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Structural and geomorphological aspects of the Bonito River basin, Caiapônia Region, Goiás, Brazil

Aspectos estruturais e geomorfológicos da bacia hidrográfica do Rio Bonito, Região de Caiapônia, Goiás, Brasil

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Abstract: The present research was conducted in the Bonito River Hydrographic Basin, located in the state of Goiás, Brazil, in the Cerrado Biome environment. The objective was to carry out an integrated characterization of the aspects of Geology, Landforms, and Pedology by preparing thematic maps, graphs, and tables, including a synthesis in all geomorphology units. The data were acquired in secondary vector data surveys processed with the support of QGIS 3.28 software, Firenze. The mapping detected geological, geomorphological, and pedological classes, with a significant presence of sedimentary rocks from Paleozoic formations, obtaining an important highlight, on the southwestern erosive edges of the basin, the Serra do Caiapó in the region under research, in the municipality of Caiapônia. Where it is shaped by landforms characterized by erosive, flattened, and weathered residues of sedimentary rocks, detecting a hypsometric amplitude of an average of 500 meters between the highest point upstream in the Serra do Caiapó to the mouth of the Bonito River. In conclusion, soil surveys demonstrate greater class extensions of Oxisols, favored by the pedogenic evolution of areas with smooth-undulating landforms.

Keywords: Geology; Landform; Soils.

Resumo: A presente pesquisa, foi realizada na Bacia Hidrográfica do Rio Bonito, localizada no estado de Goiás, Brasil, ambiente do Bioma Cerrado. O objetivo constituiu em realizar a caracterização de forma integrada dos aspetos de Geologia, Formas de Relevos e Pedologia, por meio da elaboração de mapas temáticos, gráficos e tabelas, incluindo síntese no conjunto das unidades de geomorfologia. Os dados foram adquiridos em levantamentos secundários de dados vetoriais, processados com apoio do software QGIS 3.28, Firenze. A partir dos mapeamentos, detectaram-se, classes de geológicas, geomorfológicas e pedológicas, com presença expressiva de rochas sedimentares, de formações paleozoicas, obtendo um destaque importante, nas bordas erosivas sudoeste da bacia, a Serra do Caiapó na região em pesquisa, no município de Caiapônia. O ambiente encontra-se moldado por formas de relevos, com características de residuais erosivos, aplainados e desgastados de rochas sedimentares, detectando-se amplitude hipsométrica de média de 500 metros entre o ponto mais elevado à montante na Serra do Caiapó até a foz do Rio Bonito. Concluindo, os levantamentos de solos, demostram maiores extensões da classe dos Latossolos, favorecidos pela evolução pedogenética de áreas de relevos suave-ondulados.

Palavras-chave: Geologia; Relevo; Solos.

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1. Introduction

Geomorphological studies are developed based on traditional landform mapping (LIMA; FURRIER, 2020). Starting from classic proposals from Tricart (1977), influenced by the Germanic school of Walter Penck's theoretical principles, to several renowned authors from Brazil, who reflected the genesis of morphostructural phenomena in their research into geomorphology themes (CHRISTOFOLETTI, 1980; GUERRA, 2007; ROSS, 2014).

In this context, Costa (2022) states that the steps related to the genetic delineation of landforms are standard in geomorphology work, mainly identification, characterization, and classification, procedures applied in different environments with descriptive and morphometric purposes, as recently applied by Barros and Galvíncio (2022).

Paschoal et al. (2016) applied geoindicator parameters obtained through the adjustment of classic geomorphological procedures, adapting them with the application of new mapping techniques, highlighting that the process of geomorphological analysis has been evolving into more accurate results of geomorphological mappings.

Currently, Lima (2021) clarifies there is a logic behind investigating the genesis of geomorphological facies over time, as for contemporary society, it is of fundamental importance due to events and the dynamics of geomorphological processes directly or indirectly affecting various human activities. Likewise, the advancement of ravines and gullies can modify the relief and make the use of land for certain activities unfeasible.

Geomorphological studies seek to identify large-scale areas of general processes such as Morphosculptural Units (FLORENZANO, 2008; ROSS, 2014), but they allow mapping more specific local relief forms, such as those carried out by Jacoby, Peterson and Dogwiler (2011); Martha, Saha and Kumar (2012); Melo et al. (2015); Melo and Couto Junior (2017), Bertolini, Deodoro and Boettcher (2019), Corrêa et al. (2021); Guerra and Lazzari (2021), among other studies carried out on a smaller scale, such as the one applied in this more detailed research of geomorphological features.

Physiographic aspects are related approaches to environmental understanding and can complement proposals for structural landform assessment. Guerra and Lazzari (2021) applied geomorphological assessment and other landscape components, in addition to geology, in Tuscany, Romagna, and the Marchean Apennines as a geoheritage inventory tool. A similar study was developed by Lima (2020), mapping the geoproperties of the municipality of Caiapônia, in the state of Goiás, the same region where the present study was applied, focusing on correlating structural aspects.

For the application of the research, it was essential to organize a database containing bibliographic references and storage of physical geographic data information, with radar image information, thematic maps, and photographic records in the field.

Thus, it was essential to carry out this research, correlating cartographic data to understand the geomorphological forms, as it helps in identifying the morpho-sculptural units of the landscape, and with the combination of descriptions and observations in the field, they respectively provided even more accurate data for the analysis of the final synthesis of the research.

In this context, the present work aimed to characterize and correlate data from different mappings of the main structural physiographic factors (geology, landforms, and pedology) through comparison included in the set of geomorphology units encompassing the Bonito River hydrographic basin based on analysis relevant to the topic, proposed by Arruda et al. (2008), Silva (2009) and Melo and Couto Junior (2017).

Therefore, the research approached structural aspects in an integrated manner to subsidize the study by mapping the understanding of geology, landform, and local pedology, obtaining a greater knowledge of geomorphological dynamics as it directly affects the processes of environmental risk assessment, anthropic activities, and the configuration of the landform itself.

2. Methodology

2.1. Study Area

The area delimited in this research comprises the Bonito River Hydrographic Basin, with 2015 km² of area covered and 149 km in length. It is located in the territorial space of the municipalities of Arenópolis, Caiapônia, and Palestina de Goiás. The watercourses are developed on top of sedimentary rocks, identifying drainage with a dendritic pattern. According to Christofoletti (1980), the courses occur mainly in areas of homogeneous rocks or horizontal layers, uniformly and may also appear in resistant layers, with little or almost no controlling influence on the forms.

In the basin, the main springs begin near the Cuesta do Caiapó mountain range in the municipality of Caiapônia, where one of the tributary courses, the Córrego das Galinhas, supplies the urban area of Caiapônia, continuing to

Palestina de Goiás, bordering the municipalities of Piranhas and Arenópolis, with its mouth on the Caiapó River, an important contributing basin to the Araguaia River (Figure 1).

