

Assessment of granted water volumes and water availability in the Azul River basin, Paraná, Brazil

Avaliação dos volumes de água outorgados e a disponibilidade hídrica na bacia do rio Azul, Paraná, Brasil

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ABSTRACT: Water plays a crucial role in various activities concerning a watershed. However, the unregulated utilization of water resources and the absence of effective management can jeopardize the diverse uses of water, turning a particular region into a critical area. Therefore, the aim of this study was to conduct a comprehensive analysis of water demands in relation to water availability in the Azul River Watershed, Paraná state, Brazil. To achieve this objective, data on licenses for water resources use issued by the state regulatory agency have been utilized, and the study area was defined using geographic coordinates. By segmenting the hydrographic unit, it is possible to identify different types of water uses (consumptive and non-consumptive), permitted water outflows, specific purposes, and water users. Furthermore, an examination of the conflicts between demand and water availability was also conducted. The findings revealed that the agricultural sector accounted for the highest water withdrawals, with the greatest number of active permits. Additionally, regarding consumptive uses, aquaculture emerged as the largest consumer of water, accounting for 62% of the total water consumption. The water demand of users in the Rio Azul basin cannot be achieved considering the current licensing criteria. This indicates that water resource management requires special attention to the relationship between demand and water availability.

Keywords: watershed management, water conflicts, water permits.

RESUMO: A água desempenha um papel crucial em várias atividades dentro de uma bacia hidrográfica. No entanto, a utilização não regulamentada dos recursos hídricos e a ausência de uma gestão eficaz podem comprometer os diversos usos da água, transformando uma determinada região em uma área crítica. Portanto, o objetivo deste estudo foi realizar uma análise abrangente das demandas hídricas em relação à disponibilidade de água na Bacia do Rio Azul, no estado do Paraná, Brasil. Para atingir esse objetivo, foram utilizados dados de licenças de uso de recursos hídricos emitidas pela agência reguladora estadual, e a área de estudo foi definida utilizando coordenadas geográficas. Segmentando a unidade hidrográfica, é possível identificar diferentes tipos de usos da água (consuntivos e não consuntivos), vazões permitidas, finalidades específicas e usuários da água. Além disso, também foi realizado uma análise dos conflitos entre demanda e disponibilidade de água. Os resultados revelaram que o setor agrícola foi responsável pelas maiores retiradas de água, com o maior número de outorgas ativas. Além disso, dentro dos usos consuntivos, a aquicultura surgiu como o maior consumidor de água, representando 62% do consumo total de água. A demanda hídrica dos usuários na bacia do Rio Azul não pode ser atendida considerando os critérios de outorga atuais. Isso indica que a gestão dos recursos hídricos requer atenção especial quanto a relação entre demanda e disponibilidade de água.

Palavras-chave: gestão de bacias hidrográficas, conflitos hídricos, outorgas de água.

INTRODUCTION

Water, a limited and valuable resource essential for life, requires efficient management and regulation to promote sustainable use. The United Nations recognizes water's importance and has set goals to ensure its sustainable management and availability by 2030 (Nações Unidas, 2015). In Brazil, the National Water Resources Policy enables multiple water uses, including human consumption, animal watering, industrial processes, public supply, agriculture, transport, leisure and energy generation purposes (Brasil, 1997).

Conflicts often arise over water concession, particularly in critical areas where resources are scarce, contamination risks are high or water use takes place without adequate planning for supply and demand (Ferraço; Moraes, 2020; Boëchat *et al.*, 2021; Ana, 2021). In the state of Paraná, in southern Brazil, critical areas for water use have been identified, such as the Azul River basin. This basin is part of the drainage network of the Piquiri River, which is a large tributary of the Paraná River.

Diagnosing water demands is crucial to identify critical areas, guide management actions, and facilitate multiple water uses (Instituto Água e Terra, 2020a; 2020b). This research focuses on diagnosing water demands in the Azul River watershed using the Diagnosis of Water Permits and Outflows (DWPO) (Figueredo, 2021) to inform decision-making for rational and sustainable water use.

