CONTRIBUTIONS OF WATER RESOURCES CHARGES ON THE PARANAÍBA RIVER

Contribuciones de los Cargos por Recursos Hídricos en el Río Paranaíba

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Contribuições da Cobrança de Recursos Hídricos no Rio Paranaíba

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Resumo: O crescimento populacional e a demanda por água exigem que os gestores garantam sua disponibilidade e qualidade. Dentre os instrumentos definidos pela lei nº. 9.433/1997, destaca-se a cobrança pela água. Assim, objetivou-se avaliar a evolução das cobranças pelo uso dos recursos hídricos no Brasil, com ênfase na bacia do rio Paranaíba. A metodologia baseou-se em duas fases, uma de revisão de artigos disponíveis em periódicos da Capes e outra de consulta de planilhas da Agência da Bacia Hidrográfica do Rio Araguari sobre cobrança pelo uso da água sob jurisdição da União na bacia do rio Paranaíba. Os resultados mostraram que a cobrança pelo uso dos recursos hídricos constitui um instrumento relevante para disciplinar e atrair recursos financeiros que permitirão melhorias no planejamento e gestão do uso da água. Vale ressaltar que a irrigação aparece como principal usuária da vazão captada no rio Paranaíba. Contudo, a principal fonte de recursos para arrecadação provém do abastecimento público. Entre as Unidades da Federação, o Distrito Federal revelou-se o maior contribuinte da bacia do rio Paranaíba.

Palavras-chave: Água. Bacia hidrográfica. Instrumentos. Planejamento. Gerenciamento.

Abstract: *Population growth and demand for water require managers to ensure its availability and quality. Among the instruments defined by law no. 9,433/1997, the charge for water stands out. Thus, the objective was to evaluate the evolution of charges for the use of water resources in Brazil, with emphasis on the Paranaíba river basin. The methodology was based on two phases, one of reviewing articles available in Capes journals and the other of consulting spreadsheets from the Araguari River Basin Agency on charging for the use of water under the Union's jurisdiction in the Paranaíba river basin. The results showed that charging for the use of water resources constitutes a relevant instrument for disciplining and attracting financial resources that will allow improvements in the planning and management of water use. It is noteworthy that irrigation appears as the main user of the flow captured in the Paranaíba river. However, the main source of resources for collection comes from public supply. Among the Federation Units, the Federal District proved to be the largest contributor in the Paranaíba river basin.*

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Keywords: *Water. Hydrographic basin. Instruments. Planning. Management.*

Resumen: *El crecimiento demográfico y la demanda de agua exigen que los gestores garanticen su disponibilidad y calidad. Entre los instrumentos definidos por la ley no. 9.433/1997, se destaca el cobro por agua. Así, el objetivo fue evaluar la evolución de las tarifas por el uso de los recursos hídricos en Brasil, con énfasis en la cuenca del río Paranaíba. La metodología se basó en dos fases, una de revisión de artículos disponibles en las revistas de la Capes y otra de consulta de hojas de cálculo de la Agencia de Cuenca del Río Araguarí sobre el cobro por el uso del agua bajo jurisdicción de la Unión en la cuenca del río Paranaíba. Los resultados mostraron que el cobro por el uso del recurso hídrico constituye un instrumento relevante para disciplinar y atraer recursos financieros que permitirán mejoras en la planificación y gestión del uso del agua. Se destaca que el riego aparece como el principal usuario del caudal captado en el río Paranaíba. Sin embargo, la principal fuente de recursos para la recaudación proviene del suministro público. Entre las Unidades de la Federación, el Distrito Federal resultó ser el mayor contribuyente en la cuenca del río Paranaíba.*

Palabras clave*: Agua. Cuenca hidrográfica. Instrumentos. Planificación. Gestión.*

INTRODUCTION

The last decades have been a period of significant institutional reformulation and updating of the water resources management system. It is important to clarify that water, as an essential substance for life, also integrates social relations. Therefore, there is no possibility of separating the circulation of water from anthropic actions, neither of ignoring the hydrological circumstances that affect society. But, its importance reflects consequences for future generations, requiring decision-making by the State.

Based on this, a relationship of interdependence is created between society and water resources, considered a "hydrosocial" cycle (Ióris, 2012), in which this cycle is manipulated to satisfy human needs, giving rise to the intervention process called "water resources management." Problems arising from water resources management, such as producing to meet market demands, ignoring the demand for natural resources beyond ecologically sustainable limits, require a dominant model of water management for a transformation in the role of the State.

When recognizing sustainability as a problem of modern society, two elements arise: the way in which the physical world presents restrictions on the use of resources by society and the way in which the organization of society is reflected in the intensity and patterns of resource use (Pedrão, 2011).

In Brazil, since the implementation of the water resources regulatory framework, there have been different moments linked to the evolution of water resources management, with the main tool being the institution of the National Water Resources Policy - PNRH, through Federal Law n°. 9,433/1997, enabling the reduction of use conflicts, encouraging the rational use of water resources, in order to ensure the quality and quantity of water for current and future demands.

Even with complex and expensive introduction of the institutional structure, in practice, slightly changes have been observed in planning and water resources management. Despite having a solid theoretical foundation, the implementation of the charge was initially slow in Brazil due to disputes within and outside the government. Only eight years after the implementation of the PNRH, during the process of advances and setbacks, a new level of political consensus allowed the National Water Resources Council to approve the operational criteria and priorities for the application of resources from the charge for water use in 2005.

The historic decision of the National Water Resources Council was based on a political agreement between economic groups that realized that, in addition to not threatening their interests, the charge can be highly instrumental to them. Pedrão (2020) highlights that underdevelopment processes are conditioned by the global power struggle and are determined by the final effects of capital and income concentration movements. Even with apparently democratic channels, such as river basin committees, the structure remains dominated by the same economic and political sectors.

