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# Physiographic characterization of water basins in Minas Gerais (Brazil) as a contribution for environmental planning

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## ABSTRACT

Characterizing natural features of the environment, such as soil, vegetation, and climate help understanding the dynamics of a hydrographic basin, making it possible to propose appropriate measures for use and occupation, aiming to minimize impacts on the environment and water quality. This research aimed to characterize the physiographic attributes of the watersheds of the stations monitored by Instituto Mineiro de Gestão das Águas, using geotechnologies and secondary data, to generate information that assist environmental planning. All geoprocessing was performed in ArcGIS GIS. Initially, records on climate, soil and natural vegetation characteristics were collected from free databases, and then they went through a process of homogenization of geodetic reference. The slope map was generated in ArcGis from 96 SRTM images, made available by the American Geological Survey, with intervals of 1 arc-seg (30 m resolution). The results showed that most of the basins under study, 47.11% of the total, are in the Atlantic Forest biome and 31.35% of the total are in Cerrado. As for climate, according to the Köppen classification, classes Cwa, Cwb, and Aw are prevalent. The predominant slope class in the hydrographic basins is the 12 to 30% class, which covers 67.78% of the watersheds. As for soil types, the most comprehensive soil classes are Latosols with 53.94% (267 basins) and Cambisols with 18.59% (92 basins), confirming the data found in the research. The individual cartographic products of each watershed may provide more accurate information and make the environmental planning of each area more adequate. The database created in the present research may support environmental and territorial planning of the basins under study.

**KEYWORDS:** Geoprocessing, GIS, Geotechnologies, ArcGIS, physical environment.

## 1 INTRODUCTION

Several studies propose the use of the hydrographic basin as a unit of study, as well as environmental and territorial planning, due to the ease of integration of elements from natural, anthropic, and socioeconomic environments, which interact in the area surrounding the basin, making it possible to perform a quantitative-qualitative analysis (MEDEIROS et al., 2014). In Brazil, the Federal Law No. 9,433, from 1997 (BRAZIL, 1997), defines the hydrographic basin as the territorial unit for the implementation of the National Water Resources Policy and the Water Resources Plan (WRP).

Law No. 9,433/1997 defined actions and implemented water resources management by the territorial unit of hydrographic basins, one of its basic principles being to carry out its current diagnosis, elucidating its physical characteristics for plan implementation, aimed at the conservation /recovery of water resources. Basins' WRPs are long-term and must contain a diagnostic of the water resources' current situation, considering that one of the basic steps is to know the aspects of physical, biotic, and socioeconomic environments.

The knowledge of environmental components (such as rocks, landforms, soils, water, vegetation, climate, and human action), and the understanding of their interrelationships, help in the detection of conditions that alter or may alter the functioning of natural systems, which end up affecting the quality and quantity of available water in a basin (CARVALHO, 2014).

The physiographic characterization of the watershed is of great value when well designed, as it provides information that can assist the planning process of the physical environment, to minimize impacts (ZIANI et al., 2017).

Medeiros et al. (2014) argued that characterizing the natural elements of a water basin, as well as performing the interaction of such elements, allow identifying how they interfere in the dynamics of the watershed, making it possible to propose appropriate forms of land use and occupation, aiming to minimize environmental impacts.

In natural resources planning, geotechnologies have become an instrument of great potential, as they present numerous applications that allow research development, analysis, and management in a short period of time, which ends up facilitating the implementation of management plans, and assists the supervision by authorities (LUPPI et al., 2015; SANTOS et al., 2016).

In this context, this research aimed to characterize the physiographic attributes of 571 hydrographic basins of the points of water quality monitoring in the state of Minas Gerais, using geotechnologies and secondary data, in order to provide support to environmental and territorial planning of these watersheds.

## 2 MATERIALS AND METHODS

This study involved gathering and organization of secondary data, and the use of geotechnologies to elaborate cartographic products aimed at characterizing climate and landform aspects, and the soil types of the hydrographic basins of the state of Minas Gerais (MG), Brazil.

## 2.1 Watershed delimitation

Initially, the water quality monitoring stations in the state of Minas Gerais (MG) were investigated. The information was provided by Instituto Mineiro de Gestão das Águas (IGAM), that supplied a spreadsheet containing the following data of 571 stations: name of the station, description of the sampling point, latitude and longitude in decimals, and water quality records. These various monitoring points had their contribution area upstream, that is, their drainage basin was delineated.

The dataset with the coordinates of the monitoring stations, in the .xls extension, was added to ArcGIS, transformed into a shapefile (.shp) and overlapped on the SRTM radar images. For the delimitation of the basins, an automatic method was used in the SGI ArcGIS. ArcHydro, an extension composed of a set of hydrological tools that can be installed free of charge, was used. This method involved the following steps, based on the guidelines provided by Khan et al. (2014): filling of depressions of the elevation model, flow direction and accumulated flow, and, finally, the delimitation of basins through the following hydrology tools: fill sinks, flow direction, flow accumulation and watershed, respectively.

As input data, we used raster flow direction and flow accumulation with 15 arc-sec resolution, provided by the Hydro SHEDS project – Shuttle Elevation Derivatives at multiple Scales (LEHNER et al., 2008). These raster files are products derived from the terrain elevation images generated by SAR (Synthetic Aperture Radar) during the SRTM – Shuttle Radar Topography Mission, in 2000, through a partnership between the German Space Agency, the Italian Space Agency and NASA (FARR et al., 2001). Finally, all 571 were delimited and had their area calculated.

