



Esta obra está licenciada com uma Licença Creative Commons Atribuição-Não Comercial-Compártilha Igual 4.0 Internacional.

Vinícius Santos Lima<sup>ORCID</sup>

Universidade Estadual do Norte Fluminense Darcy Ribeiro

[vinicius.ubermensch@gmail.com](mailto:vinicius.ubermensch@gmail.com)

Carlos Eduardo de Rezende<sup>ORCID</sup>

Universidade Estadual do Norte Fluminense Darcy Ribeiro

[crezende@uenf.br](mailto:crezende@uenf.br)

Received:

02/15/2023

Accepted:

09/29/2023

Available online:

12/01/2023

## Socio-environmental risk of flooding in the basin of the Macabu River, Hydrographic Region of Baixo Paraíba do Sul and Itabapoana, Rio de Janeiro, Brazil

*Risco socioambiental às inundações na bacia do rio Macabu, Região Hidrográfica IX (Baixo Paraíba do Sul e Itabapoana), Rio de Janeiro, Brasil*

*Riesgo socioambiental por inundaciones en la cuenca del río Macabu, Región Hidrográfica IX (Bajo Paraíba do Sul e Itabapoana), Rio de Janeiro, Brasil*

*Risque socio-environnemental d'inondations dans le bassin du fleuve Macabu, Région Hydrographique IX (Qui comprend le bas Paraíba do Sul et le fleuve Itabapoana), Rio de Janeiro, Brésil*

### ABSTRACT

This study aimed to understand the integrated occurrence of floods and anthropogenic interventions in the Macabu River basin, focusing on their effects on land use and vegetation cover. A georeferenced multi-criteria database was created using GIS (ArcGIS 10.6.1), analyzing variables such as slope, elevation, drainage density, precipitation, and land use to generate a socio-environmental risk model for flood-prone areas, categorized into four classes: low or no risk, medium, high, and extremely high. The “high and very high” risk classes together account for 37.8% of the basin. All the mapped land uses are located in flood-prone areas, particularly non-agropastoral anthropogenic areas (78%) and non-forested natural areas (90.3%). The obtained results can inform the territorial and environmental planning of the basin, as well as areas with similar socio-environmental conditions.

**KEYWORDS:** geotechnologies; natural disasters; fluminense north; Rio de Janeiro; Brazil.

### RESUMO

No presente trabalho objetivou-se compreender a ocorrência integrada das inundações, bem como das intervenções antrópicas na bacia do rio Macabu, Rio de Janeiro, atentando para seus efeitos sobre o uso da terra e cobertura vegetal. Para tanto, criou-se um banco de dados georreferenciados multicriterial em ambiente SIG (ArcGIS 10.6.1), onde foram analisadas as variáveis de declividade, elevação, densidade de drenagem, precipitação e usos da terra para se gerar o modelo do risco socioambiental das áreas sujeitas às inundações, divididas em 4 classes: baixa ou nula, média, alta e muito alta. Juntas, as classes “alta e muito alta” somam 37,8% da bacia. Todos os usos da terra mapeados estão em áreas sujeitas a inundações, notadamente as áreas antrópicas não-agropastoris (78%) e as áreas

naturais não florestadas (90,3%). Os resultados obtidos podem auxiliar o planejamento e ordenamento territorial-ambiental da bacia, ou de áreas em condições socioambientais similares.

**PALAVRAS-CHAVE:** geotecnologias; desastres naturais; norte fluminense; Rio de Janeiro; Brasil.

## RESUMEN

Este estudio tuvo como objetivo comprender la ocurrencia integrada de las inundaciones, así como las intervenciones antrópicas en la cuenca del río Macabu, Rio de Janeiro, enfocado en sus efectos sobre el uso de tierras y la cobertura vegetal. Con este objetivo, fue organizada una base de datos georreferenciada multicriterio en ambiente SIG (ArcGIS 10.6.1), donde se analizaron las variables de pendiente, elevación, densidad de drenaje, precipitación y uso de la tierra para generar el modelo socioambiental de las áreas sujetas a inundación, divididas en 4 clases: baja o nula, media, alta y muy alta. En conjunto, las clases “alta y muy alta” representan 37,8% de la cuenca. Todos los usos de tierra cartografiados se encuentran en zonas sujetas a inundaciones, especialmente las zonas antrópicas no agrícolas (78%) y las zonas naturales no forestales (90,3%). Los resultados obtenidos pueden ayudar en la planeación y en el ordenación territorial-ambiental de la cuenca o de zonas en condiciones socioambientales similares.

**PALABRAS-CLAVE:** geotecnologías; desastres naturales; fluminense norte; Rio de Janeiro; Brasil.

## RÉSUMÉ

Cette étude vise à comprendre l'occurrence intégrée des inondations, ainsi que les interventions anthropiques dans le bassin de la rivière Macabu, dans le nord de l'état de Rio de Janeiro au Brésil, en prêtant attention à leurs effets sur l'utilisation des terres et la couverture végétale. À cette fin, une base de données géoréférencées multicritères a été créée dans un environnement SIG (ArcGIS 10.6.1), où les variables de la pente, de l'altitude, de la densité de drainage, des précipitations et de l'utilisation des terres ont été analysées afin de générer le modèle socio-environnemental des zones sujettes aux inondations, divisé en 4 classes : faible ou nul, moyen, élevé et très élevé. Les classes “élevée et très élevée” représentent ensemble 37,8% du bassin. Toutes les occupations cartographiées se trouvent dans des zones inondables, notamment les zones anthropiques non agricoles (78%) et les zones naturelles non boisées (90,3%). Les résultats obtenus peuvent aider à la planification et à l'aménagement territorial et environnemental du bassin ou de zones présentant des conditions socio-environnementales similaires.

**MOTS-CLÉS :** géotechnologies ; catastrophes naturelles ; nord fluminense ; Rio de Janeiro ; Brésil.



Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES

Volume 3, n. 37  
July-December, 2023  
ISSN: 2175-3709

## INTRODUCTION

The history of human occupation in the world is marked by the replacement of natural environments with increasingly artificialized ones (SANTOS, 2004). Drainage basins of various sizes have had their landscapes shaped by the dynamics of human societies in their particular way of using land and dealing with vegetation cover. The United Nations (UN), by the Sustainable Development Goals (SDG) of the 2030 Agenda<sup>1</sup>, understands that the current path of economic development, which privileges only a tiny portion of the world's population, has had a negative socio-environmental impact in the face of climate change.

In this context, natural disasters, such as floods, and their effects on land use and vegetation cover are included. This is reflected in SDG 13, which emphasizes the urgency of combating climate change and its impacts. Following this, we have SDG 15, which aims to protect, restore, and promote the sustainable use of terrestrial ecosystems, manage forests sustainably, combat desertification, halt and reverse land degradation, and halt biodiversity loss,

contributing to the mitigation of flood effects.

Floods are phenomena influenced by the intensity, distribution, and duration of rainfall, terrain slope and elevation, drainage density, soil water saturation and infiltration capacity, vegetation cover, and land use and occupation. They affect both urban and rural drainage basins (SOUZA, 2005; BOTELHO & SILVA, 2007; AMARAL & RIBEIRO, 2009).

According to the Annual Statistical Report of Disasters from *Emergency Disasters Database* (EM-DAT) and the *United Nations Office for Disaster Risk Reduction* (UNDRR), floods, in the first two decades of the 21st century, accounted for a total of 3,254 (44%) natural disaster occurrences, affecting approximately 1.65 billion people and resulting in an estimated cost of \$651 billion worldwide. During this period, 104,614 people died as a result of floods, representing 9% of the total deaths from natural disasters (UNDRR, 2020).

In Brazil, the Report on Material Damages and Losses from Natural Disasters (2020) assessed 64,429 records repor-

**Table 1.** Higher records of deaths and economic losses due to floods in 2022.

Countries	Deaths (2022)	Loss (USD)(R\$)
India	2,035	4.2 billion
Pakistan	1,739	15 billion
Nigeria	603	4.2 billion
South Africa	544	S-D
Brazil	272	S-D
China	S-D	5 billion
Australia	S-D	6.6 billion
<b>TOTAL</b>	<b>5,193</b>	<b>35 billion</b>

Source: EM-DAT (2023).

1. The 17 SDGs of the 2030 Agenda emerged from the continuity of the Millennium Development Agenda (2000 – 2015), in a global effort coordinated by the UN in which 193 States participate.