Alho da Costa (2022) reports that the pressure exerted by the main water users – large users – on the politicians responsible for implementing the charge is a factor that contributes to the “setback”, even influencing the non-application of instruments in many bodies of water, which are being used deliberately. Large users include companies linked to the public supply, irrigation, mining and industrial sectors, which differ from water users who use it for their survival.

Therefore, instead of charging those directly responsible for the degradation of the aquatic environment, as they are considered large users, the burden is distributed to society, even to those who have never had access to public water and

sewer services in the past. Given this, there is a need to investigate at which stage the charging of water resources from users in the Paranaíba river basin is, as this information will contribute to the control of water resource utilization, which is subject to scarcity and degradation of quality.

The choice of the Paranaíba River Basin was motivated by the recent implementation of charging for water resources on this federal river. Furthermore, the river basin is relevant on the national scene, involving four units of the federation (Goiás, Minas Gerais, Mato Grosso do Sul and the Federal District) with rapid population expansion and demand for water resources.

The Paranaíba River hydrographic basin is the second largest unit in the Paraná Hydrographic Region, occupying 25.4% of its area, and is located between the 15° and 20° south parallels and the 45° and 53° west meridians, with a drainage area of 222.6 thousand km². Positioned in the central region of Brazil, it occupies around 2.6% of the national territory and includes the states of Goiás (63.3%), Mato Grosso do Sul (3.4%) and Minas Gerais (31.7%), and the Federal District (1.6%). The basin has 197 municipalities, in addition to the Federal District (ANA - National Water Agency, 2013).

In this sense, this article proposes to evaluate the evolution of water resources charging in Brazil, with emphasis on the Paranaíba river basin. Also if this manage-ment tool still has improvements to be added besides being a tool to indicate to users the real value of water.

The research is characterized as qualitative, through exploratory research and the use of systematic literature review techniques, with a search in CAPES journals to compile and analyze sets of existing research data, that is, articles published between the dates 2001 and 2022 following the inclusion criteria. The second, quantitative stage involved analyzing the billing data carried out in the Paranaíba river channel provided by ABHA – the Multisectoral Association of Water Resources Users of the Araguari river basin, responsible for implementing the decisions of the Paranaíba River Basin Committee (CBH – Paranaíba).

The review follows a logical order, with an introduction that presents the problem and objective. In the literature review, the evolution of management is addressed, as well as the instruments proposed by the National Water Resources Policy, including water billing. In the methodology, there are two stages: the first involves a bibliographic search in the Capes journals, and the second involves data collection on water billing in the Paranaíba river channel. The results and discussion present the bibliometrics and the data collected on water billing. Finally, considerations and references are made.

2 – LITERATURE REVIEW

As presented by Campos (2013), Integrated Water Resources Management (IWRM) began to be considered internationally in the mid-1970s. In Brazil, the debates were initiated in March 1983 at the International Seminar on Water Resources Management in Brasília, marking the beginning of widespread discussions on the topic at the symposiums of the Brazilian Association of Water Resources (ABRH). By the end of the 1980s, the states of São Paulo and Ceará began reforming their water administration systems by developing water resource master plans.

After the development of these master plans, it was observed that there was a distinct treatment between the drought-prone regions and the humid regions. The issue of water in the semi-arid region was anticipated due to the catastrophic

drought from 1877 to 1879, while the legislation on water in the humid regions of Brazil had a greater influence due to the hydropower sector. In this context, Brazil had two sets of water legislation, one for the humid region and another for the drought-prone region, according to Campos (2013). With the dissemination of new paradigms, state and national policies were strongly influenced, leading to the National Water Law No. 9.433 (Brasil, 1997).

In the context of ensuring availability and future demands without generating conflicts, there were needs to establish goals and limits for the use of water resources available in Brazil to ensure that it would not affect future generations. Therefore, with the publication of Law 9.433/97, all those who used water resources would be held responsible and charged.

Based on the National Water Resources Policy, established by Law 9.433/97 (Brasil, 1997), the National Water Resources Management System (SINGREH) was created, based on Article 1. This text will focus on paragraph II, which refers to the principle that "water is a limited natural resource, endowed with economic value."

Among the instruments offered for water resources management, presented in Article 5 of Law 9.433/97, are:

Article 5. The instruments of the National Water Resources Policy are:
I – Water Resources Plans;
II – Water bodies classification according to their predominant uses;
III – Granting of water use rights;
IV – Charging for the use of water resources;
V – Compensation to municipalities;
VI – Water Resources Information System.

The IV clause (Charging for the use of water resources) will be the instrument used as the basis for all the text developed and discussions that will be raised later. Article 19 aims to recognize water as an economic asset and give users an indication of its real value, with fees charged according to Article 20 for water resources subject to authorization. So, charging for the use of water, under the terms of the Law, aims to conserve these water resources, as well as to provide economic resources for environmental maintenance and consequently for water availability.

Although charging for the use of water resources and, mainly, financial compensation are relatively new mechanisms, they are widely recognized in the literature and more recently in international forums (Carrera-Fernandez and Ferrera de Lima, 1999).

The SINGREH would be responsible for coordinating, arbitrating, planning, regulating, and controlling the use, preservation, and recovery of water resources, as well as promoting charging for the use of water resources. The National Water Agency (ANA), which integrates SINGREH, is responsible for fostering discussions about the charging for the use of these water resources in the Basin Committees, especially in those under federal jurisdiction, such as the Paranaíba river.

According to Santin and Goellner (2013), water resources management as a public policy involving all users and the population were a necessary step to overcome the focus on attacking only localized effects of pollution and increasing demand. The focus on planning and the use of management tools, such as granting the right to use water and charging for its use, have ensured effective results in the recovery, conservation, and better sharing of water resources in countries where they are applied.

