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MORPHOMETRIC ANALYSIS AND ORGANIC CONTRIBUTIONS OF THE BAIANO RIVER MICROBASIN, MUNICIPALITY OF ASSIS CHATEAUBRIAND, BRAZIL

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ABSTRACT

The objective of this study was to characterize the morphometry and morphology of the Baiano River watershed, providing essential technical information to assess the viability of sustainable fish farming initiatives. The watershed was delimited using a Digital Elevation Model (DEM), with a spatial resolution of 30 meters. The satellite image processing and calculations of morphometric indicators were performed using the free software QGIS®. The mapping of the excavated ponds was performed using high-resolution Google Earth images, using the QuickMapServices plugin. The watershed has a predominantly flat relief, with a low drainage density, and three hypsometric bands ranging from 220 to 620 meters. The predominant soil types in the watershed are Red Latosol and Red Nitosol. Most of the area is occupied by agricultural activities, especially soybean cultivation. In the micro-basin area, 59 excavated ponds were mapped, totaling 27.76 hectares of water surface. The micro-basin has the potential for the sustainable development of fish farming, taking into account its water resources and the morphological and morphometric characteristics present in the hydrographic micro-basin.

Keywords: Phosphorus. Geotechnology. Nitrogen. Fish farming. Land Use and Occupation.

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INTRODUCTION

River basins play a fundamental role in environmental balance, being natural units for planning and managing water resources (Américo-Pinheiro; Benini, 2018). Studies related to these areas provide crucial information for understanding environmental dynamics and guiding sustainable land use. In recent decades, river basin analysis has stood out in research that addresses physical, hydrological, and anthropic aspects as an indispensable tool for the integrated management of natural resources (Junior; Ferrão, 2018; Castro, 2022).

Among the methods used in the study of river basins, morphometry, and hypsometry emerge as important approaches (de Salis et al., 2019). Morphometric analysis involves the evaluation of the physical characteristics of the basin, such as area, perimeter, drainage density, flow pattern, and shape. For Souza and Cunha (2022), these calculations are widely used to estimate the hydrological response and susceptibility to erosion processes. Hypsometry, in turn, provides information on the altimetric distribution of the relief, enabling the identification of stages of geomorphological evolution and the inference of environmental degradation processes (Lima, 2008; Rocha, 2022).

Geosciences play a crucial role in assessing the effects of human actions on land use and occupation, especially in regions of high environmental and economic relevance (Pereira et al., 2023). In the Brazilian context, changes in land use are often linked to agricultural expansion and urban growth and pose considerable challenges to the preservation of water resources (Uelma et al., 2023). In places intended for aquaculture, such as excavated ponds, careful planning of the infrastructure is essential to ensure the sustainability of productive activities (Lira et al., 2019; Rios et al., 2024).

Therefore, the objective of this study was to analyze the essential variables for the environmental and geomorphological characterization of the Baiano River micro-basin, one of the several sub-basins that make up the Piquiri River basin, the third largest in the state of Paraná in the physical area; it covers 24,731 km² and includes 71 municipalities. In this context, the technical information in this study has the potential to support the assessment of the viability of initiatives aimed at sustainable fish farming. The study considered the interactions between the physical attributes of the environment and the possibility of aquaculture practices.

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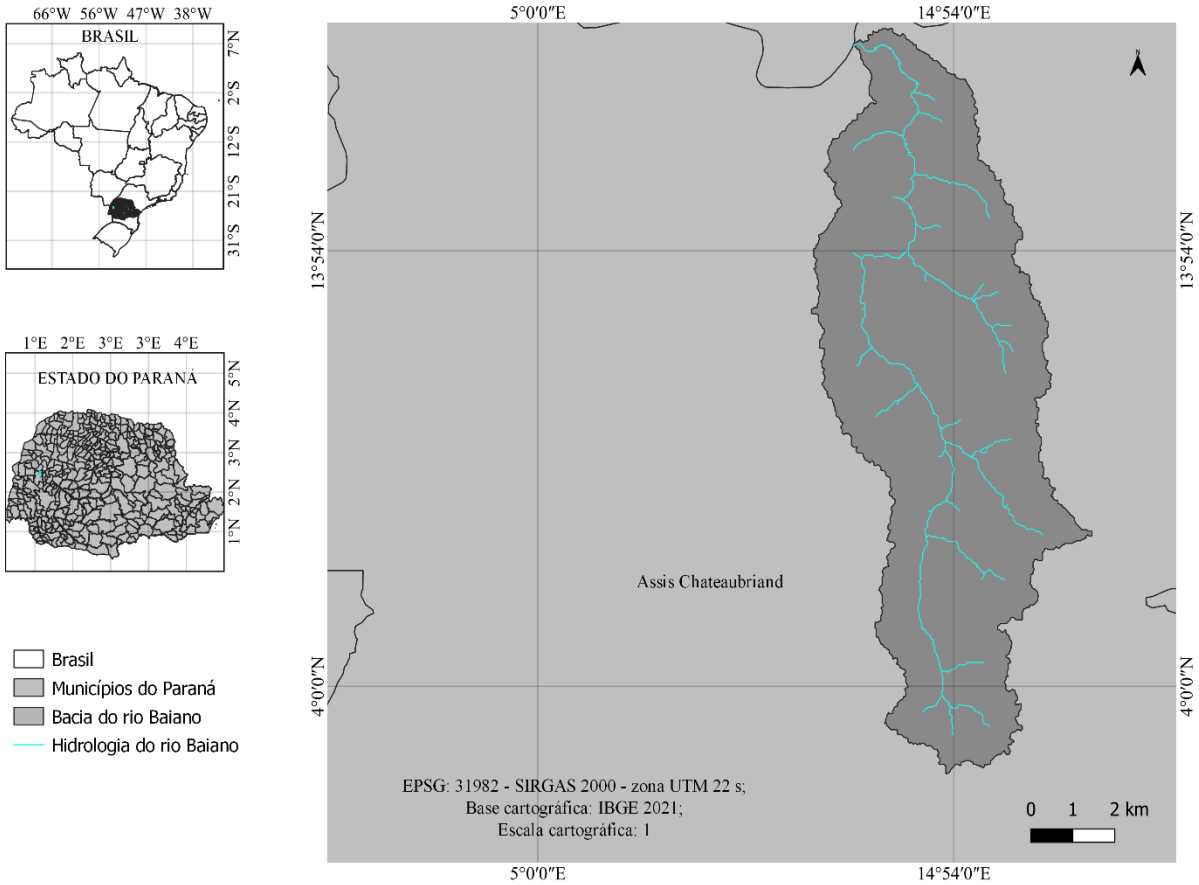
METHODOLOGY