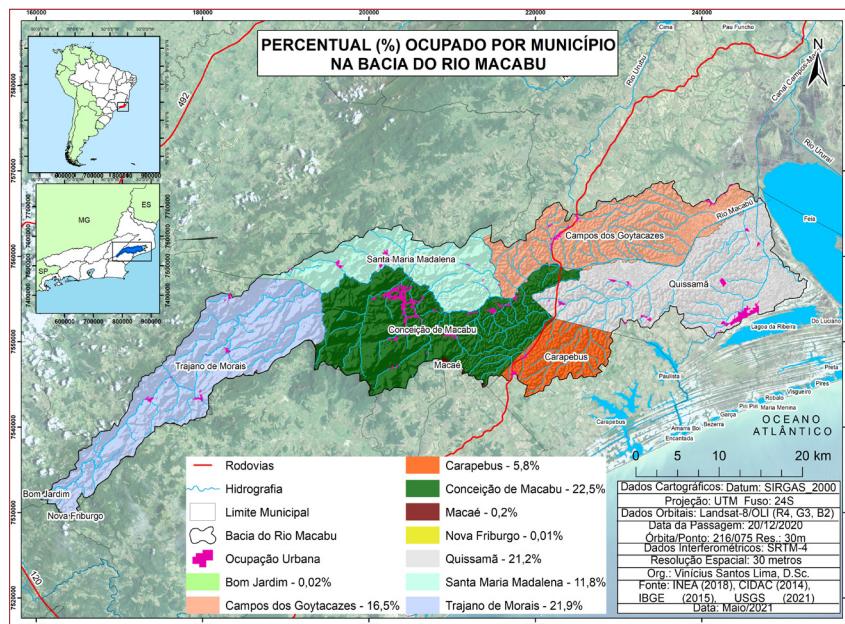
ted by municipalities and states from 1995 to 2019. The total estimated amount of damage and loss during the 25 years is R \$333.36 billion. Within the category of hydrological disasters, there were 3,238 recorded flood events in urban and rural drainage basins, amounting to a total cost of R\$32 billion for public and private purses across the country.

Understanding the occurrence of floods and their associated impacts requires an integrated effort. Traditionally, the drainage basin is conceptualized as a framework that facilitates systematic reflections. The understanding of a drainage basin is extremely complex, requiring prior knowledge of the natural functioning of the environment, such as climate, geology, relief, vegetation cover, and river dynamics (HESS, 2014; CUNHA, 2003; BIGARELLA, 2003; SUGUIO and BIGARELLA, 1990; CHRISTOFFOLETTI, 1981).

In addition to the aspects mentioned above, hydrodynamic analyses, such as average flow and cross-sectional profile (Araujo and Rocha, 2010; Genz and Luz, 2007; Cunha, 2002) must be integrated with socioeconomic themes, including political decisions, legislation, territorial issues, and cultural aspects (ASHMORE, 2015; GREGORY, 2006; BOTEELHO & Silva, 2004; SENRA, 2001). This integration is necessary because decision-making leads to landscape transformation.

In the northern region of the state of Rio de Janeiro, some of these decisions are made without sufficient prior understanding of the natural conditions of the transformed environment. Climate change, combined with inadequate planning and territorial-environmental management (VASCONCELOS, 2021) has exacerbated the challenges of mitigating flood impacts, turning them into a municipal management issue.

**Figure 1.** Map of municipalities belonging to the Macabu river basin



Source: From the authors



Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES

Volume 3, n. 37  
July-December, 2023  
ISSN: 2175-3709



The occurrence of floods in the Macabu river basin (Figure 1) has been known to the Government, Civil Society, and Universities for decades. The study area is a sub-basin of the Feia Lagoon, which in turn is part of the Paraíba do Sul River basin, Hydrographic Region IX<sup>2</sup>, related to its Lower Course of this river and the Itabapoana River, also in the state of Rio de Janeiro. It partially covers the municipalities of Campos dos Goytacazes, Carapebus, Conceição de Macabu, Macaé, Quissamã, Santa Maria Madalena, Nova Friburgo, Bom Jardim, and Trajano de Morais, comprising approximately 1,171 km<sup>2</sup> of land.

Flood events in the Macabu River basin, as well as their associated impacts, are closely related to atmospheric processes. The main atmospheric systems that contribute to weather variation in the study area are South Atlantic Convergence Zone (SACZ), which operates in the region from October to March; Frontal Systems (FS), which act throughout the year, influencing rainfall and temperature indices and; South Atlantic Subtropical High (SASH), which during the summer, or nearby seasons, feeds the SACZ with moisture from the Atlantic Ocean, and, during the winter, works as a blockade of the cold fronts contributing to the reduction of rainfall indices (VAREJAO-SILVA, 2005; MENDONÇA and DANNI-O-LIVERIA, 2007).

Despite the atmospheric systems operating in the study area and their direct influence on the

occurrence of floods, relief also plays a key role in the distribution of matter and energy within the basin. Lima (2019) conducted a study on floods in the Imbé-Ururaí river basin, which is adjacent to the one examined in this research. The study examined various variables including slope/clinographic projections, morphosculpture/elevation, drainage density, precipitation, soils, and land uses. It concluded that the geomorphological system, including clinographic projections, morphosculpture, and drainage density, is the most important variable in determining these phenomena, particularly slope/clinographic projections.

The history of human occupation has always involved the development of techniques acting as mediators in the relationship between humans and their milieu (SANTOS, 2004; AB'SABER, 2006). Thus, basins of various orders and patterns underwent anthropogenic interventions.

Planning is not recent, nor are anthropic interventions to control floods in the study area. In 1939, engineer Hildebrando de Araújo Góes prepared a map entitled "*The Sanitation of the Baixada Fluminense*", which was later published by the Directorate of Sanitation of the Baixada Fluminense (DSBF) of the now-defunct National Department of Sanitation Works (NDSW).

According to Law No. 819, enacted on September 19, 1949, which established the cooperation regime for the execution of sanitation works, NDSW was assigned the responsibility of

2. Resolution No. 32, issued on October 15, 2003, by the National Water Resources Council, delineates a hydrographic region as a territorial expanse in Brazil encompassing a basin, a cluster of adjacent basins, or sub-basins with uniform or comparable natural, social, and economic attributes. The primary objective is to guide water resource planning and administration.

carrying out drainage, irrigation, and flood defense works in collaboration with state governments, municipal governments, the Federal District and Territory, as well as individuals or private legal entities.

NDSW, in trying to reclaim land for large landowners, was responsible for the extensive transformation of drainage networks in the study area. Groups of real estate speculators became wealthy by selling their properties at inflated prices in areas prone to flooding (BV/UERJ, 2013).

However, floods have continued to occur, with the most recent records being in 2007, 2008, 2009, 2019, 2020, and 2022. In this sense, the research justifies conducting an integrative analysis of the natural systems (slope, elevation, drainage density, and precipitation) and anthropic factors (land uses) within the Macabu river basin, located in the North Fluminense region. The objective of this project is to develop a socio-environmental risk model for floods. The model will categorize the probability of floods into four classes: Low or Null, Medium, High, and Very High, and it will serve as a foundation for public managers in their planning and territorial-environmental planning efforts. The goal is to prevent floods and minimize their impact.

Having examined both the natural landscape and the impact of human activities on floods, we are left with the following guiding question: How have human interventions altered the landscape in response to flood effects?

Where are the areas subject to the effects of flooding, and what is the probability (Null, Low, Medium, High, and Very High) of this phenomenon occurring due to land use in the study area?

Thus, the general objective was to understand the integrated occurrence of floods, as well as anthropogenic interventions in the Macabu River basin, focusing on their effects on land use. We also aimed to achieve the following objectives: 1 - analyze the changes in the landscape caused by anthropogenic interventions in response to flooding; 2 - characterize and quantify the natural (slope, elevation, drainage density, and precipitation) and anthropic (land uses) systems in the Macabu River basin through sand and linear measurements; and 3 - gain an integrated understanding of flooding occurrences in the study area, considering both the natural system and land use.

## METHODOLOGY CARTOGRAPHIC, ORBITAL AND INTERFEROMETRIC DATA ACQUISITION

The cartographic data were acquired from the Brazilian Institute of Geography and Statistics (IBGE, in Portuguese) in *Shapefile format*. The satellite image, acquired from the *United States Geological Survey (USGS)*, is from 12/20/2020. The satellite/sensor chosen was *LandSat-8/OLI*, orbit/point 216/075, with spatial resolution of 30 meters.

The cartographic products and mappings, as well as the



Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES

Volume 3, n. 37  
July-December, 2023  
ISSN: 2175-3709

processing of vector and matrix data, were carried out using the *ArcGIS 10.6.1* Geographic Information System (GIS) *software*. The UTM projection system, *Datum* SIRGAS-2000, Zona 24 Sul (IBGE, 2005), was used at a scale of 1:250,000. The mapping was produced by cartographic standardization (MENEZES E FERNANDES, 2013; SLOCUM et al., 2008).

