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MORPHOMETRIC CHARACTERIZATION OF THE MICROHYDROGRAPHIC BASIN OF THE BUCRÉCIA DAM, STATE OF RIO GRANDE DO NORTE, BRAZIL

Caracterização morfométrica da microbacia hidrográfica da barragem de Lucrécia, estado do Rio Grande Do Norte, Brasil

Caracterización morfométrica de la cuenca microhidrográfica de la presa de Lucrécia, estado de Rio Grande do Norte, Brasil

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ABSTRACT

Sustainable water resource planning and management, especially in semiarid regions, are of utmost importance. This study aimed to characterize the Lucrécia Dam Micro-Watershed, located in the semiarid region of Rio Grande do Norte, Brazil, using geoprocessing and remote sensing techniques. Through the application of Digital Elevation Models (DEM), the basin was automatically delimited, allowing a detailed analysis of the physical and morphometric aspects, such as geometric shape, relief and drainage network. The microbasin covers the municipalities of Lucrécia, Frutuoso Gomes, Martins and Antônio Martins, and is influenced by the high altitude areas of the region's mountain ranges. The results indicate that the basin has a regular drainage density, which suggests a lower propensity for significant flooding compared to other microbasins in the region, which often have higher densities. This characteristic is beneficial for local agriculture, reducing the risk of flood-related damage. In addition, the slope of the main channel is low, which favors water infiltration into the soil. These characteristics make the micro-basin suitable for agricultural activities, such as agriculture and livestock farming, due to its low tendency to major flooding and the rapid accumulation of water in the Lucrécia reservoir. In view of this, it is essential to adopt strategic and environmental planning for the occupation of the basin's territory, ensuring the sustainable use of water resources and the preservation of water quality.

Keywords: Water resources; Geoprocessing; Geographic Information System (GIS).

RESUMO

O planejamento e gestão sustentável dos recursos hídricos, especialmente em regiões semiáridas são de extrema importância. Este estudo teve como objetivo caracterizar a Microbacia Hidrográfica da Barragem de Lucrécia, localizada no Semiárido do Rio Grande do Norte, Brasil, utilizando técnicas de geoprocessamento e sensoriamento remoto. Através da aplicação de Modelos Digitais de Elevação (MDE), foi realizada a delimitação automatizada da bacia, permitindo uma análise detalhada dos aspectos físicos e morfométricos, como a forma geométrica, o relevo e a rede de drenagem. A microbacia abrange os municípios de Lucrécia, Frutuoso Gomes, Martins e Antônio Martins, sendo influenciada pelas áreas de altitude das serras da região. Os resultados indicam que a bacia apresenta uma densidade de drenagem regular, o que sugere uma menor propensão a enchentes significativas em comparação com outras microbacias da região, que frequentemente apresentam densidades maiores. Essa característica é benéfica para a agricultura local, reduzindo o risco de danos relacionados a inundações. Além disso, a declividade do canal principal é baixa, o que favorece a infiltração da água no solo. Essas características tornam a microbacia propícia para atividades agropecuárias, como a agricultura e a pecuária, devido à sua baixa tendência a grandes enchentes e ao rápido acúmulo de água no reservatório de Lucrécia. Diante disso, é fundamental adotar um planejamento estratégico e ambiental para a ocupação do território da bacia, garantindo o uso sustentável dos recursos hídricos e a preservação da qualidade da água.

Palavras-chave: Recursos hídricos; Geoprocessamento; Sistema de Informações Geográficas (SIG).

RESUMEN

La planificación y gestión sostenible de los recursos hídricos, especialmente en las regiones semiáridas, es fundamental. Este estudio tuvo como objetivo caracterizar la microcuenca de la presa Lucrécia, ubicada en la región semiárida de Rio Grande do Norte, Brasil, mediante técnicas de geoprocesamiento y teledetección. Mediante la aplicación de Modelos Digitales de Elevación (MDE), se delimitó automáticamente la cuenca, permitiendo un análisis detallado de los aspectos físicos y morfométricos, como la forma geométrica, relieve y red de drenaje. La microcuenca abarca los municipios de Lucrécia, Frutuoso Gomes, Martins y Antônio Martins, siendo influenciada por las áreas de alta altitud de las sierras de la región. Los resultados indican que la cuenca presenta una densidad de drenaje regular, lo que sugiere una menor propensión a inundaciones significativas en comparación con otras microcuencas de la región, que suelen presentar densidades más altas. Esta característica es beneficiosa para la agricultura local, reduciendo el riesgo de daños relacionados con las inundaciones. Además, la pendiente del canal principal es baja, lo que favorece la infiltración de agua en el suelo. Estas características hacen que la microcuenca sea adecuada para actividades agropecuarias, como la agricultura y la ganadería, debido a su baja tendencia a grandes inundaciones y a la rápida acumulación de agua en el embalse de Lucrécia. Por tanto, es imprescindible adoptar una planificación estratégica y ambiental para la ocupación del territorio de la cuenca, asegurando el uso sostenible de los recursos hídricos y la preservación de la calidad del agua.

Palabras clave: Recursos hídricos; Geoprocesamiento; Sistema de Información Geográfica (SIG).

