Region - Water Conservancy, 2024 , Volume7, Issue2
DOI: 10.32629/rwc.v7i2.3116
ISSN Online: 2630-4902

Hydrogeomorphometry of the Cutia river microbasin, South-Western Amazon, Brazil

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Abstract: Planning the management of natural resources is essential for sustainable development in the Amazon region and is based on information associated with the characteristics of the landscape. In view of the above, this work aims to provide geometric, topographic and hydrographic information on the Cutia river basin, which belongs to the Guaporé river basin, an important basin in the state of Rondônia. This information was obtained using equations available in the literature and remote sensing, using QGIS 2.10.1, TrackMaker and Google Earth software, and altimetric images from the ALOS satellite (Palsar Sensor). The watershed has an area of 19.20 km^2, with a perimeter of 24.79 km, an elongated shape, low susceptibility to flooding, altitudes of 261 m to 346 m, predominantly gentle undulating relief (47.45%). 90.36% of the area is suitable for agricultural mechanization, with low influence on the spread of fires. The drainage network has a dendritic pattern, with 5th order drainage, high density of springs, and high drainage density. The maintenance coefficient is 342.7 m^2 m^{-1} , rambling main channel and low concentration time. The Cutia river basin has the potential to be used for farming systems, but soil and water conservation management practices are recommended to mitigate the impact of these systems on natural resources. Studies are also recommended on the spatial distribution of native vegetation in areas protected by law in the watershed (legal reserves and permanent preservation areas), to help delimit priority areas for the conservation of water resources.

Key words: geoprocessing; physiographic characteristics; natural resources; environmental planning and management

1 Introduction

The microwatershed is the smallest part of the watershed (Cavalheiro & Vendruscolo, 2019) and its size makes it possible to obtain detailed landscape information at low financial cost and in a timely manner when using geotechnologies (Soares, et al., 2019). Detailed landscape information is desirable for environmental planning and proper management of natural resources, which explains why micro-basins are recommended (Vendruscolo et al., 2021a) and often used as management units, as observed in work carried out in the state of Rondônia by Vendruscolo et al. (2021b), Souza et al. (2021), Silva et al. (2021), Donegá et al. (2021) and Santos et al. (2021).

Remote sensing and the Geographic Information System (GIS) are examples of geo-technologies (Florenzano, Lima & Moraes, 2011) used to obtain detailed information about the landscape. Remote sensing makes it possible to acquire information on the earth's surface without having direct contact with the objects (Moreira, 2001). GIS makes it possible to insert and integrate spatial information from cartographic data, census data, urban and rural land registers, satellite images, networks and numerical terrain models into a single database. It also offers tools for combining information through manipulation and analysis algorithms, as well as for consulting, retrieving and visualizing the contents of the georeferenced database (Jucá, Carvalho & Aguiar Júnior, 2006). Because of these characteristics, remote sensing and GIS have great potential for acquiring landscape information in the Amazon region.

The Cutia river basin is part of the Guaporé river basin, sub-basin of the Vermelho river, and covers approximately 37 private agricultural establishments (INCRA, 2018). Despite its great socio-economic and environmental importance, there is a scarcity of information about the landscape of this watershed in the literature. Therefore, the aim of this study is to use geotechnologies to provide geometric, topographic and hydrographic information on the Cutia river basin, in order to help plan and manage the region's natural resources.

2 Methodology

2.1 Location and general characteristics of the study area

The Cutia river basin is part of the Vermelho river sub-basin, located in the municipality of Vilhena (Figure 1). This region has a Tropical Monsoon climate, with average temperatures between 24°C and 26°C (Alvares et al., 2013) and annual rainfall of 1,728.9 mm to 1,843.7 mm, which is concentrated in the months of November to March (Franca, 2015), and soils classified as Quartzarenic Neosols (SEDAM, 2002).

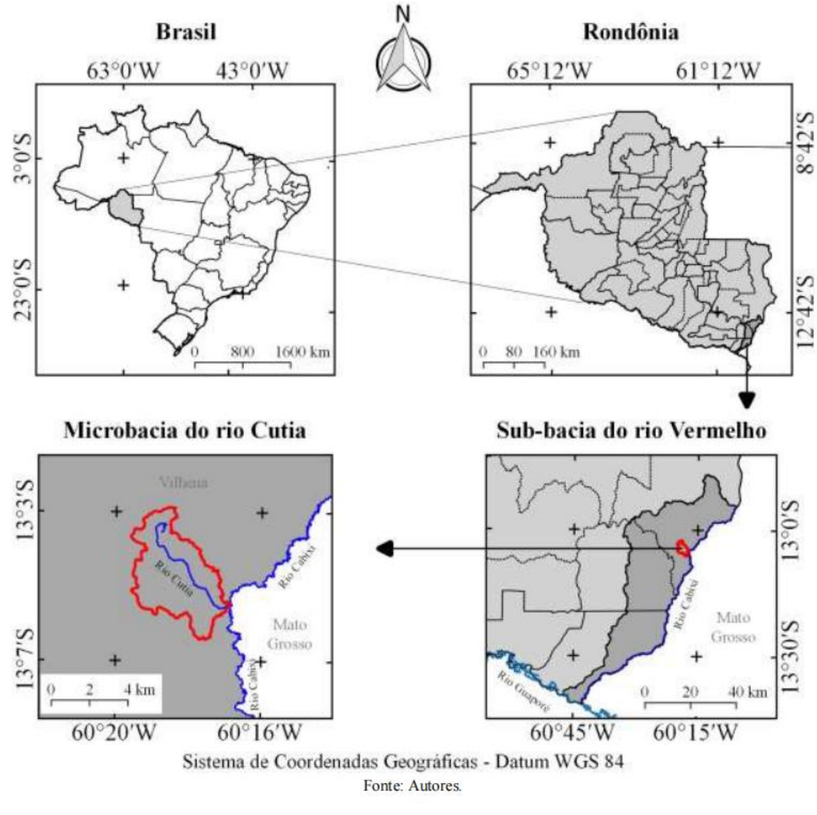

Figure 1. Location of the Cutia river basin, South-Western Amazonia, Brazil

Source: Authors

2.2 Landscape characteristics

QGIS 2.10.1 (Pisa version), Google Earth and TrackMaker Free (Version 13.9.596) software were used to acquire the landscape features and draw up the maps, along with altimetry images from the ALOS satellite (Palsar Sensor), with a spatial resolution of 12.5 m (ASF, 2017). The methodologies are quantitative and qualitative, as they allow the identification and analysis of landscape characteristics through the measurement and interpretation of values (Pereira et al., 2018), and were carried out in four stages, described in detail below:

Stage1 - Geometric characteristics

The TauDEM tool (steps: Pit Remove < D8 Flow Directions < D8 Contributing Area - 1st version < Stream Definition By Threshold < Editing the outflow point < D8 Contributing Area - 2nd version) and altimetric images from the Alos satellite (Palsar Sensor) (ASF, 2017), are used with a spatial resolution of 12.5 m. The matrix file generated in TauDEM was transformed into vector format, then dissolved, smoothed and adjusted in Google Earth software, taking into account the characteristics of the drainage network and relief. The area and perimeter were then calculated using the "field calculator" tool.

The shape factor, circularity index and compactness coefficient parameters were calculated using equations 1 (Villela & Mattos, 1975), 2 (Christofoletti, 1980) and 3 (Villela & Mattos, 1975), and compared with data from the literature (Table 1).

$$F = \frac{A}{L^2}$$ (Equation 1)

Where: F = shape factor; A = area of the watershed (km^2); L = length of watershed axis (km)

$$Ic = \frac{12{,}57xA}{P^2}$$ (Equation 2)

Where: Ic = circularity index; A = area of the watershed (km^2); P = perimeter of the watershed (km)

$$Kc = 0{,}28x\frac{P}{\sqrt{A}}$$ (Equation 3)

Where: Kc = coefficient of compactness; A = area of the watershed (km^2); P = perimeter of the watershed (km)

Table 1. Classification of geometric parameters: shape factor, sinuosity index and compactness coefficient

Parameter	Limit	Class
Shape factor[1]	< 0,50	Not subject to flooding
	0,50 – 0,75	Average tendency to flooding
	0,76 – 1,00	Subject to flooding
Circularity index[2]	< 0,51	Elongated shape
	0,51 – 0,75	Intermediate form
	0,76 – 1,00	Circular shape
Coefficient of compactness[1]	1,00 – 1,25	High propensity to flooding
	1,26 – 1,50	Average tendency to flooding
	> 1,50	Not subject to flooding

Source: [1]Lima Júnior et al. (2012); [2]Silva (2012)

Stage 2 - Topographical features

The minimum and maximum altitudes were obtained directly from the altimetric images, and the average altitude was measured using the "statistics by zone" tool. The relief was obtained based on the slope of the terrain, which was then classified as flat (0%-3%), gently undulating (3%-8%), undulating (8%-20%), strongly undulating (20%-45%) and mountainous (45%-50%) (Santos et al., 2013). The relief was also classified in terms of its influence on the spread of fires and its suitability for agricultural mechanization to help with the landscape analysis (Table 2).

Table 2. Classification of influence on fire spread and suitability for agricultural mechanization according to slope

Parameter	Declivity (%)	Class

Influence on the spread of fires[1]	≤ 15 16-25 26-35 36-45 > 45	Low Moderate High Very high Extremely high
Suitability for agricultural mechanization[2]	0,0-5,0 5,1-10,0 10,1-15,0 15,1-20,0 > 20,0	Extremely fit Very fit Fit Moderately fit Not fit

Source: [1]Ribeiro et al. (2008); [2]Höfig & Araujo-Junior (2015)

Stage 3 - Hydrographic characteristics

The rivers were generated in Google Earth software, saved in KML format, and merged in TrackMaker software to form the drainage network. The drainage pattern was then identified by means of a visual analysis, comparing the spatial distribution of the drainage network of the watershed under study with the spatial distribution of reference drainage networks provided by Parvis (1950), and classifying the order of the rivers according to Strahler (1954).

The parameter density of springs, drainage density, maintenance coefficient, sinuosity index and time of concentration were calculated using equations 4 (Christofoletti, 1980), 5 (Horton, 1932), 6 (Santos et al., 2012), 7 (Villela & Mattos, 1975) and 8 (Kirpich 1940, apud Targa et al., 2012).

$$Dn = \frac{N}{A} \quad \text{(Equation 4)}$$

Where: *Dn* = density of springs (springs km^{-2}); N = number of springs; A = area of the watershed (km^2)

$$Dd = \frac{L}{A} \quad \text{(Equation 5)}$$

Where: *Dd* = drainage density (km km^{-2}); L = length of the drainage network (km); A = area of the watershed (km^2).

$$Cm = \frac{1}{Dd}x1000 \quad \text{(Equation 6)}$$

Where: Cm = maintenance coefficient (m^2 m^{-1}); Dd = drainage density (km km^{-2})

$$Is = \frac{L-Dv}{L}x100 \quad \text{(Equation 7)}$$

Where: Is = sinuosity index (%); L = length of main channel (km); Dv = vector distance of main channel (km)

$$Tc = 57x\left(\frac{L^3}{H}\right)^{0,385} \quad \text{(Equation 8)}$$

Where: Tc = time of concentration (minutes); L = length of the main channel (km); H = gradient between the highest part and the control section (m)

The values of the parameters river order, density of springs, drainage density and sinuosity index were classified according to the literature (Table 3).