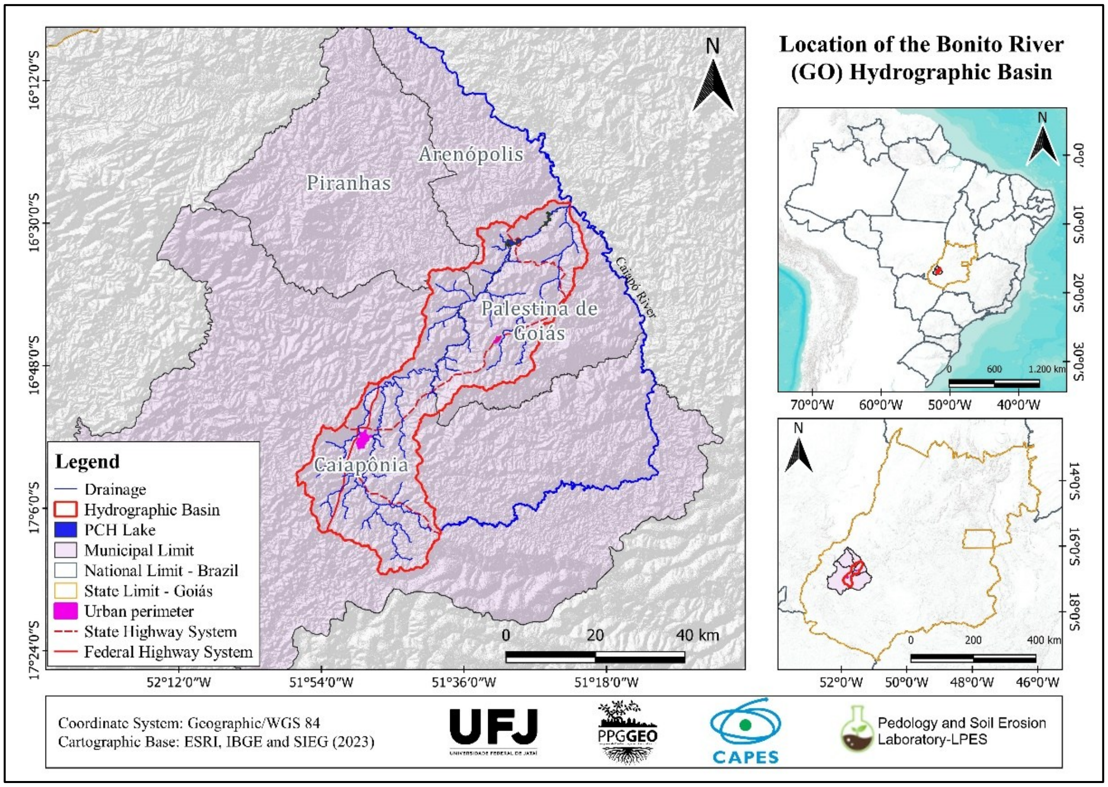

Figure 1 – Location of the study area.
Source: Authors (2023).

In the main river course, three Small Hydroelectric Plants (PCH) were inserted, the Bonito River, Tamboril, and Rênic PCHs, with significant hydroelectric uses, and anthropogenic activities occupy the region due to the advancement of agriculture with grain crops and pastures (PEREIRA, 2021; PEREIRA; MARTINS, 2022). Thus, the use of water resources and land has been responsible for changes in the natural environment.

The research environment is located in the southwestern portion of the State of Goiás, in the Cerrado Biome, the birthplace of large Brazilian river basins. The vegetation covers the State of Goiás and 10 other states, being a phytophysiognomy that is among the most anthropized in recent times, occupied by agriculture, forestry, mining, and other uses (SANO et al., 2020).

The climate of the Cerrado Biome is marked by months where the distribution of average annual precipitation in the Cerrado is presented by Sano et al. (2020) in data with an annual average of 1,394 mm, with a standard deviation of 255 mm, according to results from the processing of data from the sensors of the Tropical Rainfall Measuring Mission (TRMM) satellite. In the central portions of the biome, close to the transition areas, the precipitation changes, similar to the Caatinga biome (650 mm) and the Amazon (2,250 mm).

2.2. Cartographic procedures

The core research process revolved around mapping, accomplished through the acquisition of thematic vector data from bases in shapefiles refined by the Superintendency of Geology and Mining (SIC). The information is available on the State Geoinformation System platform (SIEG) of the state of Goiás, at a scale of 1:250,000, Datum Sirgas 2000, zone 22 South, in cartographic sections (Sheets SE-22-VD of Jataí and SE-22-VB of Iporá) for the study area (IBGE, 2018).

Subsequently, the organization of the database was based on the use of digital data processing techniques, spatial and operational information resources of GIS (Geographical Information System) to prepare the mappings, free geoprocessing software, QGIS version 3.28 Firenze, was used, following the procedures recommended by Dalla Corte et al. (2020), both vector and matrix data.

The radar images from the SRTM mission (Shuttle Radar Topography Mission) of the Jataí and Iporá sheets, with a spatial resolution of 30 meters, were acquired in a Digital Elevation Model (DEM) (USGS, 2015) and used to delimit the river basin and determine the drainage network, carried out automatically using the QGIS software, specifically the SAGA toolbox, under the Terrain Analysis – Channels option, with the algorithm 'Channel network and drainage basins' (DALLA CORTE et al., 2020).

From the geology, geomorphology, and pedology bases, it was possible to create the maps according to the processing of vector-type layer data for the shapefiles extension in the GIS software used, and the classes followed the colorimetry standards of the technical manuals from IBGE (Brazilian Institute of Geography and Statistics) for geology and geomorphology (IBGE, 2009), and from SIBCS (Brazilian Soil Classification System) for pedology (SANTOS et al., 2018).

Considering geomorphology, mappings were carried out based on the large Geomorphological units of Latrubesse and Carvalho (2005), available by the Superintendency of Geology and Mining (SIC), on the platform of the State Geoinformation System (SIEG) and the standards of landforms acquired on the IBGE geosciences platform (2018).

Martha, Saha, and Kumar (2012) demonstrated an integrated study using MDE image databases and a geomorphological mapping method according to structural genesis, which were fundamental for the study of topography and landform identification.

Thus, the large geomorphological units constituted the basis for relating the structural variables, as the geomorphological system represents important conditions for controlling the structural aspects that are part of the physiographic characterization analysis (CHRISTOFOLETTI, 1980; GUERRA, 2007; ROSS, 2014).

2.3. Data processing: systematization, synthesis, and field observation

After the mapping, graphs and tables were created to measure the results, using calculations of the areas covered by the mapped classes in spreadsheets in the Microsoft Excel software (.xlsx), with the final display of graphs to disseminate the summarized data.

Analyses of the physical characteristics of the basin were also used, generated from cartographic sections in classes of distinct geomorphological units, aiming to identify the influences exerted by structural physiographic factors, as well as characteristics and exposure of properties that explain the particularities of these units, based on the analyzes by Arruda et al. (2008), Silva (2009) and Melo and Couto Junior (2017).

Subsequently, longitudinal profiles were drawn up in each geomorphological unit, presenting the elevation discontinuities observed along the path, created using the Terrain Profile tool of QGIS, version 3.28 Firenze, and then exporting the data table in a compatible format to finalize the profile layout, in Excel software (.xlsx).