STUDY AREA

The Baiano River micro-basin is located on the north side of the municipality of Assis Chateaubriand, in the western region of the state of Paraná, its exultation is on the right course of the Piquiri River (Figure 1). The climate is typically humid subtropical mesothermal, with an annual rainfall of 1,250 to 1,500 mm on average.(Melo *et al*., 2010a).

Figure 1. Location of the Baiano River basin, a tributary of the Piquiri River, western region of the state of Paraná, Brazil.



Source: prepared by the authors, 2024.

DELIMITATION OF THE BAIANO RIVER MICROBASIN

The delimitation of the Baiano River micro basin was carried out using a Digital Elevation Model (DEM) image with a spatial resolution of 30 meters. The images were obtained from the United States Geological Survey (USGS) website (USGS, 2021). The satellite image processing was done using QGIS® software, version 3.22.1. The correction of potential errors found in the DEM was performed using the r.fill.dir algorithm. The micro basin and hydrology delimitation were initially created with coordinates from the Piquiri

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River confluence, with the help of the Geographic Resources Analysis Support System (GRASS) software, using the r.watershed and r.water.outlet algorithms. The rasters produced during the delimitation were vectorized using the r.to. Vector algorithm (Morsoleto et al., 2023).

MORPHOLOGY AND MORPHOMETRY

To perform the morphological calculations and morphometric indices, the attribute calculator located in the attribute table of the shapefile files was used. The morphological calculations for the microbasin were: area, perimeter, main river length, and channel lengths. The morphometric indices are shown in Table 1 (Luiz Junior et al., 2024).

Table 1. Morphometric indices, formulas, descriptions, and reference values used for the Baiano River micro basin, western Paraná, Brazil.

Index	Formula	Description
Kc – Compaction Coefficient	$Kc=0.28*(P/\sqrt{A})$	P: Perimeter of the basin (m); A: Area of the basin (m²)
F – Shape Factor	$F=A/E^2$	A: Area of the basin (m²); E: Length of the basin's axis (m)
Ic - Circularity Index	$Ic=(12.57*A)/P^2$	A: Area of the basin (m²); P: Perimeter of the basin (m)
Dd - Drainage Density	Dd=Lt/(A/1000)	Lt: Length of the drainage network (km); A: Area of the basin (km²)
Tc - Concentration Time	$Tc=57*((L/1000^3)/H)0.385$	L: Length of the main riverbed (km); H: Difference in altitude between the highest point and the control section (m)
Is - Sinuosity Index	Is=(100×(L-Lr))/L	L: Length of the main river (m); Lr: Length of the main riverbed (m)
Er - Elongation Ratio	$Er=1.128\times\sqrt{A}/E$	A: Area of the basin (m²); E: Length of the basin's axis (m)
Rr - Relative Relief	Rv=H/P	P: Perimeter of the basin (m); H: Altimetric range (m)

Source: Morsoleto et al., 2023.

MAPPING OF PHYSICAL AND NATURAL RESOURCES

The slope and hypsometry maps of the Baiano River microbasin were created using the DEM, through QGIS software, version 3.22.14 BIATOWIEZA (QGIS Development Team, 2021), similar to the work of Macedo et al. (2023) and Werneck et al. (2023a). Land use and occupation analysis were obtained from the MapBiomas project website, in raster (GeoTiff) format with a scale of 1:100,000 and a spatial resolution of 30 meters (Brazil, 2019).

The soil type map was developed using the methodology of Francisco et al. (2019) and Morsoleto et al. (2023). The soil type analysis was based on information from the Brazilian Agricultural Research Corporation (EMBRAPA) (dos Santos et al., 2018), presented in vector format at a scale of 1:250,000 (IBGE, 2021).

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The road map was created according to the methodology of Luiz Junior et al. (2024). Road vectors at a scale of 1:250,000 were obtained from the Brazilian Institute of Geography and Statistics (IBGE, 2021). The micro basin delimitation was used to clip the roads located within it.

MAPPING OF EXCAVATED PONDS

Vectorization, classification, and quantification of the excavated ponds located in the Baiano River watershed were performed using high-resolution Google Earth images, through the algorithm available in the QuickMapServices plugin of QGIS®, with a scale of 1:600. The classification followed the methodologies described by Francisco et al. (2019) and Morsoleto et al. (2024).

ESTIMATION OF TOTAL NITROGEN AND TOTAL PHOSPHORUS INPUT

The estimates of Total Nitrogen (TN) and Total Phosphorus (TP) residuals in the environment and volumes incorporated as effluents from the cultivation were calculated based on Coldebella et al. (2020). The estimates considered the cultivation area and biomass of the mapped ponds. The average stocking density considered was 5 kg fish/m² of water surface. Table 2 indicates the reference values for the calculations of Nitrogen and Phosphorus in their respective classes and production phases (Coldebella et al., 2020).

Table 2. Reference values for estimates of Total Nitrogen and Total Phosphorus input, according to pond class, during cultivation (9 months) and harvesting.