Table 3. Classification of hydrographic features

Parameters	Unit	Limit	Class
Order of the rivers[1]	Units	1-3	Small streams

		4-6	Medium streams
		> 6	Large rivers
Order of the rivers[2]	Units	1	Unlikely fish habitat
		2	Poor housing conditions
		3	Moderate housing conditions
		≥ 4	High housing conditions
Density of springs[3]	Springs km^{-2}	< 3	Low
		3-7	Average
		7-15	High
		> 15	Very high
Drainage density[4]	km km^{-2}	< 0,50	Low
		0,50-2,00	Average
		2,00-3,50	High
		> 3,50	Very high
Sinuosity index[5]	%	< 20	Very straight
		20-29	Straight
		30-39	Wandering
		40-50	Sinuous
		> 50	Very winding

Source: [1]Vannote et al. (1980); [2]Adaptado de Fairfull & Witheridge (2003); [3]Lollo (1995); [4]Beltrame (1994); [5]Romero, Formiga & Marcuzzo (2017)

Stage 4 - Drawing up the maps

The maps of altitude, relief, drainage network and spatial distribution of the springs were drawn up with the "new print composer" tool, using the geographic coordinate system and the WGS 84 Datum as references.

3 Results and discussion

3.1 Geometric characteristics

The Cutia river basin has an area of 19.20 km^2 ,with a perimeter of 24.79 km, a shape factor of 0.33, a circularity index of 0.39 and a compactness coefficient of 1.58, which denotes an elongated shape and low susceptibility to flooding from a geometric point of view (Table 1). A basin with an elongated shape is less susceptible to flooding because it has a lower probability of simultaneous rainfall over the entire area, compared to circular basins of equivalent area (Vilella & Mattos,1975). This shape may be related to the presence of Quartzarenic Neosols, which provides good water infiltration capacity in the soil, and consequently less dissection of the relief (Calil et al., 2013). In basins located in the states of Minas Gerais and Rio de Janeiro, elongated values and low susceptibility to flooding are observed, demonstrating that these characteristics also occur in other Brazilian states (Cardoso et al., 2006; Tonello et al., 2006; Oliveira et al., 2010).

The shape of the basin also influences the time of concentration, which means the time needed for the entire basin to contribute to the outflow of water after a rainfall (Tonello et al., 2006). In elongated basins, the tributaries reach the main watercourse at various points along it, unlike circular basins, in which the concentration of runoff occurs at a single point, reducing the concentration time and increasing the chances of flooding (Villela & Mattos, 1975).

3.2 Topographical features

Altitude values vary from 261 m to 346 m, with an average value of 300 m (Figure 2), and an altimetric range of 85 m.

Altitude influences temperature (Fritzons, Mantovani & Aguiar, 2008; Fritzons, Where & Mantovani, 2015; Fritzons, Mantovani & Where, 2016), rainfall and evaporation (Villela & Mattos, 1975), and consequently the spatial distribution of plant species (Figueiredo et al., 2015). In view of the above, it can be seen that there are more than 20 species of economic interest that are suited to the altitude range of the Cutia river basin, for example (Bourke, 2010): 1) Avocado (Persea americana); 2) Pumpkin (Cucurbita moschata); 3) Rice (Oryza sativa); 4) Banana (Musa spp.); 5) Sweet potato (Ipomoea batatas); 6) Cocoa (Theobroma cacao); 6) Conilon coffee (Coffea canephora var. robusta); 7) Tea (Dioscorea alata); 8) Beans (Phaseolus vulgaris); 9) Yam (Dioscorea esculenta); 10) Orange (Citrus sinensis); 11) Lemon (Citrus limon); 12) Cassava (Manihot esculenta); 13) Watermelon (Citrullus lanatus); 14) Melon (Cucumis melo); 15) Maize (Zea mays); 16) Cucumber (Cucumis sativus); 17) Black pepper (Piper nigrum); 18) Okra (Abelmoschus esculentus); 19) Rubber tree (Hevea brasiliensis); 20) Taioba (Xanthosoma sagittifolium) and 21) Urucum (Bixa orellana). However, due to the dominance of Quartzarenic Neosols (SEDAM, 2002), soil management measures such as liming, maintaining soil organic matter, and fertilization are needed, as these soils often have low natural fertility and low cation exchange capacity.

The region has the following relief classes: flat (14.90%), gently undulating (47.45%), undulating (34.58%), strongly undulating (3.02%) and mountainous (0.05%) (Figure 3). Considering that increasing slope increases the risk of water erosion, especially in sandy soils with no vegetation (Bertoni & Lombardi Neto, 2014), it can be inferred that the regions most susceptible to soil loss due to erosion are located in the mountainous, strongly undulating and undulating soils, respectively. It is also important to remember that the soils in the micro-basin are classified as Quartzarenic Neosols (SEDAM, 2002), i.e. they have textures classified as sand or sandy loam in all horizons up to a depth of at least 150 cm from the soil surface or up to a fragmentary lithic or lithic contact (Santos et al., 2018). The texture of Quartzarenic Neosols limits or even prevents the formation of aggregates in the soil, and reduces water storage capacity, making them highly susceptible to erosion and water scarcity. Therefore, it is recommended to use integrated conservation management practices to increase the infiltration capacity and water storage in the soil and reduce surface runoff (Bertoni & Lombardi Neto, 2014), opting mainly for vegetative practices that favor the continuous contribution of organic matter and cover the soil throughout the year for the formation and stabilization of aggregates (Wohlenberg et al., 2004).

The watershed has regions classified as having a low (90.36%), moderate (8.54%), high (0.94%), very high (0.10%) and extremely high (0.05%) influence on the spread of fires. In order to reduce the risk of fires in the most critical areas, burning should be avoided on rural properties and along roadsides. This information is essential for the owners of private agricultural establishments, environmental agencies and the fire department, since identifying the risk of fire using a GIS allows managers to strategically plan long-term prevention activities (Paz et al., 2011).

With regard to suitability for agricultural mechanization, the watershed has 34.69%, 39.32%, 16.35%, 6.56% and 3.07% of areas considered extremely suitable, very suitable, suitable, moderately suitable and not suitable for mechanization, respectively. This confirms that if coffee cultivation is used as a reference, most areas in the basin have no slope restrictions on agricultural mechanization. However, as these are Quartzarenic Neosols, if mechanization is used, caution must be exercised to avoid potential soil erosion issues due to high rainfall in the area.