Fieldwork was carried out in June 2023 to understand the basin's landform better. During field verification, photographs were recorded to understand the distribution of geomorphology. In addition to the pictures, the landform characteristics of each geomorphology unit were observed, and their respective geographic coordinates were marked to corroborate the description of the geomorphological aspects of the landscape, with a focus that covered the main facies present in the geomorphology units.

3. Results and Discussions

The results initially provide associations between the structural physiographic factors of rock layers (Geology), landforms (Geomorphology), and soils (Pedology) and the distribution of these classes in geomorphology units. This category serves as the basis for analyzing patterns that highlight similarities in each unit separately, based on the overlapping characteristics of each mapping.

Thus, analyses using the physical relationships associated with landform units were applied in studies developed by Arruda et al. (2008), Silva (2009), and also Melo and Couto Junior (2017) to recognize the interrelationships that exist between the different elements of the landscape, with variables ranging from environmental constituents to land use and anthropogenic interference.

3.1. Physiographic aspects

Figure 2 presents the physiographic characterization maps, which four types of basic maps of structural elements of the study area.

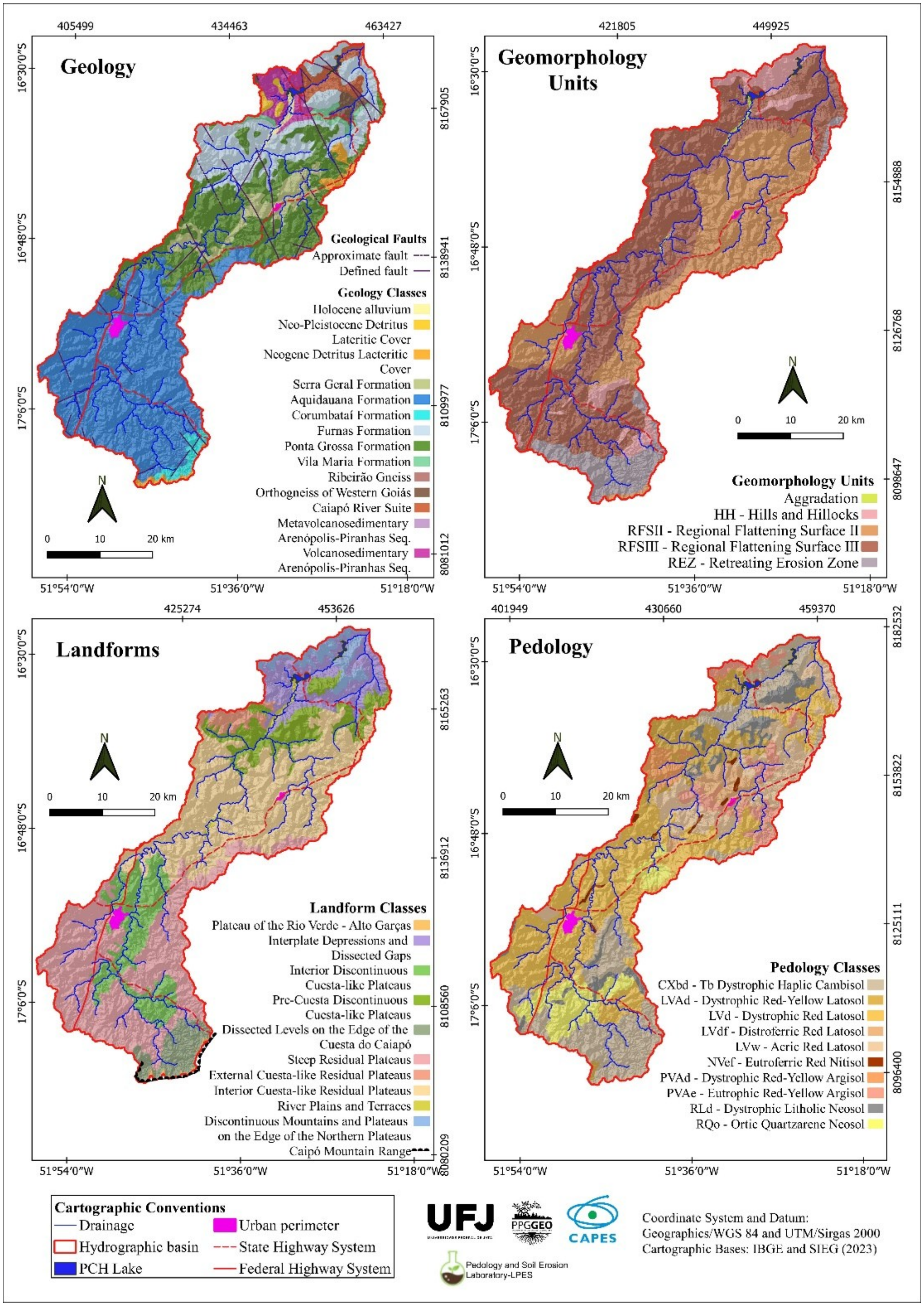

Figure 2 – Maps of the physiographic characterization of the Bonito River Basin (GO).
Source: Authors (2023).

According to the geology map, there is great diversity, with 14 different types of lithological units. The most prominent are the Aquidauana and Ponta Grossa formations, with great exposure in the area, with clayey and sandy sediments from 359 to 299 million years ago (RADAMBRASIL, 1983; MOREIRA et al., 2009). Other relevant lithological formations are highlighted, such as the Furnas Formation (Paleozoic) of feldspathic sandstone from the Paraná group and the Serra Geral (Mesozoic), close to the central region of the basin and the river channel of the Bonito River. The igneous rocks of the Serra Geral Formation were formed from fissure volcanism and subsurface cooling, formed by basalts, dikes, and diabase sills (HASSUI et al., 2012; POPP, 2014).

The geomorphology is distributed in five basic geomorphological units, described by Latrubesse and Carvalho (2005) as denudational genetic units generated by the razing/planning of a terrain surface, with a predominance of resistant forms provided by erosive residuals and areas of Cenozoic sedimentary deposits, based on the similarity of relief forms and relative altimetry. They were the basis for relating the other variables in the physiographic characterization analysis of the present research.

The areas of Plateaus of the external and internal cuestiform types and the cliff type are concentrated in the region between the upstream and the bank of the Bonito River, surrounded in the south by the dissected plateaus of the edge of the Cuesta do Caiapó and in the north of the basin by the Depressions and Dissected Interplateau Gaps. The Interior and Pre-cuesta Cuestiform Plateaus are located between river valleys and close to residual plateaus of the aforementioned types.

The soils found in the basin were defined according to Santos et al. (2018); occupying the largest area were the Dystrophic Red Latosol (LVd), the Dystrophic Red-Yellow Latosol (LVAd), and the Dystrophic Tb Haplic Cambisol (CXbd), which together cover most of the basin. Subsequently, other soils are present in the region, such as the Eutrophic Red-Yellow Argisol (PVAe) and the Dystrophic type (PVAd), the Dystrophic Litholic Neosol (RLd), and the Eutrophic Red Nitisol (NVef), with less representation.