LITERATURE REVIEW

The global water crisis is a reality that directly impacts human life, social development, and economic growth. In Brazil, water scarcity is an increasing challenge, with recurrent droughts affecting several sectors, especially agriculture and human water supply. The causes are multifactorial, including climate change, deforestation, rapid urbanization, and inadequate use of water resources. Integrated water resources management with a focus on sustainability is crucial to mitigate the impacts of the water crisis and ensure water access for future generations (Ana, 2021).

Inadequate management of water resources can lead to conflicts over water use, as growing demand clashes with limited availability. These conflicts involve different sectors, such as agriculture, industry, energy generation, and human water supply, creating disputes that negatively affect socioeconomic development (Lima *et al.*, 2018).

The diagnosis of critical areas, as proposed by the National Water Resources Policy (PNRH), is fundamental for identifying and managing areas at risk of water conflicts and scarcity. The implementation of the DWPO allows for an analysis of the relationship between water demand and availability, aiding in efficient water management to ensure sustainable multiple uses (Figueredo, 2021; Instituto Água e Terra, 2020b).

MATERIAL AND METHODS

The Azul River watershed covers an area of 435.184 km² (Velooso, 2016). It is located in the western region of the state of Paraná, south Brazil, it is a tributary of the Piquiri river and to the Paraná River basin, one of the main river basins in Brazil (Ribeiro, 2015). Three municipalities have part of their territories within the basin: Assis Chateaubriand (10.66%), Palotina (46.40%) and Maripá (42.92%) (**Figure 1**), having around 71.000 inhabitants (Instituto Brasileiro de Geografia e Estatística, 2022). The main economic activities in these

municipalities are agriculture and aquaculture (**Table 1**).

The Azul River watershed is in northwest Paraná and is classified as a third-order river. It has a drainage area of 337,701 km² and a perimeter of 101.37 km. The main channel stretches 62.62 km with a 0.37% gradient and consists of 321 water channels totaling 326.09 km in length.

Collected data consisted of bibliographic sources, such as books, papers and conference proceedings. Relevant documentation on conflicts related to multiple water uses and critical areas were also consulted. The research used keywords such as "water use conflicts," "water crisis," "multiple uses of water," "water management in Paraná," "critical areas," "Brazilian water legislation," "consumptive uses," and "National Water Resources Policy."

To identify water demands in the Azul River watershed and survey permits, the DWPO (Diagnosis of Water Permits and Outflows) created by Figueredo (2021) has been used. The license database of the environmental agency responsible for licenses in the state of Paraná has also been used. Data access is available through the FTP area's Dados_Outorgas_Emitidas folder. The data, in .csv format, covers permits granted in Paraná from 2018 to 2022 and was filtered in layers using Excel. The permits were categorized based on various factors such as current status, type of use (consumptive or non-consumptive), flow permitting, source of capture, multiple uses, and primary purpose. Data separation was done by municipalities, watersheds, and geographic location using latitude and longitude coordinates (DATUM SIRGAS-2000).

Figure 1. Location of the Azul River basin in the state of Paraná and Brazil, highlighting the municipalities with territories within the basin