1 INTRODUCTION

Water resource management in Brazil is regulated by Law No. 9,433, of January 8, 1997, which establishes the National Water Resources Policy (PNRH) and designates river basins as strategic territorial units for political, water, and social planning (BRASIL, 1997).

A river basin, also referred to as a hydrographic unit, corresponds to the natural catchment area of precipitation and is defined according to the region's topography. This territorial configuration directs both surface and groundwater flow to a single point of convergence, known as the outlet (Porto; Porto, 2008). Furthermore, basins can be classified hierarchically and are referred to as sub-basins or micro-basins according to their hydrological and spatial characteristics (Gomes; Bianchi; Oliveira, 2021).

The micro-watershed offers advantages for the integrated management of natural resources, as it allows for the simultaneous and interdependent administration of environmental, social, and economic aspects of the region. The integrated approach enables more efficient planning of water and land use, enhancing the synergy between natural and anthropogenic processes and fostering community organization for environmental conservation (Ryff, 1995 apud Sabanés, 2002). In this way, analyzing the physical and hydrological characteristics of micro-watersheds is essential to support decision-making aimed at the sustainable management of water resources.

In this context, Dias et al. (2020) emphasize that the morphometric and hydrological characterization of a watershed is essential for hydrological and environmental analyses, as it enables a comprehensive understanding of its dynamics. Morphometric characterization, in particular, provides fundamental quantitative information for the planning and management of water resources, including parameters such as drainage area, drainage density, compactness coefficient, basin shape, and average slope. These factors directly influence surface runoff dynamics, flood susceptibility, erosion processes, and water availability, and are crucial for the implementation of conservation and sustainable management strategies (Villela & Mattos, 1975; Alves & Castro, 2003).

With technological advancements, Geographic Information Systems (GIS) and geoprocessing techniques have become essential tools for the planning and environmental management of watersheds. These technologies provide a dynamic environment for the processing, storage, and analysis of spatial data, enabling a more accurate and efficient approach to the hydrological and morphometric characterization of basins (Dias et al., 2019; Silva, 2019; Alves & Barros, 2021). According to Pessoa Neto et al. (2021), the processing of Digital Elevation Models (DEM) within a GIS environment allows for the automated delineation of watersheds, identification of the preferred surface runoff path, and extraction of geometric parameters such as stream network length and elevation values. The integration of these data through mathematical models enables a more precise definition of the basin's morphometric characteristics, contributing to the development of sustainable water resource management strategies (Alves et al., 2020).

The Lucrécia Dam, located in the city of the same name in the state of Rio Grande do Norte, positioned at the geographic coordinates 6°06'56" S and 37°49'58" W, is situated in a semi-arid climate region characterized by irregular rainfall and long dry periods. In this context, the dam stands out as a strategic reservoir essential for the sustainability of agricultural and livestock activities (ANA, 2020). Its watershed exhibits typical characteristics of semi-arid regions, with low-infiltration soils and a drainage network influenced by climatic seasonality, which directly impacts groundwater recharge and water availability throughout the year (Medeiros et al., 2018).

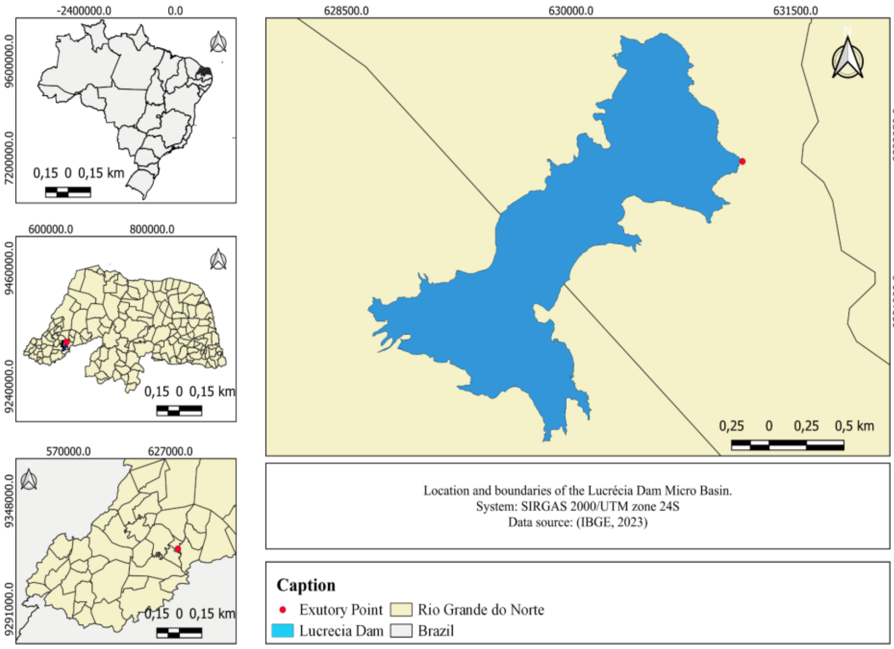
Given the importance of the reservoir for the region and its location in a semi-arid environment, it becomes essential to carry out the morphometric characterization of the Lucrécia/RN micro-watershed using GIS tools. The objective is to provide technical support that contributes to the efficient management of water resources and environmental conservation in the area. Additionally, the aim is to characterize, map, and identify the main physical and morphometric aspects of the watershed, expanding knowledge about its natural dynamics and sustainable use potentials.