The Digital Elevation Model (SRTM-4) was acquired from the *USGS* at a spatial resolution of 30 m. From this data, maps of morphosculptures, slope, and drainage density were produced. The rainfall map was generated from a 30-meter resolution *raster*, derived from interpolation data provided by the State Environmental Institute (SEI). The land use map was created using the *shapefile* made available by SEI (2018) in collaboration with Cruz et al. (2018).

## ELABORATION OF CARTOGRAPHIC PRODUCTS

### Morphoescultural Map

The *Fill* command was used to correct the model using the *SRTM data*. After being corrected, it was reclassified using the *Reclassify command*. The adoption of the values and their respective classes took place in accordance with the geomorphological mapping methodology for the state of Rio de Janeiro proposed by Silva (2009). To achieve this, two numerical fields (*Double*) were created in the attribute table. One field is

related to the percentages, while the other field is related to the areas of each class within the total basin.

However, the interval between classes was changed during the reclassification process as follows: 0 to 20m (Fluviomarine Plain); 20 to 100m (Plateau and Hill); 100 to 400m (Isolated Ridge and Local Ridge); and above 400m (Steep Ridge).

### SLOPE MAP

For the slope map, the methodology proposed by the Brazilian Agricultural Research Corporation (EMBRAPA, 1979) was adopted. To this end, 6 intervals were reclassified, namely: 0 – 3% (Flat); 3 – 8% (Mild Wavy); 8 – 20% (Wavy); 20 – 45% (Strong Wavy); 45 – 75% (Mountainous); >75% (Scarp).

### Precipitation map

For the preparation of the precipitation map, an interpolated *raster* was used, made available by INEA (2010), and reclassified to the following ranges: 0 – 1,100mm; 1,101 – 1,200mm; 1,201 – 1,300mm; 1,301 – 1,400mm; >1,400mm.

### Drainage Density Map

From the *SRTM*, the following main commands were used to make the drainage density map: *FlowDirection*; *FlowAccumulation*; *Con (value > 200)*; *StreamtoFeature*; *SmoothLine*; *LineDensity* and *Reclassify*. Thus, the following values were adopted: 0.0 – 0.5 km km<sup>-2</sup>; 0.5 – 1.0 km<sup>-2</sup>; 1.0 – 1.5 km km<sup>-2</sup>; 1.5 – 2.0 km km<sup>-2</sup> and; >2km km<sup>-2</sup>.

## Land Use MaP

For the elaboration of the map of land uses, the *clip* command of the results obtained by Cruz et al. (2018) and INEA (2018) was carried out, for the whole state of Rio de Janeiro for the delimitation of the basin. Subsequently, the classes, their areas and percentages were extracted. Once this was done, the product was converted to *raster* format and reclassified.

## BUILDING THE FLOOD SOCIAL AND ENVIRONMENTAL RISK MODEL

With the reclassified physical maps (natural system) and the land use map (anthropic system) – both systems properly standardized and quantified – map algebra modeling was carried out in a GIS environment, as proposed by Lima (2019). The integration of the variables described above, to obtain a summary map of the socio-environmental risk of floods in the Macabu River basin, was carried out on a scale of 1:250,000. To this end, four (4) risk classes were proposed, namely: Low or Null; Medium; High; Very High.

The process of creating the model of floodable areas was based on the adaptation of the Emerging Basin Fragility proposal. This involved defining coefficients/degrees of importance ranging from 1 to 5 (ROSS, 1994), where: Declivity = 5; Morphoesculpture = 1; Drainage Density = 2; Precipitation = 1; and Land use = 1. The values translate into the adaptation of physical characteristics and land use and occupation, where 5 cor-

responds to the “Very High” class and defines the size of the cells as 30 x 30 m, which is appropriate for the scale of the study object.

Thus, the following classes and coefficients (Table 2) of Slope (Weight 5) were adopted: 0 to 3% (value = 5); 3 to 8% (value = 4); 8 to 20% (value = 2); 20 to 45% (value = 1); 45 – 75% (value = 1); >75% (value = 1). Morphoesculpture (Weight 1) received the following values: 0 – 20 m (value = 5); 20 – 100 m (value = 4); 100 – 400 m (value = 1); and above 400 m (value = 1). The Drainage Density (Weight 2) has the following values: 0.0 – 0.5 (value = 1); 0.5 – 1.0 (value = 2); 1.0 – 1.5 (value = 3); 1.5 – 2.0 (value = 4); and a density greater than 2.0 km<sup>2</sup> (value = 5).

The variable “Precipitation” (Weight 1) - annual value - (30-year interval) received the following weights: 0 - 1,100mm (value = 5); 1,100 - 1,200mm (value = 2); 1,200 - 1,300mm (value = 1); 1,300 - 1,400mm (value = 1); and volume (mm/year) greater than 1,400 (value = 1).

Finally, the anthropic variable, represented by “Land Uses” (Weight 1), received the following values: Agropastoral Anthropogenic Areas - AAG (value = 4); Non-Consolidated Agropastoral Anthropogenic Areas - AAG\_N\_CONS (value = 4); WATER (value = 5); Non-Agropastoral Anthropogenic Areas - ANA (value = 5); Forested Natural Areas - ANF (value = 1); Non-Forested Natural Areas - NNF (value = 5); SANDY COASTAL DUNES (value = 4); SILVICULTURE (value = 3).



Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES

Volume 3, n. 37  
July-December, 2023  
ISSN: 2175-3709



**Table 2.** Variables, classes, weights, and coefficients adopted

Decliv. (%)	Coeff.	Morpho sculpture (m)	Coeff.	D/D (km km <sup>-2</sup> )	Coeff.	Precip. (mm)	Coeff.	UT	Coeff.
<i>Weight 5</i>		<i>Weight 1</i>		<i>Weight 2</i>		<i>Weight 1</i>		<i>Weight 1</i>	
0 – 3	5	0 – 20	5	0,0 – 0,5	1	0 – 1.100	5	AAG	4
3 – 8	4	20 – 100	4	0,5 – 1,0	2	1.100 – 1.200	2	WATER	5
8 – 20	2	100 – 400	1	1,0 – 1,5	3	1.200 – 1.300	1	ANA	5
20 – 45	1	> 400	1	1,5 – 2,0	4	1.300 – 1.400	1	ANF	1
45 – 75	1	-	-	> 2,0	5	> 1.400	1	NNF	5
> 75	1	-	-	-	-	-	-	REST.	4
-	-	-	-	-	-	-	-	SILVI.	3

Source: From the authors

The combination of variables for creating the map of flood-prone areas is achieved using map algebra with the *RasterCalculator* function  $AI = (DC + ME + DD + PR) / 4 + UT / 2$ . Where: AI represents Flooded Areas; DC represents Slope; ME represents Morphoesculpture; DD represents Drainage Density; PR represents Precipitation; and UT represents Land use. Finally, they were reclassified into four classes of socio-environmental flood risk: Low or Null, Medium, High, and Very High.

## RESULTS AND DISCUSSION

The proximity of the basins of Macabu River and Imbé-Ururaí River results in flooding events under the influence of the same variables. These two systems belong to the same geomorphological compartments and, therefore, have similarities in their morphometric and morphological characteristics of the relief, such as slope, elevation, and drainage density. They also exhibit similar distribution, duration, and intensity of the rainfall regime. Associated with this is the history of land use and occupation, as well as anthropogenic changes in the landscape in response to floods

(CARNEIRO, 2003; SOFFIATI NETTO, 2013; LIMA & COELHO, 2017).

In order to assess the extent of human-induced changes in the landscape, old maps were georeferenced. One such map was the “*Corographic and Administrative Map of the Province of Rio de Janeiro and the Neutral Municipality*,” which was prepared by Viscount J. de Villiers de L’Ile Adam and published in 1888 (SOFFIATI NETTO, 2005). The Feia lagoon in this projection is characterized by a central body that is more or less circular, as well as an elongated body that runs parallel to the coast. In a GIS environment, the process of georeferencing using Terrestrial Control Points and subsequent vector editing was conducted to extract the water surface of the Feia lagoon and calculate its area and perimeter. It was concluded that in 1888, the Feia lagoon had an area of 336 km<sup>2</sup> and a perimeter of 151 km, primarily due to minimal human interventions.

Another important cartographic record is the map entitled “*O Saneamento da Baixada Fluminense*,” published by the Directorate of Sanitation of Baixada Fluminense - DSBF. This map was created by engineer Saturnino de Brito and published in 1939 by engineer

Hildebrando de Araújo Góes. In this publication, it is possible to note the planning of a series of structural measures to be carried out in the study area to address the problem of floods, such as straightening and channel dredging (LIMA, 2019). The area and perimeter values were extracted from the 1939 map, being, respectively, 290 km<sup>2</sup> and 123 km.