Class	Size (m²)	Reference values	Cultivation	Harvesting
I	300 - 3000	Nitrogen (kg/ha)	2,047.70	54.59
		Phosphorus (kg/ha)	261.91	16.47
II	3,001 – 6,000	Nitrogen (kg/ha)	1,951.05	120.49
		Phosphorus (kg/ha)	197.30	26.11
III	> 6,000	Nitrogen (kg/ha)	2,055.85	81.56
		Phosphorus (kg/ha)	260.99	12.18

Source: adapted from Coldebella, 2020.

RESULTS AND DISCUSSION

MORPHOLOGY AND MORPHOMETRY

The Baiano River micro basin occupies an area of 68.62 km², with a main river length of 67.75 km. The geomorphological analysis indicates that the main channel has low sinuosity, being classified as linear according to the sinuosity classification (Christofoletti, 1980), which ranges from “very straight” to “very sinuous”. The micro basin is characterized by fourth-order rivers, according to the fluvial classification hierarchy system, which

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considers the connection and integration of smaller tributaries to define the complexity of the drainage network (Pelech, 2021). Geologically, the basin is entirely located in basic volcanic rocks from the Serra Geral Formation (Scherer; Lavina, 2006).

Table 3 shows the morphometric indices of the Baiano River micro basin. The Compaction Coefficient (Kc) greater than 1 suggests an elongated and irregular shape, resulting in reduced efficiency in concentrating water flows. These data are corroborated by the Circularity Index (Is) of 0.19, and the Shape Factor (F) of less than 0.5, confirming the elongated characteristic of the basin, which reduces the risk of immediate flooding. Similar values were observed by Macedo et al. (2023) in micro basins with an elongated shape and low flooding risk, thus considered an area with a tendency for conservation.

The drainage density (0.76) indicates a low-density drainage network, with a concentration-time of 4 hours and 49 minutes to disperse water from the rainfall event to its mouth. This interval is considered long, especially given the small area of the micro basin; however, it is considered acceptable due to the low altimetric variation, as evidenced in Table 3.

Table 3. Morphometric indices of the Baiano River watershed, a tributary of the Piquiri River, western Paraná state, Brazil.

Morphometric Indices	Results	Morphometric Indices	Results
Kc	2.290	Tc	4h 49 min
F	0.21	Is	27.48
Ic	0.19	Er	0.513
Dd	0.76	Rv	0.003

Source: created by the authors, 2024.

Figure 2 illustrates the slope map of the Baiano River micro basin. The micro basin predominantly has a flat relief, with very gentle slopes of less than 3%. This geomorphological configuration results in an area with minimal altimetric variation, giving the relief a homogeneous nature. The Tatuí River micro basin, located in the municipality of Terra Roxa/PR, also presents a predominance of flat slope, where most of its area varies between 0 and 2% (Bonzanini et al., 2022). These conditions are favorable for the establishment of excavated ponds due to the ease of excavation and controlled surface runoff. The micro basin also presents a slightly undulating relief, where slopes do not exceed 8%. The relief is shaped by hills and small spurs with gently flattened tops, and valleys predominantly in a “V” shape (Melo et al., 2010b). This favors diversified uses, from agricultural activities to efficient water management.

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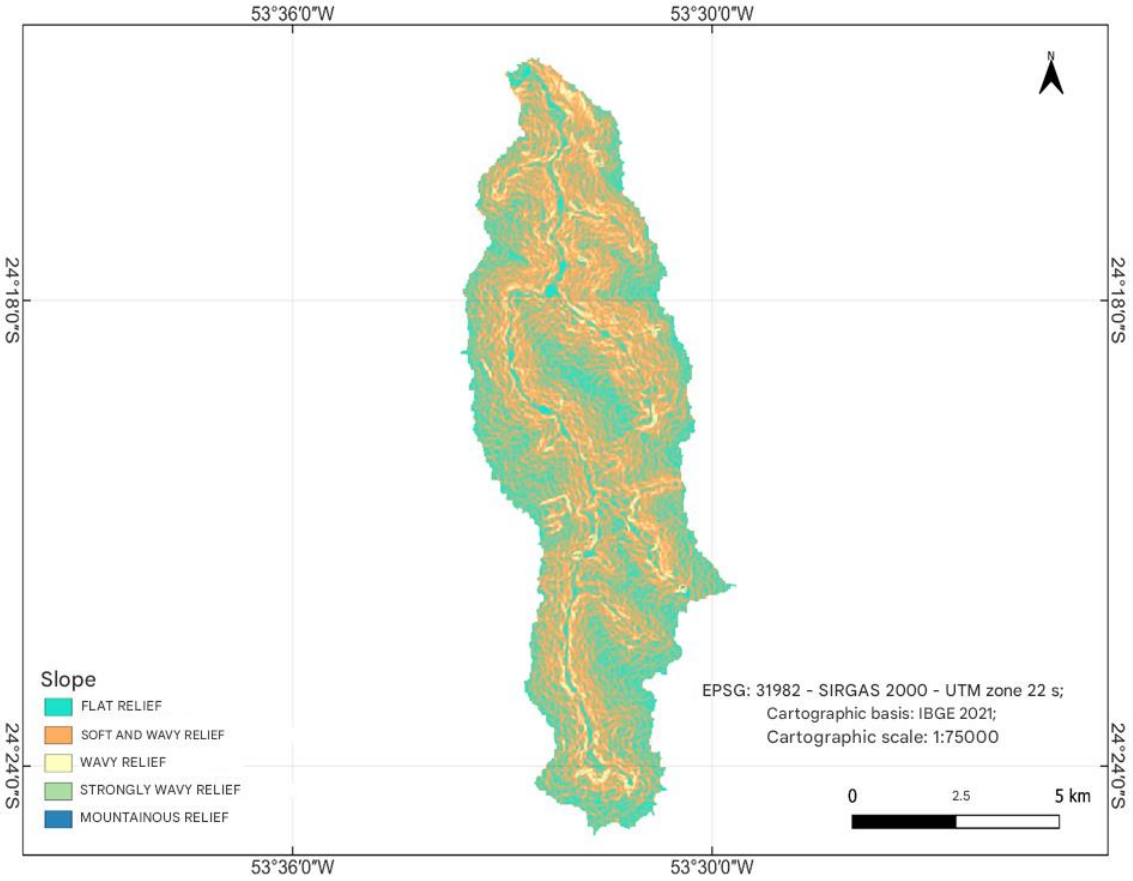
Figure 2. Slope of the Baiano River basin, a tributary of the Piquiri River, western Paraná state, Brazil.



