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# Morphometric Study of the Jacuí River Watershed in João Monlevade (MG): A Geographic Perspective

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## ABSTRACT

Knowledge of the characteristics of a watershed is fundamental to understanding the environmental dynamics of this planning unit. In this sense, the objective of this work was to characterize the morphometric aspects of the Córrego Jacuí watershed, located in the municipality of João Monlevade (MG), since this characterization makes it possible to understand the hydrological behaviour of the watershed and provide subsidies for its management. The bibliographic survey showed that there are no morphometric studies available for the watershed studied. Considering the increasing urbanization of the basin, these first studies are important to understand its dynamics. The study was carried out using the Shuttle Radar Topographic Mission (SRTM) image with a resolution of 30 m and the digital elevation model (DEM) generated from it. The geoprocessing of the watershed information was carried out using tools from the free software Quantum Gis (QGIS). The morphometric parameters determined for the studied basin were area, perimeter, total length of tributary channels, compactness coefficient ( $K_c$ ), shape factor ( $K_f$ ), drainage density ( $D_d$ ) and circularity index ( $I_c$ ). The results indicate that the basin has an elongated shape, with moderately developed dendritic drainage and a low to moderate propensity to flood under average annual rainfall conditions. It should be noted, however, that land use and occupation activity that interferes with the main channel can alter this trend by silting up the watercourse, making flooding more frequent than the morphometric characteristics of the watershed indicate.

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*Keywords:* Watershed; morphometry; geoprocessing, urbanization

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## 1. INTRODUCTION

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According to Federal Law No. 9.433 of January 8, 1997 [1], river basins are considered territorial planning units and play important territorial roles as they constitute basic landscape units, as highlighted by [2]. Studies involving this unit can be developed taking into account physical, environmental, economic and population aspects related to land use and occupation, as well as the management of water resources in the basin, such as [3], [4] and [5].

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The characteristics of a watershed, according to [6] and [7], depend on factors that are interrelated with climate, geology and the environment, and whose interaction promotes different combinations that result in watersheds of different origins and physical conditions. These factors also act on different scales, since a watershed can vary in size from a few hectares to millions of square kilometers.

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The hydrological behaviour of a basin and the runoff depends, among other factors, on the physical characteristics, especially those associated with the relief, shape and drainage network, according to [8], [9], [10], [11], [12], [13] and [14].

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[15] point out that in systemic studies of a basin, there are two approaches to analysis: the fractal relationships in the geometry of the network and the dimensions of the river system. These interactions of geomorphological and hydrological processes are dealt

31 with in four (04) dimensions: 1) the longitudinal, which comprises upstream-downstream and  
32 tributary-stem relationships, 2) the lateral, which deals with slope-channel and channel-plain  
33 relationships, 3) the vertical, which includes flood levels and surface-subsurface interactions,  
34 and 4) the temporal, which comprises magnitude, frequency and synchronism of water and  
35 sediment movement, disturbance regimes and patterns resulting from disturbances, with the  
36 morphometric characterization carried out here falling within dimension one.

37 According to [16], [17]and [18], the longitudinal analysis of the basin's morphometry  
38 represents the upstream-downstream and tributary-trunk relationships of the basin chosen  
39 for analysis and it makes it possible to verify the correlations between descriptive  
40 parameters of this basin and their correlation with surface hydrological behaviour.

41 These parameters include area and perimeter, shape, altimetric amplitude, total  
42 stream length, total channel length, number of rivers, drainage density, river density,  
43 bifurcation ratio, dissection index and roughness index ([19], [17]).

44 This analysis is currently easily carried out using technologies since obtaining  
45 morphometric properties using GIS is faster than traditional treatments and manual  
46 evaluation of topographic maps. It even allows analysis to be incorporated over a given  
47 period, as highlighted by the works of [20], [21], [22], [5], [23], [24], [25] and [26], among  
48 others.

49 Considering the importance of knowing the characteristics of river basins to  
50 understand their hydrological behaviour, especially in an urban environment, where  
51 anthropogenic action rapidly modifies the environment, this work aimed to characterize the  
52 JacuíRiverWatershed through its morphometric parameters, also as a subsidy for future  
53 hydrological and environmental analyses, since knowledge of the basin's physical  
54 characteristics is the starting point for its planning and occupation.

