



ISSN:1984-2295

Revista Brasileira de Geografia Física

Homepage: <https://periodicos.ufpe.br/revistas/rbgfe>



Geospatial intelligence applied to the analysis of morphometric aspects and land use and land cover in a hydrographic basin in the Brazilian Cerrado

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Artigo recebido em 03/07/2021 e aceito em 03/02/2022

ABSTRACT

The morphometric analysis provides information on the hydrological response of the hydrographic basins regarding the aspects of maintenance, susceptibility to erosion and flooding that can support the planning and implementation of use and conservation measures. Thus, the objective was to understand the relationships between morphometric aspects, anthropic actions (land use and cover) and the conservation of the hydrographic basin of the Montividiu River, located in the southwest of the state of Goiás, Brazil. This hydrographic unit is the main source of water for public supply to the urban population of the municipality of Montividiu, in addition to being a water source for several irrigation projects for agricultural production. The study was carried out using the Shuttle Radar Topography Mission (SRTM) model, specific mathematical equations, Sentinel-2 image and Geographic Information System (GIS). It was observed: from the geometric results ($K_c = 2.18$, $K_f = 0.13$ and $I_c = 0.21$), an elongated structural arrangement that favors the conservation of the hydrographic basin, due to the reduced propensity to flooding; predominance of smooth wavy (49.05%) and flat (37.66%) reliefs, followed by wavy (12.96%) and strong wavy (0.33%); low drainage density with reduced number of river channels and highly permeable soil ($C_m = 2,012 \text{ m}^2.\text{m}^{-1}$, $D_d = 0,49 \text{ km.km}^{-2}$ and $E_p = 1,006 \text{ km}$); and high altimetric amplitude (360 m). From the joint analysis of the morphometric characteristics and land use and coverage, in which there is a predominance of agricultural areas, followed by the category of native vegetation and others, it is emphasized that anthropic actions must be aligned with modern management and conservation practices from soil.

Keywords: anthropic actions, geotechnologies, water resources, morphometric variables.

Inteligência geoespacial aplicada à análise de aspectos morfométricos e do uso e cobertura da terra de uma bacia hidrográfica no Cerrado brasileiro

RESUMO

A análise morfométrica fornece informações sobre a resposta hidrológica das bacias hidrográficas quanto aos aspectos de manutenção do corpo d'água, susceptibilidade à erosão e inundação que podem subsidiar o planejamento e implementação de medidas de uso e conservação. Assim, objetivou-se compreender as relações entre aspectos morfométricos, ações antrópicas (uso e cobertura da terra) e a conservação da bacia hidrográfica do Rio Montividiu, localizada no Sudoeste do estado de Goiás, Brasil. Essa unidade hidrográfica é a principal fonte de água para o abastecimento público da população urbana do município de Montividiu, além de ser fonte hídrica de diversos projetos de irrigação para a produção agropecuária. O estudo foi realizado por meio do modelo Shuttle Radar Topography Mission (SRTM), equações matemáticas específicas, imagem Sentinel-2 e Sistema de Informação Geográfica (SIG). Observou-se: a partir dos resultados geométricos ($K_c = 2,18$, $K_f = 0,13$ e $I_c = 0,21$), um arranjo estrutural alongado que favorece a conservação da bacia hidrográfica, devido a reduzida propensão a enchentes; predominância de relevos suave ondulado (49,05%) e plano (37,66%), seguidos de ondulado (12,96%) e forte ondulado (0,33%); baixa densidade de drenagem com reduzido número de canais fluviais e solo altamente permeável ($C_m = 2.012 \text{ m}^2.\text{m}^{-1}$, $D_d = 0,49 \text{ km.km}^{-2}$ e $E_p = 1,006 \text{ km}$); e alta amplitude altimétrica (360 m). A partir da análise conjunta das características morfométricas e do uso e cobertura da terra, no qual há predominância de áreas agrícolas, seguidas da categoria de vegetação nativa e outras, ressalta-se que as ações antrópicas devem ser alinhadas com modernas práticas de manejo e conservação do solo.

Palavras-chave: ações antrópicas, geotecnologias, recursos hídricos, variáveis morfométricas.

Pilatti, H. S. C., Alves, W. S., Pereira, M. A. B., Oliveira, L. D., Moura, D. M. B., Angelini, L. P.

Introduction

One of the main challenges faced by society nowadays is the protection of the ecosystems due to the degradation from the continuous increase of human pressures and its demands for environmental resources, as the inefficiency of policies that dispose over the use and cover of the land, intensifying changes that, sometimes, are irreversible in hydrographic basins (Desta and Fetene, 2020). This happens because the soil and water resources are basic and critical elements for countries where most of society and the general national economy depend on the agricultural production system. Thus, the activities for soil and water preservation in areas of interest demand environmental planning with the understanding of its physical characteristics (Asfaw and Workineh, 2019). That occurs due to the absence of knowledge of the characteristics of the planning unit which can affect the availability and quality of the water resources (Santos et al., 2018a). Therefore, studying a hydrographic basin is essential for its best use and management (Hirata and Burkert, 2020), ensuring water availability, rational use and prevention, and the defense against critical hydrological events of natural origin or inappropriate use (Brazil, 1997; Braga et al., 2020; Braga et al., 2021; Caldas et al., 2021; Martins et al., 2021), based on a participatory and decentralized water management model, established in the National Water Resources Policy (Brazil, 1997; Aires et al., 2021).

The morphometry portrays aspects of the relief and the existing environmental dynamics in a hydrographic basin through indicators related to its structure, because of the shape, declivity, or other aspects of the drainage network, making it possible to verify if they're favorable attributes or not to its preservation (Santos et al., 2018a; Charizopoulos et al., 2019), making the understanding of the physical parameters of the basin in the hydrological regime easier (Alves et al., 2020). Among these aspects, it is exemplified that the area of the basin implies the water volume produced as runoff, the shape factor and the relief act on the rate or regime of this water production, as well as the sedimentation rates, and the drainage pattern affect the rate of runoff formation (Back, Carlos and Pavei, 2021; Silva and Farias, 2021). Furthermore, the close relationship between the hydrological cycle and morphometry helps predict floods and inundations (Silva and Silva, 2021). And, the correlation between morphometry and land use and cover in the adjacencies of a hydrographic basin allows establishing the degree of human interventions in the unit, assessing the natural

susceptibility to actions external to the basin (Vale et al., 2021).

According to Bertolini, Deodoro and Boettcher (2019), the analysis of quantitative parameters (such as drainage network, geomorphology, lithology, and other physical factors) are a starting point for the development of environmental studies in hydrographic basins. The first morphometric parameters (for the study of a hydrographic basin) were proposed by Horton (1945) and Strahler (1952) and systemic approaches continue to be improved (Santos et al., 2019; Rossete et al., 2021). This type of analysis not only provides an elegant description of the hydrographic landscape, but it can also be used as an effective tool for comparing shape and hydrological performance between basins that may be temporally and spatially separated (Radwan et al., 2020; Crispim et al., 2021; Martins et al., 2021).

However, one of the biggest obstacles in the adoption and methodological proposition of hydrographic basins, as spatial units for integrated environmental planning, lies on their multiple dimensions and spatial expressions (Souza et al., 2021). However, the in-situ method demands a lot of capital and labor and takes a lot of time. Therefore, researchers as Miotto et al. (2014), Franco and Santo (2015), Leal and Tonello (2016), Moura et al. (2018), Fiorese and Torres (2019), Alves et al. (2020), and Hirata and Burkert (2020) accomplished morphometric analysis through the implementation of geoprocessing and confirmed that detailed and updated information of the drainage basin can be generated systematically, simplifying the process. The improvement of the geoprocessing tools has been contributing to better results and representativity, once it favors the delimitation of the contribution area and optimizes the data collection (Asfaw and Workineh, 2019; Fiorese, 2021), becoming a differential in the management of water resources and agri-environmental studies (Borges et al., 2020).

The geoprocessing uses geo-referenced databases through computer techniques to generate information and provide analysis and synthesis that will be used as a support for decision making related to environmental resources (Silva, 2009a; Cavalcante, Grigio and Diodato, 2021). According to Silva and Rosa (2019), the insertion of geoprocessing in the environmental analysis is necessary and positive for mapping, because it enables the compatible and low-cost apparatus. The evolution of techniques and methods of environmental evaluation get space in scientific studies of all areas, having as

Pilatti, H. S. C., Alves, W. S., Pereira, M. A. B., Oliveira, L. D., Moura, D. M. B., Angelini, L. P.

main objective to achieve more precise results consistent with the environmental reality (Batista et al., 2017). The achievement of quick results and the cost reduction promoted by geoprocessing, stimulated government agencies to implement this mechanism in their procedures, implying progress in terms of territorial planning and the inherent decision-making process (Sofia, 2020).