## 2.2 Characterization of environmental features of the watersheds

Initially, a search was carried out in free spatial datasets. Using ArcGIS, the obtained cartographic documents were analysed for their scale. Larger scale products were prioritized and then, the homogenization was performed for the coordinate system, cartographic projection, and the geodetic reference to the Universal Transverse Mercator projection system – UTM, WGS 1984, using the Project Raster tool.

To characterize the natural biome, the biome shapefile at the 1:150,000 scale from MapBiomas Project (2018) was used. Watersheds were inserted on the shapefiles' base so that spatial clip could be performed by the Geoprocessing > Clip command. As spatial clips were generated, it was possible to define the predominant biome and quantify it by the Calculate geometry tool.

As for the climate attribute, we used the cartographic document in the raster format, from Köppen's climate classification, at the 1:500,000 scale, which was produced by Alvares et al. (2013). Watersheds were inserted on the raster base and, in order to make the spatial processing, the Raster processing> Clip tool was used. Quantification of climate classes within each water basin was defined by the number of pixels of each class by the Calculate geometry tool.

The slope chart of the 571 hydrographic basins was generated in ArcGis. For this, 96 SRTM images were downloaded. These had an interval of 1 arc-seg, a 30-meter resolution from surface, covering the state of Minas Gerais. Such images were made available by the American Geological Survey (USGS, 2020) on the Earth Explorer portal. Using the slope command, the slope of all the scenes was created, and then the Mosaic to new raster tool was applied to unite the scenes and allow space clipping of the watersheds. The classifications adopted to slice the slope map followed the recommendations of the Instituto Geológico of the University of São Paulo.

Regarding the soil attribute, the cartographic document in the shapefile format was supplied by the Department of Soils, Centre of Agrarian Sciences (2010), at the 1:650,000 scale. To obtain the type of soil of the water basins, the spatial clipping of the cartographic base was performed using the Geoprocessing > Clip command. Quantification, in percentage, was done by the Calculate Geometry tool. All the above procedures were performed in ArcGis version 10.5 GIS and the generated data was exported to Excel for better visualization and analysis.

## 3 RESULTS AND DISCUSSION

### 3.1 Biomes

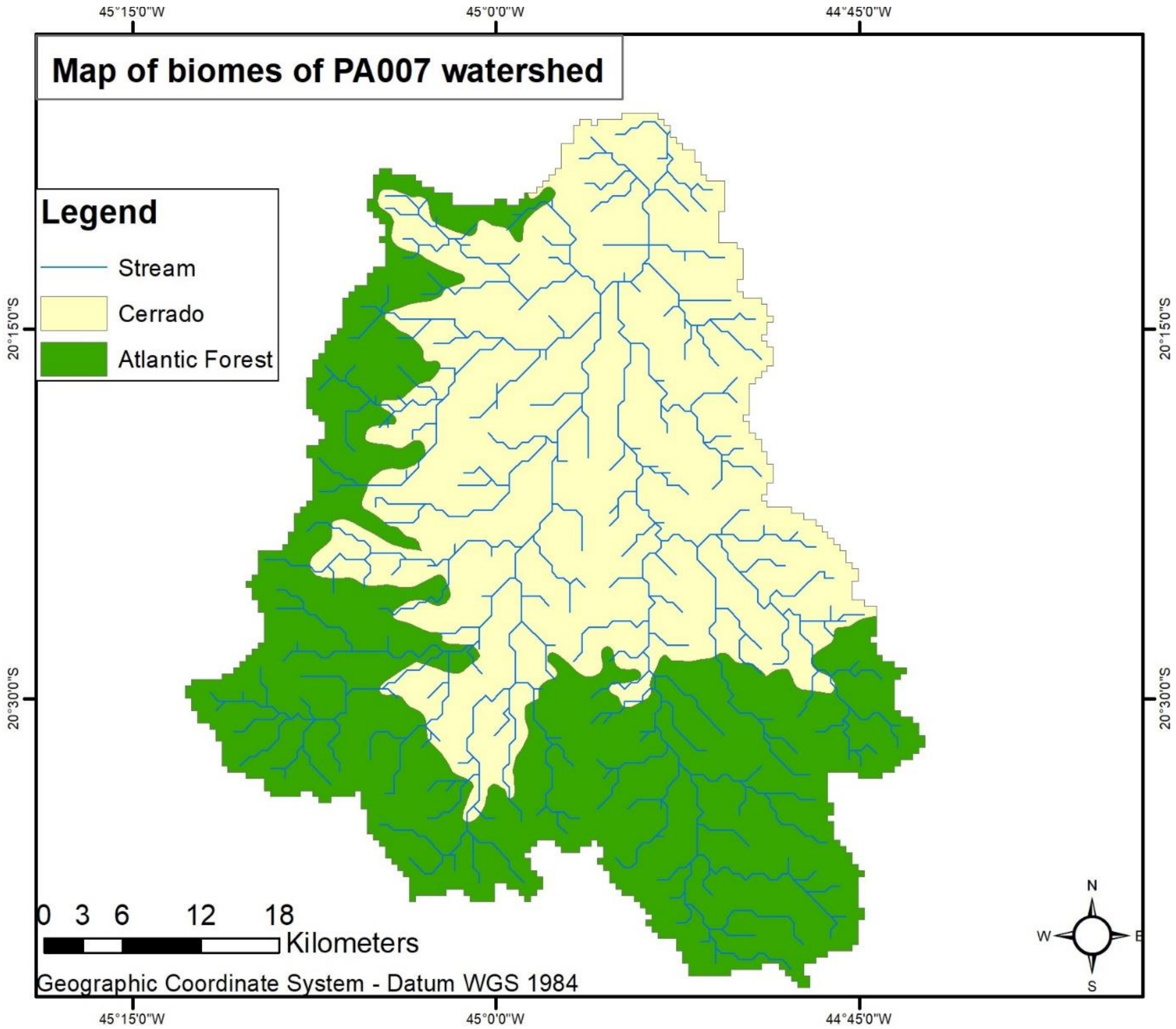
The MapBiomas shapefile classifies Brazil in the following classes: Amazon, Caatinga, Cerrado, Atlantic Forest, Pantanal, and Pampa. In the state of Minas Gerais, there are three classes of biomes: Caatinga, Cerrado, and Atlantic Forest. Considering the 571 hydrographic watersheds monitored by IGAM, the predominance of Atlantic Forest (47.11 %) and Cerrado (31.35%) stands out. The Atlantic Forest biome is characterized by occupying a large part of the interior of the Southeast and South of the country, and Cerrado, considered the second largest biome in Brazil, behind the Amazon, extends from the north coast to the centre-west (IBGE, 2014). Table 1 presents the number of Minas Gerais' basins included in each type of biome.