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## 56 2. MATERIAL AND METHODS

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### 58 2.1 Characterization of the study area

59 The municipality of João Monlevade, located in the central-eastern region of the  
60 state of Minas Gerais, has an area of 99.158 km<sup>2</sup> [27] and belongs to the Doce River basin.  
61 The sub-basins draining the municipality are the Santa Bárbara, Carneirinhos and  
62 JacuíRivers, according to [28].

63 The study looked at the JacuíRiverwatershed, which covers an area of 28.82 km<sup>2</sup>  
64 and encompasses 23% (twenty-three percent) of the municipality's urban population. The  
65 basin's location in the municipality can be seen in Figure 1.

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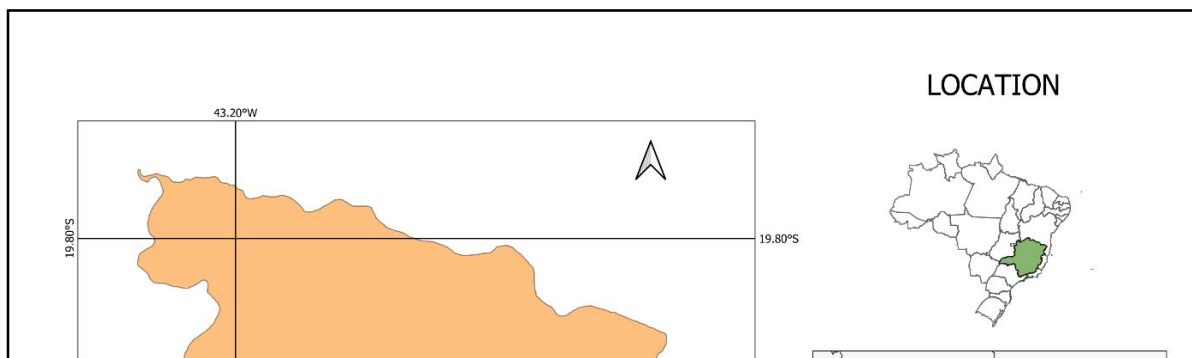
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77 Figure 1- Location map of the region where the municipality of João Monlevade (MG) is  
78 located and the study basin

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93 Source: Author (2023)

94 The municipality's natural vegetation cover consists of Atlantic Forest[29], but this  
95 has been partially replaced by urban occupation and pasture.

96 As for the physical aspects, the municipality has a relief formed by high hills and mountain  
97 ranges and secondarily by hills and low hills, according to [30] and the soils are mainly  
98 represented by dystrophic red latosols, according to [31].

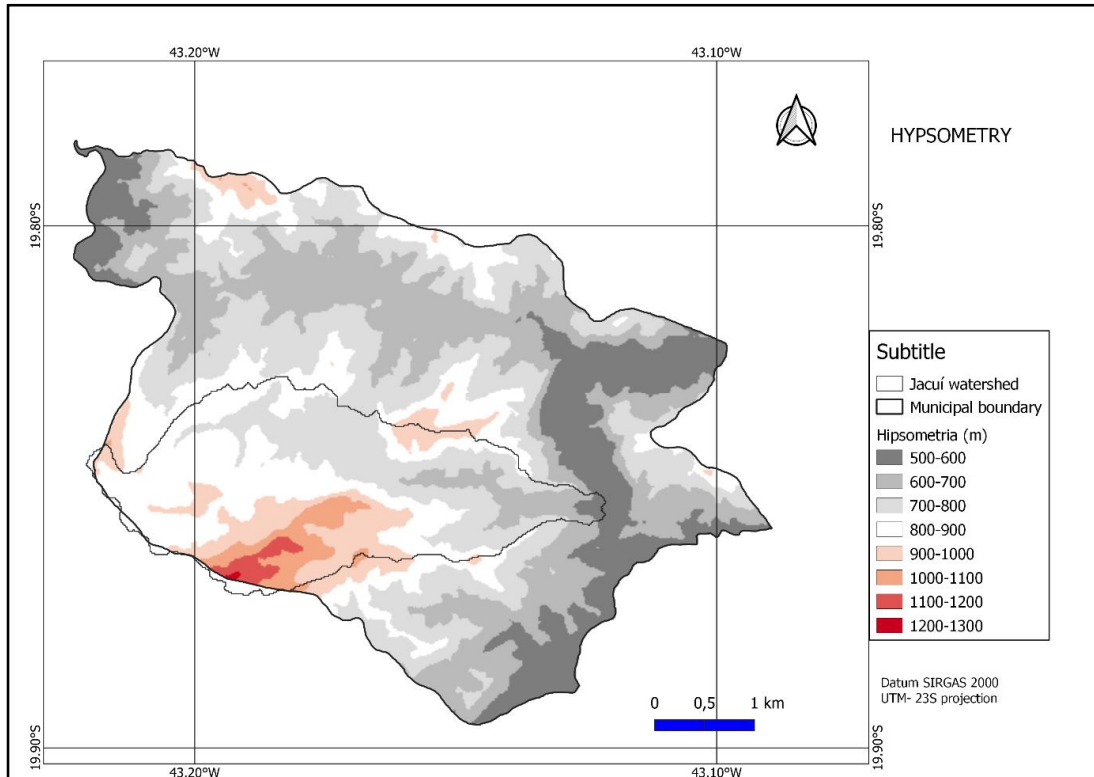
99 The general geology is mainly made up of metagranites and metasyenogranites of  
100 alkaline affiliation, late to post-collisional and fine to oriented biotite granites with associated  
101 pegmatites, from the Borrachudos Suite with ages of 1.7 Ga, according to [32].