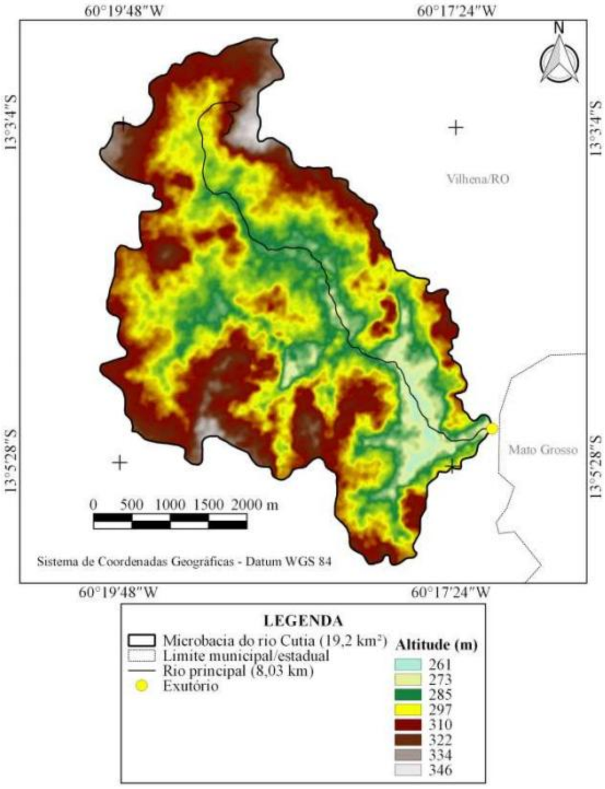

Figure 2. Altitude of the Cutia river basin, South-Western Amazonia, Brazil

Source: Authors

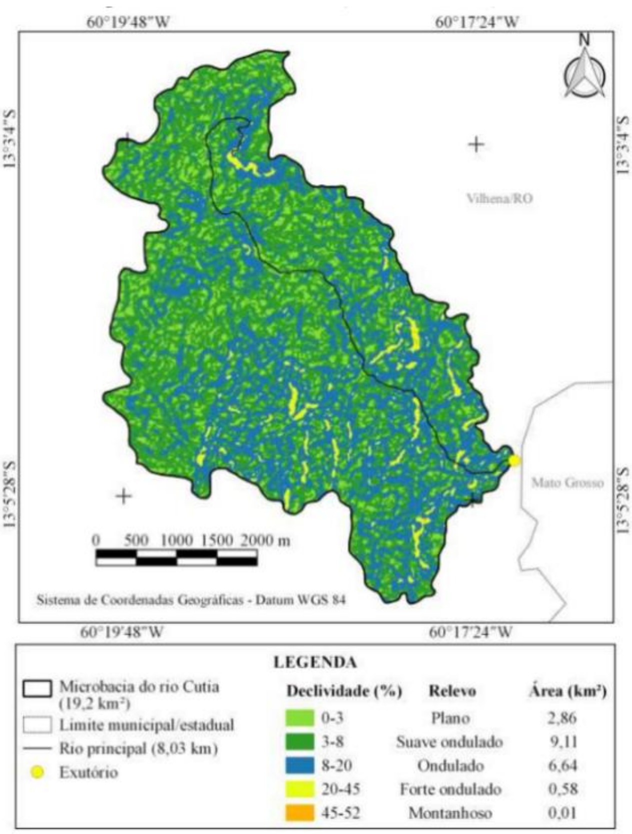

Figure 3. Relief of the Cutia river basin, Amazonia, Brazil

Source: Authors

3.3 Hydrographic characteristics

The Cutia river basin has a drainage network of 56.02 km, with a 5th order dendritic pattern (Figure 4), 7.81 springs km^{-2} (Figure 5), a drainage density of 2.92 km km^{-2} , a maintenance coefficient of 342.7 m^2 m^{-1} , a sinuosity index of 35.37% and a concentration time of 1.90 h.

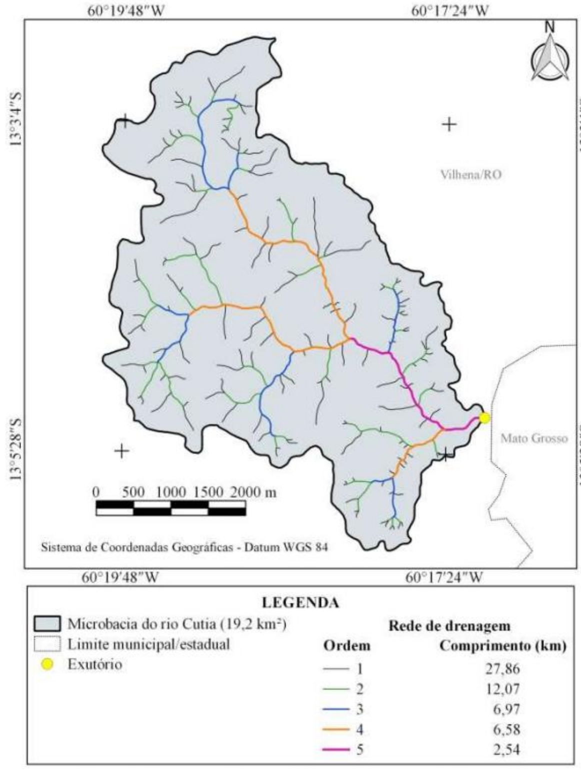

Figure 4. Drainage network and river order in the Cutia river basin, South-Western Amazonia, Brazil