It is important to note that despite losing 46 km<sup>2</sup> of its water mirror from the 19th century to the first half of the 20th century, the Feia lagoon still maintained a circular shape and remained connected to a slightly modified drainage network. The changes to the lagoon and its drainage network only occurred in the second half of the 20th century, when 69 km of dikes were constructed northeast of the Feia lagoon. Many dates of anthropogenic interventions that led to the reduction of surface water are not known. However, the years close to the mid-twentieth century stand out

as a period of significant transformations, notably carried out by the National Department of Works and Sanitation (NDWS).

According to Law No. 8.847 (dated January 24, 1946) NDWS is responsible for promoting, guiding, supervising, studying, designing, executing, contracting, supervising, and instructing all projects or matters related to the construction, improvement, conservation, modification, and exploitation of sanitation and flood defense works. Thus, NDWS was also responsible for straightening the main course of the Macabu River basin. The vectorization process yielded a length of 37 km out of a total of 140 km (Figure 2) for a river pattern that was previously meandering. This pattern was formed on Holocene land over the last 7,000 years due to the migratory process of the Paraíba do Sul River, leading to its current mouth in the district of Atafona, municipality of São João da Barra, Rio de Janeiro.

**Figure 2.** Map of the straightened portion of Macabu River.



Source: From the authors.



Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES

Volume 3, n. 37  
July-December, 2023  
ISSN: 2175-3709

The engineering efforts to control the floods have resulted in the continued and intensified occurrence of these natural disasters. Despite the construction of dikes by both private and government entities, the development of an intricate network of artificial channels, the dredging of these channels, the straightening of rivers, and, more recently, the removal of dikes (LIMA & COELHO, 2017), the Macabu River basin remains susceptible to constant flooding, particularly in the lower areas of the Tertiary Tablelands valley and the extensive Quaternary Plain over the Cenozoic Sedimentary Basin.

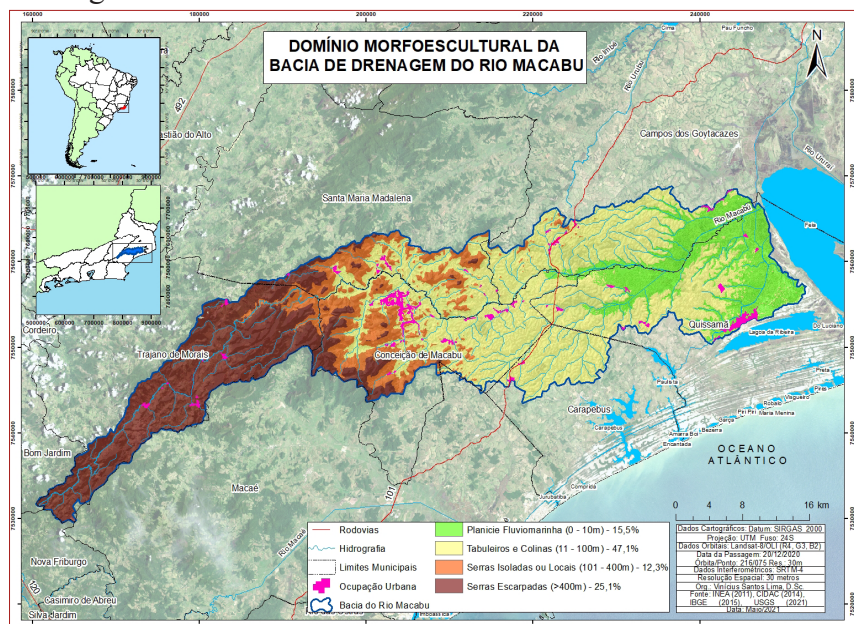
The intricate relationship between human societies and the dynamics of natural systems has required particular attention in environmental sciences. In this context, it is sometimes necessary to isolate spatial entities and analyze them to reintegrate them into the understanding of floods.

To achieve this goal, the elected variables to be utilized in developing the socio-environmental risk model of the Macabu river basin were characterized and quantified.

The state of Rio de Janeiro was divided into two aspects (SILVA, 2009) based on the mapping of the RadamBrasil Project (1983) and CPRM (2000): morphostructural domains and morphocultural domains. Silva (2009) identified two morphostructural classes in Rio de Janeiro: the orogenic belt of the Atlantic Ocean and the Cenozoic sedimentary basin.

The second level pertains to the morphocultural domain and was established through elevation and field experience for mapping (SILVA, 2009). To this end, the cartographic record includes four (4) classes: 1) fluvio-marine plain; 2) plateaus and hills; 3) isolated or local mountains; and 4) rugged mountains.

**Figure 3.** Map of the morphostructural domain of the Macabu river drainage basin



Source: From the authors.



The fluvio-marine plain class (see Figure 3) covers 181 km<sup>2</sup> of the basin, accounting for 15.5% of its total area. Attention should be given to the Tabuleiros e Colinas class, which alone covers almost half of the study area, accounting for 551.9 km<sup>2</sup>, corresponding to 47.1% of the total.

The Isolated or Local Mountain Chain and Escarpment classes occupy 144.6 km<sup>2</sup> and 293.7 km<sup>2</sup> of the territory, respectively, covering 12.3% and 25.1% of the area. It is noteworthy that the areas at the highest risk of flooding (fluvio-marine plains/trays and hills) also have the highest spatial occurrence, accounting for 62.6% of low-lying areas. These areas are primarily distributed in flat, gently sloping, and undulating terrain.

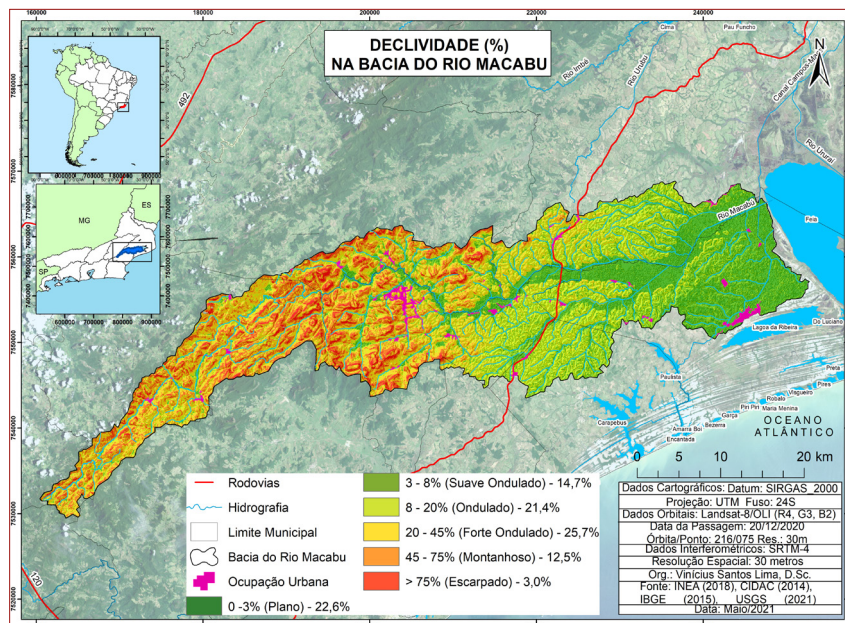
The slope is a crucial morphometric variable in determining active geomorphological processes, including areas of erosion and deposition, as well as locations prone to flooding

(SOUZA, 2013). Slope mapping (Figure 4) is a way of representing the spatial behavior of the relief, and has the most diverse applications, such as geomorphology and territorial planning, both to comply with Brazilian environmental legislation and to evaluate the efficiency and impacts of human interventions on the environment (ROMANOVSKI, 2001).

Areas between 0 and 3% (flat relief) correspond to the lowlands and account for 264.8 km<sup>2</sup> of the basin, representing 22.6% of the total study area. This class has the second-largest spatial extent and is where most floods occur.

The area with slopes between 3 and 8% (smooth undulating relief) covers 172.6 km<sup>2</sup> and represents 14.7% of the drainage basin. This area, to a lesser extent, also poses a risk of flooding. The area with a slope between 8 and 20% (undulating relief) covers 250.8 km<sup>2</sup>, which represents 21.4% of the total area.