102 The municipality's climate is classified as Am (humid or sub-humid tropical climate)  
103 according to Köppen-Geiger, with an annual rainfall of around 1400 mm and two well-  
104 defined seasons, with a dry winter and minimum, maximum and average temperatures of  
105 16.7oC, 26.5oC and 20.7°C respectively ([29], [33]).

106 The hypsometric map (Figure 2) was made from a raster layer of the digital elevation  
107 model of the SRTM image and then rendered using a color scale that represents the  
108 variation in altitude in the area, ranging from 800m to 1300m, showing that the relief of the  
109 basin is made up of hills with altitudes between 1000 and 1300m and flatter areas where  
110 neighbourhoods such as Nova Monlevade, Tanquinho, Cruzeiro Celeste, Teresópolis and  
111 others have been established.

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Source: Author (2023)

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## 2.2 Data acquisition and determination of morphometric parameters

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To determine the morphometric parameters, an SRTM (Shuttle Radar Topographic Mission) image was first used, provided free of charge by the United States Geological Survey (USGS) with a spatial resolution of 30 meters. From the digital elevation model (DEM), the r.fill tool was used to generate a depressionless elevation map.

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The basin was delimited, and the flow segments and drainage directions were obtained using the GRASS add-on in the Qgis software. For delineation, the r.watershed tool was used, in which the user indicates the location of the river or basin of interest and the program generates the river's area of influence based on the indicated exit point.

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After delimitation, the drainage network was measured using the SRTM image and the morphometric parameters were calculated: drainage area, perimeter, circularity index, elongation ratio, shape factor, compactness coefficient and drainage density.

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### a) Drainage area (A) and basin perimeter (P)

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The drainage area is the area drained by the entire river system between its topographic dividers, projected on a horizontal plane and is the basic element for calculating various morphometric indices. The perimeter (P) represents the total length of the line that delimits the basin through the watershed [34]. It is an important parameter because it influences the amount of water produced as runoff [35].

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In addition to the area and perimeter, which are measures commonly used to describe a watershed, according to [7], the shape of the basins is analyzed using the circularity index (Ic), the compactness coefficient (Kc), the elongation ratio (Re) and the shape factor (Kf).