3.2. Analysis of the distribution of structural physiographic factors in Geomorphology Units

When mapping the Geomorphology Units, 5 distinct classes were presented, as shown in Table 1, with the percentage distribution of occupation in the area of the basin in question. With a small extension, there is the Aggradation class (with 13.27 km² and 0.66% of the area), located in the river channel, involving depositions of recent sediments. Rock exposures are evident in the HH areas of (hills and hillocks areas), with an area size of 143 km², equivalent to 7.13%.

On the upstream edges of the basin, the Retreat Erosion Zone (REZ) is present, comprising 157.89 km², the third smallest class in the basin, representing 7.84% of the basin. The two largest representatives of the Geomorphology Units were the regional flattening surface units, RFSII between 550-750 m (covering 32.14% of the area, with 647.87 km²) and RFSIII of 750-1250 m (with 52.23%, 1052.40 km², more than half of the basin area), and make up the largest representatives of the environment, covering the central part of the territorial space of the Bonito River hydrographic basin, distinguishing according to the altimetric curves.

Table 1 – Data on the area occupied by the Geomorphology Units.

Geomorphology Unit Classes	km²	%
Aggradation	13.27	0.66%
HH	143.68	7.13%
RFSII	647.87	32.14%
RFSIII	1052.40	52.23%
REZ	157.89	7.84%
Total	2015.12	100.00%

Source: Authors (2023).

The segments referring to the geology classes are inserted in the units and are related to external factors of exposure to erosive events over geological time. The Aggradation class with lesser expression, represents areas of sedimentary accumulation and identifies the Holocene Alluvium with 5.77 km2, followed by the Ponta Grossa Formation in the center of the basin, 3.49 km2, but exposes the meta-volcanosedimentary sequence at 3.13 km2. Thus, in the highest portion of the landform, it exposes the shale facies of the Ponta Grossa Formation and to the river channel near the mouth of the Bonito River, the accumulations of recent Holocene sediments, with a band of more resistant rocks, already close to the HH unit (Figure 3).

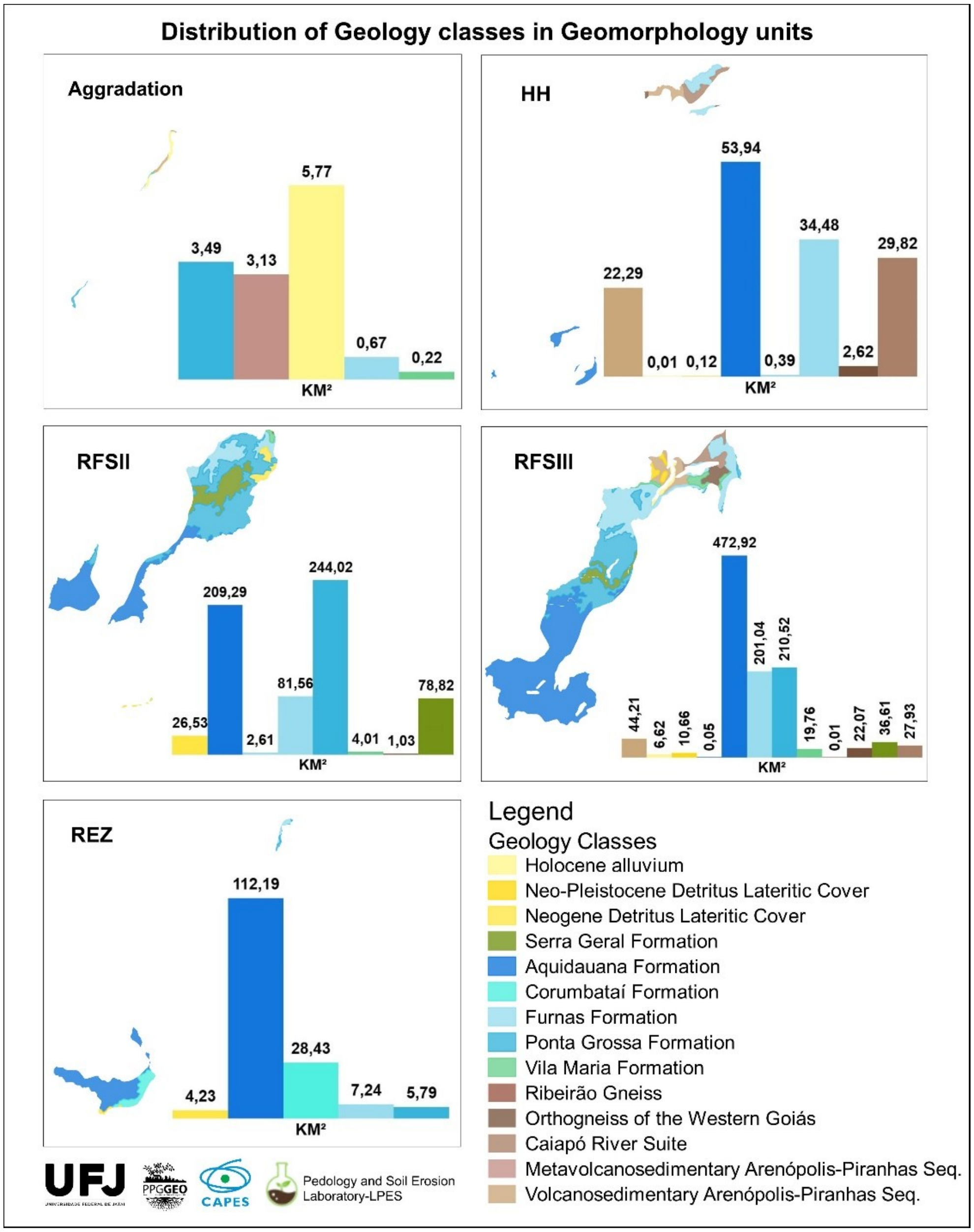

Figure 3 – Distribution of geology classes in geomorphology units.
Source: Authors (2023).

The *Morros e Colinas* (Hills and Hillocks) unit is found in sectorized parts of the basin, close to the lowest and highest parts, allowing comparisons of different lithologies. Upstream, the Aquidauana Formation prevails, and downstream, the Furnas Formation and igneous and metamorphic rocks of the Goiano complex (HASSUI et al., 2012).

The RFSII and RFSIII units, as well as the REZ, bring the Aquidauana, Ponta Grossa, and Furnas Formations with fragile sedimentary packages, which have been dissecting the landform, representing more than half of the basin space, and erosion processes have already taken part of these geological units close to the region of the mouth of the Bonito River.

The patterns of landforms correspond to geological formations and lithological resistance. When observed in the center of RFSII and RFSIII, the cuestiform residual plateaus are comprehensive. While at the edge of the basin, in the zone of receding erosion, the dissected plateaus of the edge of the Cuesta do Caiapó comprise 68.93 km2, as well as the External Cuestiformes Residual Plateaus, with 71.85 km2 (Figure 4).