Beyond that, the reality brought by Morais *et al.* (2018) is that the model applied for charging management by committees was designed to work

autonomously, but the committees have not yet acquired this autonomy. As the resources from charging for water use were collected, it would give them the conditions to develop without depending on state governments, financially or politically. However, as charging for water use is an essential condition for financial sustainability, and consequently, autonomy will depend on how charging is established in these committees.

Using the water resources legislation to which the Paranaíba Basin Committee is subordinate, participatory planning is implemented in the basin, as according to Oliveira *et al.* (2020), the committee, by participating in water resources policy, ends up defining the direction of the territory. Therefore, when planning something for a particular location in the basin, there may be impacts on the entire basin, both positive and negative, ratified the importance of the role of the committee in applying effective integrated management to plan the future of the watershed.

The analysis of contributions from different sectors in water charges reveals varied patterns. In the context of Brazil, besides irrigation and public supply, the industry and the hydropower sector also play significant roles. Studies show that while irrigation is the primary water user in many regions, the industrial sector can be a major contributor in more urbanized and industrialized areas. For example, in states like São Paulo and Minas Gerais, chemical, food and beverage industries, and steelworks are major water consumers and significant contributors to charges.

Furthermore, the public supply sector exhibits variations depending on population density and the available water distribution infrastructure in different regions (ANA, 2020). The variability in contributions reflects Brazil's economic and climatic diversity, influencing local water resource management policies.

For Pasqualetto *et al.* (2022a) an important detail, which cannot go unnoticed, is the migratory flow that occurred to the Central-West region of Brazil, becoming a breadbasket for grain and meat production. Between 1960 and 2020, the population increase in the region was 675%, demanding greater water consumption.

For charging for the use of Union water resources in the Paranaíba river basin, there is normative nº. 115/2020 (Paranaíba River Basin Committee – CBHRP, 2020), which regulates and provides for the update of mechanisms and values (Table 1).

Table 1 - Unit public prices (UPPs) for charging for the use of Union-owned water resources in the Paranaíba river basin.

Type of use	Sector user	UPP[1]	Unit
Capture	Public Water Supply	0.0345	BRL /m³
	Human Consumption	0.0345	BRL /m³
	Industry	0.0345	BRL /m³
	Mining	0.0345	BRL /m³
Launch	Irrigation	0.0045	BRL /m³
	Animal Farming	0.0045	BRL /m³
	Aquaculture – excavated tank	0.0045	BRL /m³
	Others	0.0345	BRL /m³
	All	0.1837	BRL /Kg

[1] Unit public prices.
Source: Paranaíba River Basin Committee – CBHRP, 2020.

The normative also directs the collected values to be applied according to the water resources plan of the basin. Of these, 60% of the total amount collected is directed to expenses related to the implementation and maintenance of organs and entities integrated into SINGREH, prioritizing the state where it was collected. The collection of updated values is of great importance to CBH Paranaíba, as well as the correct application of these values to improve and ensure the functioning of the entire system, in addition to influencing the autonomy of the committee.

In order of the collection to encourage a reduction in consumption and contribute to the processes of improving quality, it would be necessary to control the volumes withdrawn and used, as well as the organic load present in the sewage water that returns to the system. Thus, the collection could achieve the objective of reducing the volume used per property and improving the conditions of the natural resource (Ladwig *et al.* 2017).

It is also worth highlighting the importance of the quality of these water resources. Jiang *et al.* (2023), when studying Pinglin District, Taiwan, warned us, through hydrological simulations, that under the high emissions scenario (RCP 8.5 - Representative Concentration Pathway), water quality will deteriorate by 2050. BOD (bio-chemical oxygen demand) concentrations) and E. coli in the river will increase by 110.1% and 117.3%, respectively, compared to 2018 levels.

In many municipalities, especially in small rural communities, water quality control is carried out sporadically and the precarious plumbing and collection infrastructure (artesian wells or fountains) makes the system vulnerable to contamination (Marques *et al.*, 2010).

For Stamm (2022), investigating articles on water consumption and economic growth, he observed that the increase in interest on the topic can be justified by the rapid population growth in urban areas, a fact that may not have been accompanied in the same proportions by the infrastructure system cities.

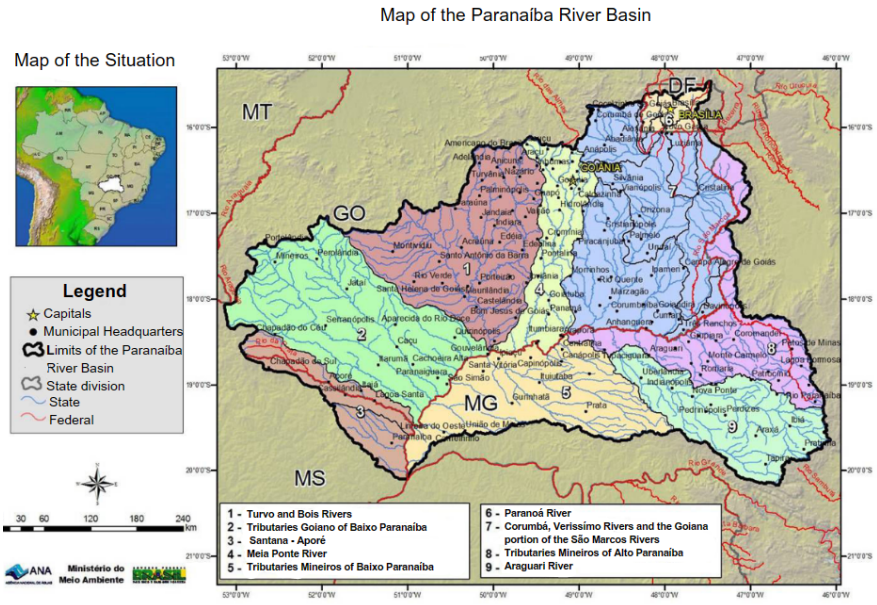
This reinforces the Municipal Master Plan, as an urban policy, as it provides guidelines for achieving sustainable development and promoting the health of the population. Da Silva *et al.* (2000) observed that the Curitiba Master Plan has as an urban policy the objective of carrying out sanitary sewage treatment, as well as preserving the region's water sources.