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143 *b) Circularity index (Ic) and elongation ratio (Re)*

144 Circularity is determined by the ratio between the area of the basin (A) and the area  
145 of a circle with a perimeter equal to the area of the basin (Ac), as expressed in Equation 1.  
146 When this index is below 0.4, the basin tends towards an elongated shape controlled mainly  
147 by the geological structure and the closer this value gets to one, the more circular the shape  
148 of the basin is, according to [7].

$$149 \quad I_c = \frac{4 \cdot \pi \cdot A}{P^2} \quad (1)$$

150 The elongation ratio, unlike the circularity index, expresses the relationship between  
151 catchment area and basin length (Lb) and can be obtained from Equation 2 ([36], [7]).

$$152 \quad R_e = \frac{A^{0.5}}{L_b} \quad (2)$$

153 [37]proposes the classification of the river basin depending on the value of Re in:

154 Re < 0.7- elongated

155 Re between 0.7-0.8- less elongated

156 Re between 0.8-0.9- oval

157 Re >0.9- circular

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159 *c) Compactness coefficient (kc)*

160 This coefficient, determined according to equation 3, based on the relationship  
161 between the basin's perimeter and area, associates the shape of the basin with that of a  
162 circle and the greater the irregularity of the basin, the greater the compactness coefficient  
163 will be, according to [5]. Thus, a circular basin has a coefficient close to or equal to one  
164 (unity), while larger coefficients represent less circular or elongated basins. Thus, the  
165 propensity to flooding is greater in basins with a Kc close to unity than for basins with a Kc  
166 greater than one (1.0) ([38]).

$$167 \quad K_c = 0,28 \frac{P}{\sqrt{A}} \quad (3)$$

168 Where: Kc - compactness coefficient, P - basin perimeter (m) and A - drainage area(m<sup>2</sup>).

169 [21] indicate that Kc can be used to indicate a tendency to flooding, according to the  
170 following ranges:

171 1.00 ≤ Kc < 1.25 - basin with a high propensity to major flooding.

172 1.25 ≤ Kc < 1.50 - basin with a medium tendency to major flooding.

173 Kc ≥ 1.50 - basin not prone to major flooding

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175 *d) Shape factor (Kf)*

176 This is another measure of the relationship between catchment area and length and  
177 is calculated using Equation 4.

$$178 \quad K_f = \frac{A}{L^2} \quad (4)$$

179 [38] point out that the lower the Kf of a watershed, the less prone it is to flooding.  
180 This is because a low Kf depends on a longer basin length, which shows that the basin is  
181 narrow. Thus, Kf values above 0.75 indicate basins with a high tendency to flood, while  
182 values below 0.50 reduce this tendency.

183 *e) Drainage density (Dd)*

184 Calculated according to Equation 5, this is the sum of the length of all the channels  
185 in the drainage network (Lt) by the drainage area (A) ([19]).

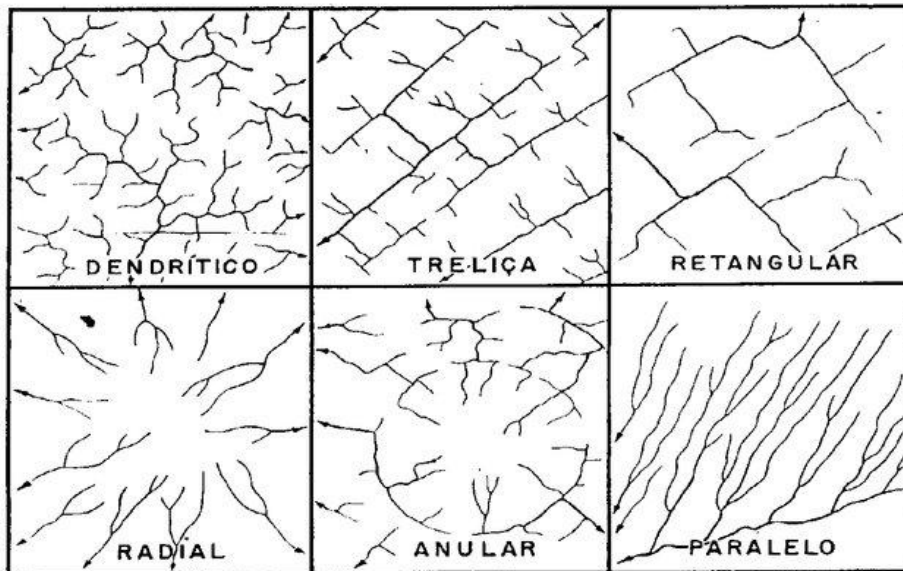
$$186 \quad D_d = \frac{L_t}{A} \quad (5)$$

187 [5] point out that drainage density is a parameter that expresses the development of  
188 a watershed's drainage system.