For each of the 571 basins, a biome map was produced. Figure 1 displays an example of a map produced for the characterization of the biome of the watershed from PA007 monitoring station, located on Itapecerica River, downstream of the city of Divinópolis, demonstrating the coverage of Cerrado and Atlantic Forest biomes within the water basin.

Table 1. Predominant biomes in hydrographic basins of Minas Gerais state

| Biomes | Number of watersheds | % |
|---|---|---|
| Caatinga | 3 | 0.53 |
| Caatinga and Cerrado | 12 | 2.10 |
| Caatinga, Cerrado, and Atlantic Forest | 10 | 1.75 |
| Cerrado | 179 | 31.35 |
| Cerrado and Atlantic Forest | 98 | 17.16 |
| Atlantic Forest | 269 | 47.11 |
| Total | 571 | 100 |

Figure 1. Map of biomes of PA007 watershed



The Atlantic Forest consists of a vegetation complex, with great biodiversity of flora and fauna, with distributed rainfall and high humidity. Fragmentation of forest remains has been gradually increasing throughout the years, causing loss in biodiversity to, often, prioritize commercial plantations of Eucaliptus spp. (COURA, 2007).

Cerrado is formed by savanna and grassland forest formations, composed of scattered trees and shrubs. Despite occupying most of MG, this biome had a large part of its area replaced by intensive agriculture and pasture, which may still be intensified due to the lack of environmental legislation that values its environmental conservation (RABELO et al., 2009).

As for the obtained data regarding the predominant biome within the hydrographic basins, characterized as the Atlantic Forest, the importance of preserving such vegetation is highlighted, due to the occurrence of dense forests and high biodiversity. These contribute to the maintenance and improvement of water quality and quantity, prevents river silting, protects springs and recharge areas of water sources.

### 3.2 Climate

The Köppen climate classification consists of dividing the world's climate into five large groups represented by the letters A, B, C, D and E, and subdivisions, which define the climate zone through temperature and precipitation, rainfall distribution and variation. of seasonal temperature (ALVARES et al., 2013; JÚNIOR, 2009).

The most representative climate group among the hydrographic basins was Cwb, which appeared in 47.58% of the total. This class consists of dry winter, with rainfall of less than 60 mm in at least one winter month, and a moderately warm summer with temperatures higher than 22 ºC and an average of 10 ºC (JUNIOR, 2009). Table 2 presents the distribution and quantification of the watersheds on the Köppen climate classification, considering classes of wider scope within the basins. Arranging the watersheds in the shapefile of climate data, the predominance of the three groups was observed: A, B and C, with the distribution of the following climate classes:

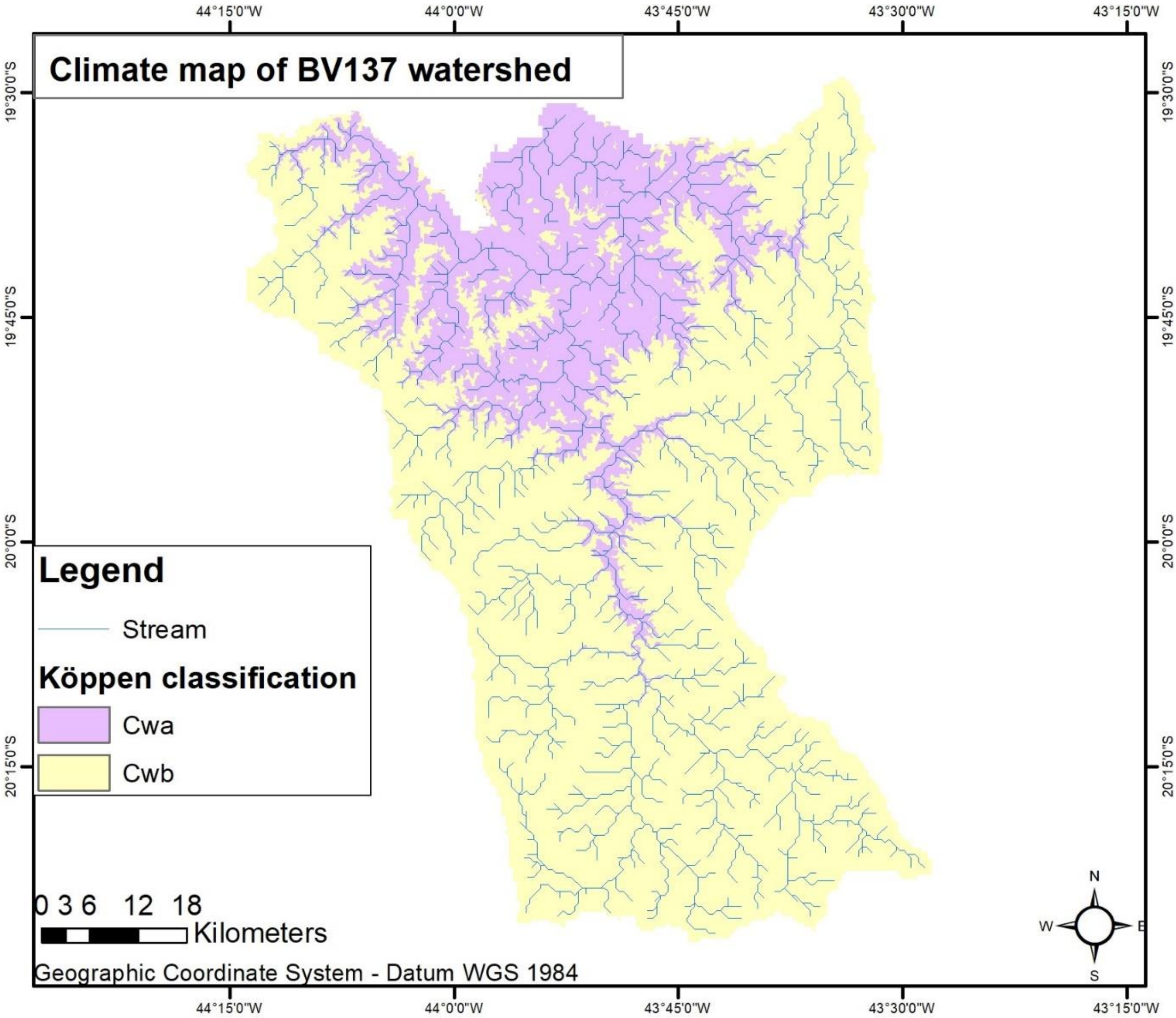
- As – Tropical climate with a dry summer season.
- Aw – Tropical savanna climate with dry winter season.
- BSh – Hot steppe climate.
- Cfa – Humid subtropical climate with hot summers.
- Cfb – Humid subtropical climate with moderate summer.
- Cwa – Humid subtropical climate with dry winters and hot summers.
- Cwb – Humid subtropical climate with dry winters and moderately hot summers.

Table 2. Predominant Köppen climate classes in the watersheds

| Climate classification | Number of watersheds | % |
|---|---|---|
| As | 38 | 6.65% |
| Aw | 110 | 19.26% |
| Bsh | 1 | 0.18% |
| Cfa | 3 | 0.53% |
| Cfb | 5 | 0.88% |
| Cwa | 140 | 24.52% |
| Cwb | 274 | 47.58% |
| Total | 571 | 100% |

Figure 2 illustrates a map made for the climate characterization of the watershed from monitoring station BV137, located in Velhas River, on Raul Soares Bridge, in the municipality of Lagoa Santa. It demonstrates the predominance of Cwa and Cwb climates.

Figure 2. Climate map of BV137 watershed



It was observed that Cwb class predominates in 47.58% of the basins, and, in 24.52% of them, there is a predominance of Cwa, while Aw class predominates in 19.26 % of the watersheds. According to Alvares et al. (2013), Cwb climate is predominant in south-eastern Brazil, mainly in the centre-south region of MG in altitudes higher than 800 metres (e.g., Serra da Canastra and Serra da Mantiqueira regions). The Cwb climate class covers approximately 11 % of the total area of Minas Gerais state (REBOITA et al., 2015), behind Aw class, which covers 67% of the study area and Cwa (21%).