To understand the behavior of the environment strategies are used as modeling of natural systems, considering variables that embrace potentialities and fragilities of the area (Barbosa et al., 2018). After all, strategies to increase the resilience of the hydrographic basins due to uncertainties demand dynamic, space and time dynamics, adaptable to local and regional scales (Tsvetkova and Randhir, 2019), which offer basic information over hydrogeological aspects, areas prone to erosion, and characteristics of the hydrographic basin according to the potential of the underwater and superficial one (Asfaw and Workineh, 2019). Besides that, the quantitative analysis of the morphometric properties through remote sensing products and Geographic Information System (GIS) and the application of mathematic measures has been widely used for multiple uses, to evaluate flooding risk potential (Alam et al., 2020), having an important role to understand the land's relief and dynamics, geological and geomorphological aspects, being also able to prevent impacts (Castro and Carvalho, 2009). The characteristics of the environment, as drainage order, declivity, hypsometry, and other physical factors allow correlating natural elements and anthropic actions (Batista et al., 2017).

The GISs are computer tools used for geoprocessing that can be used as geographic database and storing of geospatial information (like satellite images and digital models of the terrain) used to produce cartographic documents (Câmara and Queiroz, 2001). The use of relief information in a GIS environment makes it possible to understand the physical characteristics of hydrographic basins (Lopes, Ramos and Leal, 2018; Alves and Barros, 2021). And, therefore, they are widely used in research in the environmental area to contribute to the planning and suitability of economic actions practiced in the geographic space (Schnorr, Sccoti and Petsch, 2021).

Due to the importance of the analysis, the

studies by Alves et al. (2016), Alves et al. (2017), Batista et al. (2017), Alves et al. (2018), Pinto et al. (2018), Sahoo and Jain (2018), Santos et al. (2018a), Santos et al. (2018b), Alves et al. (2019), Asfaw and Workineh (2019), Charizopoulos et al. (2019), Domazetović et al. (2019), Alam et al. (2020), Wegner et al. (2020), and others have used the morphometric aspects as useful variables in the hydrological characterization of the hydrographic basin, whether to estimate aspects of water availability, susceptibility to erosion, or floods.

Therefore, due to the necessity of environmental planning that incorporates the understanding of the water resources, the study has as objective to analyze, through remote sensing products, and geoprocessing techniques, morphometric aspects, anthropic actions (land use and coverage), and the preservation of the hydrographic basin of Rio Montividiu (HBRM), Southwest of Goiás state, Brazil. This study area was chosen due to being the water source for the supply of the urban population of the municipality of Montividiu, and besides fulfilling the water demand of the agribusiness, mainly irrigation projects for high production of grains (predominantly soy, and corn), cattle farming, poultry, and swine. The results will subsidize the environmental management of this resource and substantiate several academic studies.

Material and methods

Study area

The hydrographic basin of Rio Montividiu is located in the Southwest of Goiás state, Brazil (Image 1). Its main watercourse is born in the following geographic coordinates 51°39'50,84"W/17°17'34,50"S, and it drains into Rio Verde or Verdão, in the following coordinates 50°59'38,56"W/17°19'25,88"S. It was observed a grant of rights of the water use of Rio Montividiu to supply the demand of the urban population of the municipality of Montividiu, estimated by Instituto Brasileiro de Geografia e Estatística (IBGE, 2020) of about 13,672 inhabitants, being captured a volume of 60 L.s⁻¹ (from 12/26/2015 to 10/16/2027), referring to the process n°. 18922015 of Secretaria de Estado de Meio Ambiente e Desenvolvimento Sustentável (SEMAD, 2018).

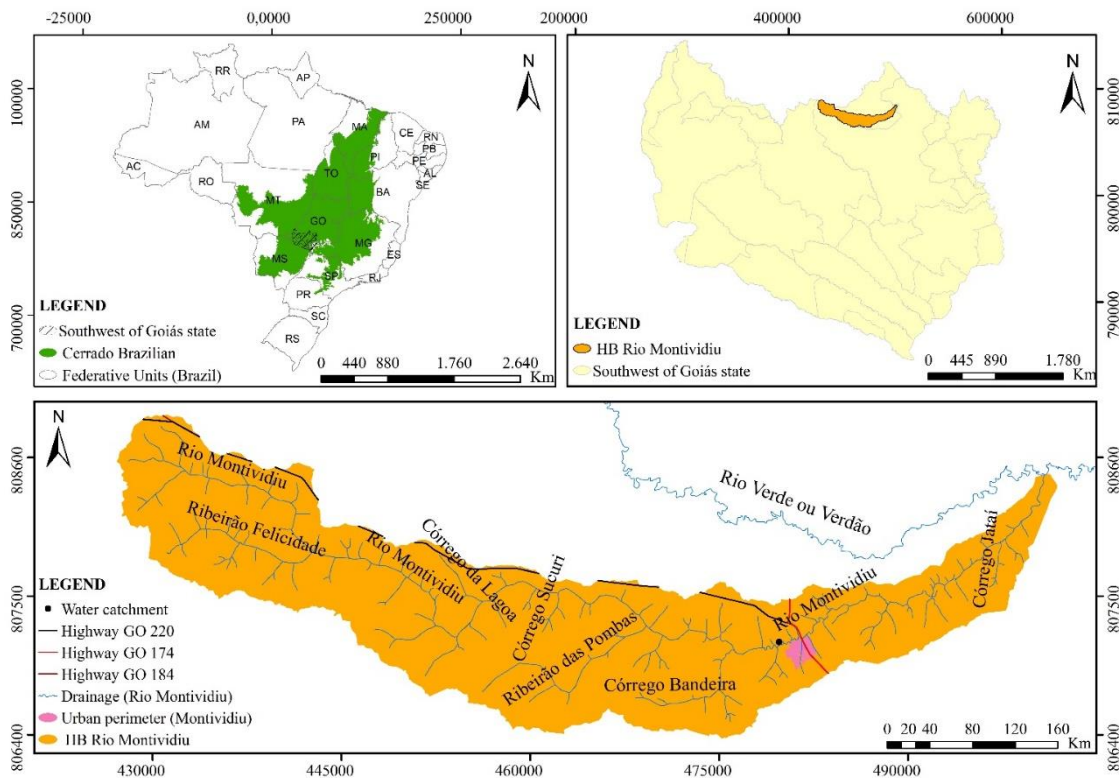


Image 1. Location of the hydrographic basin of Rio Montividiu, Southwest of Goiás state, Brazil.

Source: Map organized by the authors from the database enabled by SIEG (2020).

Elaborated in the Plane Coordinates System: Datum Sirgas 2000, UTM, 22S Zone.

The climate of this region is classified by Köppen-Geiger as Aw or semi-humid tropical, with well-defined seasons, with winter during from May to September, and characterized by strong water deficiency, and the rainy season (summer) from October to April, a period in which occurs more than 90% of the annual rainfall (Cardoso, Marcuzzo and Barros, 2014; Silva et al., 2019a; Silva et al., 2019b; Cassino et al., 2020). Observing a period of 34 years, from January 1986 to December 2019 of the water station of Montividiu (code #1751004), the total monthly average is 120.54 mm and the average annual rainfall index is 1,446.44 mm, with the data presented in Image 2 (ANA, 2020).

The climatic variation is characterized by the seasonality of the Cerrado in which in rainy periods there's the intensification of the rainfall indexes with an increase in the temperature and in the drought period which presents low relative humidity

and cold fronts, with Indian Summer days in both seasons (Malheiros, 2016).

Considering the about 50% of the Cerrado area is under agricultural use (Santos et al., 2021), and that the practice occurs mainly in the rainy season, albeit the average rainfall is considered enough for many crops, the "Indian summer" is a limiting factor when it occurs during the growth stage of the plant, being able to cause the reduction of productivity (Assad et al., 1993; Silva et al., 2019a), considering soy as one of the most affected crops by climatic changes, showing itself highly vulnerable to temperature increase (Machado Filho et al., 2016). Thus, the production balance shows itself as directly dependent on the weather and its variability, which makes it indispensable to know the characteristics of each season and the cycle of life of the crops to determine the planting according to the water conditions of the soil (Silva et al., 2009b).

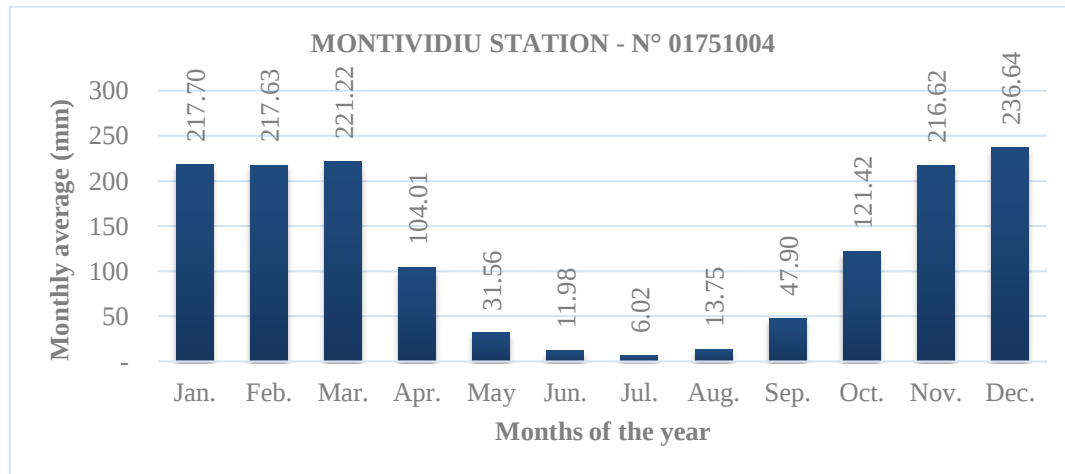


Image 2. Monthly rainfall average from January 1986 to December 2019, in the basin of Rio Montividiu, Southwest of Goiás state, Brazil.