189 The drainage pattern provides information on the evolution of the drainage network  
190 and sediment input. [14]and [7] state that the drainage pattern is a product of the lithology  
191 and geological structures of a region and describes how the tributaries and the main river  
192 are connected (Figure 3). The dendritic pattern is the most common form and develops in  
193 areas where there is no structural control, and the tributaries join the main current drainage  
194 at angles of less than 90°. The lattice or parallel patterns show structural control, often with  
195 connection angles close to 90° (right angle) at the junction of the channels.

196 [12] points out that the Dd parameter varies from 0.55 to 2.09 km/km<sup>2</sup> in humid  
197 regions and is an important parameter in estimating water travel time of water.  
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199 Figure 3- Drainage patterns



200 Source: Fryis and Brierley (2013)  
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### 203 3. RESULTS AND DISCUSSION

204 The morphometric analysis of the JacuíRiver watershed made it possible to  
205 recognize the hydrological conditions that operate in it and to provide input for future work.  
206 Studies on the morphometry of a watershed provide data and models that express the main  
207 characteristics and the most active processes in the area, contributing to the planning,  
208 organization and management of water resources.

209 The morphometric characteristics determined for the watershed under study were  
210 total area, perimeter, compactness coefficient, circularity index, shape factor, elongation  
211 ratio and drainage pattern, as shown in Table 1.  
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213 Table 1- Parameters and characteristics of the JacuíRiverwatershed

PARAMETER VALUE	CLASSIFICATION
Area (km <sup>2</sup> )	28,82
Perimeter (m)	24.575
Total length of main drainage (m)	9.693

Total length of channels -Lc (m)	41,880.62
Circularity index (Ic)	0,60
Compactness index (Kc)	1,28
Elongation ratio (Re)	0.55
Shape factor (Kf)	0.307
Drainage density (Dd)- km/km	1,68
Dendritic drainage pattern	Dendritic

214 Source: Author

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216 The circularity index (Ic) of 0.60 and the elongation ratio (Re) show that the basin  
217 has an elongated shape, which can also be seen in Figure 1.

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219 As for the propensity to flooding, analyzed based on the shape factors (kf) and  
220 compactness index (kc), this watershed is classified as having a low to medium tendency to  
221 the hydrological phenomena of flooding and inundation.

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222 In a basin with an elongated and narrow shape, with a low form factor, there is an  
223 increase in the concentration-time of the flow and so the possibility of intense rainfall  
224 simultaneously covering the entire length of the basin and generating floods is lower.

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225 However, the occurrence of this phenomenon depends not only on the geometry of  
226 the basin, but also on the use and occupation of the land. Thus, considering that about 30%  
227 of the study area is in an urban expansion area according to [40], there are still areas that  
228 will be used for housing and that will change the use and occupation of the land in the areas  
229 occupied by forests in the next few years.

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230 The main impact of urbanization on a drainage system is the increase in peak flood  
231 flow, the anticipation in time of this maximum flow and the increase in the volume of surface  
232 runoff, which can result in floods that harm the surrounding population ([39]). Thus,  
233 urbanization and other anthropogenic changes tend to alter surface hydrological conditions,  
234 and so maintaining the trend of low to medium propensity to flooding is only confirmed if the  
235 other characteristics of the basin remain constant.

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236 Regarding the lengths of the drainages obtained by Qgis, a histogram was created  
237 to observe the distribution of these channels and their lengths, and it observed that channels  
238 with lengths between 29.0 and 309.9 m predominate in the study area (Figure 4),  
239 representing 1st and 2nd-order drainages. This result is similar to that of [41]López-Ramos  
240 (2023), in which channels of 1st and 2nd order represent the majority of the drainage, with  
241 those of order 1, as they are smaller and shorter in length than the others, prevail in areas  
242 where there is find the steepest slopes.