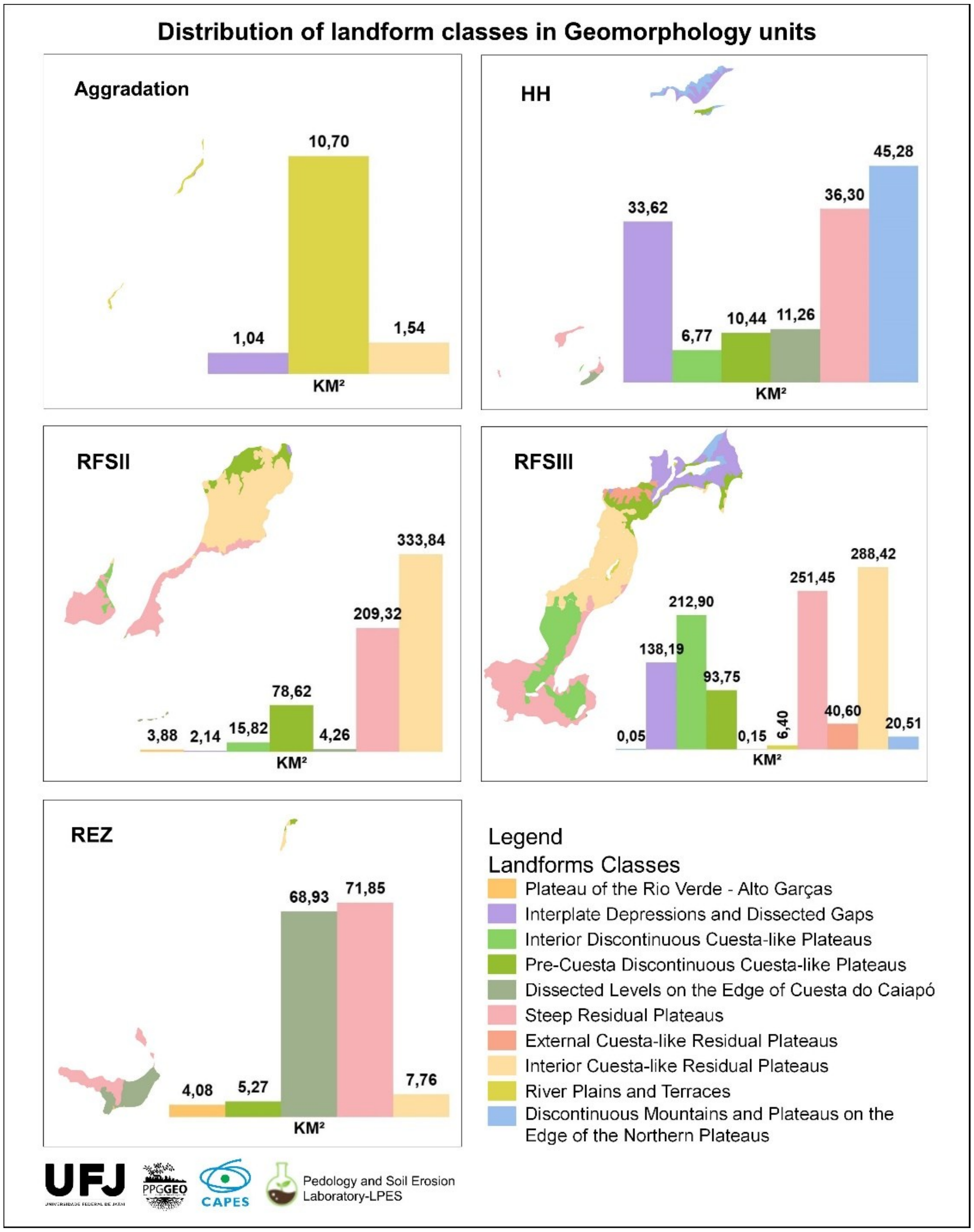

Figure 4 – Distribution of landform classes in geomorphology units.
Source: Authors (2023).

The areas of Depressions and Dissected Interplateau Gaps are found at lower altitudes, where the Aggradation, HH, and RFSIII units remain, located close to the mouth of the Bonito River, exposing older lithological units.

In the geomorphology units with smaller sizes (Aggradation, HH, and REZ), the Tb Dystrophic Haplic Cambisol was the prominent representative. In RFSII and RFSIII, the Dystrophic Red Oxisols had the highest value, occupying 212.51 km² in the RFSII unit and 432.19 km² in the largest geomorphological unit RFSIII, the other types: Dystrophic Red-Yellow, Distroferric Red, Ácric Red, among others, are found in smaller proportions in the other classes, as shown in Figure 5.