Source: Elaborated by the authors from data enabled by ANA (2020).

According to the Geological Map of the State of Goiás and Distrito Federal (1:500,000 scale), created by Superintendência de Geologia e Mineração/ Secretaria Estadual de Indústria e Comércio (SGM/SIC) and made available by SIEG (2020), the HBRM is composed by rocks with ages which vary from the Neogene and Cretaceous, from sedimentary formations (undifferentiated detrital coverage unit and Bauru Group – Vale do Rio Peixe Formation) and igneous (São Bento Group - Serra Geral Formation).

It's possible to observe in the study area the predominance of undifferentiated detrital coverages (about 72.08% of the total area), followed by Serra Geral Formation (about 21.38% of the total area), and Vale do Rio do Peixe Formation (about 6.54% of the total area) (SIEG, 2020).

While observing the Soils Map of the Plano Diretor da Bacia do Rio Paranaíba (1:250,000 scale), created on March 2005 by Universidade Federal de Viçosa (UFV, 2005),/ Fundação Rural Minas (RURAL MINAS, 2005), and made it available by SIEG (2020), the region of the HBRM has three types of soils: Haplic Gleysol Tb Plintosolic Dystrophic (GXbd) with clayey texture (about 2.32% of the total area), Dystroferic Red Latosol (LVdf) of clayey texture or very clayey texture (about 72.27% of the total area).

The Gleysols occupy a small portion of the basin and are located close to the water source and water bodies (hydromorphic soils), which limits the use for agriculture, mainly because they are areas destined for the preservation of riparian forests. However, they have agricultural potential, since they aren't in the environmental protection

perimeter and that they don't present high aluminum content, sodium, and sulfur (Moura et al., 2020).

The latosol class is the most used for the development of agricultural activities due to the geographic condition and softer relief, contemplating a third of the national territory (Ker, 1997). The predominance of smooth-wavy relief is a characteristic of the Southwest of Goiás state, formed by dissected plateaus (Sousa et al., 2006).

The vegetation of the area presents different physiognomies of the Cerrado which vary from forest formations (densely treed Savannah or Cerradão, Riparian Forests, and Gallery), forestry until typically rural formations (Dirty Fields). Cerradão is characterized as sclerophyll with a poor and rarefied herbaceous/subshrub layer, formed by trees that vary from 8 to 15 m average height and coverage between 50 and 90% (in other words, the treetops meet each other). The Riparian Forests outline the rivers and consist of a set of trees that reach 20 to 25 m tall, being a formation of semideciduous aspect. The Gallery Forest, on the other hand, follows the drainage network and present evergreen trees with an average height between 20 and 30 m. While the Dirty Field characterizes by the predominance of grasses and less developed vegetation with scrubs and smaller trees (Oliveira, 2014).

Morphometric variables

For the characterization and morphometric analysis of the basin maps were elaborated such as maps of hydrography, altimetry, watercourses order and declivity with the use of ArcGIS Advanced 10.8.1® software, licensed by the code #647261 (ESRI, 2020), geographic information of the Sistema Estadual de

Geoinformação de Goiás (SIEG, 2020), and images from Shuttle Radar Topography Mission (SRTM) with a spatial resolution of 30m x 30 m, generated by National Aeronautics and Space Administration (NASA, 2020) and made available by the United States Geological Survey (USGS, 2020).

The hydrography was extracted from the drainage by the Digital Vector Cartographic Basis (1:100,000 scale), generated by Agência Nacional de Águas ANA (2006) and made available by SIEG (2020).

The maps of declivity, hypsometry, and order of the channels were elaborated using a 1:150,000 scale, following the proposal of the definition of IBGE's scale (1999), in which the spatial resolution is divided by the visual acuity factor (0.2 mm transformed into 1000 constant scale). And, it was also used the Geocentric Reference Coordinate System for the Americas (Sirgas) 2000, Universal Transverse Mercator projection (UTM), Zone 22 South (S).

From the SRTM base, secondary data were collected for calculus of morphological aspects: area, perimeter, number of watercourses, axial length, average height, length of the main channel, length of the total of the channels, average vector equivalent in a straight line and the declivity of the basin. The equations used are presented in Chart 1

for the obtention of the morphometric indexes, recommended by Christofoletti (1980).

For the declivity, it was used, as Embrapa's classification parameter proposed by Santos et al. (2018c) and presented in Chart 2. For the drainage density, the classification was accomplished according to Beltrame's proposal (1994), Chart 3, while the water density according to Villela and Matos (1975) who consider a variation from 0.5 km.km⁻² (hydrographic basins poorly drained) to 3.5 km.km⁻² (hydrographic basins exceptionally well-drained). The analysis of hydrographic density also covered the classification accomplished by Lollo (1995), Chart 4. And the hierarchical order of the hydrographic channels was used according to Strahler (1957).

The coefficient of compactness was analyzed according to Spanghero, Meliani and Mendes (2015), who considered the minimum value of 1 to basins with the shape of a perfect circle and, the bigger the coefficient, the longer the format.

The rugosity index, on the other hand, was qualified according to the declivity and the proposition by Sousa and Rodrigues (2012), Chart 5. In addition, for the shape factor, it was used as a parameter the classification proposed by Villela and Matos (1975), and presented in Chart 6.

Char 1. Mathematical equations used to obtain morphometric indexes

Morphometric Index	Equation	Unit	Source
Compactness coefficient (Kc)	$Kc = \frac{0,28P}{\sqrt{A}}$	Dimensionless	Villela and Mattos (1975)
Shape factor (Kf)	$Kf = \frac{A}{La^2}$	Dimensionless	Villela and Mattos (1975)
Circularity Index (Ic)	$Ic = \frac{12,57A}{P^2}$	Dimensionless	Muller (1953)
Hydrographic density (Dh)	$Dh = \frac{N}{A}$	Channels.km ⁻²	Horton (1945)
Maximum altimetric amplitude (Hm)	$Hm = PI - PII$	m	Strahler (1952)
Rugosity index (Ir)	$Ir = Hm * Dd$	Dimensionless	Melton (1957)
Declivity of the main channel (S1)	$S1 = \frac{100Hm}{Lcp}$	%	Villela and Mattos (1975)
Sinuosity index of the main watercourse (Is)	$Is = \frac{Lcp}{Ev}$	km.km ⁻¹	Schumm (1963)
Relief ratio (Rr)	$Rr = \frac{Hm}{Lcp}$	m.km ⁻¹	Schumm (1956)
Drainage density (Dd)	$Dd = \frac{Lt}{A}$	km.km ⁻²	Horton (1945)
Maintenance coefficient (Cm)	$Cm = \frac{1000}{Dd}$	m ² .m ⁻¹	Schumm (1956)
Superficial course extension (Eps)	$Eps = \frac{1}{2Dd}$	km	Horton (1945)

A: area of the basin (km²); P: perimeter of the basin (km); La: axial length of the basin (km); N: number of channels of the first order; PI: maximum altitude of the topographic divisor (m), PII: river mouth altitude (m); Lcp: length of the main watercourse plan (m); Ev: average vectoral equivalent in straight line (km); Lt: total length of the drainage network (km); Esc: extension of the superficial course (km).

Source: Elaborated by the authors (2020).

Chart 2. Declivity classes

Declivity	Classification
0 – 3%	Flat
3% – 8%	Smooth-wavy
8% – 20%	Wavy
20% – 45%	Strong-wavy
45% – 75%	Mountainous
> 75%	Rugged

Source: Santos et al. (2018c).

Chart 3. Drainage density classes

Drainage density (km.km ⁻²)	Classification
< 0.5	Low
0.5 – 2	Average
2.01 – 3,5	High
> 3.5	Very high

Source: Beltrame (1994).

The circularity index is calculated according to Muller (1953), which varies between 0 and 1: the proximity to the unit corresponds to a basin of a circular shape, and, consequently, prone to floods; values equal to 0.51 present a moderate flow; while, a value under 0.51 correspond to basins in an extended shape, which favors the flow (Moura et al., 2018).