Source: Authors

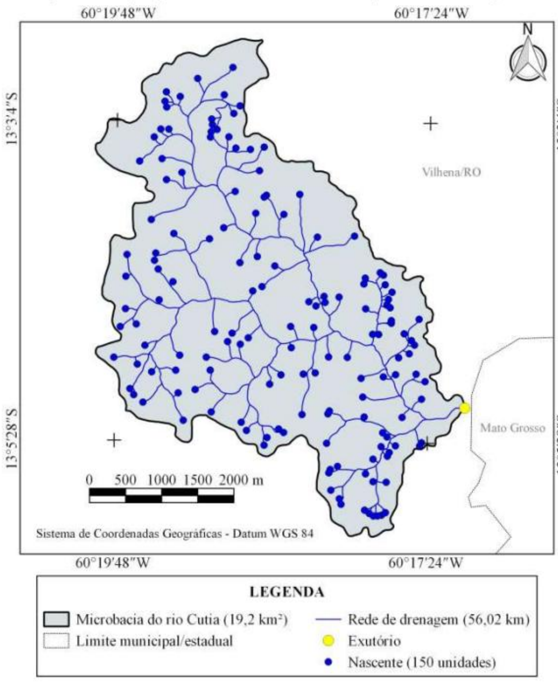

Figure 5. Spatial distribution of springs in the Cutia river basin, South-Western Amazonia, Brazil

Source: Authors

The dendritic drainage pattern is also known as arborescent, due to its resemblance to a tree (Smith 1943 apud Parvis, 1950), and denotes a good spatial distribution of water resources, which can be seen in Figure 5. This type of drainage pattern has channels that run in all directions over the surface and come together to form acute angles of varying degrees, but without reaching right angles (Christofoletti, 1980), which was also observed in the micro-basins of the Mutum (Souza et al., 2021), Paraíso (Lima et al., 2021) and Gavião (Donegá et al., 2021).

The number of orders confirms the formation of a medium-sized stream (Table 3) with a complex drainage system (Horwitz, 1978), and high conditions for fish habitation (Table 3). In a study carried out by Vannote et al. (1980) on rivers of the 1st to 12th order, it was found that biotic diversity was higher in rivers of the 4th to 5th order. Based on this information, more detailed studies into the complexity of the aquatic ecosystem are recommended in order to develop strategies aimed at maintaining water resources, taking into account water quantity and quality, and consequently the conservation of the region's native fish species.

The densities of springs and drainage are considered high (Table 3). These characteristics suggest that the watershed has a high capacity to generate new watercourses (Christofoletti, 1969) and good drainage capacity (Villela & Mattos, 1975). Both densities are associated with a combination of factors, including slope (Vendruscolo et al., 2020a; Vendruscolo et al., 2020b), texture and soil cover (Bertoni & Lombardi Neto, 2014), since the increase in slope, the presence of sandy soils and the absence of vegetation favor water erosion and the formation of furrow channels. This type of erosion can evolve over time, passing to the ravine type and then to the gully, until reaching the water table (Guerra, 1997), originating new channels and new springs.

Considering the presence of Quartzarenic Neosols in the watershed, there is a need to maintain native vegetation in the riparian zone, in order to avoid the collapse of the margins and silting of water resources, and in other areas of the landscape, it remains to help with the soil aggregation process to ensure the availability and quality of water, and the contribution of organic matter to the soil from plant. Native vegetation performs different eco-hydrological functions (Tambosi et al., 2015), depending on its location in the landscape: supplying the water table (hilltops), containing erosion processes (slopes), filtering pollutants and contaminants (riparian zone) and auxiliary functions (intervals). In this context, studies on the temporal and spatial analysis of land cover are recommended, in order to understand the dynamics of land use and occupation, select soil conservation management practices in agricultural systems and delimit priority areas for the maintenance of native vegetation. In addition, in the watershed region, there are cerrado patches (BIGS, 2012), a theme ecosystem of great importance for the biodiversity of the state of Rondônia and that has been continuously transformed into agricultural areas (Sccoti & Sccoti, 2019).

The maintenance coefficient provides the minimum area required for the maintenance of one meter of flow channel, so that 342.7 m^2 of area is required to maintain 1 m of river. This value is lower than those observed in the watersheds of the Águas Claras rivers (366.5 m^2 m^{-1}) (Santos et al., 2021), Mutum (499.4 m^2 m^{-1}) (Souza et al., 2021), Jacuri (1,102.9 m^2 m^{-1}) (Panza et al., 2020) and Gavião (1,250.00 m^2 m^{-1}) (Donegá et al., 2021). Therefore, the Cutia river watershed needs a smaller area to maintain water resources, compared to the mentioned watersheds.

The sinuosity index value confirms the presence of a meandering channel (Table 3), similar to the main channel of the Águas Claras watershed (Santos et al., 2021), and different from the main channels of the Três Galhos (Silva et al., 2021), Paraíso (Lima et al., 2021) and Tamarupá (Vendruscolo et al., 2021b) watersheds, which have a sinuous channel. This parameter is a controlling factor of the flow (Villela & Mattos, 1975), and directly interferes with the time of concentration. Wandering channels tend to accumulate sediment, and this accumulation of sediment in the inner part of meanders is essential for the formation of freshwater beaches, which are used by some turtle species as a natural nursery in the Amazon region (Ferreira Júnior, 2009). Therefore, the Cutia river basin has potential for studies aimed at identifying natural nurseries and protecting wildlife.

With regard to the time of concentration, it was found that it takes 1.90 h for the water to travel 8.03 km, denoting a water flow with an average speed of 4.23 km h^{-1}. It is found that the concentration time is lower than that in other watersheds, such as: São Jorge 3.63 h (adapted from Pacheco et al., 2020), Médio Rio Escondido 4.46 h (adapted from Vendruscolo et al., 2020b) and Alto Rio Escondido 5.02 h (adapted from Vendruscolo et al., 2020a). These differences in concentration time are associated with the length of the channel, since according to the authors, the micro-basins mentioned have longer channels, with lengths of 16.07 km, 24.05 km and 27.93 km, respectively. It can also be seen that the time of concentration is shorter when compared to the time of precipitation in the region (Santos Neto, 2014). Therefore, the entire area of the micro-basin can simultaneously contribute to the river's flow, increasing the risk of flooding, even if the basin has been classified as geometrically low probability.