Source: prepared by the authors, 2024.

The micro basin area presented 3 hypsometric bands that vary from 220 meters to 620 meters (Figure 3). The first hypsometric band (220 - 320 m) in altitude occupies an area of 1,494.59 ha, corresponding to 21.78%. The band from 320 to 520 m in altitude occupies an area of 5,198.97 ha, corresponding to 75.76% of the total area of the micro

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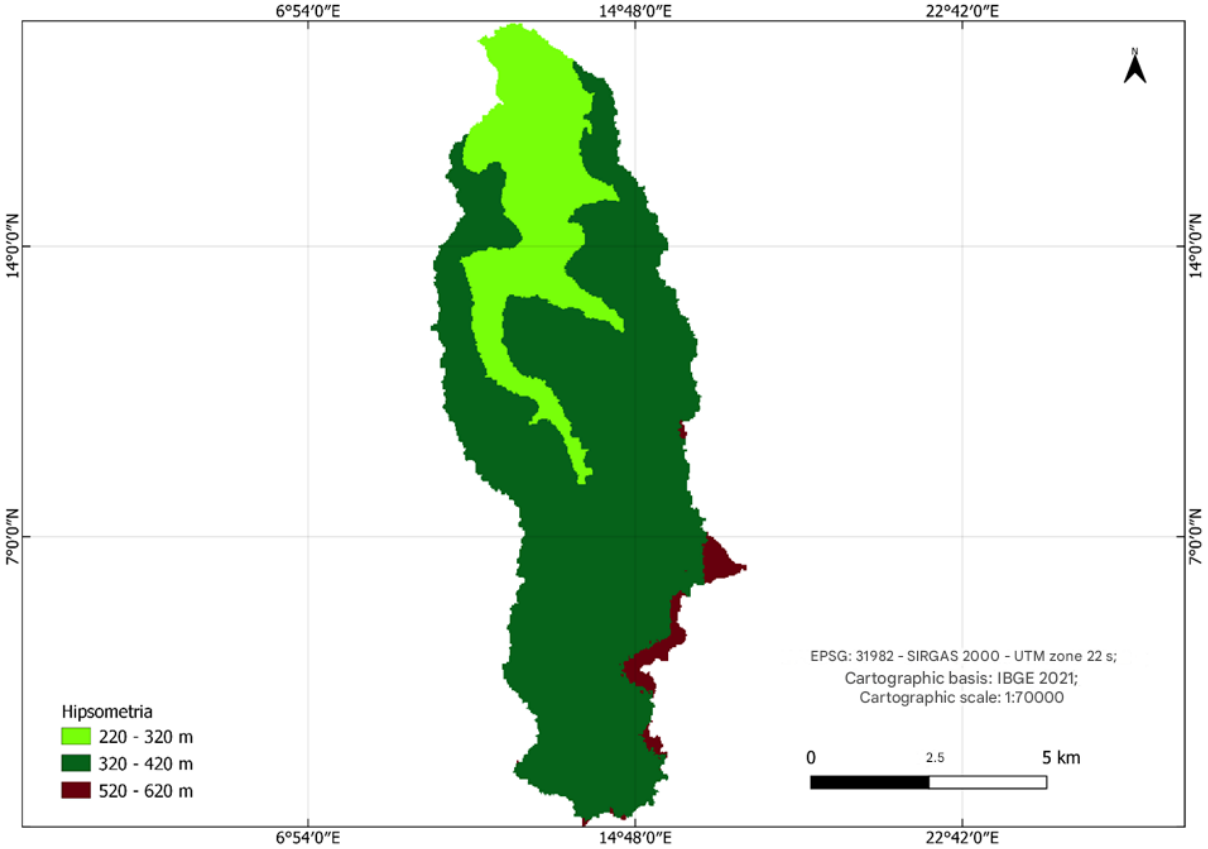
basin, while the band from 520 to 620 m occupies an area of 168.65 ha, corresponding to 2.46%.

Figure 3. Hypsometry of the Baiano River basin, a tributary of the Piquiri River, western Paraná state, Brazil.



Source: prepared by the authors, 2024

Figure 4 shows the soil types of the Baiano River basin, where the Red Latosol predominates, with 4,128.97 ha (61%), characterized by its clayey texture. Next is the Red Nitosol with 2,640.23 ha (39%), which also has a clayey texture, but with a higher concentration of nutrients compared to the Latosol. On the east side of the municipality of Assis Chateaubriand is the Azul River, where the same type of soil occurs, characterized by high permeability and smooth, flat relief surfaces, typical of areas with less slope, evidencing good drainage. (Souza; Barsi, 2024).