3 – METHODOLOGY

3.1 - STUDY AREA CHARACTERIZATION

Regarding the Paranaíba river basin (Figure 1), the river originates in Minas Gerais and runs approximately 1000 km, encompassing four Brazilian states: Goiás, Minas Gerais, Mato Grosso do Sul, and the Federal District.

Figure 1 - Paranaíba River Hydrographic Basin (Federation Units: Goiás, Mato Grosso do Sul, Minas Gerais, Federal District), Brazil, 2023.



Source: Regulatory Agency of Water, Energy and Basic Sanitation of the Federal District – ADASA, 2023.

Therefore, the water resources from the Paranaíba river basin are subject to charging since they are under the Union's domain.

3.2 - FIRST PHASE – CAPES JOURNAL ARTICLES

The applied methodology comprised an exploratory investigation. The method used was a systematic literature review, with the interest of compiling and analyzing sets of existing research data (Donato and Donato 2019).

The question of interest was: How is the evolution of water resource charging in Brazil, with emphasis on the Paranaíba river basin? With the intention of answering this question, a research was developed in January 2023, the investigation was directed to studies in Brazil, using CAPES journals, with the interest of analyzing all articles published between 2001 and 2022.

With the previous determination of the question of interest, databases were analyzed through inclusion and exclusion criteria of articles, with combinations of keywords, connected by boolean operators "AND" and "OR": ("Charging" AND "Water resources" AND "Brazil" OR Charning AND "Water resources" AND "Brazil"). The combination of keywords, boolean operators, quotes and parentheses were used as a search mode to limit or restrict information and ensure greater

accuracy of the research. Thus, articles of quality were sought, or in other words, fundamentals that dealt with relevant subjects and were available for analysis (Galvão and Pereira, 2014).

Firstly, the articles were classified, observing aspects such as year of publication, author, journal, field of investigation and justifications for inclusion or exclusion of the article. Based on the registration of the most general information, the titles, abstracts, and keywords of all identified articles were read and verified, to filter the search for articles that clearly discussed water resource charging in Brazil. Regarding the exclu-sion criteria, review articles that were not available in full-text PDF format and articles that were repeated in the platform search were not included. After the initial classifi-cation, in the subsequent stage, the articles were read in full, which made it possible to exclude other works that did not meet the inclusion criteria.

3.3 - SECOND PHASE – FEDERAL WATER RESOURCE CHARGE DATA FOR THE PARANAÍBA RIVER BASIN

With the aid of a data spreadsheet for water resource charges carried out in the Paranaíba river basin in 2021, provided by ABHA – Multisectoral Association of Water Resource Users in the Araguari river basin, responsible for managing the Paranaíba River Basin Committee (CBH – Paranaíba), data were compiled and presented in figures and tables.

Among the analyzed variables were:

a) Purpose of water resource use: Among the uses charged in the Paranaíba river basin, they were classified as follows: Public Supply, Aquaculture in Excavated Tanks, Human Consumption, Animal Husbandry, Sanitary Sewage, Industry, Irrigation, Mining – Sand/Gravel Extraction, Mining – Other Extractive Processes, and finally, other purposes.

b) Users by Purpose (Unit): The total number of users per type of water resource use charged in the Paranaíba river basin was quantified.

c) Withdrawal Flow (m^3): The volumes withdrawn and charged for different purposes were measured.

d) Discharge Flow (m^3): The volumes of discharge resulting from post-use of water resources were measured.

e) Amount Charged (BRL): The revenues obtained from the charge for water resources extracted from the Paranaíba river basin were quantified by purpose of use and federal unit.

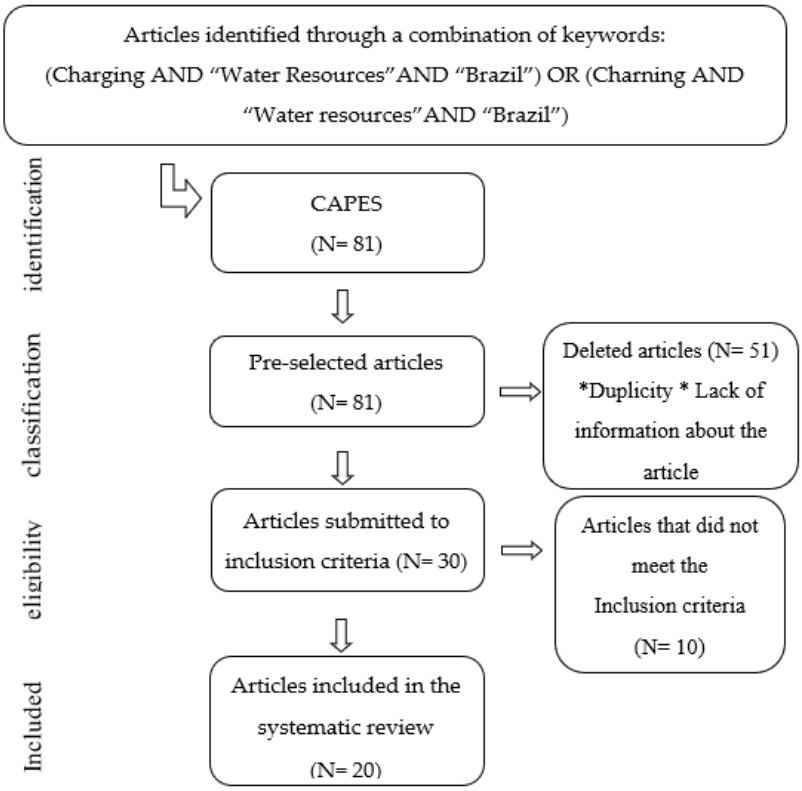
Finally, the main municipalities that contribute the most to the revenue (BRL) from the water resource charge in the Paranaíba river basin were listed, according to the main purpose of use.