2 MATERIAL AND METHODS

2.1 Study area

The study area focused on the Lucrécia Micro-Watershed, which belongs to the Apodi-Mossoró Watershed. This micro-watershed has its outlet located at the public reservoir historically known as the Lucrécia Reservoir, officially named Lucrécia Dam by public authorities (Figure 01). This reservoir, situated in the municipality of Lucrécia, in the state of Rio Grande do Norte, was built in 1934 by the Department of Works Against Droughts (DNOCS) and later transferred to the State Government. According to the Water Management Institute of Rio Grande do Norte (IGARN), the basin area of the dam is approximately 587.27 hectares, with a maximum capacity of 27,270,000 m³ of water and a dead volume of 1,483,125.00 m³ (Instituto de Gestão das Águas do Rio Grande do Norte, 2023).

Figure 01 – Location Map and Delimitation of the Study Area



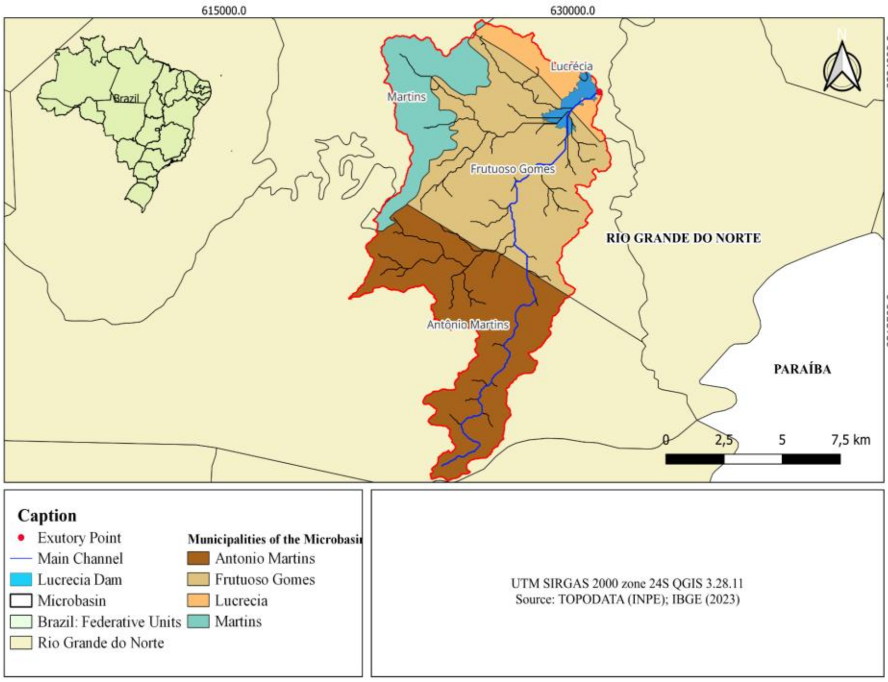
Source: Prepared by the Authors, 2023.

The reservoir, located in the municipalities of Lucrécia and Frutuoso Gomes, is part of the Apodi/Mossoró River basin, which covers an area of 14,276 km². It is characterized as a lentic water body and accounts for 26.8% of the total area of the state. Geographically, the reservoir is situated 500 meters south of the city of Lucrécia, with coordinates of 9,323.69 km north and 630.479 km east (IGARN, 2023). Its structure consists of two homogeneous earth dams, called embankment 01 and embankment 02, with lengths of 657.50 meters and 202.00 meters, respectively. The water intake comprises a control bridge located upstream and a tubular gallery, essential elements for controlling water flow and maintaining the dam (Soares; Carvalho, 2022).

This region is located in the Umarizal microregion and features a characteristic Northeastern semi-arid climate, with rainfall predominantly occurring from January to June and an annual average precipitation of about 900 mm. Temperatures range from a minimum of 26ºC to a maximum of 31ºC. The predominant vegetation is hyperxerophilous caatinga, characterized by small-sized species that shed their leaves during the dry season, with cacti commonly present. The region's topography consists of transitional terrain between the Borborema Plateau and the Apodi Plateau, with metamorphic rock formations dating from the Upper Precambrian period. The predominant soil class is eutrophic red-yellow argisol, typical of areas with gentle to undulating relief, medium texture, good drainage, and high fertility levels (Brazilian Institute of Geography and Statistics, 2021).

The Lucrécia micro-watershed encompasses four municipalities: Lucrécia, Frutuoso Gomes, Martins, and Antônio Martins, with most of its area located in Frutuoso Gomes, as shown in Figure 02. However, this study focuses only on the municipalities within Rio Grande do Norte, which are Lucrécia, Frutuoso Gomes, Martins, and Antônio Martins. It is worth noting that Martins plays a fundamental role in the formation of the basin, despite contributing a relatively small area, due to the high altitudes of its mountain range. The reservoir represents an important resource for the municipality's development; however, reckless use has exacerbated harmful environmental impacts, compromising the ecosystem's carrying capacity. This may lead to significant changes in water resources and the lifestyle of people living in the region.