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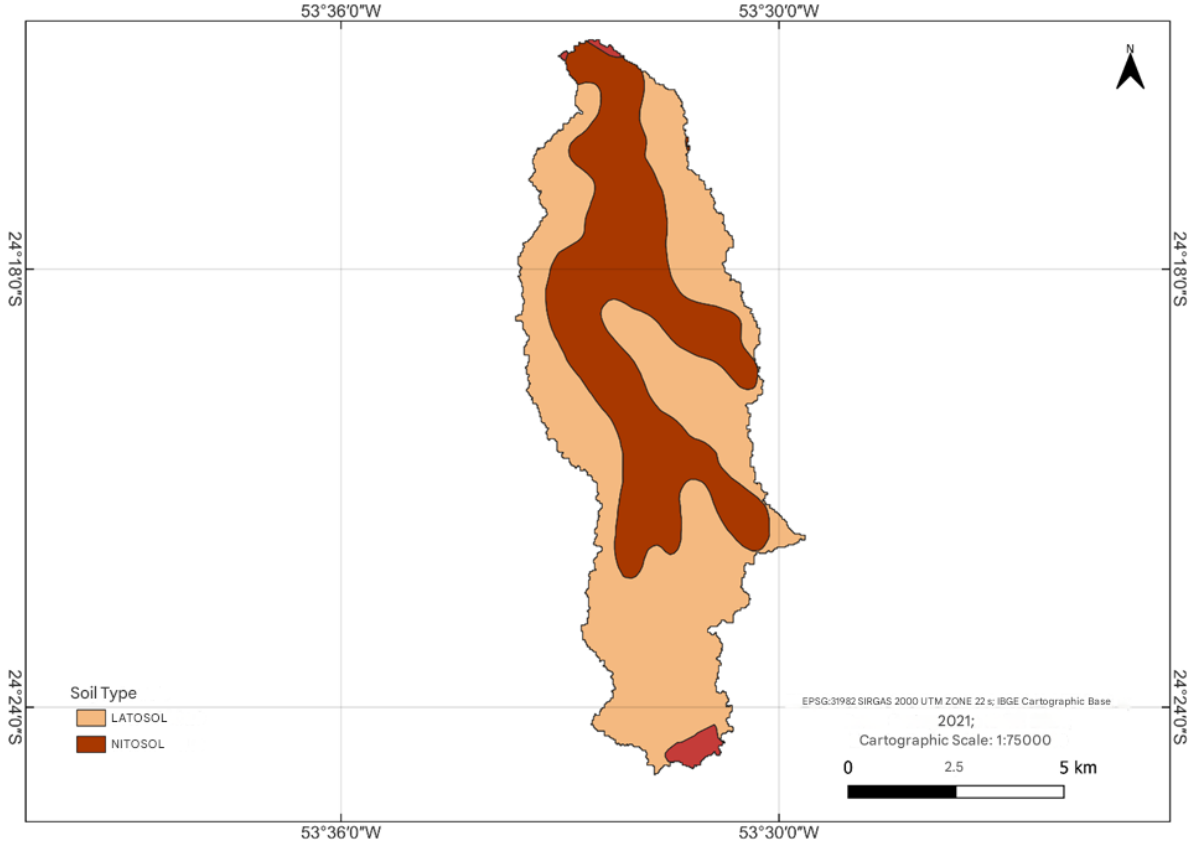
Figure 4. Soil type of the Baiano River basin, a tributary of the Piquiri River, western Paraná state, Brazil.



Source: prepared by the authors, 2024

Most of the area of the Baiano River micro basin is predominantly occupied by temporary agricultural activities, with an emphasis on soybean cultivation, as illustrated in Figure 5. Forestry and coffee cultivation stand out due to the favorable climatic and topographic conditions. Another relevant land use in the micro basin is forest formation, concentrated mainly in Permanent Preservation Areas (APPs). The expansion of agriculture in Paraná, covering the Piquiri basin, from the middle of the 20th century onwards, caused a drastic reduction and fragmentation of native vegetation (Rocha; Bade, 2018; Silva et al., 2022). According to the Department of Rural Economy, soybean production in the municipality of Assis Chateaubriand, in 2020, was 263,181 tons (Paraná, 2021). The municipalities of Paraná that grew in irrigated areas, such as Assis Chateaubriand, saw a 99% increase in the area allocated to agriculture between 2006 and 2017 (Ferrarini, 2022, 2022).

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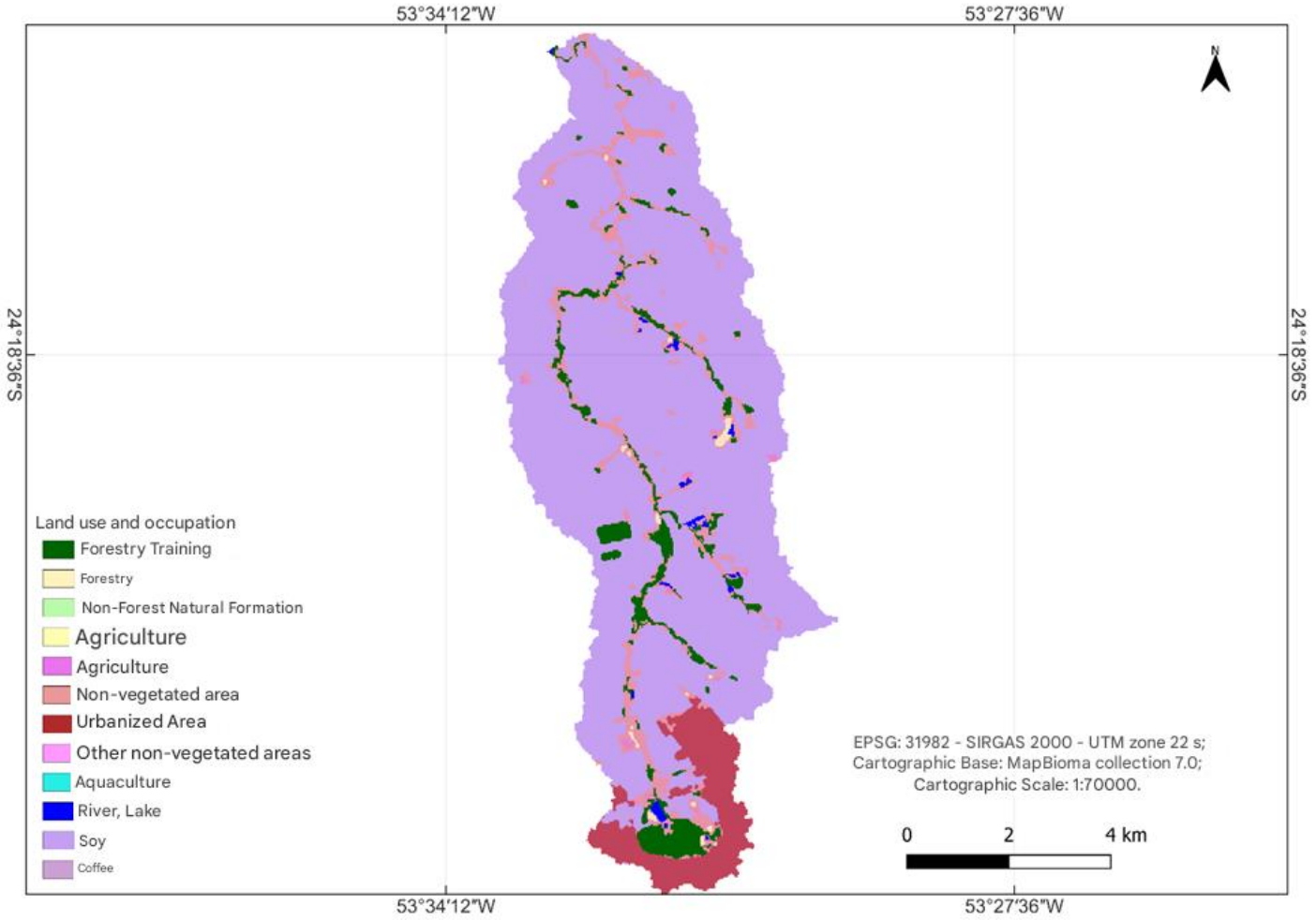
Figure 5. Land use and occupation of the Baiano River basin, a tributary of the Piquiri River, western Paraná state, Brazil.