### 3.3 Slope

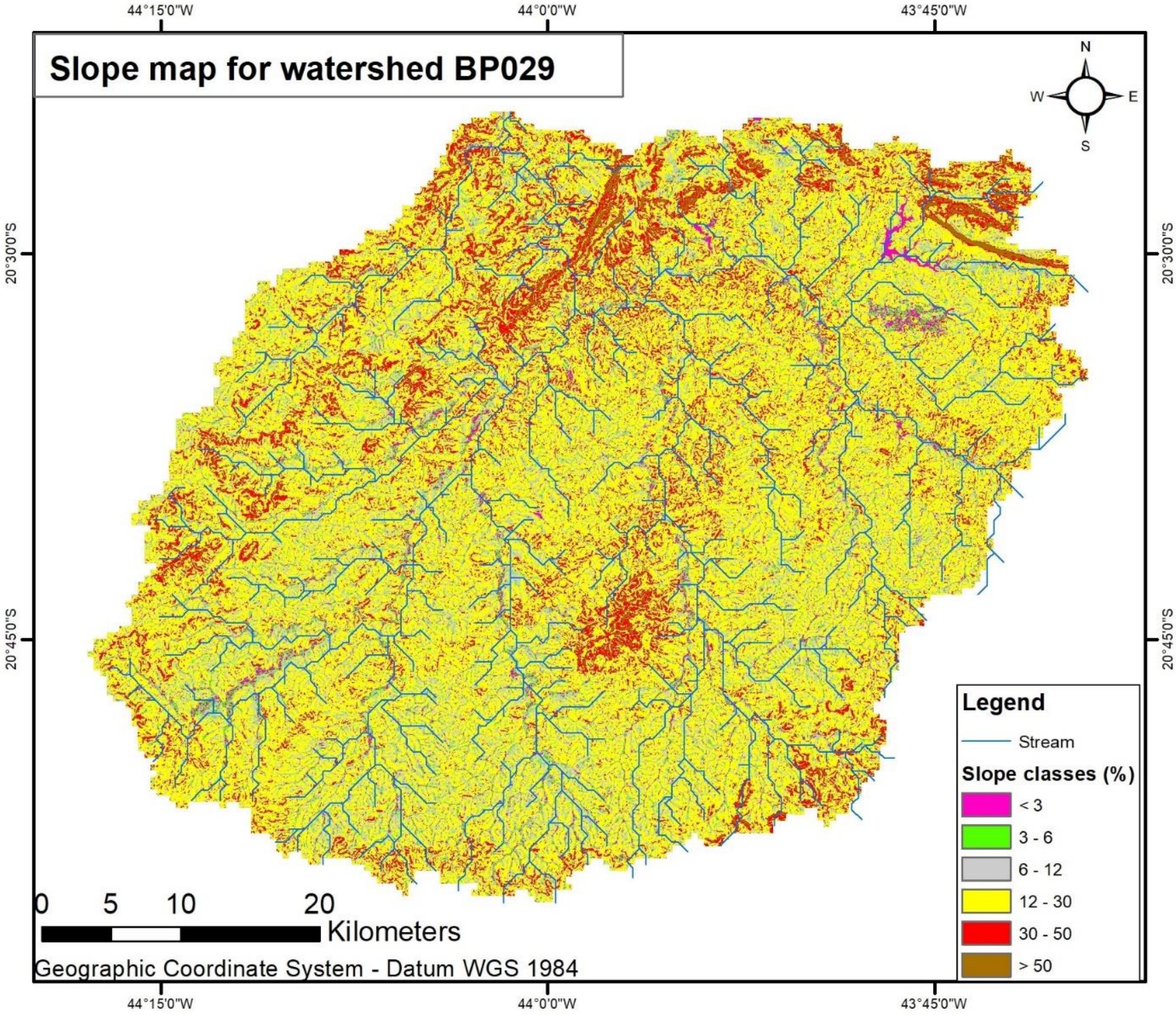
Slope is one of the main attributes to be considered for a physiographic characterization of hydrographic basins, as it has a direct influence on existing elements in the environment. In addition, it acts on controlling the speed of surface runoff due to rainwater, as well as the water infiltration time into the soil, which affect the susceptibility to soil erosion (DUARTE et al., 2007, MEDEIROS et al., 2014). Watersheds' slope classes were defined through the analysis of the final cartographic product of each basin, where the class with the greatest coverage within its total area was observed. Table 3 presents the predominant slope classes for the hydrographic basins.

Table 3. Predominant slope classes in the hydrographic basins

| Slope classes | Number of watersheds | % |
|---|---|---|
| 0% to 3% | 28 | 4.90 |
| 3% to 6% | 45 | 7.88 |
| 6% to 12% | 82 | 14.36 |
| 12% to 30% | 387 | 67.78 |
| 30% to 50% | 28 | 4.90 |
| >50% | 1 | 0.18 |
| Total | 571 | 100 |

It should be noted that the most predominant slope class within the watersheds is 12 to 30%, which covers 67.78% of the basins. As this class presents features of high susceptibility to erosion and landslides, special management techniques are required in the area, as well as practice restrictions for agriculture, for instance, because it could further accelerate the natural occurrence of these erosive processes. Figure 3 displays a slope map produced for the watershed at the BP029 monitoring station, located on Paraopeba River, where there is a predominance of classes ranging from 12% to 30%.

Figure 3. Slope map for watershed BP029, with a predominance of slope classes from 12% to 30%




The slope class from 0% to 3% prevails in 4.90% of the watersheds. This class is considered to have very low susceptibility to erosion and landslides, with soil depths greater than 10 m. The 3% to 6% class presents low susceptibility and very low susceptibility to erosion and landslides, respectively. Due to its slow surface runoff, it is more prone to flooding. About 7.88% of the hydrographic basins have a predominance of this class. The 6% to 12% class has medium propensity to erosion and very low susceptibility to landslides. It presents medium soil, ranging from 5 to 10 meters deep. About 14.36% of the watersheds have a predominance of this class.

The 12% to 30% slope class is considered to have high to very high susceptibility to erosion, whereas the likeliness for landslides is low, with the presence of shallow soils with a depth of 3 to 5 meters. About 67.78% of the hydrographic basins have a predominance of this class in their area. The 30 to 50% class has very high susceptibility to erosion, but it is of medium propensity to landslides, with the presence of very shallow soils with a depth of less than 3 meters, where rapid flows and floods occur. About 4.90% of the water basins have a predominance of this class. It is considered that the >50% slope class presents very high susceptibility to erosion and high to very high susceptibility to landslides, with the presence of shallow soils with a depth of less than 3 meters, where runoff and rapid flooding occur. Only 0.18%, that is, only one watershed, has a predominance of this class in its area.