Figure 02 – Location of the Lucrécia Dam Microbasin/RN containing the political division of the municipalities included



Source: Prepared by the Authors, 2023.

2.2 Collection and processing of morphometric data

To carry out the data collection and processing, it was essential to define the study area, corresponding to the Lucrécia Micro-Watershed. Initially, the automatic delimitation of the watershed was performed using a Digital Elevation Model (DEM), obtained from the TOPODATA project, made available by the National Institute for Space Research (INPE). The DEM used has a spatial resolution of 30 meters and is georeferenced in the Universal Transverse Mercator (UTM) projection system, with the Coordinate Reference System (CRS) based on the World Geodetic System (WGS84), zone 24 South. The 06S39_ZN topographic map sheet used in the analysis contained essential altimetric information for characterizing the micro-watershed, contributing to the acquisition of accurate data on the region's morphometry and hydrography.

The spatial analysis was conducted using QGIS software, version 3.28.11, an open-source and free Geographic Information System (GIS) platform. For the automatic and efficient delineation of watersheds, the SAGA plugin was employed—a set of tools widely recognized for its fast and accurate processing capabilities in this task (Medeiros & Bezerra, 2016). The integration of these technologies enabled a detailed spatial analysis, providing greater accuracy in defining the micro-watershed boundaries and facilitating the extraction of relevant information for the study.

The morphometric analysis of the Lucrécia Dam Micro-Watershed was carried out based on thematic maps generated from the Digital Elevation Model (TOPODATA DEM), processed using QGIS 3.28.11 software. The Fill Sinks methodology was applied to correct depressions in the DEM, enabling the definition of water flow and the delineation of micro-watersheds (Wang & Liu, 2006). The SAGA plugin in QGIS was used for hydrological modeling, enhancing the drainage network and allowing for the analysis of the distribution of watercourses. Additionally, information such as river length, maximum and minimum elevation, and drainage network hierarchy was extracted. The physical characterization of the watershed was complemented by calculations and comparisons within the GIS environment, as presented in Table 01.

Table 01 – Morphometric parameters to be evaluated in the Microbacteria of the Lucrécia Dam/RN

Geometric Features		
		Equation
Drainage area (A)	Flat area (horizontal projection) included between its topographic dividers (km²)	A

Basin perimeter (P)	Imaginary line that delimits the basin through a main watershed (km)	P
Compactness coefficient (kc)	Ratio between the basin perimeter and the perimeter of a circle with the same area as the basin.	$k_c = 0{,}28\frac{P}{\sqrt{A}}$
Form factor (Ff)	Where: A is the drainage area of the basin (km²), and L is the length of the main watercourse of the basin (km), as evaluated according to Villela and Mattos (1975).	$F_f = \frac{A}{L^2}$
Relief Characteristics		
Maximum and minimum elevations of the microbasin, and highest elevation of the main channel (Hmin; Hmax; HCmax)	The elevations were expressed in meters	Hmin; Hmáx; HCmáx;
Elevation range (DH)	Difference between the maximum and minimum elevations occurring in the basin.	⊗H= Hmáx; -Hmin;
Average slope of the basin (I)	Where: I is the average slope of the basin (%); D is the vertical equidistance between contour lines (km); CN is the total length of the contour lines (km); and A is the drainage area of the basin (km²)	$I = \frac{D}{A}\left(\sum_{i=1}^{n} CN_i\right)100$
Slope of the main watercourse – channel bed (Ieq)	Where: Ieq is the equivalent slope (m km⁻¹); DH is the altimetric range of the main watercourse (m); and L is the length of the main watercourse (km).	$I_{eq} = \frac{\Delta H}{L}$
Hypsometric curve	Variation of the elevation of the different terrains in the basin with reference to the mean sea level.	
Drainage Network Characteristics		
Length of the main watercourse (L):	It is usually expressed in kilometers (km)	L
Drainage network. (Rd)	Sum of the lengths (in km) of all watercourses within a river basin, including perennial, intermittent, and ephemeral streams.	Rd = ©Li

Drainage density (Dd)	Where: Dd is the drainage density (km/km² or m/ha), Rd is the drainage network, or the sum of the lengths of the rivers (km or m), and A is the drainage area of the basin (km² or ha).The classification is based on Beltrame's criteria. (1994).	$Dd = \frac{Rd}{A}$
Drainage network density (DR)	Relationship between the number of drainage channels and the basin area	$DR = \frac{N}{A}$
Average length of surface runoff (Cm)	Relates the drainage density of the watershed to the average lateral length of the drainage network.	$Cm = \frac{1}{4xDd}$
Sinuosity of the main watercourse(S)	Relationship between the length of the main channel (L) and the length of its thalweg (Lt)	$S = \frac{L}{L_t}$
Order of watercourses	The classification proposed by Strahler was used in this study. (1957)	

Source: Prepared by the authors, 2023, based on Aires, Costa, Bezerra & Rêgo, 2021.