Source: prepared by the authors, 2024.

MAPPING OF EXCAVATED PONDS

A total of 59 excavated ponds were identified, covering 27.76 hectares of mapped water surface, as shown in Figure 6. The most frequent class among the ponds was Class I, small-sized ponds. Regarding the water surface area, the predominant class was III, large-sized ponds, as described in Table 4.

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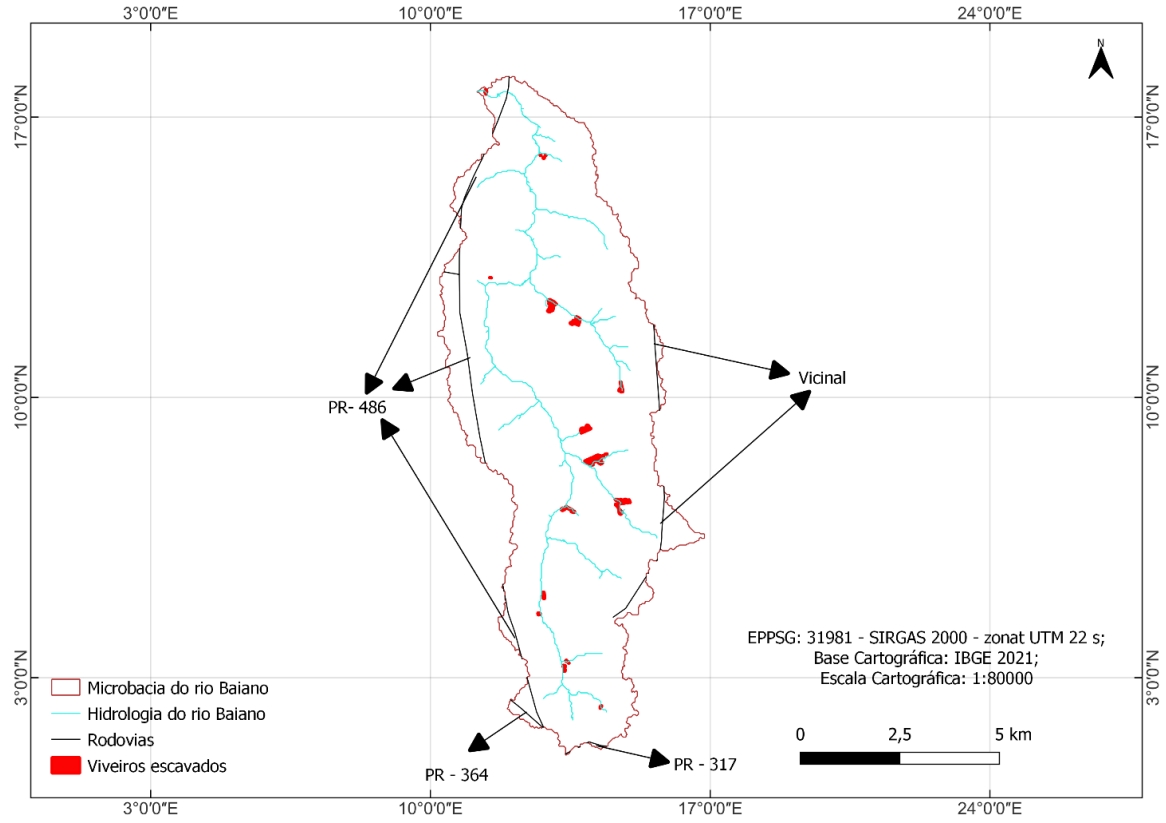
Table 4. Excavated ponds in the Baiano River watershed, a tributary of the Piquiri River, western Paraná state, Brazil.

Class	Size (m²)	Average (m²)	Number of Units	Unit (%)	Area (ha)	Area (%)
I	300 – 3,000	1,539	22	37.29	3.38	12.17
II	3,001 – 6,000	4,430	20	33.90	8.86	31.92
III	>6,000	9,132	17	28.81	15.52	55.91
Total			59	100	27.76	100

Source: created by the authors, 2024.

