed, as shown in Figure 7.

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Figure 7: Soil preparation for planting off-season corn in the Santana River Basin

Source: Sousa, 2018.

In the landscape unit where the relief is gently undulating, the headwaters of the drainages were observed. It was also possible to observe the marshy areas, that is, the presence of Glei soils and the formation of paths (figure 8).

Figure 8: Concave slopes, with smooth slopes, gently undulating relief in the Santana River Basin

Source: Sousa, 2018.

Where the slope is greater, areas have been used for pasture. In the field, the presence of Taboa (Typha domingensis), an exotic species to the region, was observed. In the alluvial plain landscape unit formed by the Santana River, sedimentation areas were observed.

6 CONSIDERATIONS

As the Santana River Hydrographic Basin is important for the municipality of Itapuranga, as pointed out throughout the text, this study showed basic characteristics of the physical environment that can enable, and support studies aimed at the planning and management of that basin. Thus, studies like this can help to reduce and mitigate socioeconomic impacts on water sources.

The morphometric analysis of the Santana River basin showed that it can be divided into three distinct landscape units with distinct dynamics and processes. However, due to the lack of a more detailed cartographic base, further studies with this focus are necessary, so that the inferences of landscape metrics can assume values closer to reality.

Thus, it is argued that the techniques of Geographic Information Systems (GIS) and Digital Elevation Models (DEM) were of great contribution to the development of primary studies of the base of the physical environment for the Santana River Basin. From that, it was possible to carry out the landscape metrics, through morphometric mapping. Such analysis can be replicated in other basins, thus contributing to the planning and management of water resources.

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