4 Conclusion

The Cutia river basin has an area of 19.20 km^2 , with a perimeter of 24.79 km, an elongated shape, low susceptibility to flooding, altitudes of 261 m to 346 m, and predominantly gentle undulating relief (47.45%). 90.36% of the area is suitable for agricultural mechanization, with low influence on the spread of fires, drainage network with a dendritic pattern, 5th order drainage, high density of springs, high drainage density, maintenance coefficient of 342.7 m^2 m^{-1}, rambling main channel and low concentration time.

The characteristics of the landscape confirm the potential for implementing farming systems, including mechanized farming in most areas of the watershed. However, soil and water conservation management practices are recommended to mitigate problems with flooding and the negative impact of farming systems on natural resources. Studies are also recommended on the spatial and temporal distribution of native vegetation, especially in areas protected by law (legal reserves and permanent preservation areas), to help delimit priority areas for the conservation of water resources and for the conservation of threatened forest ecosystems in the state.

Conflicts of interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] Alvares, C. A., Stape, J. L., Sentelhas, P. C., Gonçalves, L. M., & Sparovek, G. (2013). Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift*, 22(6), 711–728. 10.1127/0941-2948/2013/0507.

[2] ASF - Alaska Satellite Facility (2017). *Imagem altimétrica*. https://www.asf.alaska.edu/

[3] Beltrame, A. V. (1994). *Diagnóstico do meio ambiente físico de bacias hidrográficas: modelo de aplicação.* Florianópolis: Universidade Federal de Santa Catarina.

[4] Bertoni, J., & Lombardi Neto, F. (2014). *Conservação do solo*. (9a ed.), Ícone.

[5] Bourke, R. M. (2010). *Altitudinal limits of 230 economic crop species in Papua New Guinea*. In: Haberle, S. G., Stevenson, J., & Prebble, M. (eds). Altered Ecologies: Fire, Climate and Human Influence on Terrestrial Landscapes. ANU E-Press.

[6] Calil, P. M., Oliveira, L. F. C., Kliemann, H. J., & Oliveira. V. A. (2013). Caracterização geomorfométrica e do uso do solo da bacia hidrográfica do Alto Meia Ponte, Goiás. *Revista Brasileira de Engenharia Agrícola e Ambiental*, 16(4): 433-442. 10.1590/S1415-43662012000400014

[7] Cardoso, C. A. C, Dias, H. C. T., Soares, C. P. B., & Martins, S. V. (2006). Caracterização morfométrica da bacia hidrográfica do rio Debossan, Nova Friburgo, RJ. *Revista Árvore*, 30(2), 241-248. 10.1590/S0100-67622006000200011

[8] Cavalheiro, W. C. S., & Vendruscolo, J. (2019). Importância de estudos em bacias hidrográficas para o manejo sustentável dos recursos hídricos em Rondônia. *Revista Geográfica Venezolana*, especial, 256-264.

[9] Christofoletti, A. (1969). Análise morfométrica de bacias hidrográficas. *Notícia Geomorfológica*, 18(9), 35-64.

[10] Christofoletti, A. (1980). *Geomorfologia*. Edgard Blucher.

[11] Donegá, M. V. B., Souza, T. W. S., Lima, M. M., Panza, M. R., Pacheco, F. M. P., Saraiva, J. G., Cavalheiro, W. C. S., & Vendruscolo, J. (2021). Caracterização hidrogeomorfométrica da microbacia do rio Gavião, Amazônia Ocidental, Brasil. *Research, Society and Development*, 10(1), 1-14. 10.33448/rsd-v10i1.11844

[12] Fairfull, S., & Witheridge, G. (2003). *Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings*. NSW Fisheries.

[13] Ferreira Junior, P. D. (2009). Aspectos ecológicos da determinação sexual em tartarugas. *Acta Amazônica*, 39(1), 139-154. 10.1590/S0044-59672009000100014

[14] Figueiredo, S. M. M., Venticinque, E. M., Figueiredo, E. O., & Ferreira, E. J. L. (2015). Predição da distribuição de espécies florestais usando variáveis topográficas e de índice de vegetação no leste do Acre, Brasil. *Acta Amazonica*, 45(2), 167-174. 10.1590/1809-4392201402834

[15] Florenzano, T. G., Lima, S. F. S. & Moraes, E. C. (2011). Formação de professores em geotecnologia por meio de ensino a distância. *Educar em Revista*, 40, 69-84. 10.1590/S0104-40602011000200006

[16] Franca, R. R. (2015). Climatologia das chuvas em Rondônia – período 1981-2011. *Revista Geografias*, 11(1), 44-58.

[17] Fritzsons, E., Mantovani, L. E., & Aguiar, A. V. (2008). Relação entre altitude e temperatura: uma contribuição ao zoneamento climático no estado do Paraná. *Revista de Estudos Ambientais*, 10(1): 49-64, 2008. 10.7867/1983-1501.2008v10n1p49-64

[18] Fritzsons, E., Mantovani, L. E., & Wrege, M. S. (2016). Relação entre altitude e temperatura: uma contribuição ao zoneamento climático no estado de Santa Catarina, Brasil. *Revista Brasileira de Climatologia*, 12(8), 80-92, 2016. 10.5380/abclima.v18i0.39471

[19] Fritzsons, E., Wrege, M. S., & Mantovani, L. E. (2015). Altitude e temperatura: estudo do gradiente térmico no Rio Grande do Sul. *Revista Brasileira de Climatologia*, 11(16), 108-119, 2015. 10.5380/abclima.v16i0.39665

[20] Guerra, A. J. T. (1997). Ravinas: processo de formação e desenvolvimento. *Anuário do Instituto de Geociências*, 20, 9-26.