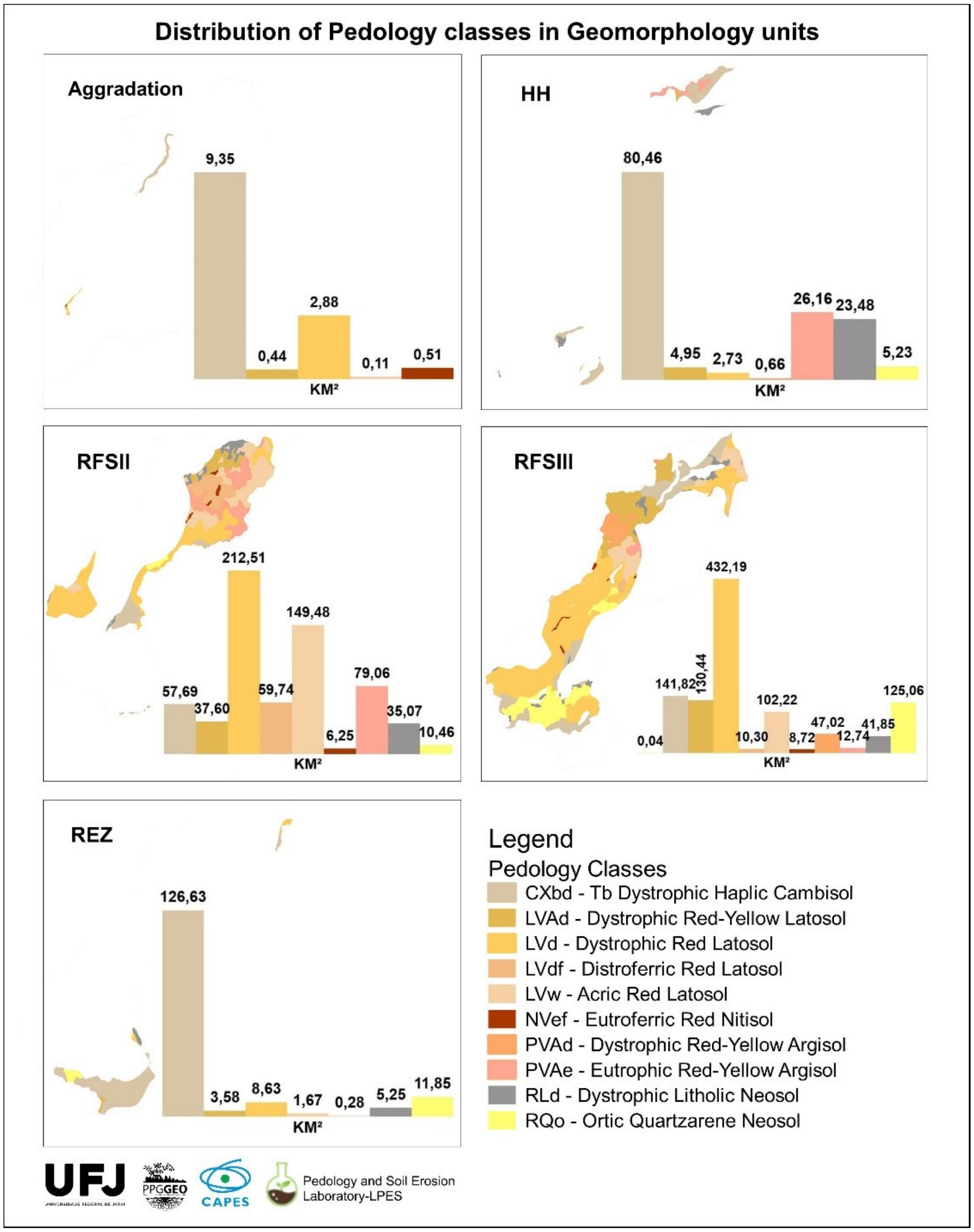

Figure 5 – Distribution of pedology classes in geomorphology units.
Source: Authors (2023).

These soils were distributed in the model due to geomorphological characteristics; as Motta et al. (2002) found, the landform is a conditioning factor for the spatial distribution of soils. In the basin, the geomorphology, together with the oxisols, contributes to anthropogenic occupations of agricultural uses, according to Pereira (2021).

3.3. Analysis of topographic profiles in Geomorphology Units

The transverse profiles of the basin were analyzed in sets after tracing in the Terrain Profile extension of the QGIS software, version 3.28 Firenze, recording the topographic discontinuities in tables.

To record the altimetric profiles, each segment was highlighted, making them compatible with the geomorphology units since they conditioned the spatial organization with a decline in the hypsometric variation. The method follows the application of geomorphology mappings of the RADAMBRASIL project (1983), as well as the very pronounced distribution of altimetric amplitudes in the Barra Grande river basin by Bertolini, Deodoro, and Boettcher (2019). Thus, a variation in altitude was detected, with an average amplitude of 500 meters, obtained between the highest point upstream in the Serra do Caiapó to the mouth of the Bonito River (Figure 6).

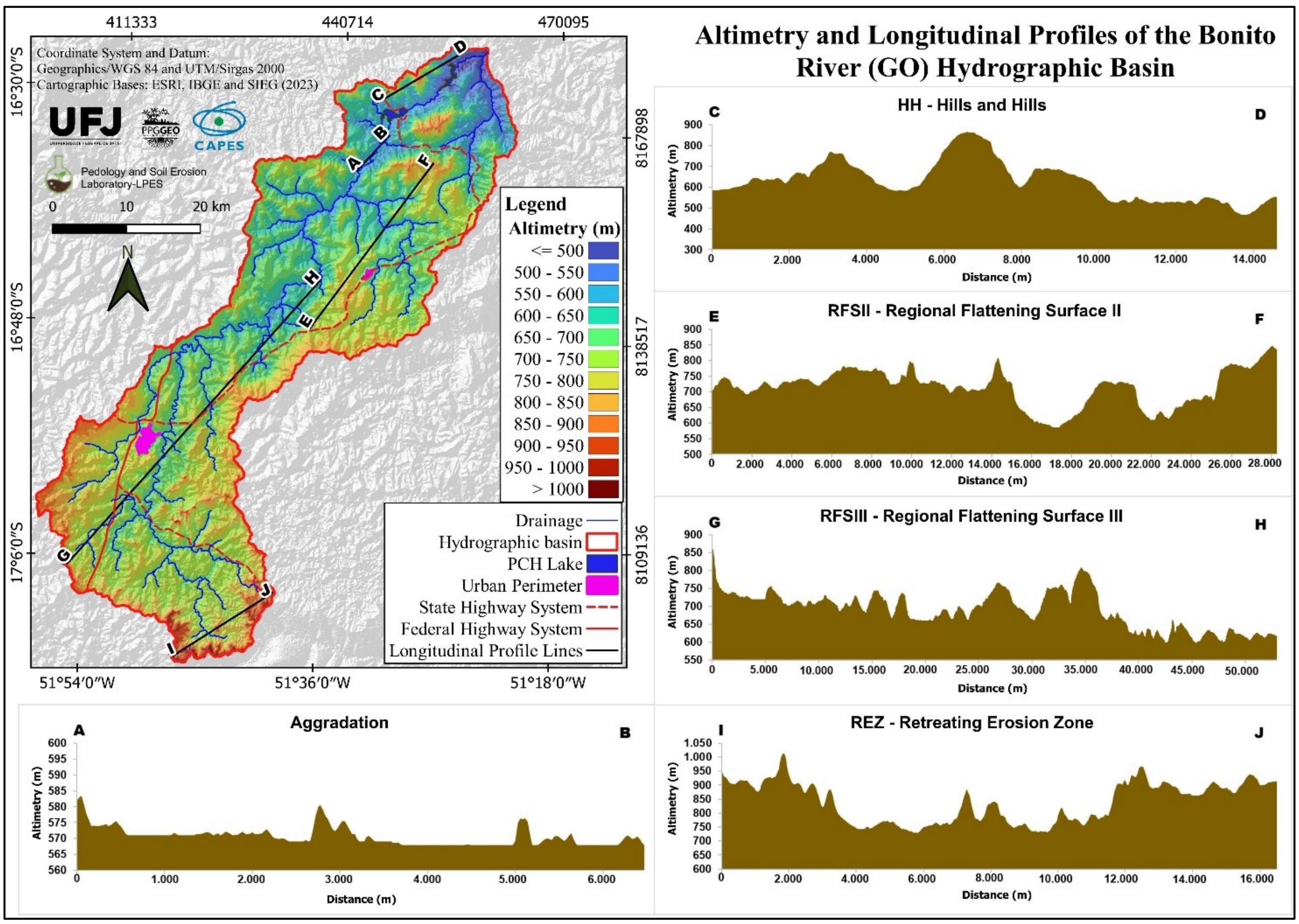

Figure 6 – Altimetry Map and Longitudinal Profiles in Geomorphology Units.
Source: Authors (2023).

To represent the altimetric assessment, 5 longitudinal profiles were drawn within each geomorphology unit to identify variations in terrain altitude in each unit. Values between 570 and 575 meters were observed in the Aggradation part, with flat and soft undulating terrain. The profile of the CD section comprises 580 to 880 meters and represents isolated hills in the HH unit, located on the edge of the Bonito River mouth, comprising concave and convex forms in the landform.