The slope map was created using the raster analysis tool in QGIS. Then, using the GRASS plugin and the r.reclass command, the data were refined according to the slope classes established by EMBRAPA (1979), as shown in Table 02. This process allowed a more precise categorization of relief variations, contributing to the morphometric analysis of the microbasin.

Table 02 – Slope classification according to EMBRAPA (1979).

Slope Classes (%)	Relief
0 – 3	Flat
3 – 8	Gently Undulating Relief
8 – 20	Undulating Relief
20- 45	Strongly Undulating Relief
45 – 75	Mountainous Relief
> 75	Highly Mountainous Relief

Source: Prepared by the authors, 2023, based on EMBRAPA, 1979.

3 RESULTS AND DISCUSSION

Based on the processing of micro-watershed data and the calculation of physical parameters, results were obtained that provide detailed information about the geometric, topographic, and drainage network characteristics of the micro-watershed, as presented in Table 03. These data are essential for understanding the morphology and hydrological dynamics of the study area.

Table 03 – Morphometric characteristics of the Lucrécia Dam watershed, RN.

Characteristics	Parameters	Acronyms	Units	Values
Geometric	Basin Area	A	km²	109,66
	Perimeter	P	km	74,16
	Compactness Coefficient	Kc	-	1,98
	Form Factor	Kf	-	0,21
Relief	Highest Elevation of the Basin	Hmáx	m	753,02
	Highest Elevation of the Main Channel	HCmáx	m	528,95
	Lowest Elevation of the Basin	Hmín	m	203,84
	Altimetric Amplitude	∆H	m	549,18
	Average Basin Slope	I	%	15,15
	Slope of the Main Watercourse	Ieq	m/km	24,28
Drainage Network	Basin Order	-	Order	4ª
	Total Number of Streams	N	units	104
	Length of the Main Watercourse	L	km	22,62
	Length of the Thalweg	Lt	km	16,64
	Sinuosity Index	Sin	-	1,36
	Drainage Network	Rd	km	101,73
	Drainage Density	Dd	km/km²	0,93
	Drainage Network Density	Dr	drainage/ km²	0,95
	Average Length of Surface Runoff	Cm	km	0,27

Source: Prepared by the Authors, 2023.

The current morphometry of the micro-watershed reflects not only the natural features of the terrain and drainage network, but also anthropogenic interferences related to the presence of the dam. Structures such as the Lucrécia reservoir directly impact the hydrological dynamics of the basin, altering the natural flow of water and influencing parameters such as drainage density, average surface runoff length, and the slope of the main channel (Li, Zhang, & Li, 2024).

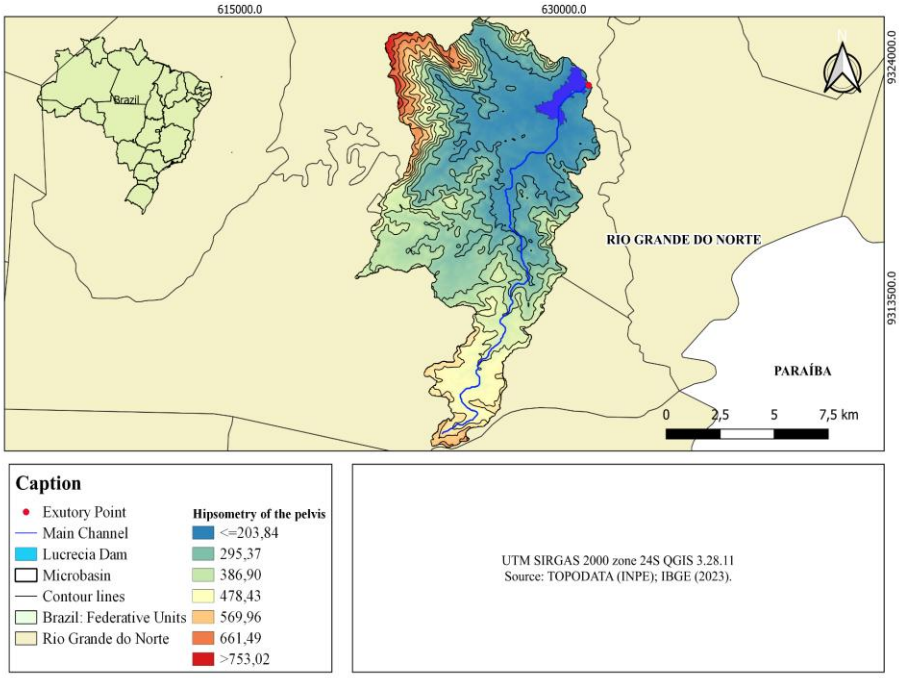
In the absence of the dam, it is likely that the functional morphometry of the basin would exhibit a different behavior, with more concentrated surface runoff, lower water retention, and, consequently, greater susceptibility to flooding or erosion. Furthermore, the presence of the dam introduces a new dynamic of water retention and redistribution, affecting the connectivity of the drainage network and the concentration time of flows (Li, Zhang, & Li, 2024). Therefore, the dam represents a significant anthropogenic modification, with direct effects on local hydrology and indirect impacts on land use and land cover within the basin.