**Figure 4.** Map of the slope in the Macabu River Basin



Source: From the authors

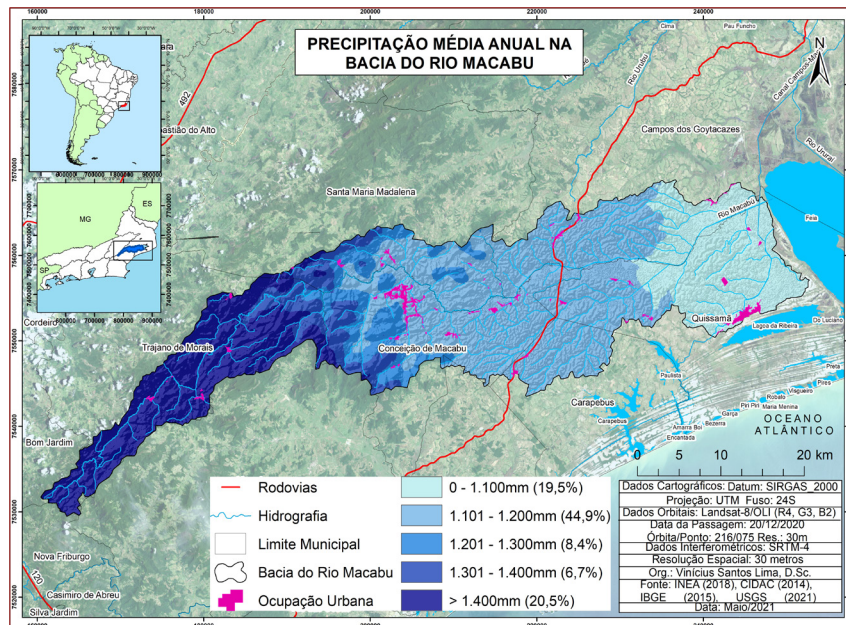


Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES

Volume 3, n. 37  
July-December, 2023  
ISSN: 2175-3709



**Figure 5.** Map of Average Annual Rainfall in the Macabu River Basin



Source: INEA (2010).

In contrast, the area with a slope between 20 and 45% (strong undulating relief) spans 301.2 km<sup>2</sup>, accounting for 25.7% of the entire basin and being the most representative class.

The classes representing the intervals between 45% and 75% (mountainous relief) and greater than 75% (steep relief) account for 146.3 km<sup>2</sup> and 35.3 km<sup>2</sup> of the drainage basin surface, respectively, and make up 12.5% and 3% of the total study area. The latter class has the lowest spatial occurrence. The distribution of rainfall in the basin is directly associated with the morphometric and morphological characteristics of the relief.

Different atmospheric systems operate in the study area, namely: ZCAS, ASAS, and frontal systems. In this sense, the State Environmental Institute (INEA, 2010) generated an interpolated model (Figure 5), in raster format, of rainfall data in the basin, based on the average annual rain-

fall, given in millimeters (mm) between 1950 and 2000.

The relationship between rainfall concentration and topography is notable, with higher areas, such as the rugged mountain chains (Serra do Mar), receiving nearly double the amount of rainfall compared to flatter areas like the fluvial-marine plain and plateaus.

The average annual rainfall ranging from 0 to 1,100 mm is characteristic of plains, plateaus, and hills, covering a total area of 228.3 km<sup>2</sup>, which accounts for 19.5% of the total. The area between 1,101 and 1,200 meters covers 526.4 km<sup>2</sup>, representing 44.9% of the basin.

The classes ranging from 1,201 to 1,300 mm and from 1,301 to 1,400 mm, collectively cover an area of 176.5 km<sup>2</sup>, accounting for 15.1% of the total system. The Serra do Mar region experiences the highest rainfall rates, with an annual average exceeding 1,400

mm. This area covers 240.2 km<sup>2</sup>, which is equivalent to 20.5% of the study area.

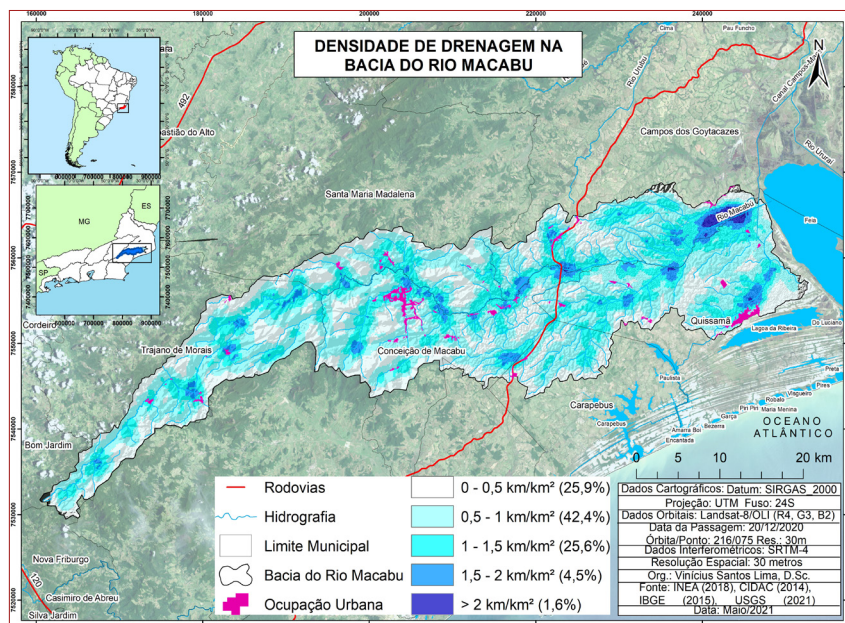
In any basin, the precipitation regime is intrinsically associated with drainage density, represented as Dd (STEVAUX & LATRUBESSE, 2017) (Figure 6). According to the authors, water runoff in a drainage basin can occur on the surface or underground, varying according to the environmental conditions of each system. The drainage by surface runoff occurs mainly through the network of channels, being generated by the work carried out through the flow of the drained water.

The drainage network can be classified based on various parameters, such as pattern, ordering, or even the temporal relationship with the basin's geology. The drainage density controls the efficiency of runoff and most directly reflects the climate, relief, lithology, soils, land use, occupation, and vegetation cover in a basin.

Stevaux and Latrubesse (2017) established a close relationship between drainage density and rainfall. They found that basins located in semi-arid regions have higher drainage density to the detriment of humid climate basins, such as the one adopted for this study, with rates less than 1 km<sup>-2</sup>.

The class with a range between 0 and 0.3 km<sup>-2</sup> is the one with the highest spatial occurrence (744 km<sup>2</sup>), distributed throughout the basin and representing more than 50% of the total system. And there is a range between 0.3 and 0.4 km<sup>-2</sup>, with an approximate area of 311 km<sup>2</sup>, totaling 21% of the basin. The class between 0.4 and 0.5 km km<sup>-2</sup> is distributed over 221 km<sup>2</sup> and occupies 15% of the study area. However, values greater than 0.5 km km<sup>-2</sup> are distributed over a total of 202 km<sup>2</sup>, representing the lowest spatial occurrence, with 14% of the study area.

**Figure 6.** Map of drainage density in the Macabu River Basin



Map of drainage density in the Macabu River Basin



Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES

Volume 3, n. 37  
July-December, 2023  
ISSN: 2175-3709



The drainage density, slope, morphosculpture, and average annual rainfall are the variables of the physical environment considered in this study. Thus, for the anthropic variable “Land Use” in the Macabu River basin, we relied on findings presented by Cruz et al. (2018) in collaboration with INEA (2018), obtained through the Land Cover Mapping Project and the Detection of Changes in Forest Coverage in the State of Rio de Janeiro, Olho no Verde.

Currently, the study area includes the following land uses: AAA (Agropastoral Anthropic Areas), AAA\_N-Cons (Non-Consolidated Agropastoral Anthropic Areas), Water, N-AAA (Non-Agropastoral Anthropic Areas), FNA (Forested Natural Areas), NNF (Non-Forested Natural Areas), Restinga, and Silviculture.

