APPLICATIONS OF COMPUTING IN GEOMORPHOLOGY STUDIES – A CASE STUDY

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Abstract. *In recent years, the discourse in geomorphology has taken on a new perspective, through interdisciplinary discussions involving geotechnologies, focusing on the application of computing, especially geographic information systems (GIS). Geotechnologies have demonstrated the potential to establish themselves as tools for environmental planning and risk management. This study delves the using of geotechnologies in the morphometric analysis of the hydrographic basin of Pirapó River (Maringá, Paraná, Brazil).*

1. Introduction

In recent years, the study of Geomorphology has been increased in several fields of study as Geography, Agronomy, Environmental Sciences, Engineering and Computing Sciences [Xiong et al, 2021]. The terrain analysis is one of the most important contents in the research of geographical information science (GIS).

One of the subjects of the Geomorphology studies is the hydrographic basin morphometric analysis. Teodoro et al (2007) and Barrella (2001) define that the analysis of hydrographic basin is one of most important debates in the Geosciences and assists the management of the environment.

In the same way, the study of geotechnologies has increased in the last few years. The geotechnologies as an applied computing field delves solutions to environmental issues as an environmental impact risk management [Cavallin, et al. 1994]. Studies like Câmara (1995), Câmara (2001) and Casanova et al (2005) propose the use of geotechnologies from the construction of spatial databases.

2. Methods

2.1. Review

The systematic review is proposed by an adapted-PRISMA method. The PRISMA method consists in a 27-point-checklist about title, abstract, methods and results. For this study, the systematic review was chosen by two sources: Google Scholar and Scientific Electronic Library Online (SciELO).

The eligibility criteria are: relevance (by number of citations and impact factor), title, abstract, keywords and availability to the open access.

2.2. Area of Study

The study was developed in the Pirapó River Basin, localized in Maringá (State of Paraná, Brazil). The river is a tributary of the Paranapanema river that receives water from more than 100 tributary rivers. For this case study the emphasis will be given to the main river.

About the geology and pedology, the soils of the Paraná Third Highland (also called às Terceiro Planalto Paranaense, in Portuguese) have high agricultural fertility, mainly because of the basalt spill of the São Bento's group and from the sandstones from Bauru group [Rigon and Passos, 2014].

According Rigon and Passos (2014, page 42)

> The topography of the basin displays landforms resulting from incisions and erosive processes endured over time on the geology and lithology present there. While varying patterns of altitude and slope are observed when comparing different compartments of the basin, the overall conformation is characterized by gently inclined reliefs

The slopes of the hydrographic basin will be discussed in the results. However, the knowledge and the characterization of the topography and soils are important for the analysis of the Pirapó River Basin. Although the region has a complexity of processes once the Pirapó River Basin localizes in a climate and geomorphopedogenetical transition zone [Passos, 2006].

For the morphometric analysis was delimited the digital elevation model (DEM) based in a cartographical database. The model is often utilized in environmental analysis [Garbrecht and Martz, 2000; Polidori and El Hage, 2020].

2.3. Geoprocessing

For the obtaining data was implemented a statistical routine in QGIS framework [Graser and Olaya, 2015; Congedo, 2021]. The software used was QGIS 3.18.1 version integrated with the plugin SAGA GIS and Orfeo Toolbox.

For the construction of the image database, the vector files (.shp) and matrix files (raster) from the Advanced Land Observing Satellite (ALOS) with spatial resolution of

12,5m were utilized. The database used to obtain the images was IBGE data (Brazilian Institute of Geography and Statistics).

Passos de Jesus, Silva and Faria (2021) discusses the preliminary results of a morphometric analysis developed in 2021.

3. Review

3.1. An introduction to Geomorphology

Geomorphology can be defined according Xiang et al (2021) as a discipline within Geography and Geology that considers the morphological characteristics, formation mechanisms, distribution patterns and evolution rules of earth's surface. According to Li et al (2016), nowadays geomorphology faces the challenge of anthropogenic transformations, also called "antropocen", that is considered as a new science paradigm [Silva, Oliveira, 2022]. The "antropocen" discusses how humanity changes the earth's shape and the consequences of that. Thus, Geomorphology becomes an interdisciplinary science once one of the study objects is the discussion of environmental and territorial management.

3.2. A review about Geoprocessing

A database is a set of structured information stored in a computing system, controlled by a database manager system (DMS). A spatial database is a part of a GIS (Geographic Information System) and is defined by Burrough (1998) as a system that processes graphic and non-graphic data with emphasis in spatial analysis and surface modeling. Thus, Aronoff (1995) defines GIS as a manual or computational set of procedures for storing and manipulating georeferenced data.

A GIS has the following components: user interface, input and integration of data, processing functions for graphics and images, visualizing and plot functions for maps, storage and recovering [Câmara, 1995]. Thus, the abstraction occurs in four levels: real world, conceptual world, representation and implementing level.

Thus, a geoprocessing system stores the registers of georeferenced data. However, the data has a diversity of sources and formats. This constitutes a challenge about the management of spatial databases.

The 3D models for terrain representation as a numeric terrain model (NTM) is used to denote a continuous measure. In turn, the digital elevation model (DEM), according to Mesa-Mingorance and Ariza-López (2020) is utilized to express the height of the points of the surface versus the sea level.