The evaluation of the geometric configuration of the micro-watershed revealed a Compactness Coefficient (Kc) of 1.98 and a Form Factor (Kf) of 0.21. These values indicate that, under normal conditions, the basin has a low probability of experiencing major floods. The high Kc value suggests that the basin does not have a circular shape, which is associated with a lower likelihood of significant flooding. According to Villela and Mattos (1975), the geometric characteristics of the micro-watershed indicate that it is not prone to flooding, even during high precipitation events. Regarding the Form Factor (Kf), low values indicate a more compact shape, which results in more efficient runoff and, consequently, a lower flood risk. Thus, a basin with a low Kf value tends to be more elongated, which reduces flood vulnerability. These data demonstrate that the micro-watershed has an elongated configuration rather than a circular one, as noted by Almeida (2017) and Villela and Mattos (1975).

Based on the elevation variation data, it was possible to draw contour lines indicating the different altimetric levels of the basin. Figure 03 presents the contour lines at 50-meter intervals, illustrating the elevation changes across the micro-watershed area. The terrain of the micro-watershed displays a topographic profile ranging from 200 to 700 meters above mean sea level, reflecting its mountainous nature. The observed elevation variation suggests a hilly or mountainous relief, characterized by higher-altitude features such as hills, slopes, and even mountains. These topographic characteristics play a significant role in the region’s hydrological dynamics, directly affecting surface runoff, drainage patterns, and the distribution of water resources within the micro-watershed. The steep terrain influences the speed of surface flow, the formation of watercourses, and the basin's water storage capacity—factors that are fundamental for effective local water resource management.

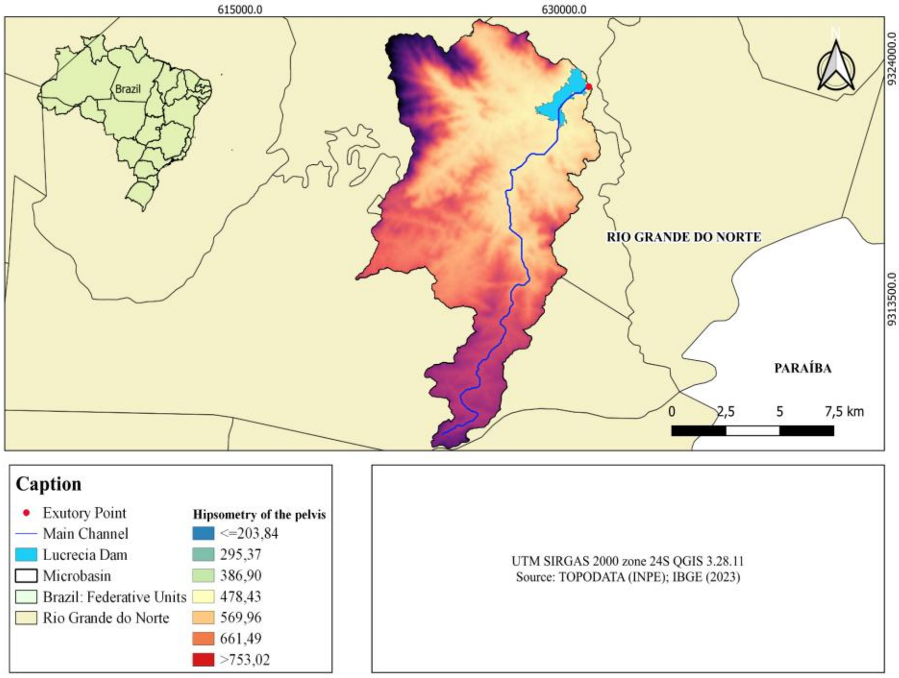
The representation of elevation variations in the micro-watershed, including the maximum and minimum altitudes along with the main channel, is shown in Figure 04. The hypsometric analysis revealed an altimetric variation in the topographic profile of the micro-watershed, with elevations ranging from 203.84 to 753.02 meters. Lower elevations are concentrated near the clear water body that forms the analyzed reservoir, while the higher elevations are located at the far end of the micro-watershed, in the mountainous region near the city of Martins. These elevation differences are essential for understanding surface runoff dynamics and the distribution of water resources, as higher-altitude areas tend to promote faster water flow, whereas lower-altitude areas near the reservoir facilitate water accumulation and storage. Moreover, the presence of such elevation gradients directly influences the location of watercourses and the water retention potential of the micro-watershed, impacting both water resource management and the region's water security.

Figure 03 – Contour Map of the Lucrécia Dam micro-watershed, RN



Source: Prepared by the Authors, 2023.

Figure 04 – Hypsometric Map of the Lucrécia Dam micro-watershed, RN



Source: Prepared by the Authors, 2023.

The micro-watershed under study presented a drainage density (Dd) of 0.93 km/km², which is classified as moderate according to Beltrame (1994). This parameter is important for indicating the degree of development of the basin's drainage system, providing insights into the efficiency of surface runoff.