Chart 4. Hydrographic density classes

Hydrographic density (canais km ⁻²)	Classification
< 3	Low
3 – 7	Average
7 – 15	High
> 15	Very high

Source: Lollo (1995).

Chart 5. Rugosity index classes

Rugosity index	Classification
0 – 150	Low
151 – 550	Average
551 – 950	Strong
> 950	Very strong

Source: Sousa and Rodrigues (2012).

Chart 6. Classes of the shape factor

Shape factor	Verification
< 0.5	Low propensity to floods.
0.5 – 0.75	Average propensity to floods.
0.75 – 1	Basins susceptible to floods.

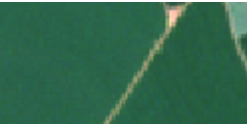
Source: Villela and Mattos (1975).

The sinuosity index indicates that values close to 1.0 present a tendency of the main watercourse to be rectilinear, values above 2.0 imply tortuous channels, and intermediate values belong to channels with transitional shapes (Lana et al., 2001).

The classification of the relief ratio happened due to the proposal by Piedade (1980): low (0.0 to 0.10), average (0.11 to 0.30), and high (0.31 to 0.60).

The map of land use and cover was drawn by an image of March 2020 from the satellite Sentinel-2/sensor Multi-Spectral Instrument (MSI). The bands (B) used were B3 (Green), B4 (Red), and B8 (Near-infrared), in the combination B8, B4, and B3 (false color). At first, classification tests were accomplished through the non-supervised and interactive supervised classifications, not presenting any satisfactory results. Thus, there was made an option of accomplishing the regionalized classification manually. Knowing that image interpretation is an efficient correlation instrument (IBGE, 2013), the acknowledgment of areas that occurred through Google Earth Pro (Google, 2020), resulting in the classes: urban area, agricultural area, dirty field, rural building, eucalyptus, Cerrado fragments, riparian forest/gallery, pasture, water, exposed soil, industrial area, and highways. The images from Sentinel-2 and Google Earth Pro subsidized the elaboration of the interpretation key of the image from MSI Sensor (Chart 7).

Chart 7. Interpretation key of the images from Sentinel-2/MSI Sensor for the mapping and classification of the land use and vegetation cover in the basin of Rio Montividiu, Southwest of Goiás state, Brazil

Classes	Sentinel 2 / MSI Sensor	Tone/color	Texture
Cerrado/forest		Dark green	Rugged
Pasture		Light green or light pink	Flat - average
Exposed soil		Reddish	Flat
Agricultural area		Dark green to light green or white	Flat
Rural buildings		White	Flat
Water surface		Light blue/green	Flat

Source: Designed by the authors (2020) based on studies from Ayachet al. (2012); Rex et al. (2018); and Medieros, Silva and Lunardi (2019).

The validation of the classification occurred through the Kappa index (Cohen, 1960), a process in which manual and aleatory samples are selected from the image of Sentinel-2 that are crossed with a map of land use and cover, resulting in the Confusion Matrix. These samples differ from training samples used in the initial process of supervised classification.

Based on the Confusion Matrix, the Kappa index was calculated using equation 1 (E1):

$$K = \frac{n * \sum_{i=1}^c X_{ii} - \sum_{i=1}^c X_{i+} * X_{+i}}{n^2 - \sum_{i=1}^c X_{i+} * X_{+i}} \quad (E1)$$

Where: K is an estimative of the Kappa coefficient; n, the total number of samples; c, the total number of classes; X_{ii} , the diagonal value of

the confusion matrix, descending (value in line i and column i); X_{i+} , the sum of line i ; and X_{+i} , the sum of column i of the confusion matrix.

According to IBGE (2013), with this procedure it's possible to obtain a preliminary classification, that will suffer a reinterpretation after field surveys in the investigated area. Thus, after the field and the readjustments in the classification, the result was the elaboration of a map of land use and soil cover on a 1:50,000 scale (IBGE, 1999).

Results and discussion

Table 1 presents the results of the morphometric indexes of the basin of Rio Montividiu with data that characterize the geometry, relief, and drainage network, calculated to form the general character of the basin (Asfaw and Workineh, 2019).

Table 1. Values of indexes of morphometric geometry, relief and drainage network of the basin of Rio

Pilatti, H. S. C., Alves, W. S., Pereira, M. A. B., Oliveira, L. D., Moura, D. M. B., Angelini, L. P.

Montividiu, Southwest of Goiás

Characteristic	Morphometric variables	Results
Geometric	Area (A)	695.02 km ²
	Perimeter (P)	205.02 km
	Number of channels (N)	139
	Axial length (La)	73.48 km
	Compactness coefficient (Kc)	2.18
	Shape factor (Kf)	0.13
	Rugosity index (Ir)	178.92
	Hydrographic density (Dh)	0.19 channels km ⁻²
	Circularity index (Ic)	0.21
Relief	Highest point of the basin (P1)	1030 m
	Lowest point of the basin (P2)	670 m
	Average altitude	903.13 m
	Altimetric amplitude (Hm)	360 m
	Declivity of the main channel (S1)	0.37%
	Sinuosity index Is)	1.33
	Relief ratio (Rr)	4.9 m.km ⁻¹
Drainage network	Length of the main channel (L)	96.91 km
	Total length of the channels (Lt)	345.47 km
	Average vectoral equivalent in straight line (Ev)	72.54 km
	Drainage density (Dd)	0.49 km.km ⁻²
	Maintenance coefficient (Cm)	2,012 m ² .m ⁻¹
	Extension of the superficial course (Eps)	1,006 km
	Order of the main watercourse	4 th order

Source: Elaborated by the authors (2020).

It's an area of 695.02 km² with a perimeter of 205.02 km and axial length of 73.48 km, composed of 139 channels of 1st order. Ribeirão das Pombas, Ribeirão Felicidade, Córrego Bandeira, Córrego da Raiz, Córrego Jataí, Córrego Sucurí, and Córrego da Lagoa compose the hydrography (Image 3). According to Strahler's (1957) classification, the HBRM is considered 4th order (Image 4), which represents a high number of affluent in the area of interest (Santos et al., 2018a). Thus, considering that the greater the degree of ramification, the more efficient the drainage, once the rainwater flows on a short length until it finds a watercourse (Villela and Matos, 1975), the order of the HBRM becomes a favorable aspect to public supply of the municipality

of Montividiu (GO) due to a greater area of contribution to the water catchment. Such characteristic which differs it from the one identified in the basin of Ribeirão da Laje, also inserted in the Southwest of Goiás state, which has 73 channels of 1st order, and low ramification degree, being able to harm the water supply to the city of Rio Verde (GO) (Alves et al., 2018). Also, according to Fiorese, Silva and Torres (2019), the order of the basin influences projects for the recovery of Permanent Preservation Areas (PPAs), because, theoretically, the greater the hierarchy, the greater the width of the river and, consequently, the greater the preserved area.

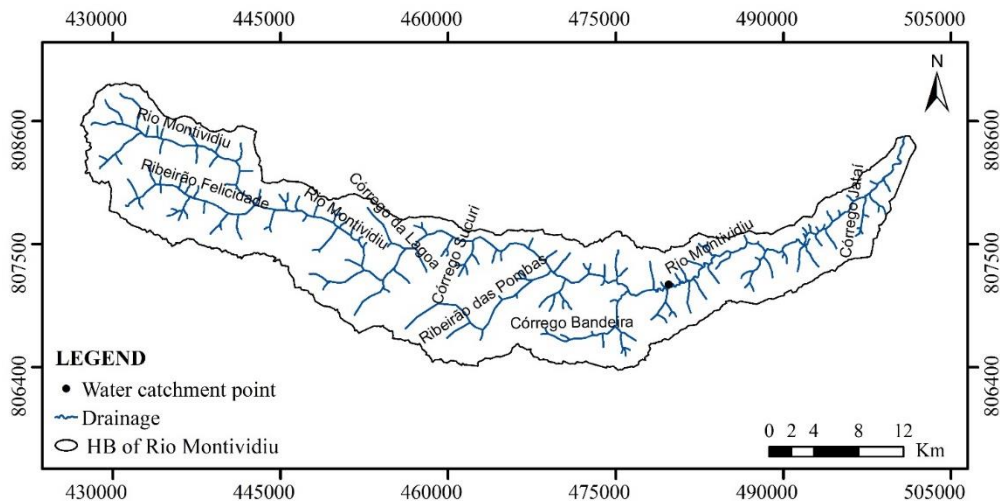


Image 3. Hydrography of the basin of Rio Montividiu, Southwest of Goiás state, Brazil.

Source: Elaborated by the authors from the database enabled by SIEG (2020), projected in the Plane Coordinates System: Datum Sirgas 2000, UTM, 22S Zone.