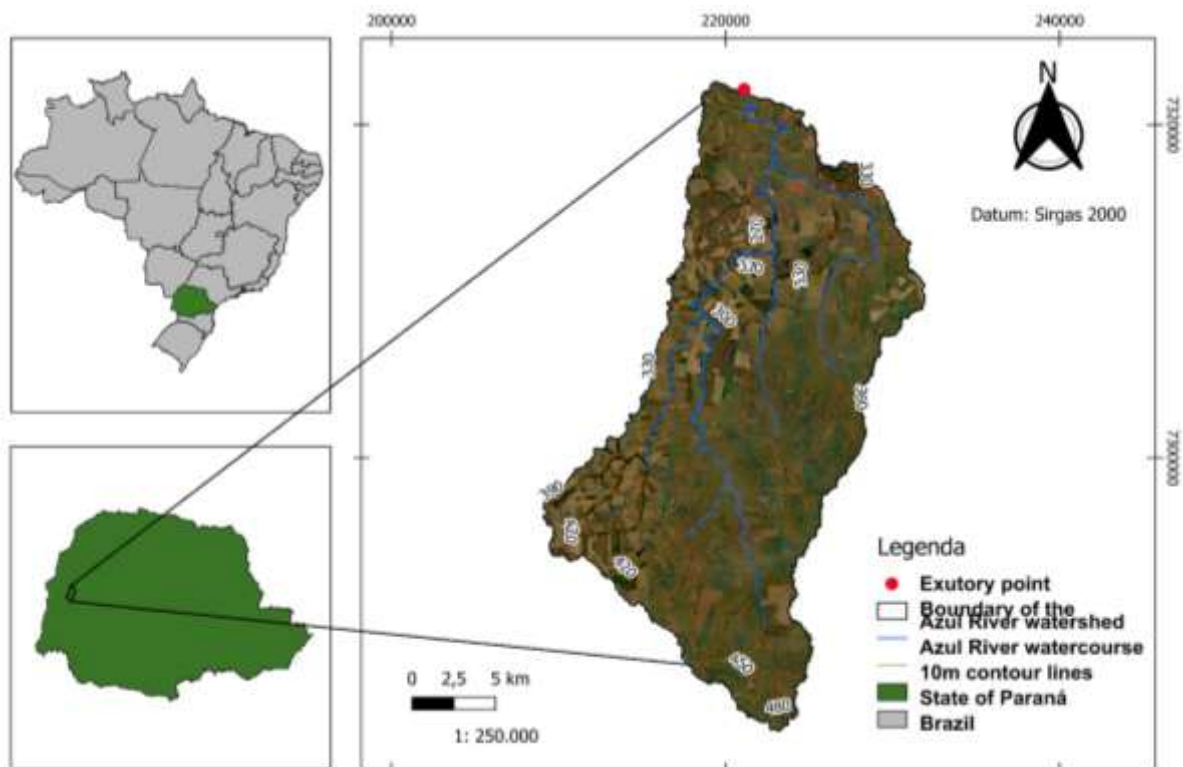


Table 1. Economic Activities, Number of Establishments, and Area in Assis Chateaubriand, Maripá and Palotina municipalities

Economic Activities	Establishments	Area (hectare)
Aquaculture	123	2.633
Horticulture and Floriculture	32	62
Permanent Crops	21	-
Temporary Crops	2.474	149.260
Livestock and Other Animal Husbandry	730	15.216
Forestry Production from Planted Forests	6	-
Total	3.386	167.171

Source: Instituto Paranaense de Desenvolvimento Econômico e Social (2022).

The water permits within the geographical perimeter of the Azul River Basin were analyzed independently of their respective municipalities. Consumptive and non-consumptive uses were differentiated, and the sectors were identified. The primary purposes determined the priority uses. This comprehensive analysis of both current and expired water permits provided a complete diagnosis of water allocations in the Azul River Basin. The variables and their explanations can be found in **Board 1** of the DWPO.

Board 1. Economic Activities, Number of Establishments, and Area in Assis Chateaubriand, Maripá and Palotina municipalities.

ITEMS	DESCRIPTION
Place	a) Municipality issuing permit
Types of use	b) Public administration;
	c) Agricultural;
	d) Business/Service;
	e) Industry;
	f) Water sanitation or
	g) Others
	Main purpose
b) Aquaculture;	
c) Animal watering;	
d) Irrigation;	
e) Vehicle wash;	
f) Cleaning;	
g) Industrial process	
h) Agricultural spraying;	
i) General use	
Quantity of outflows	a) Number of outflows permitted by demand

Source: Figueredo, 2021.

RESULTS AND DISCUSSION

Data on consumptive and non-consumptive uses of Azul River watershed have been analyzed, focusing on permits that expired after 2018. Out of the 73 current permits, consumptive uses accounted for 100% in the Azul River watershed, totaling 2579.8 m³h⁻¹ of water outflow.

In Piquiri River watershed, consumptive uses comprised 99.82% of permits (2,326 permits), while non-consumptive uses accounted for 0.75% (4 permits). The main consumptive uses of water in Brazil, as outlined in the Manual of consumptive uses of water in Brazil by the National Water Agency and Basic Sanitation (ANA, 2019), include human and animal supply, processing industry, mining, thermoelectricity, irrigation, and liquid evaporation from artificial reservoirs. Among these, irrigated agriculture stands as the largest water consumer in Brazil and worldwide.