In addition, the fluvial hierarchy classifies the drainage network into different levels, from the smallest channels (first order) to the largest channels (higher order), allowing for a deeper understanding of the organization and structure of the river and channel network in the study area. The channel organization within the micro-watershed follows the classification proposed by Strahler (1957), assigning the basin a 4th-order category. Details regarding the channel paths, as well as the correspondence between the number of channels and their lengths, are presented in Table 04 and Figure 05, which illustrates the drainage network layout with emphasis on the main channels.

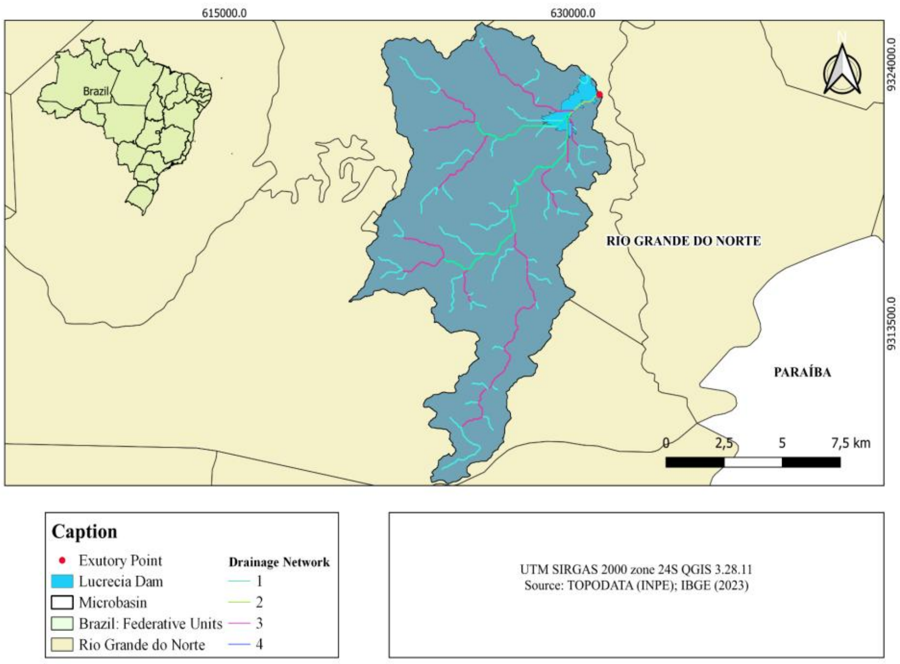
This hierarchical organization reflects the flow dynamics within the basin, providing a detailed view of how water is distributed and flows throughout the area. Analyzing this drainage network is essential for understanding runoff patterns and water volume, enabling more effective water resource management and the implementation of appropriate strategies for the conservation and sustainable use of the basin.

Table 04 – Drainage Hierarchy and the Relationship Between the Number and Length of Channels in the Lucrécia Dam Micro-Watershed, RN

Stream Order	Number of Channels	Length of Channels (Km)
1ª	53	56,65
2ª	32	33,71
3ª	16	15,73
4ª	4	1,64

Source: Prepared by the authors, 2023, according to Strahler's classification (1957).

Figure 05 – Drainage Network Map of the Lucrécia Dam Micro-Watershed, RN



Source: Prepared by the Authors, 2023.

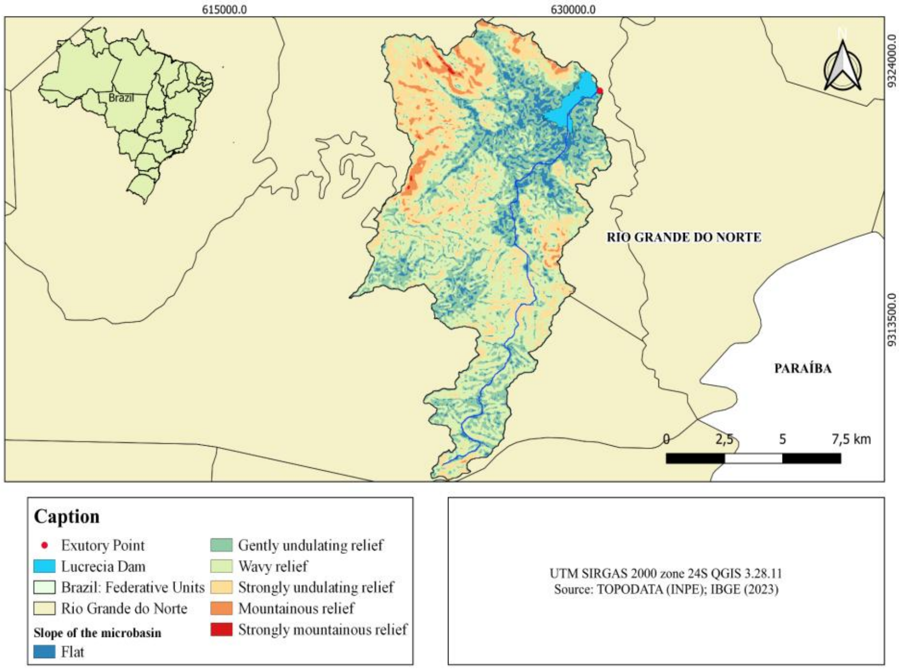
The drainage density (Dd) in the microbasin was measured at 0.95 channels/km², meaning that there are 0.95 drainage channels for each square kilometer. This value indicates a relatively low drainage network density in the microbasin, suggesting that the area has a more widely spaced drainage pattern, which can affect the distribution and runoff of water in the region. This characteristic may influence both infiltration and surface runoff velocity, impacting the hydrological dynamics and the management of water resources within the basin.