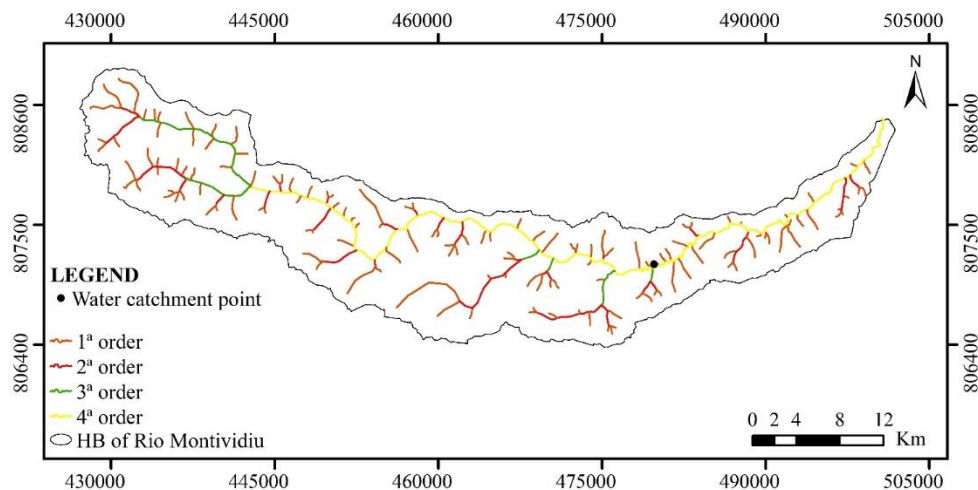


Image 4. Hierarchical order of the hydrographic channels (according to Strahler (1957)) of the basin of Rio Montividiu, Southwest of Goiás state, Brazil.

Source: Elaborated by the authors from the database enabled by SIEG (2020), projected in the Plane Coordinates System: Datum Sirgas 2000, UTM, 22S Zone, 1:150.000 scale.

The format of the basin and the related hydrological characteristics can be understood from the shape factor (K_f), compactness coefficient (K_c), and circularity index (I_c) (Spanghero, Meliani and Mendes, 2015; Santos et al., 2018a). For those variables, the obtained values were respectively, $K_f = 0.13$, $K_c = 2.18$, and $I_c = 0.21$ indicating that the HBRM has a long format (a characteristic that can be observed in the maps) with reduced propensity to the event of floods because the tendency of suffering from overflows is related to the circular shape (Moura et al., 2018).

While K_c and I_c correlate the perimeter of the interest zone and the area of the basin (Muller, 1953; Villela and Mattos, 1975), the K_f is derived from the ratio between the area and the axial length squared, being a parameter to predict the intensity

of the flow of a hydrographic basin, within its high values an indicative of high outflow of short term and vice versa. And, the lowest the value of the K_f , the longest the basin (Villela and Mattos, 1975); Asfaw and Workineh, 2019; Alam et al., 2020). The result of the K_f in the basin of Rio Montividiu represents a low flow peak with a greater duration of time. Thus, knowing that a basin with reduced K_f has fewer chances of suffering floods due to hardly ever heavy rains hit the basin on its whole at the same time (Alves et al., 2016), justifies that the low susceptibility of the basin to this type of phenomenon, considering the normal rainfall conditions (Villela and Mattos, 1975). Although its low susceptibility to floods, considering eventual torrential rainfall in the highest part of the hydrographic basin, there can be problems such as

waterspout, putting in risk bathers who are in the average-low basin, and also the landslide of the margins of watercourses, silting, devastation of the fertile layers of the soil, other environmental damages, and losses to landowners due to the devaluation of the land (Alves et al., 2020).

Similarly, the basins of Ribeirão da Laje ($K_f = 0.20$) (Alves et al., 2018), Ribeirão das Abóbora ($K_f = 0.23$) (Alves et al., 2016), Ribeirão Douradinho ($K_f = 0.30$) (Alves et al., 2019), and Ribeirão Santo Antônio ($K_f = 0.37$) (Moura et al., 2018), all located in the state of Goiás, present a longer format and reduced propensity to floods in ordinary rainfall conditions. Besides the results are similar in the analyzed basins by Santos et al. (2018a), and located specifically in the municipality of Rio Verde (GO); Rio Verdinho ($I_c = 0.26$), Ribeirão Monte Alegre ($I_c = 0.19$), and Rio São Francisco ($I_c = 0.25$).

Such characteristics were also verified in a set of basins inserted in the state of Mato Grosso by the study by Pinto et al. (2018) in the basin of Rio Santaré ($K_c = 1.91$ and $I_c = 0.26$), in the research by Costa, Galvanin and Neves (2020) in the hydrographic basin of Paraguai/Jauquara ($K_c = 1.73$ and $I_c = 0.33$), and the research accomplished by Félix and Souza (2017) in Rio Cabaçal ($I_c = 0.08$).

On the other hand, the rugosity index is a dimensionless product of the drainage and relief density which ends up determining the carving degree of the rivers on the surface of the earth and it's capable of indicating the favoring to erosion and sediment transportation, fluxes of fast peaks, and sudden floods, resulting in high values in the basins with steep slopes (Melton, 1957; Asfaw and Workineh, 2019; Medeiros, Berezuk and Pinto, 2019; Alam et al., 2020). In the HBRM, the rugosity index (178.92) is classified as average (Sousa and Rodrigues, 2012), indicating susceptibility to floods due to the characteristic of the relief that influences the superficial flow capacity, and also an average propensity to erosive processes, which requires proper management and preservation practices in the area. A classification which also embrace the basins of Ribeirão da Laje ($I_r = 189.75$) and Ribeirão das Abóbora ($I_r = 155.25$), located in the Southwest of Goiás state (Alves et al., 2016; Alves et al., 2018). The low hydrographic density of the HBRM ($0.19 \text{ channels km}^{-2}$) characterizes the study area as a reduced capacity of generating new channels, flow difficulty, favoring infiltration, and, due to the greater watercourse in the surface, propensity to erosive processes (Lollo, 1995). A corroborated aspect by the analysis of the parameters by Villela and Matos (1975), in which

the HBRM fits as poor drainage.

The morphometric aspects related to the drainage network in a hydrographic basin have also being used as useful parameters in the hydrological characterization of a basin (Sahoo and Jain, 2018). Thus, the sharing between the total length of the drainage network, and the area of the basin, the drainage density (D_d) represents the proximity of the space of the channels or the average length of the channel of the river for all the basin and it's related to the dissection of the landscape, climate, and vegetation, properties of the soil and rock, and erosive processes of the evolution of the landscape, reflecting in the infiltration capacity, water production (including the underwater potential) and sediment of the catchment area, besides the susceptibility to erosion (Horton, 1945; Asfaw and Workineh, 2019; Martins et al., 2021).

The HBRM is classified as low drainage density ($D_d = 0.49 \text{ km.km}^{-2}$), a characteristic of the highly permeable subsoil to vegetation cover and bas-relief (Beltrame, 1994; Asfaw and Workineh, 2019). Besides that, the low value of the D_d indicates inefficient drainage in the hydrographic network and it can influence the shape of the hydrologic answer, in case this basin isn't susceptible to floods (Charizopoulos et al., 2019).

Studies developed in basins of the Southwest of Goiás state indicate that the D_d is generally from low to average: in the research made by Alves et al. (2016) about the basin of Ribeirão das Abóbora it was verified a D_d of 0.661 km.km^{-2} ; Alves et al. (2018) identified $0.55 \text{ channels.km}^{-2}$ referred to the basin of Ribeirão da Laje; the D_d found for the basin of Ribeirão Douradinho was 0.59 km.km^{-2} (Alves et al., 2019); and, on the whole, the basins of the municipality of Rio Verde are characterized as from low to average drainage density (Santos et al., 2018a). Although the difference of classes between the analyzed basins and the one from Rio Mondividiu, the values of D_d described don't present a great discrepancy.

And through the coefficient of maintenance (C_m) verifies the necessary area to maintain an active meter of perennial flow in a channel of the basin (Moura et al., 2018), being necessary for the HBRM of 2.012 m^2 for the maintenance of 1 m of the channel ($2.012 \text{ m}^2.\text{m}^{-1}$). The greater the C_m value, the less dense the drainage of the basin (Alves et al., 2019). Therefore, due to the high value of the C_m , the HBRM presents itself as "poor" in watercourses, a predominant characteristic in areas with a smoother relief. In this scenery, due to heavy rainfall in plain areas, the superficial flood tends to concentrate and form preferential fluxes which compose the drainage network. On the other hand,

the value of C_m would reduce gradually as the relief becomes wavier, that happens because the superficial flood tends to follow the natural declivity of the terrain excavating the soil in spots of less resistance to the shear, enabling a greater concentration of natural channels, and, on the other hand, a greater drainage density (Queiroz et al., 2017). The basin of Rio Ivaí, located in the state of Paraná, indicates a C_m even higher than the HBRM of $4,400.476 \text{ m}^2.\text{m}^{-1}$, and, therefore, presents scarcity in the evolution of the drainage for demanding a greater area for maintenance of 1 m of channel flux (Souza et al., 2017).