4 – RESULTS AND DISCUSSION

4.1 - BIBLIOMETRIC ANALYSIS

The total number of articles found in the Capes journals, which composed the final database, was 81 (Figure 2).

Figure 2 - Flowchart of the research and classification of articles that evaluated water pricing as a management instrument for water use, obtained from Capes, until the year 2022.



Source: authors (2021).

Out of the 81 pre-selected articles, 51 were excluded due to duplication or lack of information. Then, the remaining 30 articles were read, and of these, 10 were excluded for not meeting the central theme of the research question. Finally, 20 articles met the inclusion criteria. Among the articles found, all were published from 2010 onwards and were updated each year, with the latest published in 2022. Articles published in the last 5 years were found, counting from 2015 (1), 2016 (1), 2017 (1), 2018 (3), 2019 (1), 2020 (1), 2021 (1), and 2022 (1), with 2018 being the standout year with the most publications on the subject.

In Table 2, the main conclusions observed in the selected articles on water resources charging in Brazil are presented.

Table 2 - Main conclusions observed in the selected articles on water resources charging in Brazil.

Studies	Main conclusions
Alencar et al. (2018)	The implementation of water charges in the Rio Grande basin is feasible, indicating irrigation as the activity that most uses water in the basin. Furthermore, it is suggested not to establish a limit for the economic impact on the agricultural sector, or to establish it at a significant value to encourage rational water use.
Alho da Costa (2022)	Charging for the use of water resources can be an important strategy to ensure the sustainable use of these resources in Brazil. The participation of society in the definition of charging policies and water resource

Studies	Main conclusions
	management is of significant importance to ensure equity and transparency in the process, requiring clear and effective legislation.
Almeida and Curi (2016)	It highlights that integrated water resource management involving the participation of different actors and joint actions is essential to ensure the availability of water for all uses and users. Finally, it is suggested that the implementation of public policies and incentive programs, such as tax reductions for companies that use sustainable practices, can help promote sustainable water resource management.
Campos (2013)	Integrated water resource management is a relatively recent and complex challenge that requires the adoption of conservation measures and rational water use, as well as the promotion of public policies and actions that encourage society's participation in water resource management.
Demajorovic et al. (2015)	Charging for water use can incentivize companies to adopt more sustainable and efficient water practices. The authors point out that charging can stimulate companies to invest in more efficient technologies, reduce waste, and promote water recirculation and reuse. However, water charging is not the sole solution for sustainable water resource management.
Ferreira and Oliveira-Filho (2021)	Farmers have a limited understanding of the importance of paying for water use and how this system can contribute to sustainable water resource management. While some farmers are willing to pay for water use, the majority do not recognize the need to financially contribute to water resource maintenance.
Ióris (2012)	Water resource management in Brazil has a long history marked by progress and setbacks. Despite advances in water resource management in recent decades, significant challenges remain, such as lack of financial and human resources, water pollution, and water scarcity in arid and semi-arid regions
Ladwig et al. (2017)	Charging for water use in irrigated rice production in the southern region of Santa Catarina can have a significant impact on production costs, especially for farmers with lower economic power. The study shows that costs vary according to river flow and users' capacity to pay for water, which can lead to inequalities in agricultural production and water distribution.
Leite and Vieira (2010)	Charging for water use can incentivize companies to adopt more sustainable and efficient water practices. The authors point out that charging can encourage companies to invest in more efficient technologies, reduce waste, and promote water recirculation and reuse. However, water charging is not the only solution for sustainable water resource management.
Lima et al. (2019)	Farmers have a limited understanding of the importance of paying for water use and how this system can contribute to sustainable water resource management. While some farmers are willing to pay for water use, the majority do not recognize the need to contribute financially to the maintenance of water resources.
Morais et al. (2018)	Water resource management in Brazil has a long history marked by progress and setbacks. Despite advancements in water resource management in recent decades, it still faces significant challenges such as lack of financial and human resources, water pollution, and water scarcity in arid and semi-arid regions.
Odppes et al. (2018)	Charging for water use in irrigated rice production in the southern region of Santa Catarina can have a significant impact on production costs, especially for farmers with lower economic power. The study shows that costs vary according to river flow and users' payment capacity, which can lead to inequalities in agricultural production and water distribution.
Santin and Goellner	The use of the Shapley value can be an efficient methodology for charging

Studies	Main conclusions
(2013)	for water use in river basins, especially in situations of high complexity and socioeconomic heterogeneity.
Oliveira et al. (2020)	Cost sharing is an effective tool for water resource management and can help incentivize the adoption of sustainable practices in the region. Additionally, the study highlights the importance of participation and cooperation among different stakeholders involved in watershed management.
Resende Filho et al. (2011)	Charging for water use can lead to improved technical efficiency in water and input use in agricultural production.

Source: authors (2021).

It is evident in the authors' conclusions the importance of charging for water resource use, the need for social participation, the determination of a fair and appropriate value for the purpose, as well as incentives for sustainable practices that allow for consumption reduction and improvement in the quality of discharged effluents.