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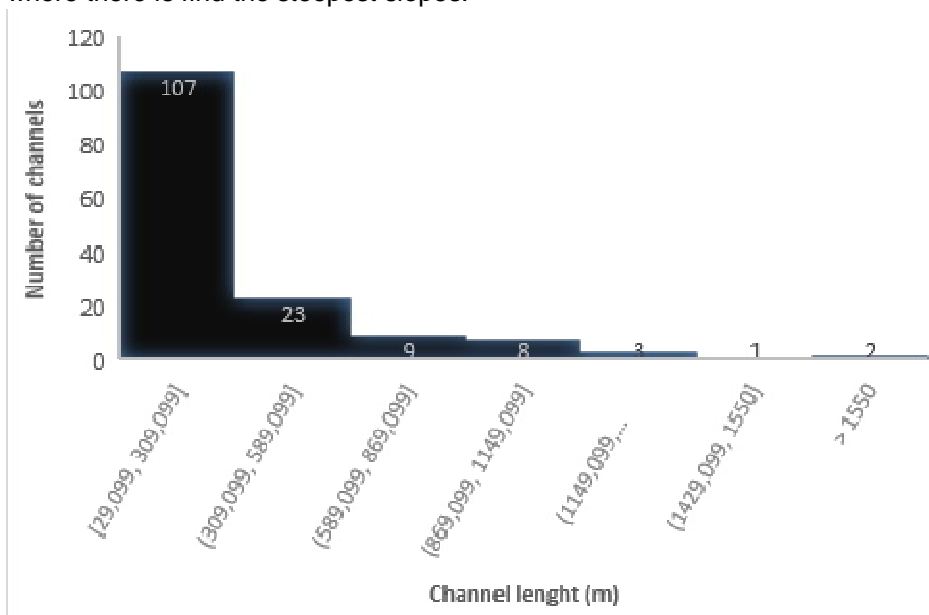
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Source: Author (2023)

According to [18], drainage density (Dd) values of less than 0.5 km/km<sup>2</sup> represent basins with low drainage density and values between 0.5 and 3.5 km/km<sup>2</sup> classify the basin as having medium drainage density.

The Dd value obtained for the JacuíRiver watershed shows a medium drainage density, with values compatible with those expected for tropical climates and regions with relatively homogeneous terrain, represented locally by sandy to sandy-clay soils and granitic rocks that make up its geological substrate. Rocks and soils (especially those covered with vegetation) with greater porosity and permeability tend to infiltrate water from rainfall, reducing the amount of surface runoff and thus the drainage density of a given geographic region.

The soils that occur in the micro-basin are mainly red latosols, evolved soils with good drainage and sandy loam to silty loam texture. The predominant dendritic pattern found in the drainage network, according to [42], indicates a diversity of structure types and is generally found in mountainous areas.

#### 4. CONCLUSION

Analysis of the data and results obtained for the JacuíRiverwatershed led to the conclusion that this watershed has an elongated shape, with shape and circularity indices that show a low to medium tendency to flood under normal annual rainfall conditions.

The drainage density and the dendritic pattern show that it has a medium degree of development over relatively homogeneous terrain, represented by soils formed from granitoid rocks.

As pointed out by [43], the physical conditions of the basin are fundamental in the process of water movement in the basin, influencing surface runoff and infiltration, processes that depend on the basin substrate, rainfall patterns, and relief.

Considering that the local relief is mountainous, there is a greater tendency for surface runoff and although the morphometric characteristics indicate a low to medium tendency for flooding problems, changes in the use and occupation of the basin will certainly contribute to an increase in these flows, as is the case in another watershed in the municipality, the CarneirinhosRiver basin, which is constantly flooded. In that regard, according to [44] the hydrographic network and its characteristics are part of the landscape and present a dynamic aspect in which geology, geomorphology, vegetation and structure correlate. They also emphasize that understanding the shape and density of the watercourses in a watershed, as well as their gradient, plays an important role in understanding the hydrological phenomena in an area.

The study also showed that the use of remote sensing data to analyze morphometric parameters can be carried out quickly and reliably, as well as allowing thematic maps to be drawn up, such as maps of land use, vegetation cover, and the relief of the area, which are part of the physical characterization of river basins.

Although the morphometric parameters indicate a low to medium trend in the occurrence of hydrological processes such as flooding, it is important to note that urbanization and deforestation tend to increase the flow of surface water, causing this initial indication to change over time. The processes of environmental degradation and changes in land use therefore reinforce the need to know the characteristics of the watershed to better manage its use and occupation.

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