On the other hand, the extension of the superficial course (Esc) is 1.006 km that, according to analyses by Alves et al. (2018) and Alves et al., (2019) referred to the basins of Ribeirão da Laje and Ribeirão das Abóboras, respectively, it's about a favorable characteristic to the preservation of the basin due to the vast distance for the flow of the flood and greater time for water concentration, reducing the susceptibility to erosion actions, besides benefiting the infiltration and recharge of water in the system.

The highest altitude of the HBRM is 1,030 m, the lowest, 670 m, resulting in an average altitude of 903.13 m and altimetric amplitude of 360 m (Image 5), that interfere with the rugosity index and relief ratio, and it's considered high, and, therefore, unfavorable to the preservation of the basin – unlike the hydrographic basin do Alto do

Rio Meia Ponte, located 60 km from Goiânia, which has a low altimetric amplitude, varying from 120 m to 240 m (Calil et al., 2012).

The relief ratio enables comparing the local altimetry to verify the rough places, from the principle that the bigger the obtained value in the calculus, the rougher the relief of the region and the greater the superficial flow of the rainfall, reflecting on a smaller infiltration-runoff relation, causing erosion (Rodrigues, Cardoso and Pollo, 2015). According to Piedade (1980), the R_r of the HBRM is 4.9 m.km^{-1} (0.0049 m.m^{-1}), indicating a low flow velocity from the water body, which enables the infiltration, and, consequently, reduces the risk of erosions and silting. Such characteristic is compatible with the predominance of the types of identified reliefs in the area of the basin, at which the greatest part consists of flat and smooth wavy. The classification of the R_r is similar in the studies by Alves et al. (2018) in Ribeirão da Laje ($R_r = 7.50 \text{ m.km}^{-1}$), Alves et al. (2019) in the basin of Ribeirão Douradinho ($R_r = 9.80 \text{ m.km}^{-1}$), Pinto et al. (2018) in Rio Sararé ($R_r = 4.0 \text{ m.km}^{-1}$) and by Félix and Souza (2017) in the basin of Rio Cabaçal ($R_r = 3.0 \text{ m.km}^{-1}$). And, differently from the value observed by Rodrigues, Cardoso and Pollo (2015) in a basin in the coast of Botucatu (SP) with R_r highly susceptible to erosion ($R_r = 0.42 \text{ m.m}^{-1}$) due to the steep relief – a situation that can be aggravated by the lack of vegetation cover.

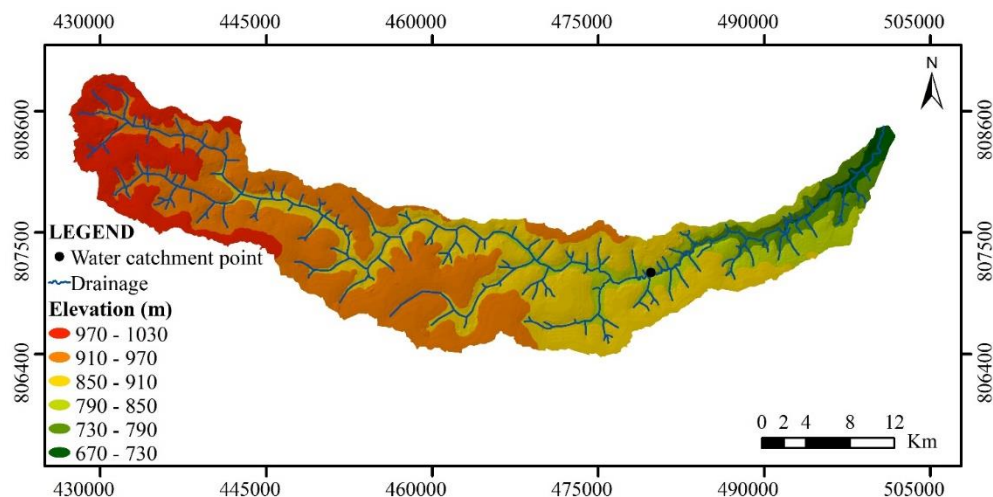


Image 5. Hypsometry map of the basin of Rio Montividiu, Southwest of Goiás state, Brazil.

Source: Elaborated by the authors from the database enabled by USGS (2020), projected in the Plane Coordinates System: Datum Sirgas 2000, UTM, 22S Zone, 1:150.000 scale.

The results of declivity of the HBRM are presented in Table 2 and Image 6, with a minimum value of 0% and a maximum of 41%, according to the classification proposed by Santos et al. (2018c). The smooth wavy relief with declivity from 3% to 8% is predominant, and represents 49.05% of the

total, corresponding to an area of 340.94 km^2 . In the second place, there's the flat type (37.66%), followed by the wavy one (12.96%), and strong wavy on a smaller scale (0.33%). In this study area, there were no mountainous and rugged relief classes identified.

Table 2. Declivity classes of the hydrographic basin of Rio Montividiu, Southwest of Goiás state, Brazil

Declivity (%)	Relief	Area	
		km ²	%
0 – 3	Flat	261.72	37.66
3 – 8	Smooth wavy	340.94	49.05
8 – 20	Wavy	90.06	12.96
20 – 45	Strong wavy	2.30	0.33
45 – 75	Mountainous	–	–
> 75	Rugged	–	–
Total	–	695.02	100

Source: Elaborated by the authors according to the classification by Santos et al. (2018c).

The predominant declivity profile in the HBRM (smooth wavy) is also identified with representativity in the hydrographic basins of Ribeirão Douradinho and Ribeirão da Laje. The study accomplished by Alves et al. (2019) in the hydrographic basin of Ribeirão Douradinho presents that 60.25% of the total area is classified as smooth wavy relief, and the research developed by Alves et al. (2018) in the basin of Ribeirão da Laje points out that 54.71% of the total area of the basin is also smooth wavy. Moreover, according to Santos et al. (2018a), most of the basins inserted in the municipality of Rio Verde, administrative unit adjacent to the one of Montividiu, presents a low declivity, confirming the prominent characteristics

of the relief in the Southwest region of Goiás state.

Complementarily, it was verified a low declivity in the main channel (S1) of the HBRM (0.37%), a percentage considered favorable to the protection of the drainage network, because it decreases the speed of the flux flow, and, consequently, reduces the erosive potential due to greater stability of the soil and the resistance to rainfall action. However, this same factor subjects the basin to the deposition of sediment that are in the lower areas of the relief, silting up water courses and contributing to the formation of technogenic deposits (Venceslau and Miyazaki, 2019; Fiorese, 2021).

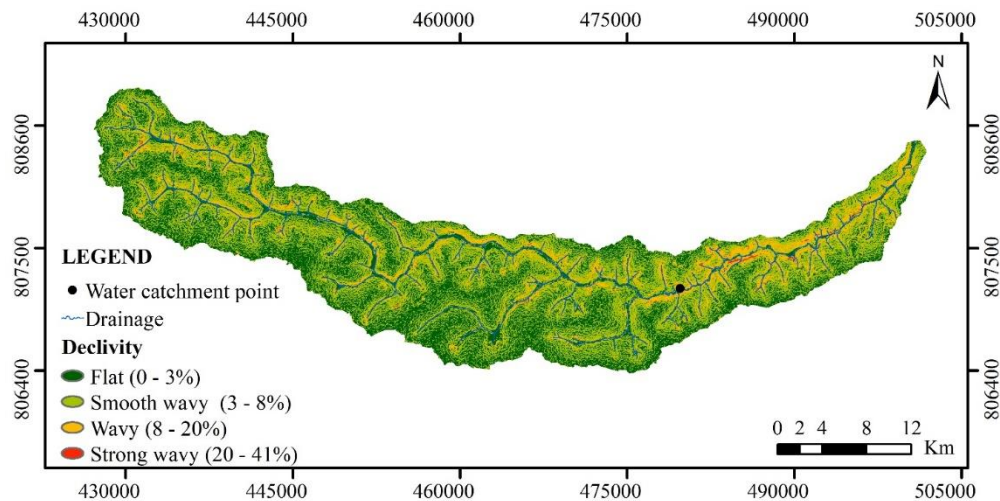


Image 6. Declivity map of the basin of Rio Montividiu, Southwest of Goiás state, Brazil.

Source: Elaborated by the authors from the database enabled by USGS (2020), projected in the Plane Coordinates System: Datum Sirgas 2000, UTM, 22S Zone, 1:150.000 scale.

Moreover, the sinuosity index of 1.33 of the main channel implies a basin of transitional shapes, regular and irregular ones, which suffer the influence in their physical and geological structures, a load of sediment, and lithology (Lana et al., 2001). According to Batista et al. (2017), the Is characterizes the flow speed of the watercourse, since the smaller the sinuosity, the greater the facility

of the flow to get to the river mouth, and, with a high sinuosity, it will find a greater difficulty. A similar result to the one found by Silva et al. (2018) while studying the basin of Riacho Rangel in Piauí state, where it was obtained the Is of 1.18. On the other hand, Batista et al. (2017) identified an Is of 2.41 in the basin of Ribeirão Santo Antônio, Goiás state, describing a water body composed of sinuous

channels which must receive special attention regarding the monitoring, it can be a factor which can intensify erosive processes.