4.2 - FEDERAL WATER RESOURCE CHARGING IN THE RIO PARANAÍBA

Table 3 presents the data on the withdrawal and discharge flow (m^3), number of users by purpose (Un), and charged amount (BRL) for federal water resources in Rio Paranaíba (Table 3).

Table 3 - Users by purpose, withdrawal, and discharge flow (m^3), and charged amount according to the purpose of use of water resources extracted from the Rio Paranaíba channel (Federation Units: Goiás, Mato Grosso do Sul, Minas Gerais, Federal District), Brazil, 2021.

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Purpose	Users by Purpose (Un)	Capture Flow (m^3)	Discharge Flow (m^3)	Charged Value (BRL)
Public Water Supply	17	284.626.793,76	119.275.453,99	4.901.701,50
Aquaculture in Excavated Tanks	18	2.707.809,05	2.707.809,05	5.696,54
Human Consumption	13	114.548,87	114.548,87	2.428,3
Animal Farming	18	84.575,04	84.575,04	382,33
Sanitation	15	179.616.266,40	80.239.275,29	200.960,02
Industry	27	150.514.764,83	76.497.409,35	2.336.543,73
Irrigation	716	655.348.081,44	473.418.684,75	1.267.277,54
Mining - Sand/Gravel Extraction	11	866.012,00	866.012,00	15.706,45
Mining - Other Extraction Processes	7	24.766.923,28	24.640.923,28	382,33
Others	45	5.908.888,54	5.289.001,82	110.986,74

Source: ABHA (2021).

According to the data presented in Table 3, it is possible to observe that the purpose with the highest capture flow is irrigation, followed by public supply and sewage treatment. However, when analyzing the value charged per purpose (Figure 3), it is seen that the highest revenue comes from public supply, followed by industry and ir-rigation. Therefore, even if the purpose has the highest capture flow, its value charged in the Rio Paranaíba riverbed will be established differently through the value table presented by Normative Instruction nº. 115/2020.

The justification is that irrigation, despite having the highest volume of water intake, its value is based on the market and its real purpose. If its charge increases, it may become unfeasible for activities that use irrigation, especially agriculture, or in the worst-case scenario, it would increase production costs, ultimately affecting the final selling price.

According to Ladwig *et al.* (2017), if the charge increases, agricultural producers will consider water as a significant input cost, which may lead to water rationing to maximize its use, prevent waste, and reuse water in the system. Although the market price is variable, it can be below or above the profit price of the production, which may vary throughout the agricultural year. In other words, if production costs are high, it may be an obstacle to implementing water use charges.

Irrigation, as the primary user of water resources, has a considerable impact on water availability and quality. Inadequate irrigation practices can lead to overexploi-tation of surface and groundwater resources, causing water level reductions and af-fecting quality due to nutrient and agrochemical leaching. Regarding the evolution of water use charges, basins such as the São Francisco and Doce Rivers have implement-ed charging systems similar to those of the Paranaíba Basin. These systems aim to encourage rational and sustainable water use, promoting conservation and basin recovery through tariffs reflecting the consumed volume and users' payment capacity. The implementation of these systems in various basins has shown that, although there is initial resistance, acceptance increases with the perception of improvements in water resource management and quality.

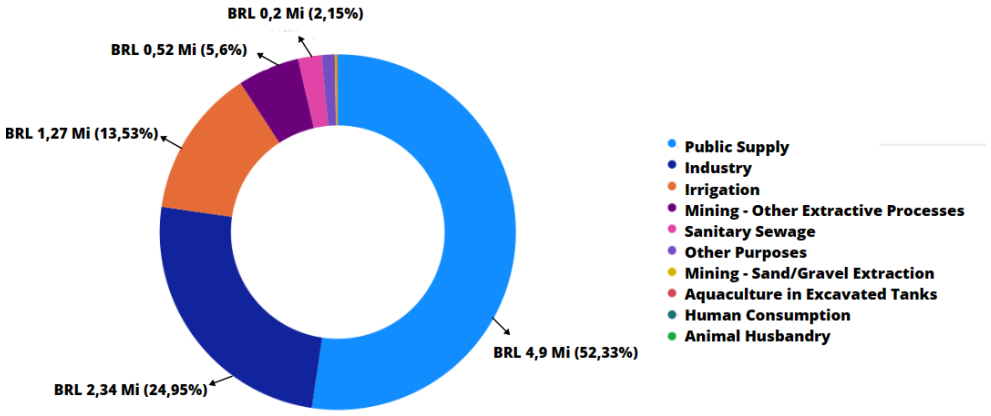
Not only in the Rio Paranaíba basin, but according to the survey conducted by Alencar *et al.* (2018), irrigation agriculture is also the sector that most uses water, accounting for 46.4% of the authorized flow in the Rio Grande basin located in the Brazilian Cerrado.

According to Pasqualetto *et al.* (2022b) between 2010 and 2020 there was an intensification of requests for federal water resource grants in Goiás; the greatest demand is concentrated in the Paraná river hydrographic region, that is, the Paranaíba river basin, which has 66% of its catchment area in Goiás, and is also the state hydrographic basin with the largest population.

It is necessary to implement new charging mechanisms indicated by the Committees for the Integration of the Paraíba do Sul River Basin (CEIVAP) and the Piracicaba, Capivari, and Jundiaí River Basin Committees (PCJ). These mechanisms' parameters are aligned with the activities existing in the basin, which can be an option to implement the CBH Paranaíba model since the difference in water intake and charges for irrigation can be observed.

Figure 3 shows the distribution of the predominant purposes by the Federal Units that compose the Rio Paranaíba Basin, namely the states of Goiás, Minas Gerais, Mato Grosso do Sul, and the Federal District.

Figure 3 - Distribution of revenues (BRL) and most used purposes of use in the Federation Units (Goiás, Mato Grosso do Sul, Minas Gerais, Federal District), Brazil, 2021.