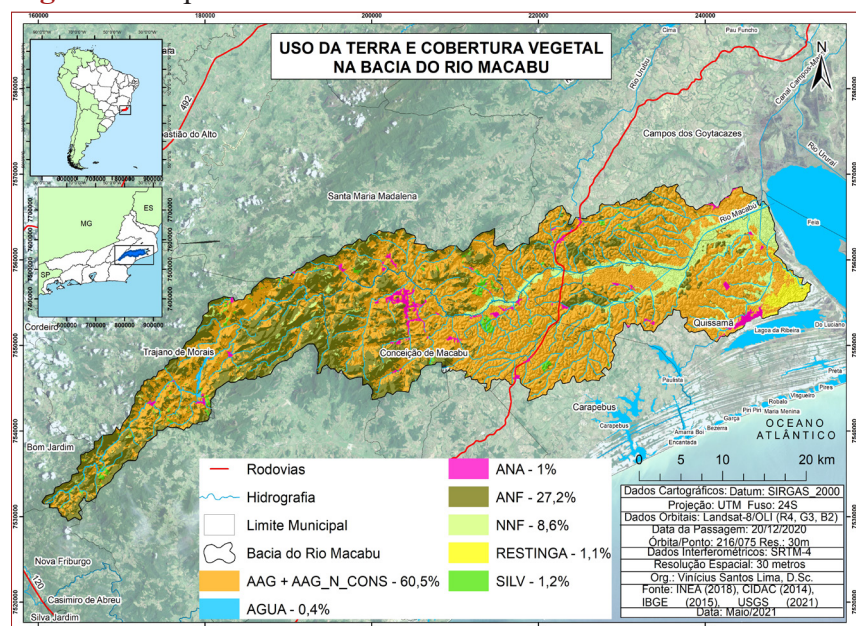
The N-AAA class encompasses 11.8 km<sup>2</sup> and corresponds to 1% of the basin, comprising residential, commercial, industrial, mining and exposed soil spaces. Despite the

low spatial occurrence, this class is important due to the effects of floods on human dwellings.

The AAA, on the other hand, are distributed over 706.7 km<sup>2</sup>, 60.4% of the total and are the class with the highest spatial occurrence. They include pasture, sparse pasture, burned pasture, perennial and temporary crops, soil in preparation, and revegetation (dirty pasture refers to the vegetation succession stage that precedes the initial stage).

The Silviculture class (SILV) covers an area of 13.6 km<sup>2</sup> and represents 1.2% of the total area. It involves the commercial planting of tree species and/or reforestation. The Forested Natural Areas (FNA) class covers 318.5 km<sup>2</sup>, which accounts for 27.2% of the arboreal vegetation, excluding forestry, regardless of the successional stage in which it is located. These areas encompass mountains, hills, and plains, and include various phytophysio- nomies of the Atlantic Forest.

**Figure 7.** Map of land uses in the Macabu River basin



Source: From the authors

In the Non-Forested Natural Areas (NNFA) class, 100.3 km<sup>2</sup> were mapped, accounting for 8.6% of the study area (Figure 7). Various types of vegetation and non-vegetation formations are found in the area, including rocky outcrops, naturally exposed soil, rocky vegetation, high-altitude fields, flooded areas, and beaches. The NNFA is a high floodable potential class distributed across the floodplain area of the Macabu River.

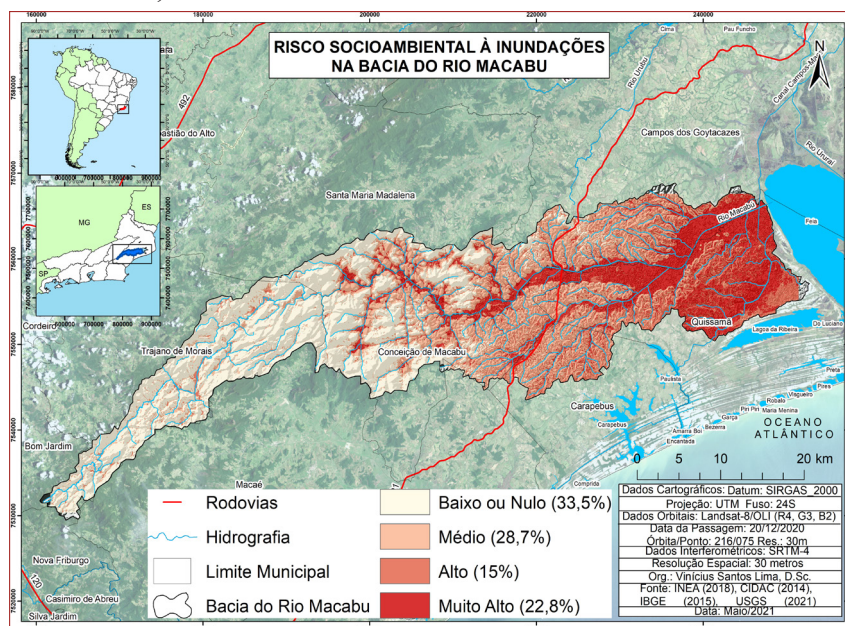
Finally, the Restinga class encompasses 13.3 km<sup>2</sup> and occupies 1.1% of the basin. The area is characterized by plant formations that thrive in sandy areas of the coastal plain, influenced by marine and fluvio-marine conditions.

Based on the results obtained so far, the variables of the natural system (morphosculpture, slope, drainage density, and precipitation) were integrated with those of the anthropic system (land use and vegetation cover).

The areas and percentages of the classes affected by flooding (ROSS, 1994; LIMA, 2019) can be categorized into two groups: high socio-environmental risk to flooding (High and Very High classes) versus low socio-environmental risk to flooding (Low or Null and Medium classes). The “Low or Null” class is the most representative in the system, occupying 33.5% and covering 392.8 km<sup>2</sup>. These areas are primarily situated within the domain of the South Atlantic Orogenic Belts, encompassing the Serra do Mar and isolated inland Massifs.

The “Average” classification class is distributed from the Fluvio-marine Plain to the Tertiary Hills and Tabuleiros of the Barreiras Group, especially in the valley bottoms. It is the second most spatially represented class, covering 336.3 km<sup>2</sup> and occupying 28.7% of the basin, as shown in Figure 8.

**Figure 8.** Map of socio-environmental risk to floods in the Macabu River basin, Rio de Janeiro



Source: From the authors.



Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES

Volume 3, n. 37  
July-December, 2023  
ISSN: 2175-3709



They were classified as “High” and “Very High” in 37.8% of the total system. Special attention should be paid to the “Very High” class as it has a greater potential for flooding. Alone, it is responsible for 266.6 km<sup>2</sup> of developed land, which accounts for 22.8% of the total study area and includes all previously surveyed land uses.

These areas are primarily situated within the Cenozoic Sedimentary Basin, particularly in the morphosculptures of the Fluvio-marine Plain and in the Tertiary Tabuleiros of the Barreiras Group. These landscapes are susceptible to flooding due to their low slopes, the morphology of the terrain (river plains, floodplains, and basin bottoms), the density of drainage, precipitation in the headwaters flowing towards the lowlands, and human occupation and environmental alteration processes.

According to the National Atlas of Natural Disasters (2013), 190 flood events were recorded in the state of Rio de Janeiro between 1991 and 2012. The most-affected regions of the state of Rio de Janeiro are the Northwest and the North Fluminense. Together, they have 107 occurrences (CEPED, 2013; CBHBPSI, 2019). In late November 2022, the land uses and vegetation cover of the Macabu River basin were once again affected by extreme events.

The population residing in the urban areas of the municipalities of Conceição de Macabu, Carapebus, and Quissamã has experienced unquantified material losses,

including fatalities. According to a report published by the local press on January 12, 2022, in the *Folha Geral* newspaper<sup>3</sup>, at least 80 individuals were evacuated and 5 rendered homeless in Conceição de Macabu due to heavy rainfall. In the Serrinha district of Campos dos Goytacazes, near the Macabu River, the floods resulted in significant damage.

To assess the factors contributing to natural disasters in the state of Rio de Janeiro, we aimed to quantify the land uses and vegetation cover of the Macabu River basin concerning the socio-environmental risk of flooding. A total of 305.9 km<sup>2</sup> out of 706.7 km<sup>2</sup> of the AAA and N-CAAs are identified as being at a high degree of socio-environmental risk of flooding, representing 26.1% of the entire basin. Non-agropastoral anthropic areas exhibit significantly high and high-risk levels, with respective values of 3.6 and 5.7 km<sup>2</sup>. The combined areas susceptible to flooding account for 78% of the total area within this particular classification in the basin.

The Forested Natural Areas encompass 1.0 km<sup>2</sup> and 16.2 km<sup>2</sup> of area at very high and high risk, respectively. Covering an area of 17.2 km<sup>2</sup>, this category accounts for 5.4% of the total 318.5 km<sup>2</sup> area used in the basin. In the Non-Forested Natural Areas, 82.8 km<sup>2</sup> and 7.8 km<sup>2</sup> were identified as having very high and high socio-environmental risks of floods, respectively. Consequently, they account for 90.3% of a total area of 100.3 km<sup>2</sup> within this specific class in the study area.

3. Cf.: <<https://www.folha1.com.br/geral/2022/12/1286558-chuva-forte-deixa-um-morto-e-cinco-feridos-em-conceicao-de-macabu.html>>.