The regional flattening surfaces RFSII and RFSIII were defined at a greater distance, with 28 and 50 km in length, as the two units have greater area occupations. Well-dissected areas with a soft, undulating pattern and concave slopes where rivers cut through the terrain are evident, displaying erosive residuals. The profile of section GH was traced perpendicularly along the Bonito River, allowing topography to be observed from 850 m from the edge and sources to the 580 m middle course of the Bonito River.

The Retreat Erosion Zone has the highest elevations in the IJ profile, up to 1,020 m, located at the ends of the profile line, cutting out areas on the edge of the Serra do Caiapó, where the sources of the Bonito River are located.

The basin has convex tops and open valleys, contrasting with the patterns described by Silva and Girão (2020), who observed a morphology characterized by hills with sharp convex tops and closed, steep valleys.

3.4. Analysis of landscapes in Geomorphology Units

It is observed that the records left by past geological processes developed intensely due to erosion, as evidenced by the highest elevation points in the river basin where the Cuesta do Caiapó mountain range is located (Figure 7).

In these areas of coverage, in the erosional facies, three landform patterns are observed: the flat hilltops of the Rio Verde Plateaus (Green River Plateaus), the erosional scarps of Cuesta do Caiapó, and the dissected facies of RFSIII.

Figure 7 – Landform of the edge of the Cuesta do Caiapó, highlighting the Retreating Erosion Zone. Date: July 2023. Coordinates of the viewpoint: 17° 9' 8.16" S; 51° 39' 12.38" W. Height: 902 m.
Source: Authors (2023).

The valley highlighted in Figure 8, on the way down the road, is between the Retreating Erosion Zone, lowering towards the flattened parts of the residual plateaus of the RFSII and RFSIII units, dissected regions, and associated with the Aquidauana Formation, marked by smooth undulating landform, in the front, in the third plane, areas of Hills and Hillocks, the residual testimonies of the past landform in the current regional landscape.

Figure 8 – Landform of residual plateaus of Regional Flattening surfaces. Date: July 2023. Coordinates of the viewpoint: 17° 7' 21.69" S; 51° 40' 45.33" W. Height: 772 m.
Source: Authors (2023).

The image in Figure 9 shows the dissection environments belonging to the lithological classes of carboniferous sandstones (Aquidauana Formation) superimposed on Devonian sandstones (Ponta Grossa Formation), mainly defined in geoforms that coincide with core zones during horizontal Cretaceous processes of denudation (LIMA, 2020), in addition, with rounded tops in the areas of medium interfluves with convex shapes, as determined in Florenzano (2008) and Costa (2022).

Figure 9 – Landform of hills and hillocks with discontinuous interior levels. Date: July 2023. Coordinates of the viewpoint: 17° 5' 1.62" S; 51° 44' 18.81" W. Height: 761 m.
Source: Authors (2023).

According to Figure 10, the Bonito River valley, an environment of fluvial accumulation, is delimited in the range of the Aggradation unit, which is sedimentary from Holocene alluvial packages. Elevations are barely noticeable, with gently undulating interfluvial groups and pronounced low elevations, where the valley slope merges with the plain. In the background, higher levels of nearby hills from another geomorphology unit are visible.

Figure 10 – Landform of sediment accumulation of the Aggradation class. Date: July 2023. Coordinates of the viewpoint: 16° 37' 40.83" S; 51° 33' 6.30" W. Height: 575 m. Width between banks: 24 meters.
Source: Authors (2023).

Thus, in the Bonito River basin, the central valley has some elevations with lower declivity in the Aggradation zone and the Regional Flattening Surfaces and more undulating to steep in the Hills and Hillocks areas, which are highlighted in the center of the flattening region, and also downstream, with rounded or flat tops, the erosive surfaces of the Retreating Erosion Zone, determine the areas of extension of the most active erosive processes in the current landscape of the basin.

4. Final considerations

The data analysis was efficient, and the products obtained in this work allowed the identification of areas with structural diversity, helping to perceive the elements of the physical characterizations observed. Furthermore, the mapped components were shown to be correlated according to the procedures applied to evaluate the correlations of the verified landscape.

A wide diversity of physiographic characteristics was analyzed, as several classes were identified and differentiated in the mapping, including 14 units of geological aspects, 10 soil classes, and 10 categories of landform, according to the geomorphological delineation processes belonging to the 5 general geomorphology units outlined as background.

Regarding geological aspects, there is a predominance in the study area of sediments from the Aquidauana and Ponta Grossa Formations, covering the lower areas of the Furnas and Serra Geral Formations. Downstream of the Bonito River, Precambrian crystalline rocks from the Goiás complex are present, exposed primarily through fluvial dissection of the landform at the confluence of the Bonito and Caiapó rivers.

According to geomorphology, the 10 identified units have different landforms, and their aspects are related to lithological and structural conditions and systems of erosive agents. For example, the southern edge of the basin is in front of the erosional retreat of the Cuesta do Caiapó; perpendicular are the Dissected Patamares, followed by the Cliffed and Cuestiformes Residual Plateaus, classes that present areas of interior hills, testimony that shows how the environments evolved in past ages.

Depending on the soil classes, different sediments were observed, both originating from erosive processes and wear of rocks from pre-existing formations, as well as different types of oxisols in areas close to smooth-undulating terrain, favoring agricultural occupations, which are already intense in the region.

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References

ARRUDA, M. B.; PROENÇA, C. E. B.; RODRIGUES, S.; MARTINS, E. S.; MARTINS, R. C.; CAMPOS, R. N. Ecorregiões, Unidades de Conservação e Representatividade Ecológica do Bioma Cerrado. In: SANO, S.; ALMEIDA, S. P. (Org.). *Cerrado*: ecologia e flora. Brasília: Embrapa, 2008. Cap 8, p. 229-270

BARROS, J. P. F. G.; GALVÍNCIO, J. D. Caracterização fisiográfica das bacias hidrográficas do rio Una e Mundaú utilizando dados do LiDAR, Pernambuco 3D. *Revista Brasileira de Geografia Física*, [S.l.], v. 15, n. 5, 2022, p. 2671-2688.

BERTOLINI, W. Z.; DEODORO, S. C.; BOETTCHER, N. Análise morfométrica da bacia do Rio Barra Grande - Oeste de Santa Catarina. *Revista Brasileira de Geomorfologia*, v.20, n.1, 2019, p.3-17.

CHRISTOFOLETTI, A. *Geomorfologia*. São Paulo: Edgard Blücher, 1980.

CORRÊA, C. V. S., et al.. Assessment of the potentiality to the debris-flow occurrence from physiographic and morphometric parameters: a case study in Santo Antônio Basin (Caraguatatuba, São Paulo State, Brazil). *Anuário do Instituto de Geociências*, v.44, 2021, p.1-14.

COSTA, J. M. L. M. Mapeamento e caracterização geomorfológica da bacia do rio Apuaê-Mirim/RS com base na distinção de patamares a partir das descontinuidades no relevo. *Geografia Ensino & Pesquisa*, Santa Maria, v. 26, e38, 2022, p. 1-40.

DALLA CORTE, A. P. et al. *Explorando o QGIS 3.X*. Curitiba: Editora: dos Altores, 2020, 396p.