4. Results

For this study was adopted the EMBRAPA (Brazilian Company of Agricultural Research) slope classification (2006), as Table 1.

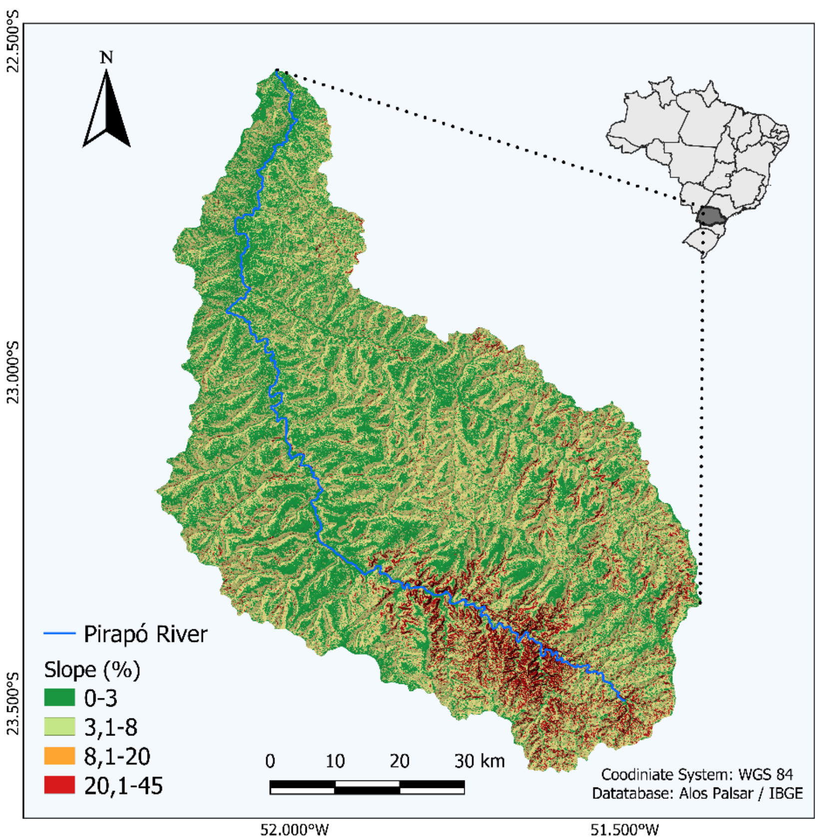
Table 1. Classification of the Slope

Interval	Relief Slope
< 3%	Flat
3% - 8%	Gently wavy
8% - 20%	Wavy
20% - 45%	Strongly wavy
45% - 75%	Mountainous
>75%	Steep

Source: EMBRAPA (2006)

For the Geomorphological study was elaborated a numeric terrain model (NTM), according the Figure 1.

Figure 1. Numeric Terrain Model (NTM) of Pirapó River Basin, Paraná, Brazil



Elaboration: The authors

For the model understanding, the red points represent the higher slopes and the greener points represent the lower slopes (expressed in percentage). For the slope calculation, the quartile method was used.

After data extraction, through routine processing, it was found that the average slope of the Pirapó basin is 7.19%, which constitutes a gently wavy relief. However, it is worth highlighting that there are points of greater slope, as will be observed later, which reach the range of 31% in the highest point, constituting a strongly wavy slope.

The basin has its own characterization, that was also obtained by geoprocessing using the Lopes et al (2018) criterion. The characteristics are area, perimeter, length and average slope. The morphometry statistics are expressed in Table 2.

Table 2. Statistical Summary of Morphometry

Index	Value	Criterion
Compactness Index (Kc)	1,52	Lopes et al (2018)
Shape Factor (Kf)	2,49	Villela and Mattos (1975)
Circularity Index (Ic)	0,43	Kirpich (1940)
Drainage Density (Dd)	0,04	Villela and Mattos (1975)

Elaboration: The authors

The Compactness Index indicates that the basin has a sinuosity once Kc > 1. An area of 5.098km² and a perimeter of 389 km was considered for statistics. According to Lopes et al (2018), if Kc = 1 the basin is a perfect circle, the Circularity Index (Ic) was calculated by Kirpich criterion and the value of 0,43 indicates a low sinuosity.

For the Shape Factor (Kf) it includes a length of 204km. The analysis by the Villela and Mattos (1975) criteria considers that the basin has a shape that resembles a line. The result of Kf ratifies the Kirpich criterion for the circularity.

The Drainage Density (Dd), according to the Villela and Mattos (1975) criterion, is an important criterion to the decision making in the area [Hooke, 1999; Wilcock et al 2003]. By the statistics, the Dd is poor. In other words, the river flow rate is slow.

5. Conclusions

Geotechnologies have been increasing prominently in interdisciplinary studies, particularly in their connections with computing. The use of spatial databases enables the dissemination of data for knowledge acquisition, as it is considered a best practice to employ open-source frameworks and publicly available data. The application of geotechnologies in the study of micro-watershed morphometry becomes a crucial tool in decision-making tasks related to environmental and territorial planning and risk management.

6. Special Thanks

CAPES – Comissão de Aperfeiçoamento de Pessoal de Nível Superior (Commission for the Improvement of Higher Education Personnel) for the scholarships.

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