### 3.4 Soils

The soil map was grouped into the following classes: Rocky Outcrop, Ultisols, Cambisols, Latosols, Neosols and Nitosols. The most predominant soil class in the total area of each basin was considered to carry out the characterization of the soil attribute, which facilitated grouping and may assist more detailed studies. Table 4 shows the quantification, and the most predominant classes present in the hydrographic basins.

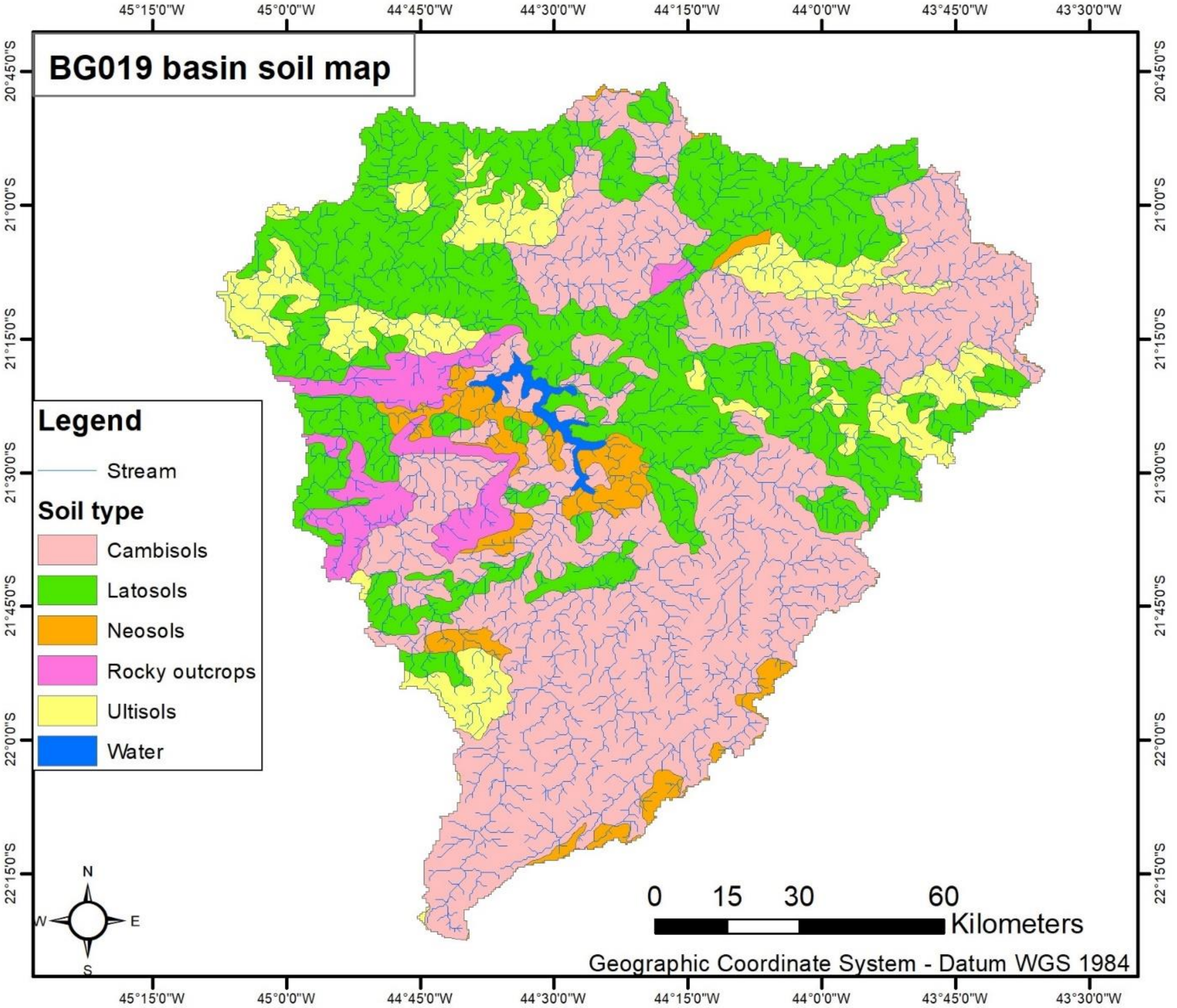
Table 4. Quantification of hydrographic basins by soil class with greater coverage

| Soil class | Number of watersheds | % |
|---|---|---|
| Rocky outcrops | 17 | 3.43 |
| Ultisols | 57 | 11.52 |
| Cambisols | 92 | 18.59 |
| Latosol | 267 | 53.94 |
| Neosols | 57 | 11.52 |
| Nitosols | 5 | 1.0 |
| **Total** | 495 | 100 |

According to Serafim et al. (2013), soil classes of greater geographic expression in Minas Gerais region are Latosols and Cambisols. In the present study, Latosols predominate in 53.94% of the watersheds, followed by Cambisols (18.59%). Figure 4 displays the map made for characterizing the soil of the BG019 monitoring station water basin, exemplifying the soil maps produced for the watersheds in the study area. In BG019 basin, a predominance of Latosols and Cambisols is observed.