Similarly, the ponds mapped in the Guaçu Creek sub-basin are small-sized (67.68%) (Werneck et al., 2024). Class I fish farming is associated with the presence of small producers, which leads to the fact that small family properties are very common in the region (Werneck et al. 2023b). The excavated ponds in the Açu River microbasin are concentrated near the banks, with uneven distribution. This arrangement reduces the self-purification capacity of the water bodies (Luiz Junior et al., 2024).

Figure 6. Geographic location of excavated nurseries and roads in the Baiano River basin, a tributary of the Piquiri River, western Paraná state, Brazil.



Source: prepared by the authors, 2024

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ESTIMATE OF TOTAL NITROGEN AND TOTAL PHOSPHORUS INPUT

The estimated results for the input of Total Nitrogen and Total Phosphorus, during the rearing and harvesting periods, show that the class III ponds (Table 5) were responsible for the majority of the nutrient input. The N/P ratio calculated for the rearing period as 8/1 and the harvesting ratio of 5/1 is considered low. These low ratios can cause eutrophication of the water body and may lead to the proliferation of algae from the cyanobacteria family, since the growth of phytoplankton depends on the availability of nitrogen, providing growth of nitrogen-fixing species (Vidal; Capelo Neto, 2013).

Table 5. Estimates for the contribution of Total Nitrogen (N) and Total Phosphorus (P) in the Baiano River sub-basin, during cultivation and fishing. Considering an average stocking density of 5 kg of fish per m² of water surface and the total area of water surface.

Classe	Biomassa (ton./ha)	Área (ha)	Criação		Despesca	
			N (ton.)	P (ton.)	N (ton.)	P (ton.)
I	169	3,38	6,92	0,88	0,18	0,05
II	443	8,86	17,29	1,75	1,07	0,23
III	776	15,52	31,91	4,05	1,27	0,19
Total	1.388	27,76	56,12	6,68	2,52	0,47

Source: prepared by the authors, 2024.

The introduction of Nitrogen and Phosphorus into water bodies may become limiting elements, and may stimulate eutrophication of the environment, due to greater primary production (Macedo; Sipaúba-Tavares, 2010).

CONCLUSION

The micro basin presents favorable conditions for the development of aquaculture activities, especially due to the availability of areas with suitable topography for the construction of nurseries and access to water resources. The use of technology tools allowed the preparation of maps of physical and natural resources, as well as the characterization of the hydrology and morphometry of the Baiano River micro basin. Therefore, the visual data (maps) and indicators for the Baiano River micro basin fulfill the objective of characterizing the micro basin to prepare data that allow the sustainable use of the physical and natural resources of the micro basin for the socioeconomic development of the municipalities that comprise it.

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REFERENCES

1. Américo-Pinheiro, J. H. P., & Benini, S. M. (Orgs.). (2018). Bacias Hidrográficas: fundamentos e aplicações (1ª ed.). ANAP.

2. Brasil, Mapbiomas. (2019). Coleção 7.1 da Série Anual de Mapas de Cobertura e Uso de Solo do Brasil. Disponível em: https://mapbiomas.org/colecoes-mapbiomas-1. Acesso em: 29 nov. 2024.

3. Bonzanini, H. L., Lupinacci, C. M., & Sanches, R. M. (2022). Análise morfométrica e feições erosivas na bacia hidrográfica do rio Taturi (PR). Geografia (Londrina), 31(1), 237-257.

4. Castro, C. N. de. (2022). Água, problemas complexos e o Plano Nacional de Segurança Hídrica. Ipea. ISBN: 978-65-5635-031-8.

5. Coldebella, A., et al. (2020). Nitrogen and phosphorus dynamics in Nile tilapia farming in excavated rearing ponds. Research, Society, and Development, 9(11), e1319119699.

6. Salis, H. H. C., et al. (2019). Caracterização morfométrica da bacia hidrográfica do Córrego do Marinheiro, Sete Lagoas-MG. Boletim de Geografia, 37(2), 186-201.

7. Santos, H. G., et al. (2018). Sistema brasileiro de classificação de solos. Embrapa.

8. Christofoletti, A. (1980). Geomorfologia: conceitos e técnicas. Edgard Blücher.

9. Ferrarini, A. dos S. F. (2022). A agricultura irrigada no Paraná: expansão de áreas e uso de recursos hídricos. Revista Paranaense de Desenvolvimento, 43(142), 41-59.

10. Francisco, H. R., Correia, A. F., & Feiden, A. (2019). Classification of areas suitable for fish farming using geotechnology and multi-criteria analysis. ISPRS International Journal of Geo-Information, 8(9), 394.

11. IBGE – Instituto Brasileiro de Geografia e Estatística. (2021). Portal de mapas. Disponível em: https://www.ibge.gov.br/geociencias/cartas-e-mapas/mapas-municipais.html. Acesso em: 01 dez. 2024.

12. Junior, J. H. P., & Ferrão, A. M. de A. (2018). Aspectos de gestão integrada de bacias hidrográficas: O caso da área urbana da microbacia hidrográfica do córrego Água Boa do município de Dourados (MS), Brasil. Cidades, Comunidades e Territórios, 37.

13. Klein, W. L., et al. (2023). Características ambientais da microbacia hidrográfica do rio São Luiz para subsidiar o planejamento sustentável da piscicultura. Cuadernos de Educación y Desarrollo, 15(10), 10139-10158.

14. Lima, W. de P. (2008). Hidrologia florestal aplicada ao manejo de bacias hidrográficas (2ª ed.). USP.

Revista ARACÊ
ISSN: 2358-2472

15. Lira, K. C. da S., Francisco, H. R., & Feiden, A. (2019). Análise morfométricas da microbacia do Rio Marreco: subsídios para cálculos do impacto ambiental. Revista Caderno Pedagógico–Studies Publicações Ltda, 1294.