Note: Absence of data that designates the purpose, therefore, they were classified as others.
Source: ABHA, 2021.

Considering that the data available in the spreadsheet contained the purpose, but occasionally lacked the Federal Unit to which it was intended, it was decided to group this incomplete information into an item called "others". In other words, they are waters taken from the Paranaíba River channel by users, charged and intended for the listed uses, but without cataloging the Federal Unit to which it belongs. It is necessary to improve the internal processes of the Paranaíba River Basin Agency and the control mechanisms of the Paranaíba River Basin Committee, as well as the National Water Agency – ANA.

By far, the main revenue is intended for public water supply, accounting for 52.33% and a revenue of R$ 4.9 million (Figure 3), although it is not the main volume captured (m3) since this occurs for irrigation (Table 1). The industry is present in second place with 24.95% and R$ 2.34 million, almost half of the uses and values attributed to public water supply. It is noteworthy that the use of water for irrigation, in third place, with 13.53% and revenue of R$ 1.27 million.

Since public water supply leads the revenue, and mostly comes from urban areas that will also generate proportional discharges, it is worth noting what Leite (2010) reports, that an added value could be charged for the use of water associated with its high levels of effluent emissions, serving as a stimulus for this sector to adopt less pol-luting practices, such as treating their sewage, which is discharged into rivers without any control most of the time. This scenario of the basin with a high level of pollution due to the precarious situation of urban sanitation is verified in cities, in such a way that the effect of sewage discharge into the waters can reach unsustainable levels if the urban sector is not properly charged or stimulated to adopt more rational practices in the use of water.

Even though irrigation is the third largest revenue generator, there is no relation to the volume of water extraction, as it is the leader in water usage. This shows, as stated by Ladwig *et al.* (2017), that the value charged for water will depend on the purpose of its use. In theory, those who consume more or pollute more should pay more for the use of water resources. However, in practice, the analysis shows that the establishment of water charges is associated with the purpose for which it is used.

Regarding industry, as the second largest revenue-generating sector and due to its importance as noted by Demajorovic *et al.* (2015), there is a need to advance in the

revision of prices applied to water consumption in the industrial sector, in order to find a value that will influence rational use of water in companies, or even adoption of water reuse. Among the purposes with the highest demand for water usage, according to Odppes *et al.* (2018), increasing the tariff for water usage following the national trend can directly affect the average production cost for the industrial sector, and adopting water reuse or rationalization techniques could be an option.

Thus, Almeida and Curi (2016) emphasize that integrated water resources management, involving the participation of different actors and joint actions, is essential to ensure the availability of water for all uses and users. Finally, they suggest that the implementation of public policies and incentive programs, such as tax reduction for companies that use sustainable practices, can help promote sustainable water resources management such as water reuse.

Lima *et al.* (2019) describe that the increase in price related to water charges was low (0.04-0.09% of production costs), indicating that it can be absorbed by the industry. On the other hand, the revenue generated by the basins can be decisive for the implementation of various actions aimed at average water quantity and quality, which is good for the industry itself. By presenting this, it is seen that there is a need for the revision of values, and yet, it should not significantly affect the production cost of industries.

Table 4 displays the charges for the use of water resources according to their purpose and the Brazilian state to which the Paranaíba river basin belongs.

Table 4 - Total values charged for water resources (BRL) according to the purpose of use and the federal unit belonging to the Paranaíba River Basin, Brazil, 2021.

Federation units (Brazil)	**Charged value (BRL)**
Distrito Federal	4,737,768.55
Goiás	2,430,934.15
Minas Gerais	1,943,371.74
Mato Grosso do Sul	68,464.44
Others	185,935.91

Notes: The absence of data that designates the UF, therefore, they were classified as others.
Source: ABHA (2021).

Of the federal charges in the channel of the Paranaíba River, the Federal District, despite having a smaller area than the state of Goiás, stands out in revenue, with almost double the amount collected. Goiás has approximately 2/3 of the Paranaíba river basin, which has its channel dividing with the state of Minas Gerais in its greatest extension. Goiás's responsibility is amplified in this scenario, and it should improve management mechanisms, especially regarding the charging for the use of water resources.

It can be observed that there are values recorded, but without reference to which state the users belong, demonstrating that the data requires greater control in entering the information in the spreadsheet provided by ABHA – Multisectoral Association of Water Resource Users of the Araguari River Basin.

At the federal level, the charging is still being instituted, meaning it is in the pro-cess of evolution, and the last milestone was precisely the beginning of charging in the Paranaíba river basins in 2017, only 20 years after the establishment of the

PNRH, which makes the basin's charging management susceptible to failures, as well as ad-justments for improvement. According to Alho da Costa (2022), in terms of the profile of the main users in each basin, there is a different majority-demanding agent, in the case of the Paranaíba River, it is the sanitation activity, usually related to public service, and it is rare for a private demander to be the most expressive within the context being analyzed.

Seeking to identify the municipal units most associated with the demand for water, the purpose of use, and the total collected, the federal capital stands out (Table 5).

Table 5 - Municipalities with the greatest demand for water resources in the Paranaíba River bed and their main purpose in the Federation Units (Goiás, Mato Grosso do Sul, Minas Gerais, Federal District), Brazil, 2021.

Municipalities	Predominant purpose of water resource use
Brasília	Irrigation
Catalão	Irrigation
Araporã	Irrigation
Santa Vitória	Irrigation
Davinópolis	Mining - Other Extraction Processes
Itumbiara	Irrigation
Ouvidor	Mining - Other Extraction Processes
Chapadão do Céu	Irrigação
Goiânia	Sanitary Sewage

Source: ABHA (2021).