Latosols are subjected to significant weathering processes of primary and secondary minerals with high concentration of clay minerals, causing the soil to have a high clay content. They are present in landforms ranging from the flatter to the most hilly, mountainous, and steep; deep soils; they have vivid colours varying from yellow to dark greyish red; and have good drainage capacity (EMBRAPA, 2006). Cambisols vary a lot from one place to another because of the heterogeneity of their origin material, landforms, and climate conditions. They may present high or low drainage capacity, be shallow or deep, present in strongly hilly/mountainous terrains, and their subclasses show similar features to the Latosols (EMBRAPA, 2006). Each soil class has its limitations for adequate land use and management, which must be put into practice aiming to eliminate possible contaminations of the soil and groundwater, which could consequently alter soil quality, as well as the water from a basin in certain region, leading to social and environmental issues.

Figure 4. BG019 basin soil map, where there is a predominance of Latosols and Cambisols classes




## 4 FINAL CONSIDERATIONS

The use of geotechnological tools, available at ArcGIS Geographic Information System, allowed characterising the attributes referring to the original biome, climate, soils, and slope of the 571 hydrographic basins of the water quality monitoring points in the state of Minas Gerais. Despite the labour intensity required, due to the large volume of data, the methods were considered easy to perform.

Most of the basins under study, i.e., 47.11% of the total, are located in the Atlantic Forest biome, and 31.35% of the total are in Cerrado. These biomes present high biodiversity and are considered hotspots, requiring special attention to preservation and conservation.

As for the climate, the predominance of classes Cwa, Cwb and Aw was noted. The main climate class in the hydrographic basins was Cwb - Humid subtropical climate with dry winters and moderately hot summers, appearing in 274 basins, which represents 47.58% of the total watersheds under study.

The predominant slope class in the hydrographic basins is the 12 to 30% class, which covers 67.78% of the watersheds. As for soil types, the most comprehensive soil classes are Latosols with 53.94% (267 basins) and Cambisols with 18.59% (92 basins), confirming the data found in research.

Elucidating the physical characteristics of the environment helps us differentiate the vulnerabilities of natural and anthropic origin, enabling us to mitigate damage from natural causes and impede the occurrence of those from human origin. The individual cartographic products of each watershed may provide more accurate information to make the environmental planning of each area more adequate.

The land use limitations of soil classes, slope, biome, and climate must always be considered prior to environmental exploiting, so that areas of high environmental gain can be avoided in case of interferences that directly influence the ecosystem, which can cause environmental imbalance. In this sense, the dataset resulted from this research project may assist and improve environmental and territorial planning of the watersheds under study.

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## DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

# Caracterização fisiográfica de bacias hídricas de Minas Gerais (Brasil) como contribuição para o planejamento ambiental

**RESUMO**

A caracterização de atributos naturais do ambiente, tais como o solo, a vegetação e o clima, auxiliam no entendimento da dinâmica de funcionamento de uma bacia hidrográfica tornando possível propor medidas adequadas de uso e ocupação, visando a minimização dos impactos no ambiente e na qualidade da água. Esta pesquisa objetivou caracterizar os atributos fisiográficos das bacias hidrográficas das estações monitoradas pelo Instituto Mineiro de Gestão das Águas, utilizando geotecnologias e dados secundários, a fim de gerar dados que auxiliem no planejamento ambiental. Todo o geoprocessamento foi realizado no SIG ArcGIS. Inicialmente os dados relativos aos atributos do clima, solo e vegetação natural foram levantados em bancos de dados gratuitos, e em seguida passaram por um processo de homogeneização do referencial geodésico. O mapa de declividade foi gerado no ArcGis a partir de 96 imagens SRTM, disponibilizadas pelo Serviço Geológico Americano, com intervalos de 1 arcseg (resolução de 30 m). Os resultados mostraram que a maior parte das bacias em estudo, 47,11% do total, estão inseridas no bioma mata atlântica e 31,35% do total estão inseridas no bioma cerrado. Quanto ao clima segundo classificação de Köppen, notou-se a predominância das classes Cwa, Cwb e Aw. A classe de declividade predominante nas bacias hidrográficas é a classe de 12 a 30%, que abrange 67,78% das bacias. Quanto aos tipos de solo, as classes de solos de maior abrangência são os Latossolos com 53,94% (267 bacias) e Cambissolos com 18,59% (92 bacias), confirmando os dados encontrados nas pesquisas realizadas. Os produtos cartográficos individuais de cada bacia hidrográfica poderão proporcionar informações mais precisas para tornar o planejamento ambiental de cada área mais adequado. O banco de dados gerados na presente pesquisa gerou subsídios para melhorar o planejamento ambiental e territorial das bacias em estudo.

**PALAVRAS-CHAVE:** Geoprocessamento, SIG, Geotecnologias, ArcGIS, meio físico.

## REFERENCES

ALVARES, CLAYTON ALCARDE; STAPE, JOSÉ LUIZ; SENTELHAS, PAULO CESAR; GONÇALVES, JOSÉ LEONARDO DE MORAES; SPAROVEK, GERD. Köppen's climate classification map for Brazil. Meteorologische Zeitschrift, v.22., n.6, p. 711-728, jan, 2013.

BRAZIL. Federal Law No. 9,433., 1997. Brazilian National Water Resources Policy. Available from: < http://www.siam.mg.gov.br/sla/download.pdf?idNorma=327>. [Acessed 15 April 2023].

CARVALHO, RODRIGO GUIMARÃES. As bacias hidrográficas enquanto unidades de planejamento e zoneamento ambiental no Brasil. Caderno Prudentino de Geografia, Presidente Prudente, n.36, p.26-43, 2014.