In the Azul River watershed, agricultural licenses predominate having 66 permits, accounting for 90.41% of authorizations. Agricultural outflows are also the highest, totaling 2,361.8 m³h⁻¹ or 91.54% of permitted water catchment area. Similarly, the Piquiri River watershed has the highest outflows for agriculture, amounting to 29,585.34 m³h⁻¹ or 59% of all permits.

In Paraná state, agricultural permits make up 40% (1,0787 permits) and account for 37% of the outflows (863,496,504 m³h⁻¹). Eastern watersheds exhibit higher agricultural outflows, while southern watersheds show greater outflows for industry and sanitation sectors (Instituto Água e Terra do Paraná, 2020a; 2020b).

Azul River watershed has a higher permitted outflow rate for water catchment area compared to the Piquiri River basin and Paraná State, indicating a strong emphasis on agriculture in the geographic region. Water sanitation is the second-largest consumer, with outflows of 190 m³h⁻¹ or 7.36% of total water catchment area. This sector specifically refers to public supply activities. Other uses and industry have the lowest permitted outflows of 23 m³h⁻¹ and 5 m³h⁻¹, representing 0.89% and 0.19% of outflows, respectively.

Analyzing the consumptive outflow rates in the Azul River watershed in 2022 (2,579.8 m³h⁻¹), agricultural use decreased by 19.04% compared to the permitted flow rate in 2018 (2,917.1 m³h⁻¹). Conversely, the sanitation sector experienced a 58.33% increase in outflow rates from 2018 (120 m³h⁻¹).

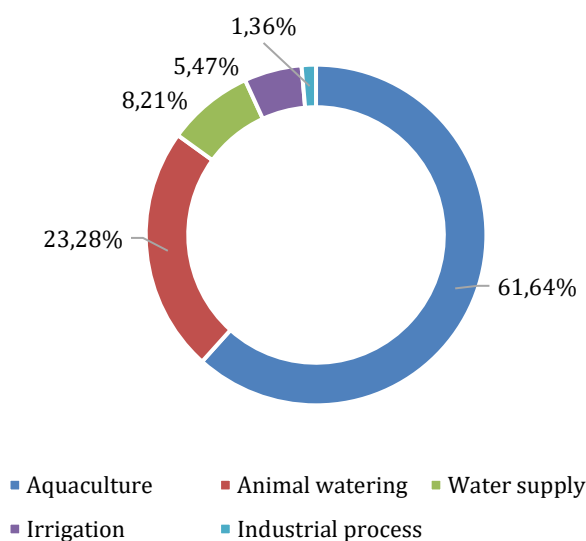
In Paraná state, sanitation use accounts for 30% of the outflow rate (697,515.120 m³h⁻¹), ranking second after agricultural use (Instituto Água e Terra, 2020a).

The purposes of water permits will determine priority activities and types of water users. Thus, analyzing the purposes, it will be possible to verify which activities consume the majority of water resources. Then, permits for the same water source may have different purposes, such as human consumption, especially for well water catchment area.

In times of water scarcity, it becomes crucial to accurately diagnose the types of uses and their respective flows. A focused diagnosis ensures that only priority outflows are maintained. Discrepancies exist between authorized activities and the priority use defined by the National Water Resources Policy (PNRH) in Brazil. For instance, non-priority activities like aquaculture, irrigation, industrial processes, and agricultural irrigation are included in the purpose of human consumption.

Aquaculture and animal watering have had the highest number of permits in the Azul River watershed. Aquaculture represents the majority, accounting for 61.64% of permits, while animal watering comprises 23.28%, as can be seen in **Figure 1**.

Figure 1. Number of permits in the Azul River watershed in the state of Paraná and Brazil



CONSIDERATIONS

This research results have revealed differences in the amount of current permits and permitted outflow to the Azul River watershed for various uses. Agriculture has had the highest demand for water resources, while water collection system has had the highest permitted flows. Aquaculture emerged as the primary purpose for water resource use, having the majority current permits and highest permitted outflows.

The demand of users in the Rio Azul basin cannot be achieved considering the current concession criteria. Further research can be conducted, also considering aquaculture effluents in the basin to analyze other situations that require licensing. Water resource management in the Rio Azul basin requires special attention to water demands and availability.

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