About the digital mapping of the land use and cover of the HBRM, it's verified in Table 3 the confusion matrix used to generate the Kappa Index, which was 0.95.

In the analysis of the confusion matrix, small confusions are observed among the classes of riparian forest/gallery, fragments of Cerrado, pasture, dirty field, agricultural area, eucalyptus, and exposed soil. Thus, the classification of the use and cover of the land can be considered as of high representativity, enabling a detailed analysis of the types of coverage and quantification for each typology (Cavalcante, Grigio and Diodato, 2021).

The results of the land use and cover of the HBRM are represented in Table 4 and Image 7, being the diversified and with the predominance of agricultural areas (76.86%), followed by fragments

of Cerrado (9.13%), pasture (4.57%), dirty field (4.42%), and other classes with less representativity.

The conversion of the native vegetation in the area of cultivation can cause serious environmental problems, because the vegetation cover protects the soil from erosive processes, while the anthropic activities with the irrational use of the land and its poor management increase the possibility of erosion (Mehri et al., 2018). That happens because in agricultural areas there's a greater compression of the soil, and, consequently, the decrease of rainfall infiltration, which associated with the exposed soil of the impermeabilized areas conjoin to the increase of the superficial flow with the drag of particles, causing an elevation of the turbidity of the water (Girardi et al., 2016), being able to harm the water treatment process for the public supply.

Table 3. Confusion matrix of the classification of the image of March 2020 of the hydrographic basin of Rio Montividiu, Southwest of Goiás state, Brazil.

Classes	Validation sample (Kappa)													Total (points)
	1	2	3	4	5	6	7	8	9	10	11	12	13	
1	264	0	0	0	0	0	0	0	0	0	0	0	0	264
2	0	10	0	0	0	0	0	0	0	0	0	0	0	10
3	0	0	62	0	0	0	0	0	2	0	0	0	0	64
4	1	0	0	153	0	0	5	0	0	1	0	0	0	160
5	0	0	0	0	25	0	0	0	0	0	0	0	0	25
6	1	0	0	0	0	216	0	0	0	0	0	0	0	217
7	0	0	0	19	0	0	156	0	0	0	0	0	0	175
8	3	0	0	0	0	0	2	312	0	11	0	0	0	328
9	5	0	3	1	0	1	0	0	152	0	0	0	0	162
10	1	0	0	0	0	0	6	0	0	194	0	0	0	201
11	0	0	0	2	0	0	0	0	0	0	37	0	0	39
12	1	0	0	1	0	0	2	0	0	2	0	52	0	58
13	0	0	0	0	0	0	0	0	0	0	0	0	8	8
Total (points)	276	10	65	176	25	217	171	312	154	208	37	52	8	1711

The classes are: agricultural area (1); others (2); rural buildings (3); riparian forest/gallery (4); urban area (5); highway (6); fragments of Cerrado (7); pasture (8); exposed soil (9); dirty field (10); water (11); eucalyptus (12); and industrial area (13). Source: Elaborated by the authors (2020).

Table 4. Land use and cover in the basin of Rio Montividiu (March 2020).

Classes	Area	
	km ²	%
Water	0.79	0.11
Agricultural area	534.22	76.86
Industrial area	0.88	0.13
Urban area	3.43	0.49
Dirty field	30.73	4.42
Rural building	0.91	0.13

Eucalyptus	0.50	0.07
Fragments of Cerrado	63.42	9.13
Riparian forest/Gallery	23.76	3.42
Others	1.20	0.17
Pasture	31.75	4.57
Highways	1.10	0.16
Exposed soil	2.33	0.34
Total	695.02	100

Source: Elaborated by the authors (2020).

The decrease of the Dd of the HBRM favors the infiltration and recharge of the aquifers, contributing to the maintenance of the base outflows of the water channels, and assuring the water supply in drought periods, on an urban or rural scale. While the simultaneous investigation of the Cm and Esc are parameters to verify the dynamic of the slopes, and the superficial and sub-superficial flow, mainly in areas of greater declivity which can favor laminar erosive processes and concentrated by the exposure of soils and unconsolidated materials, aggravated by the lack of vegetation cover (Queiroz et al., 2017). The collected data for the Cm, Esc, and the Dm

indicate data the HBRM has permeable soils, as in Córrego Bonsucesso, located in Jataí, Goiás state (Alves et al., 2017).

Therefore, the association of the anthropic interference can also extend the analysis with the Hm (high) and the Is (transitional shapes), which can influence the speed of water flow, and, consequently, the preservation of the basin. In the HBRM the regular and irregular shapes identified by the Is are a constant for the unfavorable result of the Hm. However, the necessity of conservationist practices to decrease the occurrence of erosions is pondered.

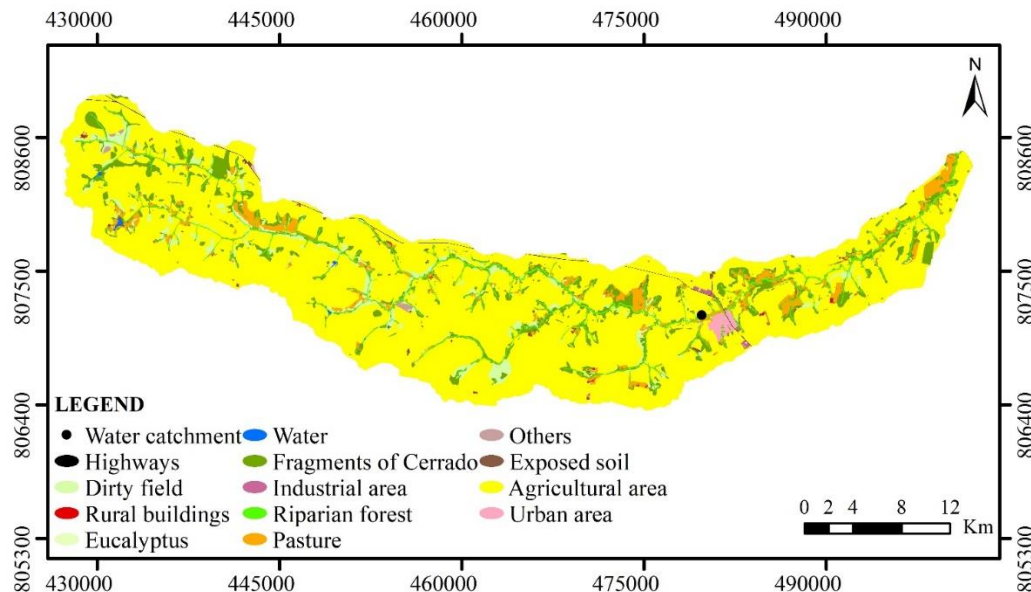


Image 7. Land use and cover map of the basin of Rio Montividiu, Southwest of Goiás state, Brazil.

Source: Elaborated by the authors from the database enabled by ESA (2020), projected in the Plane Coordinates System: Datum Sirgas 2000, UTM, 22S Zone, scale 1:50.000.

About the relief, it's presented in Table 5 which is possible to verify a scenario composed by flat relief, where there're 222.10 km² of agricultural area, the equivalent to 84.85% of the total, followed by fragments of Cerrado (4.65%), and dirty field (3.96%); similarly, the smooth wavy relief, 78.76% of the space are destined to agriculture (268.54 km²), 8% to the class of fragments of Cerrado, 4.70% to pasture, and 3.88% to the dirty field. The classes of natural vegetation of the Cerrado are, majority, as

Permanent Preservation Area (PPA), located mainly by the margins of the main watercourse and its affluent, or as Legal Reservation (LR).

The expressive area of the HBRM composed of smooth wavy and flat relief (86.71%) favors the development of livestock and agriculture with the application of simpler conservationist practices (Alves et al., 2019). And it represents also a lower probability of occurrences of water erosions, it favors the infiltration of rainwater, the preservation of the

territorial unit, and the occurrence of floods (Alves et al., 2018). The high potential for agribusiness is also identified in the hydrographic basin of Rio das Pedras, also present in the state of Goiás, favored by the relief (flat to smooth wavy) and types of soils (with a predominance of Latosols, which can be chemically corrected and of easy transit of agricultural machinery) (Souza, Nunes and Herculano, 2021).

In the case of the strong and wavy relief, which represents 92.36 km² (13.29% of the HBRM), there's a susceptibility of erosive processes due to the increase of the superficial flow speed, which requires the application of advanced preservation and environmental preservation techniques, along with the economic development, according to the Law no. 12,651/2012 (Brazil, 2012), with the socio-

environmental function of the property.