COURA, SAMUEL MARTINS COSTA. Vegetation mapping of Minas Gerais state using modis data. 2007. 150f. Dissertation. National Institute of Space Research, São José dos Campos, 2007.

DEPARTMENT OF SOILS. Centre of Agrarian Sciences (Federal University of Viçosa). 2010. Soil map of the state of Minas Gerais. 1:650,000 scale. Available from: < http://www.dps.ufv.br/?page_id=742>. [Acessed 15 May 2021].

DUARTE, CRISTINA COUTINHO; GALVÍNCIO, JOSICLÊDA DOMICIANO; CORRÊA, ANTÔNIO CARLOS DE BARROS; ARAÚJO, MARIA DO SOCORRO BEZERRA DE. Análise fisiográfica da bacia hidrográfica do rio Tapacurá – PE. Revista de Geografia, Recife, v.24, n.2, p. 50-64, mai./ago., 2007.

EMBRAPA. Centro Nacional de Pesquisa de Solos – Sistema brasileiro de classificação de solos. 2.ed. Rio de Janeiro: EMBRAPA-SPI, 2006.

FARR, T., et al. The Shuttle Radar Topography Mission, Eos Trans. American Geophysical Union, v.82, n.47, 2001.

IBGE - Instituto Brasileiro de Geografia e Estatística (Brazilian Institute of Geography and Statistics). MAPAS. Climates. Brasil: Ibge. Available from: < https://portaldemapas.ibge.gov.br/portal.php#mapa208019>. [Acessed 2 May 2021].

JÚNIOR, ARIONALDO DE SÁ. Application of the Köppen climatic classification for the zoning of Minas Gerais State, Brazil. 2009. 113f. Dissertation. Federal University of Lavras, 2009.

KHAN, A., et al. How large is the Upper Indus Basin? The pitfalls of auto-delineation using DEMs. Journal of Hydrology, v.509, p.442-453, 2014.

LEHNER, B., et al., HydroSHEDS. Technical Documentation Version 1.2, 2008.

LUPPI, ALIXANDRE SANQUETTA LAPORTI; SANTOS, ALEXANDRE ROSA DOS; EUGENIO, FERNANDO COELHO; FEITOSA, LORENA SANT'ANNA. Utilization of Geotechnology for the Mapping of Permanent Preservation Areas in João Neiva, Espirito Santo State, Brazil. Floram: Floresta e Ambiente, Espirito Santo, v.22, p.13-22, 2015.

MEDEIROS, RAFAEL BRUGNOLLI, SÃO MIGUEL, ANGÉLICA ESTIGARRIBIA; BRUGNOLLI, CLÁUDIA APARECIDA CORONADO. Physiographic characterization of hydrographic basin stream Marrecas, Dracena/SP. Fórum Ambiental da Alta Paulista, Alta Paulista, v.10, n.2, p.41-56, 2014.

PROJETO MAPBIOMAS – Coleção 2.0 da Série Anual de Mapas de Cobertura e Uso de Solo do Brasil. Available from: <http://mapbiomas.org/pages/downloads> [Acessed 30 September 2021].

RABELO, CLARISSE GUIMARÃES; FERREIRA, MANUEL EDUARDO; ARAÚJO, JOSÉ VICENTE GRANARO; STONE, LUIS FERNANDO; SILVA, SILVANDO CARLOS DA; GOMES, MARISA PRADO. Influência do uso do solo na qualidade da água no bioma Cerrado: um estudo comparativo entre bacias hidrográficas no estado de Goías, Brasil. Revista Ambiente & Água, Taubaté, v.4, n.2, p.172-187, 2009.

REBOITA, MICHELLE SIMÕES; RODRIGUES, MARCELO; SILVA, LUIZ FELIPE; ALVES, MARIA AMÉLIA. Climate aspects in Minas Gerais state. Revista Brasileira de Climatologia, Itajubá, v.17, n.11, p. 206-226, jul./dez., 2015.

SANTOS, Leonardo Sousa dos; GUTIERREZ, Carlos Benedito Barreiros; PONTES, Altem Nascimento; SOUZA, Alersson Antônio de Almeida; MARTORAN, Lucieta G.; JUNIOR, Orleno M. Silva. Geotecnologia aplicada na análise de bacias hidrográficas e rede de drenagem: Estudo das bacias hidrográficas do Murucutu e Aurá, Belém, Pará. Revista Sodebras, v.11, n.124, p.131-135, 2016.

SERAFIM, MILSON EVALDO; OLIVEIRA, GERALDO CÉSAR DE; CURI, NILTON; LIMA, JOSÉ MARIA DE; GUIMARÃES, PAULO TÁCITO GONTIJO; LIMA, VICO MENDES PEREIRA. Use potential and limitations of latosols and cambisols under a conservation coffee plantation system. Bioscience Journal, Uberlândia, v.29,n.6, p.1640-1652, nov./dez., 2013.

USGS – United States Geological Survey. 2020. Earth Explorer Portal. Available from: < https://earthexplorer.usgs.gov > [Acessed 20 March 2021].

ZIANI, PATRÍCIA; FOLETO, ELIANE MARIA.; WOLLMANN, CÁSSIO ARTHUR. Analysis and geographic characterization of Hydrographic Basin of Alto Jacuí/RS. Ciência e Natura, Santa Maria, v.39, p.58-74, 2017.

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