16. Luiz Junior, O. J., et al. (2024). Estimativa de aporte de Nitrogênio e Fósforo na microbacia hidrográfica do rio Açu utilizando ferramentas de geoprocessamento. Caderno Pedagógico, 21(3), e3138.

17. Macedo, C. F., & Sipaúba-Tavares, L. H. (2010). Eutrofização e qualidade da água na piscicultura: consequências e recomendações. Boletim do Instituto de Pesca, 36(2), 149-163.

18. Macedo, H. R., et al. (2023). Caracterização morfológica, uso e cobertura do solo da microbacia hidrográfica do Córrego Chororó, no estado do Paraná, Brasil. Cuadernos de Educación y Desarrollo, 15(10), 10268-10286.

19. Melo, O. A. G. de, et al. (2010a). Verificação da influência da imposição litoestrutural sobre a drenagem da bacia hidrográfica do rio Baiano-Assis Chateaubriand/PR a partir da aplicação de variáveis morfométricas. Revista Brasileira de Geografia Física, 3(1), 07-13.

20. Melo, O. A. G. de, et al. (2010b). Análise comparativa da Vulnerabilidade Ambiental Potencial ou Emergente da bacia hidrográfica do rio Baiano–Assis Chateaubriand/PR. Boletim de Geografia, 28(2), 17-27.

21. Morsoleto, F. M. da S., et al. (2023). Caracterização da morfometria da microbacia hidrográfica do rio Cavernoso: subsídios para o planejamento sustentável da piscicultura. Caderno Pedagógico, 20(3), 1280-1295.

22. Morsoleto, F. M. da S., et al. (2024). Sustainable planning technologies for fish farming expansion in small municipalities: a case study of Pato Bragado/PR-Brazil. Latin American Journal of Aquatic Research, 52(4). https://doi.org/10.3856/vol52-issue4-fulltext-3163.

23. Paraná. Departamento de Economia Rural. (2021). Prognóstico Agropecuário - Soja 2021/2022. Secretaria de Agricultura e do Abastecimento do Estado do Paraná, Departamento de Economia Rural – DERAL, Divisão de Conjuntura Agropecuária, 13(38). Disponível em: https://www.agricultura.pr.gov.br/sites/default/arquivos_restritos/files/documento/2022-01/soja%20(2).pdf. Acesso em: 05 dez. 2024.

24. Pelech, A. S. (2021). Classificações geomorfológicas de rios: uma breve discussão teórica. William Morris Davis - Revista de Geomorfologia, 2(2), 1-27. https://doi.org/10.48025/ISSN2675-6900.v2n2.2021.170

25. Pereira, L. R., Mendes, G. C. M., & de Melo, S. R. P. (2023). Análise descritiva das águas superficiais e subterrâneas e a utilização das geociências nesse contexto: uma revisão. Revista de Geografia, 13(1). ISSN: 2236-837.

Revista ARACÊ
ISSN: 2358-2472

26. QGIS Development Team. (2021). QGIS Geographic Information System. Open-Source Geospatial Foundation Project.

27. Rios, B., et al. (2024). Investigação geotecnológica para otimizar a piscicultura em uma microbacia hidrográfica neotropical. Observatório de La Economía Latinoamericana, 22(4), e4221-e4221. https://doi.org/10.55905/oelv22n4-125

28. Rocha, A. S. da, & Bade, M. R. (2018). Geografia da bacia hidrográfica do Paraná 3: fragilidades e potencialidades socioambientais (1ª ed., 314p). Jundiaí, SP.

29. Scherer, C. M. S., & Lavina, E. L. C. (2006). Stratigraphic evolution of a fluvial–eolian succession: the example of the Upper Jurassic—Lower Cretaceous Guará and Botucatu formations, Paraná Basin, Southernmost Brazil. Gondwana Research, 9(4), 475-484.

30. Silva, M. A., Lisboa, M. T., & Gimenez, H. M. (2022). Extremo Oeste: A historiografia regional, o Oeste e a (Tríplice) Fronteira internacional do Paraná. Revista de História Regional, 27(1), 360-386.

31. Souza, C. C., & Cunha, M. C. da. (2022). Análise dos parâmetros morfométricos da rede de drenagem e rede viária da bacia hidrográfica do Ribeirão Paraíso, Jataí-GO. Sociedade & Natureza, 34, e65404. ISSN Uberlândia, MG.

32. Souza, A. B. de, & Barsi, F. V. (2024). Caracterização morfométrica da bacia hidrográfica do rio Azul – PR. Revista de Engenharia e Tecnologia, 16(1).

33. Uema, D. Y., Muller, T., & Santil, F. L. de P. (2023). Diagnóstico da erosão, transporte e deposição de solos em pequena bacia hidrográfica: o caso do Ribeirão Jacupiranga. Geografia (Londrina), 33(1), 209–227. https://doi.org/10.5433/2447-1747.2024v33n1p209. Acesso em: 5 dez. 2024.

34. USGS, United States Geological Survey. (2021). EarthExplorer.

35. Vidal, T. F., & Capelo Neto, J. (2014). Dinâmica de nitrogênio e fósforo em reservatório na região semiárida utilizando balanço de massa. Revista Brasileira de Engenharia Agrícola e Ambiental, 18, 402-407.

36. Werneck, P. R., et al. (2023a). Caracterização da microbacia do Rio Branco e análise das unidades de produção piscícolas, através do uso de geotecnologias. Observatório de la Economía Latinoamericana, 21(5), 2749-2773.

37. Werneck, P. R., et al. (2023b). Uso do georreferenciamento como ferramenta de planejamento sustentável da produção aquícola em pequenos municípios: estudo de caso para Ouro Verde do Oeste/PR. Research, Society and Development, 12(3), e17012338683-e17012338683.

38. Werneck, P. R., et al. (2024). Estimativa de aporte de nitrogênio e fósforo da piscicultura na sub-bacia hidrográfica do Arroio Guaçu. Caderno Pedagógico, 21(10), e9125-e9125.