Besides the aspects of geometry and relief, the areas with laminar, grooves, and ravine erosions identified in the HBRM (Image 8), can be associated with anthropic aspects, such as degraded pastures or rudimentary agricultural practices. According to Alves, Martins and Scopel (2020), the degraded pasture comes from the lack of planning and management not aligned to the ecologically balanced environment or the inefficiency of the actions for that matter. The same can be applied in the second case, because the development of agricultural activities in an improper way result in the impoverishment of the soil, and, along with the deforestation of the slopes, intensify the erosive processes (Sampaio, Cordeiro and Bastos, 2016).

Table 5. Classes of relief and land use and cover in the basin of Rio Montividiu (March 2020)

Categories	Relief (km ²)				Total
	Flat	Smooth wavy	Wavy	Strong wavy	
Water	0.32	0.37	0.10	0.00	0.79
Agricultural area	222.10	268.54	43.33	0.00	534.22
Industrial area	0.31	0.39	0.18	0.00	0.88
Urban area	0.49	2.17	0.77	0.00	3.43
Dirty field	10.37	13.25	7.01	0.10	30.73
Rural buildings	0.26	0.49	0.16	0.00	0.91
Eucalyptus	0.15	0.25	0.10	0.00	0.50
Fragments of Cerrado	12.18	27.29	22.45	1.65	63.42
Riparian forest/Gallery	8.90	9.64	5.07	0.25	23.76
Others	0.35	0.73	0.12	0.00	1.20
Pasture	5.19	16.02	10.25	0.29	31.75
Highways	0.50	0.54	0.06	0.00	1.10
Exposed soil	0.60	1.26	0.46	0.01	2.33
Area (km ²)	261.72	340.94	90.06	2.30	695.02

Source: Elaborated by the authors (2020).

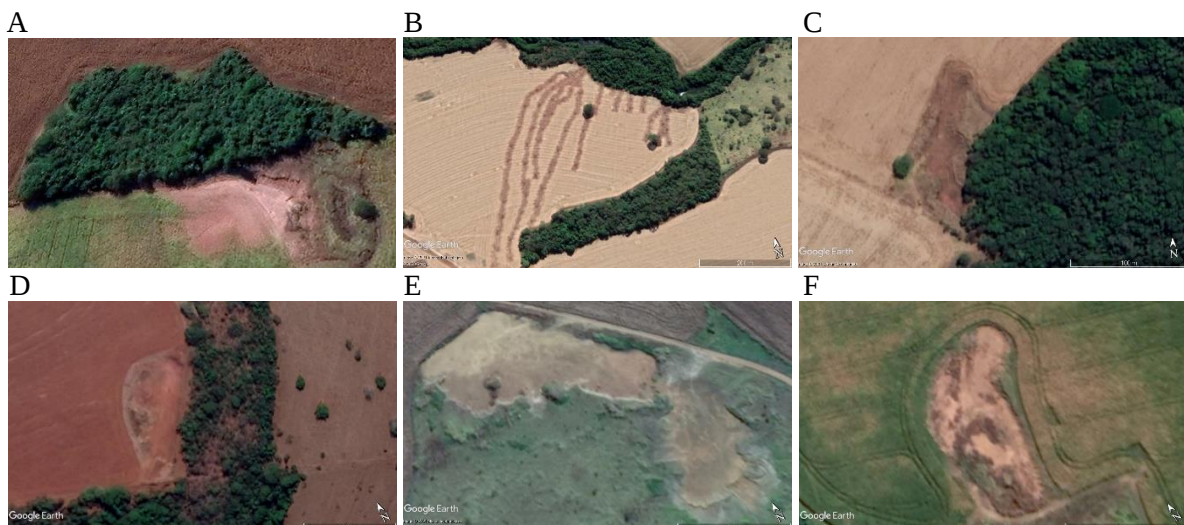


Image 8. Areas with erosion and ravines present in the basin of Rio Montividiu, Southwest of Goiás state, Brazil.

Source: Images of 2020 from Google Earth Pro.

In these wavy and strong wavy relief classes, we can find an increase in the percentage of the category of exposed soil, concerning the classes of relief of flat and smooth wavy type: initially representing 0.23% of exposed soil in the flat relief class, the category reaches 0.43% of the strong wavy class. In these places there is a higher shear stress, increasing the soil breakdown capacity and transporting a large amount of it (Santos et al., 2021). And, even in areas with smooth declivity, the absence of a good vegetation cover aggravated by the rainfall intensity can cause erosive processes, that's why the additional preservation techniques of the soil and water from the basin are so important (Alves et al., 2018; Pinto et al., 2018; Fiorese, Silva and Torres, 2019).

Aneseyee et al. (2020) affirm that the magnitude of the erosion and production of sediments is related to the physical parameters (as hypsometry and declivity) of the basin, aggravated by management practices and rainfall intensity, being verified in their research that areas with greater declivity present greater dam silting and degradation of the ecosystem in the lower part of the basin. The declivity is one of the topographical factors with an important role in the distribution and dynamics of the changes in land use and cover. For example, it is a parameter used to verify the agricultural suitability of the area, indicating the feasibility or limitation in terms of mechanization and vulnerability to erosion (Mendes et al., 2021). And as for the areas favorable for the agricultural process, as for the ones with greater declivity must go through a planned management process, aiming at environmental sustainability. This happens because such changes can negatively impact biodiversity, reduce soil productivity, increase erosion to the point of silting up, affect surface runoff, groundwater recharge and water quality in a basin, and it may devalue rural properties. (Alves et al., 2018; Desta and Fetene, 2020; Santos et al., 2021).

Due to this context, it was verified that the erosion of the soils can be descendant from natural causes such as the morphometry of the relief, and physical aspects, but it can also be intensified by anthropic actions due to the soil use and that this set of factors imply in losses to the water quality, due to the drag of superficial materials, and, consequently, silting, eutrophication or by the increase in the contamination of watercourses because of pollutants (Fia et al., 2015; Sampaio, Cordeiro and Bastos, 2016; Pereira et al., 2020; Anjinho et al., 2021).

The study of the relations between morphometric variables and the processes focused on the economic development by the management of the

land show the necessity of conservationist interventions in the investigated areas, aiming at re-establishing the environmental balance, the way instructed by Law no. 9,433 (Brazil, 1997), where a hydrographic basin is a basic planning and environmental management unit which must be used rationally and in an integrated way (Alves et al., 2019), the collective interest should prevail over political and economic interests (Servidoni et al., 2021). Therefore, it's suggested an intense inspection, to recover the PPAs, preserving the LRs, and assuring the application of pertinent legislations (Alves et al., 2019). For the recovery of degraded areas, it is important to survey native species, in order to accelerate the process of forest succession and the resurgence of fauna (Rodrigues et al., 2021).

Conclusion

The morphometric parameters of the hydrographic basin of Rio Montividiu were crucial to determining the aspects predominantly favorable to the local preservation. The results of the main variables were compared to reference values and it was observed that, from the analysis of the Kc (2.18), the Kf (0.13), and the Ic (0.21), the HBRM has a long format, with low susceptibility to floods due to the peak of low flow with greater duration of time, an ordinary characteristic of the hydrographic basins of the Cerrado in Goiás state. The Cm values (2,012 m².m⁻¹), of Dd (0.49 km.km⁻²), and the ones from the Esc (1.006 km) are due to the fact of the low declivity, the reduced capability of water recharge, and highly permeable soil, which favors the development of agricultural practices and farming activities which must be conducted along with conservationist actions of the soil and water, because there's a vulnerability of the basin due to the long distance of the main channel and elevated altimetric amplitude (360m).

Furthermore, the morphometric aspects of the HBRM, such as the Cm and the Esc, associated with the removal of the native vegetation and the changes in the land cover imply in degraded areas with the presence of ravines, laminar erosion and in grooves, factors which can imply in damages in the ecosystem, whether by interference in the distribution and availability of the water, whether for its quality.

Considering that the scenarios can change due to the influence of different factors, such as soil management and diverse management practices, it's expected that the study is the base for the implementation of specific mitigation measures to reduce the negative effects to the HBRM, and the ones who benefit from this resource. The adoption of conservationist measures can avoid soil loss and

sedimentation, reinforcing the storing and quality of the water.

This study will contribute to the environmental damage of the hydrographic basin of Rio Montividiu, an important waterbody for the distribution of water in the municipality of Montividiu, Goiás state. It will subsidize the development of management policies adequate in the adjacencies of the water resource, and it will enable data to the scientific community and population in general.

Other studies are necessary to better understand the relations between natural physical aspects, anthropic actions, and the preservation of the HBRM. Thus, studies have been accomplished over the transition of the land use and cover (from 2013 to 2020) and the water erosion, generating cartographic products and quantitative results over the dynamic of anthropic actions, types of soil (refinement in 1:100,000 scale), potential erosion (natural of the environment), and real erosion (integration of the potential erosion and anthropic actions).

Acknowledgments

To CNPq and Instituto Federal Goiano – Rio Verde Campus, in special to Programa de Pós-Graduação em Engenharia Aplicada e Sustentabilidade, and to Programa de Iniciação Científica for the scholarship of a PIBIC student, and the PIVIC student, who took part in this project.

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