In the Restinga class, an area of 8.9 km<sup>2</sup> was delineated as very high risk, while 2.2 km<sup>2</sup> was categorized as high risk. Therefore, they constitute 11.1 km<sup>2</sup> of this usage, subject to the impacts of flooding. A total of 81.6% of the Restinga ecosystem, in the study area, is exposed to socio-environmental risks associated with flooding. Finally, the Forestry class encompasses 4.1 km<sup>2</sup> of land at high risk, accounting for 30.1% of the total area within this class in the basin context.

### CONCLUDING REMARKS

The research enabled the analysis of question-answer processes within the system, including the morphometric and morphological characteristics of the relief. These characteristics sometimes present favorable conditions for extensive agricultural practices and/or the construction of urban sites, due to low slopes, an extensive fluvio-marine plain, and valley bottom areas. However, these same uses are also susceptible to the impacts of floods.

In this context, it was determined that the category of land uses known as “Agropastoral Anthropogenic Areas” accounts for 706.7 km<sup>2</sup> of the basin. Within this particular context, 26.1% of the population is exposed to high socio-environmental risk due to flooding, particularly in the floodplain areas and at the lower regions of the Morros and Tabuleiros valley. Although the class “Non-Agropastoral Anthropogenic Areas” is not well represented spatially, it warrants careful con-

sideration due to its predominant use for residential, commercial, industrial, mining, and exposed soil purposes. The area of this class is 11.8 km<sup>2</sup>, with 78% of this area classified as high risk.

The classes with the highest flood risks in terms of land use and vegetation cover were identified as “Non-Forested Natural Areas” and “Restinga”. The first area experiences this phenomenon in 90.3% of its territory. The Non-Forested Natural Areas encompass a variety of vegetation and non-vegetation formations, including rock outcrops, natural exposed soil, rupes-trian vegetation, altitude fields, flooded areas, and beaches. The Restinga area, covering 13.3 km<sup>2</sup>, exhibits a high risk of flooding, with 81.6% of the area being affected. The sandbank is a broad strip of sandy deposits that runs parallel to the beach line, resulting from successive eustatic oscillations of sea level during the Quaternary period. The Restinga also encompasses plant formations that thrive in sandy areas of the coastal plain, influenced by marine and fluvio-marine conditions.

The “Forested Natural Areas” encompass 318.5 km<sup>2</sup> and exhibit a mere 5.4% socio-environmental risk of flooding. Therefore, this class seems to pose the lowest risk compared to the others. The area includes tree vegetation (excluding Silviculture) found in various successional stages, encompassing mountains, hills, and plains, and representing diverse phytophysiognomies of the Atlantic Forest.



Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES

Volume 3, n. 37  
July-December, 2023  
ISSN: 2175-3709

Hence, it is postulated that the presence of floods and their effects on land utilization and plant cover are intricately linked to the physical environment, particularly the geomorphological system (slope, elevation, and drainage density). The findings outlined in this study may provide backing for public policies and inform the planning of the Macabu River basin in Rio de Janeiro, as well as the municipalities within it. Additionally, these conclusions may contribute to the local and regional advancement of the UN 2030 Agenda's Sustainable Development Goals, particularly in the context of territorial and environmental planning.

Nevertheless, it is crucial to emphasize the significance of conducting additional studies that are systemic and systematic, facilitating interdisciplinary dialogue among various fields

of knowledge. This is necessary due to the complexity of the demands of the contemporary world, which is dynamic and increasingly necessitates a critical and integrated approach to ongoing climate change.

In this context, it is advisable to implement structural and structuring measures, such as environmental education, which should be collaboratively conducted by Higher Education Institutions, territorial managers, and civil society. Applied research that integrates physical, biological, and anthropic aspects is necessary for the restoration of the Macabu River drainage basin. This should include efforts to renaturalize rivers by reconstructing their meanders, replanting riparian forests, and implementing responsible and integrated planning of water, land use, and vegetation cover. ●

## REFERENCES

- AB'SABER, A. N. Bases conceituais e Papel do Conhecimento na Previsão de Impactos. In: PLANTENBERG-MÜLLER, C.; AB'SABER, A. N. *Previsão de Impactos*. São Paulo: Edusp, 2006.
- AMARAL, R. do; RIBEIRO, R. R. Inundações e Enchentes. In: TOMIGANA, L. K. SANTORO, J. e AMARAL, R. (orgs.). *Desastres Naturais: conhecer para prevenir*. São Paulo, Instituto Geológico, 2009.
- ARAUJO, A. P.; ROCHA, P. C. Regime de Fluxo e Alterações Hidrológicas no rio Tibagi- Bacia do Rio Paranapanema/Alto Paraná. *Revista de Geografia*. Recife: UFPE –DCG/NAPA, v. especial VIII SINAGEO, n. 3, Set. 2010.
- ASHMORE, P. Towards a Sociogeomorphology of Rivers. *Geomorphology*. v. 251, 15 December 2015, Pages 149–156.
- ATLAS BRASILEIRO DE DESASTRES NATURAIS: 1991 a 2012 / *Centro Universitário de Estudos e Pesquisas sobre Desastres*. 2. ed. rev. ampl. – Florianópolis: CEPED UFSC, 2013. Volume Rio de Janeiro. Disponível em: <https://s2id.mi.gov.br/paginas/atlas/>. Acesso em: 10/11/2022.
- BACHA, L. *et al.* Current Status of Drinking Water Quality in a Latin American Megalopolis. *Water*, v. 15, p. 165, 2023. Disponível em: <https://www.mdpi.com/2073-4441/15/1/165>. Acesso em: 02/02/2023.
- BACHA, L. *et al.* Risk of Collapse in Water Quality in the Guandu River (Rio de Janeiro, Brazil). *Microbial Ecology* (online), v. 1, p. 1-14, 2021. Disponível em: <https://link.springer.com/article/10.1007/s00248-021-01839-z>. Acesso em: 02/02/2023.
- BIGARELLA, J. J. *Estrutura e origem das paisagens tropicais e subtropicais*. Florianópolis: Editora UFSC v.3, 2003. p. 877-1436.
- BOTELHO, R. G. M.; SILVA, A. S. da. Bacia Hidrográfica e Qualidade Ambiental. In: VITTE, A. C.; GUERRA, A. J. T. (orgs.). *Reflexões sobre a Geografia Física no Brasil*. Rio de Janeiro: Bertrand Brasil, 2007.
- BV/UERJ. Disponível em <http://www.bvambientebf.uerj.br/arquivos/comissoes/DNOS.htm>. Acesso em 17/08/2021.



Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES

Volume 3, n. 37  
July-December, 2023  
ISSN: 2175-3709



CARNEIRO, P. R. F. *Dos pântanos à escassez: uso da água e conflito na Baixada dos Goytacazes*. São Paulo: Annablume: Rio de Janeiro: Coppe/UFRJ, 2003.

CENTRE FOR RESEARCH ON THE EPIDEMIOLOGY OF DISASTERS, UNITED NATIONS OFFICE FOR DISASTER RISK REDUCTION (UNDRR). *The Human Cost of Disasters. An Overview of the Last 20 Years (2000–2019)*. 2020. Disponível em: <https://reliefweb.int/report/world/human-cost-disasters-overview-last-20-years-2000-2019>. Acessado em 14 de março de 2022.

CHRISTOFOLETTI, A. *Geomorfologia Fluvial*. São Paulo: Edgar Blucher Ltda, 1981.

COMITÊ DE BACIA HIDROGRÁFICA DO BAIXO PARAÍBA DO SUL E ITABAPOANA - CBH-BPSI. *Atlas da Bacia Hidrográfica com Baixo Paraíba do Sul e Itapoana*. 2019. Disponível em: <https://www.cbhbaixoparaiba.org.br/estudos-projetos.php>. Acesso em: 10 de novembro de 2022.

CRUZ *et al.* *Projeto de Mapeamento da Cobertura da Terra e de Detecção de Mudanças na Cobertura Florestal do Estado do Rio de Janeiro - Relatório Final de Mapeamento da Cobertura da Terra*. Convênio PRUMO LOGÍSTICA COPPETEC-SEA-INEA. Rio de Janeiro, 2018.

CUNHA, S. B. Canais Fluviais e a Questão Ambiental. *In:* CUNHA, S.B. & GUERRA, A.J. T. (orgs.) *A Questão Ambiental: diferentes abordagens*. Rio de Janeiro: Bertrand Brasil, 2003. p. 219-238.

CUNHA, S. B. Geomorfologia Fluvial. *In:* CUNHA, S.B.; GUERRA, A.J.T. (orgs.) *Geomorfologia, exercícios, técnicas e aplicações*. 2. ed. Rio de Janeiro: Bertrand Brasil, 2002. p. 157-189.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA - EMBRAPA. *Diagnóstico do Meio Físico da Bacia Hidrográfica do Rio Macabu, RJ*. Rio de Janeiro: Embrapa Solos, 2004.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA - EMBRAPA. *Serviço Nacional de Levantamento e Conservação de Solos (Rio de Janeiro, RJ)*. Súmula da 10. Reunião Técnica de Levantamento de Solos. Rio de Janeiro: 1979. 83p.