In accordance with Christofoletti (1980), drainage basins can be categorized as exorheic, endorheic, or arreic, while their geometric classification includes dendritic, trellis, and ephemeral types. The basin of the Lucrécia dam is currently classified as dendritic, as its shape resembles the branching of a tree, with multiple tributaries converging at a central point.

The Sinuosity Index of the microbasin was calculated at 1.36, which reflects the comparison between the length of the main channel and the straight-line distance between its endpoints, indicating that the main channel follows a relatively straight path. According to Moura (2013), values close to 1.0 indicate straight channels, while values above 2.0 characterize meandering watercourses. The greater the sinuosity, the longer and more complex the channel path becomes, resulting in reduced flow velocity. Thus, sinuosity directly impacts the basin's dynamics, influencing drainage efficiency and sediment transport.

Slope maps play a crucial role in assessing terrain characteristics, serving as thematic representations that show how slopes are spatially distributed within a specific area. This, in turn, supports landscape analysis. The slope of the main watercourse is an essential factor in understanding runoff behavior in the microbasin. The greater the slope values, the higher the elevation of the land, which generally results in faster and stronger runoff (Nobre et al., 2020). According to Leda et al. (2015), the main watercourse showed an average slope of 24.28 m/km, with a total channel length of 22.62 km. Figure 06 illustrates the areas within the basin with both steep and gentle slopes. The zones of higher elevation, located at the edges and center of the basin, correspond to areas of elevated terrain, such as the Serra de Martins in the state of Rio Grande do Norte. It is important to note that areas with slopes greater than 45% must be preserved and classified as Permanent Preservation Areas (APPs), as established by the Brazilian Forest Code, Law No. 12,651 of May 25, 2012 (Santos Filho, 2015).

Figure 06 – Slope Gradient Map of the Lucrécia Dam Hydrographic Microbasin, Rio Grande do Norte, Brazil



Source: Prepared by the Authors, 2023.

It can be observed that the areas with the steepest slopes are located at the edges of the basin, especially in the Martins region, indicating zones of more pronounced relief corresponding to the local mountain ranges. These areas feature significant elevations, which contribute to the intensity of surface runoff and increase susceptibility to erosion, particularly during periods of heavy rainfall. The presence of steep relief also influences the distribution and movement of water, impacting the hydrological dynamics of the microbasin and the quality of the region's water resources.

Slope maps are essential tools for terrain analysis, providing a thematic representation that reveals the spatial distribution of slope variations across the landscape. These maps play a fundamental role in understanding landform dynamics and in identifying areas susceptible to erosion and mass movement processes. The study of slope is crucial, as it is closely linked to erosion processes, which are intensified by steeper inclinations. The greater the slope, the higher the tendency for increased surface runoff velocity, which in turn accelerates the erosion process.

4 CONCLUSIONS

The analysis of the microbasin under study reveals favorable geometric and hydrological characteristics for the efficient operation of the reservoir, highlighting the main channel with a length of 22.62 km, which runs through the municipalities of Martins/RN and Lucrécia/RN.

This microbasin features a 4th-order drainage system, characterized by significant branching, indicating a well-developed network with a great capacity to capture and channel water to the reservoir. The average slope of the main channel (Ieq) of 24.28 m/km indicates a moderate inclination, resulting in a lower flow velocity and, consequently, a greater capacity for water infiltration into the soil. Conversely, the flatter areas slow down the runoff, favoring water infiltration into the soil and contributing to aquifer recharge.

The drainage density (Dd) of 0.93 km/km² classifies the microbasin as having regular drainage, indicating that the drainage system is efficient but not excessively concentrated, which contributes to a balanced distribution of water across the area. The dendritic shape of the drainage network facilitates water flow and accumulation in the reservoir, enhancing storage capacity and ensuring efficient water supply for the region. Furthermore, the distribution of areas with steeper slopes, especially at the edges of the microbasin, favors runoff toward collection points while also making the area more susceptible to erosion processes. This factor should be monitored to prevent negative impacts on water quality and sedimentation in the reservoir.

The slope analysis highlights the importance of adopting conservation measures, especially in areas with steeper inclinations, which are classified as Permanent Preservation Areas (APP) under the Forest Code. Protecting these regions is essential to prevent environmental degradation and ensure the sustainability of the microbasin. The results also reveal gaps in research regarding the quality of the springs, which are crucial water resources for the aquatic ecosystem. Human activity in these areas can affect the entire ecosystem, causing imbalances. Therefore, it is necessary to promote future studies on the subject to ensure the preservation of this vital resource.

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