[21] Höfig, P., & Araujo-Junior, C. F. (2015). Classes de declividade do terreno e potencial para mecanização no estado do Paraná. *Coffee Science*, 10(2), 195-203.

[22] Horton, R. E. (1932). Drainage basin characteristics. *Transactions, American Geophysical Union*, 13(1), 350-361.

[23] Horwitz, R. J. (1978). Temporal variability patterns and the distributional patterns of stream fishes. *Ecological Monographs*, 48(3), 307-321. 10.2307/2937233

[24] IBGE - Instituto Brasileiro de Geografia e Estatística. (2012). *Manual técnico da vegetação brasileira*. IBGE.

[25] INCRA - Instituto Nacional de Colonização e Reforma Agrária (2018). *Acervo fundiário*. http://acervofundiario.incra.gov.br/acervo/acv.php.

[26] Jucá, S. C. S., Carvalho, P. C. M., & Aguiar Júnior, J. S. (2006). A relevância dos sistemas de informação geográfica no desenvolvimento das energias renová- veis.*Ciências & Cognição*, 9, 131-136.

[27] Lima Júnior, J. C., Vieira, W. L., Macêdo, K. G., Souza, S. A., & Nascimento, F. A. L. (2012). Determinação das características morfométricas da sub-bacia do Riacho Madeira Cortada, Quixelô, CE. *Anais do Congresso Norte-Nordeste*

de Pesquisa e Inovação. Palmas, TO, Brasil, 7.

[28] Lima, M. M., Donegá, M. V. B., Souza, T. W. S., Panza, M. R., Pacheco, F. M. P., Cavalheiro, W. C. S., Hara, F. A. S., & Vendruscolo, J. (2021). Hidrogeomorfometria da microbacia do rio Paraíso: informações para auxiliar o manejo dos recursos naturais na Amazônia Ocidental. *Research, Society and Development*, 10(3), 1-20. 10.33448/rsd-v10i3.13367

[29] Lollo, J. A. (1995). *O uso da técnica de avaliação do terreno no processo de elaboração do mapeamento geotécnico: sistematização e aplicação na quadrícula de Campinas*. (Tese de Doutorado). Universidade de São Paulo, São Carlos, SP, Brasil.

[30] Moreira, M. A. (2001). *Fundamentos do Sensoriamento Remoto e Metodologias de Aplicação.* São José dos Campos: Instituto Nacional de Pesquisas Espaciais.

[31] Oliveira, P. T. S., Sobrinho, T. A., Steffen, J. L., & Rodrigues, D. B. B. (2010). Caracterização morfométrica de bacias hidrográficas através de dados SRTM. *Revista Brasileira de Engenharia Agrícola e Ambiental*, 14(8), 819-82. 10.1590/S1415-43662010000800005

[32] Pacheco, F. M. P., Vendruscolo, J., Ramos, F. H., Rodrigues, A. A. M., Cavalheiro, W. C. S., Hara, F. A. S., Rocha, K. J., & Silva, G. N. (2020). Caracterização hidrogeomorfométrica da microbacia do rio São Jorge, Rondônia, Brasil. *Brazilian Journal of Development*, 6(1), 4219-4236. 10.34117/bjdv6n1-301

[33] Panza, M. R., Donegá, M. V. B., Pacheco, F. M. P., Nagao, E. O., Hara, F. A. S., Cavalheiro, W. C. S., & Vendruscolo, J. (2020). Características da paisagem para manejo dos recursos naturais na microbacia do Rio Jacuri, Amazônia Ocidental, Brasil. *Brazilian Journal of Development*, 6(12), 101532-101558. 10.34117/bjdv6n12-592

[34] Parvis, M. (1950). Drainage pattern significance in airphoto identification of soils and bedrocks. *Photogrammetric Engineering*, 16, 387-408.

[35] Paz, S., Carmel, Y., Jahshan, F., Shoshany, M. (2011). Post-fire analysis of pre-fire mapping of fire- risk: a recent case study from Mt. Carmel (Israel). *Forest Ecology and Management*, 262, 1184-1188. 10.1016/j.foreco.2011.06.0 11

[36] Pereira, A. S., Shitsuka, D. M., Parreira, F. J., & Shitsuka, R. (2018). *Metodologia da Pesquisa Científica*. Santa Maria-RS: Universidade Federal de Santa Maria.

[37] Ribeiro, L., Koproski, L. P., Stolle, L., Lingnau, C., Soares, R. V., & Batista, A. C. (2008). Zoneamento de riscos de incêndios florestais para a Fazenda Experimental do Canguiri, Pinhais (PR). *Floresta*, 38(3), 561-572. 10.5380/rf.v38i3. 12430

[38] Romero, V., Formiga, K. T. M., & Marcuzzo, F. F. N. (2017). Estudo hidromorfológico de bacia hidrográfica urbana em Goiânia/GO. *Ciência e Natura*, 39(2), 320-340. 10.5902/2179460X26411

[39] Santos, A. A., Silva, E. C., Cardoso, L. A. P., Praia, W. M., Hara, F. A. S., Cavalheiro, W. C. S., & Vendruscolo, J. (2021). Características hidrogeomorfométricas da microbacia do rio Águas Claras, Amazônia Ocidental, Brasil. *Research, Society and Development*, 10(3), 1-16. 10.33448/rsd-v10i3.13363

[40] Santos, A. M., Targa, M. S., Batista, G. T., & Dias, N. W. (2012). Análise morfométrica das sub-bacias hidrográficas Perdizes e Fojo no município de Campos do Jordão, SP, Brasil. *Revista Ambiente & Água*, 7(3), 195-211. 10.4136/1980-993X

[41] Santos, H. G., Jacomine, P. K. T., Anjos, L. H. C., Oliveira, V. Á., Lumbreras, J. F., Coelho, M. R., Almeida, J. A., Araújo Filho, J. C., Oliveira, J. B., & Cunha, T. J. F. (2018). *Sistema Brasileiro de Classificação de Solos*. Embrapa Solos.