GENZ, F.; LUZ, L. Metodologia para considerar a variabilidade hidrológica na definição do regime natural de vazões no baixo curso do rio São Francisco. *In:* XVII Simpósio Brasileiro de

Recursos Hídricos, 2007, São Paulo/SP. Anais, 1 CD-ROM.

GREGORY, K. J. The Human Role in Changing River Channels. *Geomorphology*. Volume 79, 15 September 2006, p. 172-191.

HESS, D. Fluvial Processes. In: \_\_\_\_\_. *McKnight's Physical Geography: a landscape appreciation*, 11th ed. Pearson, 2014. Chapter 16, p. 466-497.

IBGE - Instituto Brasileiro de Geografia e Estatística. *Manuais Técnicos em Geociências: Manual Técnico de Uso da Terra*. 2 Ed. Rio de Janeiro: IBGE, 2010.

IBGE – Instituto Brasileiro de Geografia e Estatística. *Resolução IBGE nº 1/2005 que altera a caracterização do referencial geodésico brasileiro*. Disponível em: [ftp://geofpt.ibge.gov.br/metodos\\_e\\_outros\\_documentos\\_de\\_referencia/normas/rpr\\_01\\_25fev2005.pdf](ftp://geofpt.ibge.gov.br/metodos_e_outros_documentos_de_referencia/normas/rpr_01_25fev2005.pdf) (2005). Acesso em 30 de julho de 2021.

INEA - Instituto Estadual do Ambiente. Base Temática – *O Estado do Ambiente: indicadores ambientais do Rio de Janeiro*, 2010: [http://www.inea.rj.gov.br/basetematica\\_estadoambiente/](http://www.inea.rj.gov.br/basetematica_estadoambiente/). Acesso em: 2 mar. 2015.

INEA – Instituto Estadual do Ambiente. *Mapeamento de Uso do Solo e Cobertura Vegetal da RH IX - Baixo Paraíba do Sul e Itabapoana*. 2018. Disponível em: <http://www.geoservicos.inde.gov.br/geoserver/ows>. Acesso em: 04 de julho de 2022.

LIMA, V. S.; COELHO, A.L.N. *Impactos Antrópicos e Mudanças na Paisagem: Um Estudo Sobre a Lagoa Feia/Brasil*. 1. ed. Saarbrücken: Novas Edições Acadêmicas, Alemanha, 2017.

LIMA, V.S. *Relações sistêmicas na bacia do rio Imbé-Ururui (RJ) e seus reflexos nas inundações*. 2019. 128 p. Tese (Doutorado em Geografia) - Instituto de Geociências, Programa de Pós-Graduação em Geografia, Universidade Federal Fluminense UFF, Niterói – Rio de Janeiro, 2019.

MENDONÇA, F.; DANNI-OLIVERIA, I. M. *Climatologia: noções básicas e climas do Brasil*. São Paulo. Editora Oficina de texto. 206p. 2007.

MENDONÇA *et al.* Avaliação de eventos de inundação na Região Norte Fluminense, Rio de Janeiro, utilizando imagens de sensores remotos. In: *Ambi-Agua*, Taubaté, v. 7, n. 1, p. 255-267, 2012.



Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES

Volume 3, n. 37  
July-December, 2023  
ISSN: 2175-3709

MENESES, P. M. L.; FERNANDES, M. C. *Roteiro de Cartografia*. 1. São Paulo: Oficina de Textos, 288p, 2013.

NAÇÕES UNIDAS/BRASIL. *Objetivos de Desenvolvimento Sustentável*. Disponível em: <https://brasil.un.org/pt-br/sdgs>. Acesso em: 10 de novembro de 2021.

PROJETO RADAMBRASIL - *Levantamento de Recursos Naturais. Geologia, Geomorfologia, Solos, Vegetação e Uso Potencial da Terra*. v. 32, Folhas SF 23/24 Rio de Janeiro / Vitória. Rio de Janeiro: IBGE/Ministério das minas e energia – Secretaria Geral, 1983, 775 p.

RELATÓRIO DE DANOS MATERIAIS E PREJUÍZOS DECORRENTES DE DESASTRES NATURAIS NO BRASIL : 1995 –2019 /*Banco Mundial. Global Facility for Disaster Reduction and Recovery*. Fundação de Amparo à Pesquisa e Extensão Universitária. Centro de Estudos e Pesquisas em Engenharia e Defesa Civil. (Org. Rafael Schadeck). 2.ed. Florianópolis: FAPEU, 2020.

ROMANOVSKI, Z. *Morfologia e aspectos hidrológicos para fins de manejo da microbacia da Rua Nova, Viçosa-MG, para fins de manejo*. 2001. 99f. Dissertação (Mestrado) - Universidade Federal de Viçosa, Viçosa, MG, 2001.

ROSS, J. L. S. Análise empírica da fragilidade dos ambientes naturais e antropizados. *Revista do Departamento de Geografia da Universidade de São Paulo*, São Paulo, n. 8, p. 63-74.1994.

SANTOS, M. *A Natureza do Espaço: Técnica e Tempo, Razão e Emoção*. São Paulo: EDUSP, 2004.

SENRA, J. B. Á. O desafio do terceiro milênio. In: VIANA, G.; SILVA, M.; DINIZ, N. (orgs). *O desafio da sustentabilidade: um debate socioambiental no Brasil*. São Paulo: Fundação Perseu Abramo, 2001.

SERVIÇO GEOLÓGICO DO BRASIL (CPRM). *Programa Levantamento Geológico e Geomorfológico Básico do Brasil: estado do Rio de Janeiro em 1:400.000*. 2000. Disponível em: <http://www.cprm.gov.br/publique/>. Acesso em: 05 set. 2022.

SILVA, T. M. da. Geomorfologia do estado do Rio de Janeiro: distribuição espacial das feições morfológicas e contexto evolutivo. In: BICALHO, A. M. S. M.; GOMES, P. C. da C. (orgs.) *Questões Metodológicas e Novas Temáticas na Pesquisa*

*Geográfica*. Rio de Janeiro. Publit, 2009.

SLOCUM, Terry A.; MCMASTER, Robert B; KESSLER, Fritz C.; Howard, Hugh H. *Thematic Cartography and Geovisualization*, 3rd Edition, Ph. Series in Geographic Information Science, Hardcover. 2008.

SOFFIATI NETTO, A.A. *As Lagoas do Norte Fluminense: contribuição à história de uma luta*. Campos dos Goytacazes – RJ: Essentia Editora, 2013.

SOFFIATI NETTO, A.A. Ecofisionomia e História. In: SUZUKI, M.S. *et al.* *Áreas Alagáveis do Norte Fluminense*, 2005.

SOUZA, C. R. de G. Suscetibilidade morfométrica de bacias de drenagem ao desenvolvimento de inundações em áreas costeiras. In: *Revista Brasileira de Geomorfologia*, Ano 6, Nº 1, 2005. p. 45-61).

SOUZA. S. O. *Vulnerabilidade Ambiental da Planície Costeira de Caravelas (Bahia): Uma proposta geossistêmica*. 2013. 136 p. Dissertação (Mestrado). Pós-Graduação em Geografia, UFES – Vitória, 2013.

STEVAUX, J.C.; LATRUBESSE, E.M. *Geomorfologia Fluvial*. São Paulo: Oficina de Textos, Coleção Geografia, v. 3, 336 pp. 2017.

SUGUIO, K. *Geologia Sedimentar*. 1. Ed. São Paulo: Editora Blucher, 2003.

SUGUIO K.; BIGARELLA, J. J., *Ambientes Fluviais*. 2. ed. Curitiba: UFPR, 1990.

UNITED STATES GEOLOGICAL SURVEY - USGS. *Aquisição de produtos orbitais e interferométricos*. US, 2021.

VAREJÃO-SILVA, M. A. *Meteorologia e climatologia*. Recife, 2005.

VASCONCELOS, A. M. B. M. de. *O desafio da gestão urbana em Campos dos Goytacazes no contexto das mudanças climáticas: entre a construção da resiliência e a persistência de fórmulas tradicionais de governar*. 2021. 138 p. Dissertação (Mestrado em Políticas Sociais) - Universidade Estadual do Norte Fluminense Darcy Ribeiro, Centro de Ciências do Homem, Campos dos Goytacazes, RJ: 2021.



Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES

Volume 3, n. 37  
July-December, 2023  
ISSN: 2175-3709