It can be noticed from the predominant uses that irrigation is especially important in the areas surrounding Brasília, Santa Vitória, Araporã, and Catalão, suggesting the need for improved control and monitoring of these predominantly agricultural activities. For municipalities whose main activity is irrigation, Ladwing *et al.* (2017) states that cost can naturally be a limiting factor for staying in the agricultural business, especially when profits are reduced. On the other hand, following the function of the charging instrument, if the values are too low, the amount collected will not be suffcient for the environmental maintenance of SINGREH and the necessary investments in improvement actions in the hydrographic basin.

According to Ferreira and Oliveira-Filho (2021), many farmers have a limited understanding of the importance of paying for the use of water and how this system can contribute to sustainable management of water resources. Although some farmers are willing to pay for the use of water, the majority do not recognize the need to contribute financially to the maintenance of water resources.

Nevertheless, attention should be given to adopting strategies for other purposes that aim to minimize the use of water resources, such as a possible value, using averages of what is charged in other basins as an example, to show the real value to users of water resources from the Paranaíba River channel and consequently compare and adjust with the values reached, which are already charged and adequate to the needs of the channel or basin, as according to Resende Filho *et al.* (2011),

charging for water use can lead to an improvement in the technical efficiency in the use of water and other inputs in agricultural production.

Starting from the purpose with the highest usage, which is irrigation, an important point in terms of charging rule is the exemptions that may generate externalities that will negatively impact the economic situation of the basin. For example, in the case of irrigation in properties with the "small farmers" fiscal module, the producers may be exempt from the charge for the use of water (Alho da Costa 2022).

Equality and balance are the important factors that affect payments. To avoid conflicts in water demand between economic and environmental development. Based on social equity, research carried out by Fu *et al.* (2018) reveals that interval values should be used depending on the quantity and quality of the water, depending on the stretch of the river. What can be added by analyzing anthropogenic pressure due to demand for different uses.

In turn, Hao *et al.* (2021) propose an Ecological Compensation mechanism: The model suggests that downstream regions (Guangdong Province) compensate upstream regions (Fujian Province) for maintaining ecological flows. The model considers five hydrological scenarios (extreme dryness, dryness, normal flow, abundance and ex-treme abundance). Under these scenarios, the range of economic benefits and ecological compensation values is adjusted to provide more accurate and flexible decision-making options for water resource management.

Wu *et al.* (2021) analyzing 30 cases of water rights negotiations in China since 2016, the authors established a response function of the price of negotiations to the water scarcity index. They concluded that the price of negotiations should be adjusted annually based on the increase in the scarcity index. A system for assessing the scarcity of water resources was built based on four dimensions: natural endowment of water resources, supply of water resources, demand for water resources and water environment.

Serrano and Valbuena (2021), in their studies, found that European countries managed, in part, to dissociate economic growth from water consumption. Water resource management policies and sustainable international trade practices have been effective in reducing water use intensity in many sectors. Water-scarce regions can import products that require a lot of water to produce, thus relieving pressure on their own water resources.

The interaction between formal institutions (the state), users and civil society is crucial to promoting effective self-governance. The perception of water scarcity affects everyone's behavior. Communities that perceive greater water scarcity are more likely to monitor and implement sanctions to ensure compliance with the rules (Engler *et al.*, 2021).

Considering the need for integrated management of water resources, especially due to the concentration of the population in coastal cities, Chen *et al.* (2021) propose a conceptual framework for integrated management "from source to tap", which consid-ers the entire water system from capture to consumption.

CONCLUSIONS

The objective of this study was to evaluate the evolution of the charging for the use of water resources in Brazil, with emphasis on the Paranaíba river basin.

The management of water resources in Brazil took a long time to be implemented, becoming more serious after the National Water Resources Policy.

From this point on, the evolution in the management of charging for the use of water resources began. Although the management of these resources only reached the Paranaíba river basin twenty years after the National Water Resources Policy, proposing that the Paranaíba River Basin Committee is evolving, it has not developed enough to guarantee the demands (current and future), through the current values collected, according to the purpose of use.

Thus, the charging for the use of water, under the terms of Law 9433/1997, proves to be an instrument for the economy of water resources, however, the charging for the use of water from the Paranaíba river basin is considered recent for basin management, making it subject to flaws.

Irrigation stands out as the main consumer of water resources, however, given the lower price charged for captured water, it is not the main financial contributor. The supply sector is what contributes most to the collection and ends up passing it on to the end consumer. It will be up to society to find the fair value for each segment, so that they are not subsidized to the detriment of others.

The implementation and effectiveness of water use charges face several challenges, as identified in the literature. One of the main challenges is user resistance, especially in sectors that traditionally did not pay for water use or paid very low fees. Additionally, inadequate infrastructure for water use measurement and monitoring hinders the precise application of tariffs. There are also challenges related to governance and coordination among different levels of government and agencies responsible for water resource management. Transparency in the use of collected funds and the perception of tangible benefits are crucial for the acceptance of charges. Finally, cli-mate variability and changes in hydrological regimes, exacerbated by climate change, pose additional challenges for effective implementation and adaptation of water charging policies.

There is a need for adjustments to improve and evolve the existing charging, to find a more adequate value, which can be based on other basins, but taking into consideration the reality presented by the specific river basin. Finding an adequate value is a difficult task, however, the low value of the charging does not stimulate the deepening of management, including the generation of sufficient financial resources for investment in the preservation of the water quality of the Paranaíba river basin.

Among the limitations encountered are the consolidation of databases in the management bodies, which will support decision-making and definition of water resource charging values.

For future work, it is suggested to analyze, in addition to charging for water resources, the effectiveness of the application of resources in the multi-annual plans defined by the Paranaíba River hydrographic basin committee in light of the Hydrographic Basin Plan.

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