[42] Santos Neto, L. A. (2014). *Variabilidade da precipitação horária em Porto Velho – RO e suas tendências anuais*

e sazonais. (Dissertação de Mestrado). Universidade Federal de Rondônia.

[43] Santos, R. D., Lemos, R. C., Santos, H. G., Ker, J. C., Anjos, L. H. C., & Shimizu, S. H. (2013). *Manual de descrição e coleta de solo no campo*. Sociedade Brasileira de Ciência do Solo.

[44] Sccoti. M.S.V., & Sccoti, A.A.V. (2019). A vegetação natural do estado de Rondônia. In: Stachiw, R. (Org.) Nossa terra, nossa gente: uma contribuição à história e geografia de Rondônia. Gráfica e Editora Imediata.

[45] SEDAM - Secretaria de Estado do Desenvolvimento Ambiental (2002). Atlas Geoambiental de Rondônia. SEDAM.

[46] Silva, E. C., Praia, W. M., Santos, A. S., Cardoso, L. A. P., Hara, F. A. S., Cavalheiro, W. C. S., & Vendruscolo, J. (2021). Características hidrogeomorfométricas da microbacia Três Galhos, Amazônia Ocidental, Brasil. *Research, Society and Development*, 10(2), 1-17, 2021. 10.33448/rsd-v10i2.12408

[47] Silva, Q. D. (2012). *Mapeamento geomorfológico da Ilha do Maranhão*. (Tese de Doutorado). Universidade Estadual Paulista.

[48] Soares, G. S., Santos Júnior, N. R. F., Mira, S. F., Moreto, R. F., Cavalheiro, W. C. S., Vendruscolo, J., & Rosa, D. M. (2019). Uso de plataforma SIG na caracterização morfométrica da microbacia do rio Santa Teresinha, Amazônia Ocidental, Brasil. *Revista Geográfica Venezolana,* 84-95. http://www.saber.ula.ve/handle/123456789/46157

[49] Souza, T. W. S., Lima, M. M., Saraiva, J. G., Pacheco, F. M. P., Donegá, M. V. B., Panza, M. R., Cavalheiro, W. C. S., & Vendruscolo, J. (2021). Análise hidrogeomorfométrica da microbacia do rio Mutum: informações para auxiliar o manejo de recursos hídricos na Amazônia Ocidental. *Research, Society and Development*, 10(2), 1-17. 10.33448/rsd-v10i2.12448

[50] Strahler, A. N. (1954). Quantitative geomorphology of erosional landscapes. *XIX International Geologic Congress*, 13(15), 341-354.

[51] Tambosi, L., Vidal, M. M., Ferraz, S. F. B., & Metzger, J. P. (2015). Funções eco-hidrológicas das florestas nativas e o Código Florestal. *Estudos Avançados*, 29(84), 151-162. 10.1590/S0103-40142015000200010

[52] Targa, M. S., Batista, G. T., Diniz, H. D., Dias, N. W., & Matos, F. C. (2012). Urbanização e escoamento superficial na bacia hidrográfica do Igarapé Tucunduba, Belém, PA, Brasil. *Revista Ambiente & Água*, 7(2), 120-142. 10.4136/1980-993X

[53] Tonello, K. C., Dias, H. C. T., Souza, A. L., Ribeiro, C. A. A. S., & Leite, F. P. (2006). Morfometria da bacia hidrográfica da Cachoeira das Pombas, Guanhães - MG. *Revista Árvore*, 30(5), 849-857. 10.1590/S0100-67622006000500019

[54] Vannote, R. L., Minshall, G. W., Cummins, K. W., Sedell, J. R., & Cushing, C. E. (1980). The river continuum concept. *Canadian Journal of Fisheries and Aquatic Sciences*, 37, 130-137.

[55] Vendruscolo, J., Araujo, M. G. S., Ferreira, L. R., Rosa, D. M., & Hara, F. A. S. (2021b). O uso de geotecnologias na caracterização geométrica, topográfica e hidrográfica da microbacia do rio Tamarupá, Amazônia Ocidental, Brasil. *Brazilian Journal of Development*, 7(1), 4245-4264. 10.34117/bjdv7n1-286

[56] Vendruscolo, J., Boone, N. R. V., Moreto, R. F., Santos Júnior, N. R. F., Soares, G. S., Lima, A. C. R., Cavalheiro, W. C. S., Scotti, M. S. V., Maia, E., & Hara, F. A. S. (2021a). Características da paisagem da sub-bacia do rio Escondido, Amazônia sul-ocidental, Brasil. *Research, Society and Development*, 10(3), 1-25. 10.33448/rsd-v10i3.13253

[57] Vendruscolo, J., Pacheco, F. M. P., Ramos, H. F., Cavalheiro, W. C. S., & Rodrigues. A. A. M. (2020a). Hidrogeomorfometria da microbacia Alto Rio Escondido: informações para auxiliar o manejo dos recursos naturais na Amazônia ocidental. *Brazilian Journal of Development*, 6(3), 9709-9730. 10.34117/bjdv6n3-011

[58] Vendruscolo, J., Pacheco, F. M. P., Rodrigues, A. A. M., Ramos, H. F., Rosa, D. M., & Cavalheiro, W. C. S. (2020b). Características morfométricas da microbacia do Médio Rio Escondido, Amazônia Ocidental, Brasil. *Brazilian Journal of Development*, 6(1), 565-585. 10.34117/bjdv6n1-040

[59] Villela, S. M., & Mattos, A. (1975). *Hidrologia aplicada*. McGraw-Hill.

[60] Wohlenberg, E. V., Reichert, J. M., Reinert, D. J., & Blume, E. (2004). Dinâmica da agregação de um solo franco-arenoso em cinco sistemas de culturas em rotação e em sucessão. *Revista Brasileira de Ciência do Solo*. 28(5), 891-900. 10.1590/S0100-06832004000500011