FLORENZANO, T. G. (org.). *Geomorfologia*: conceitos e tecnologias atuais. São Paulo: Oficina de Textos, 2008.

GUERRA, GUERRA, A. J. T. Processos Erosivos nas Encostas. In: GUERRA, A. J. T. et al. *Geomorfologia*: Uma atualização de bases e conceitos. Betrand Brasil: Rio de Janeiro, 2007.

GUERRA, V.; LAZZARI, M. Geomorphological mapping as a tool for geoheritage inventory and geotourism promotion: a case study from the middle valley of the Marecchia River (northern Italy). *Géomorphologie relief processus environnement*, v. 27, n. 2, 2021, p. 127–145.

HASSUI, Y. et al. *Geologia do Brasil*. São Paulo: Beca, 2012.

IBGE, Instituto Brasileiro de Geografia e Estatística. *Geociências*: Downloads. 2018. Disponível em: https://www.ibge.gov.br/en/geosciences/downloads-geosciences.html. Acesso em: 15 mai 2023.

IBGE, Instituto Brasileiro de Geografia e Estatística. *Manuais técnicos em geociências*. Rio de Janeiro: IBGE. 2009.

JACOBY, B. S.; PETERSON, E. W.; DOGWILER, T. Identifying the stream erosion potential of cave levels in Carter cave state resort park, Kentucky, USA. *Journal of geographic information system*, v. 03, n. 04, 2011, p. 323–333.

LATRUBESSE, E. M.; CARVALHO, T. M. *Mapa Geomorfológico de Goiás e Distrito Federal*. Superintendência de Geologia e Mineração do Estado de Goiás, Goiânia, 2005, 67p.

LIMA, Andreia Maciel. *Avaliação da geodiversidade do município de Caiapônia – GO*. Dissertação (Mestrado) Universidade Federal de Goiás, Instituto de Estudos Socioambientais (IESA), Programa de Pós-graduação em Geografia, Goiânia, 2020. 136p.

LIMA, V. F. DE; FURRIER, M. Detail geomorphological mapping proposal: a practical application in tabular relief. *Revista Brasileira de Geografia Física*, v. 13, n. 07, 2020, p. 3478–3497.

LIMA, V. F. de. *Influência estrutural na configuração geomorfológica do setor sudeste da Paraíba e nordeste de Pernambuco*. Tese UFPB - Centro de Ciências Exatas e da Natureza (CCEN) - Programa de Pós-Graduação em Geografia, 2021. 179p.

MARTHA, T. R.; SAHA, R.; KUMAR, K. V. Synergetic use of satellite image and DEM for identification of landforms in a Ridge-Valley topography. *International journal of geosciences*, v. 03, n. 03, p. 480–489, 2012.

MELO, A. C. A. de; COUTO JÚNIOR, A. F. Os padrões geomorfológicos condicionam a organização espacial da ocupação antrópica da bacia do Rio Maranhão. In: XVIII Simpósio Brasileiro De Sensoriamento Remoto (SBSR), 2017, Santos - SP. *Anais*... São José dos Campos: INPE, 2017, p. 972-979. ISBN 978-85-17-00088-1.

MELO, D. C. D.; XAVIER, A. C.; BIANCHI, T.; OLIVEIRA, P. T. S.; SCANLON, B. R.; LUCAS, M. C.; WENDLAND, E. Performance evaluation of rainfall estimates by TRMM multi-satellite precipitation analysis 3B42V6 an V7 over Brazil. *Journal of Geophysical Research*: Atmospheres, v. 120, p. 9426-9436, Aug. 2015.

MOREIRA, M. L. O.; MORETON, L. C.; ARAÚJO, V. A. de; LACERDA FILHO, J. V. de; COSTA, H. F. da. *Geologia do Estado de Goiás e do Distrito Federal*. Goiânia: CPRM/SIC – FUNMINERAL, 2009.

MOTTA, P. E. F.; CARVALHO FILHO, A.; KER, J. C.; PEREIRA, N. R.; CARVALHO JUNIOR, W.; BLANCANEAUX, P. Relações solosuperfície geomórfica e evolução da paisagem em uma área do Planalto Central Brasileiro. *Pesquisa Agropecuária Brasileira*, Brasília, v.37, 2002, p.869-878.

PASCHOAL, L. G.; RAMOS, A. M.; CUNHA, L. J. S. da; CUNHA, C. M. L. da. Estudos Geomorfológicos em área de mineração em Portugal: Cartografia Geomorfológica para análise do impacto antrópico sobre o relevo. *Revista Brasileira de Geomorfologia*, [S. l.], v. 17, n. 1, 2016, p.61-78.

PEREIRA, R. G. *Análise empírica da fragilidade ambiental na bacia hidrográfica do Rio Bonito - GO*. 2021. Dissertação (Mestrado em Geografia) - Universidade Federal de Jataí, Jataí, 2021. 109p.

PEREIRA, R. G.; MARTINS, A. P. Fragilidade ambiental potencial e emergente na bacia hidrografica do rio Bonito-GO – Brasil. *Geoambiente On-line*, Goiânia, n. 42, 2022, p.71-86. ISSN 1679-9860.

QGIS Development Team. *QGIS Geographic Information System (versão 3.28, Firenze)*. 2023. Disponível em: http://qgis.osgeo.org. Acesso em:.10 jan. 2023.

RADAMBRASIL, Projeto. *Geologia, geomorfologia, pedologia, vegetação e uso potencial da terra*." Ministério das Minas e Energia, Folha Goiânia. SE 22, 1983.

ROSS, J. L. S. *Geomorfologia*: ambiente e planejamento. 9 ed. São Paulo: Contexto, 2014.

SANO, E. E.; BETTIOL, G. M.; MARTINS, E. S., COUTO JÚNIOR, A. F.; VASCONCELOS, V.; BOLFE, E. L.; VICTORIA D. de C. Características gerais da paisagem do Cerrado. In: BOLFE E. L.; SANO, E. E.; CAMPOS, K. S. *Dinâmica agrícola no cerrado*: análises e projeções. – Brasília, DF: Embrapa, 2020.

SANTOS, H. G. et al. *Sistema brasileiro de classificação de solos*. 5ª ed. revista e ampliada. Brasília: Embrapa. Rio de Janeiro: Embrapa Solos, 2018. 355p.

SIEG, Sistema de Geoinformação de Goiás. *Base de Dados Cartográficos*: Folhas SE-22-V-D de Jataí e SE-22-V-B de Iporá. 2018. Disponível em: http://www.sieg.go.gov.br. Acesso em: 12 abr. 2023.

SILVA, M. K. A. *Análise Geoambiental das bacias hidrográficas federais do cerrado mineiro*. Dissertação de mestrado (Pós-Graduação em Geografia). Universidade Federal de Uberlândia. 2009. 200p.

TRICART, J. *Ecodinâmica*. Rio de Janeiro: IBGE, 1977.

USGS, Science for a changing world. *Missions*: Shuttle Radar Topography Mission - SRTM. 2015. Disponível em: https://dds.cr.usgs.gov/srtm/. Acesso em: 23 abr. 2023.