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SCIENTIFIC PRODUCTION SUPPORTED BY LIMNOLOGICAL RESEARCH IN PORTUGUESE-SPEAKING COUNTRIES AND LEGISLATION RELATED TO SUSTAINABLE DEVELOPMENT GOAL 6 (SDG 6) IN CPLP MEMBER STATES

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Abstract

This study aimed to analyze limnological scientific production from 1996 to 2022 within the community of Portuguese-speaking countries. Additionally, the study investigates the decline in scientific production in 2022, potentially associated with the post-COVID-19 pandemic scenario, which brought challenges to global knowledge production. To achieve the objectives of this study, bibliographic data from scientific articles published between 1996 and 2022 in indexed journals were collected and analyzed based on scientometrics, using the ISI Web of Science (WoS). Furthermore, official websites of each selected republic were used to survey the main laws, regulations, and environmental policies in force. The data collection included the number of publications per year, and the analysis thus encompassed the geographic distribution of research with a focus on Portuguese-speaking countries, as well as the relationship of the legislation with SDG 6. The analysis results indicated a remarkable increase in the number of scientific publications in Limnology and Water Resources between 1996 and 2022. This growth could be attributed to the increasing recognition of the importance of these areas in the context of sustainable development and the preservation of water resources.

Keywords: Limnology. Aquatic Ecosystems. Community of Portuguese Speaking Countries.

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1 Introduction

In a world where environmental and social challenges are becoming increasingly interconnected, the socioecological approach has gained prominence, with an emphasis on the participation and collaboration of multiple stakeholders, including scientists, local communities, governments, non-governmental organisations, and even the private sector (ANDRADE; FREITAS, 2021).

Considering the fact that Limnology is a social science, topics such as conservation, management and restoration of aquatic ecosystems have received support from its specialists who carry out the mission of subsidising the maintenance of life on Earth. The demand for drinking water is growing worldwide, which involves the search for water resources for purposes such as potable water, food, electricity, construction, industrial supply, and leisure, among others.

In Angola, Brazil, Cape Verde, Guinea-Bissau, Equatorial Guinea, Portugal, Mozambique, São Tomé and Príncipe, and Timor-Leste, researchers have dedicated themselves to study the ecology of their water bodies, addressing topics such as water quality, aquatic community structure, biogeochemical cycles, phylogenetics, and other fundamental aspects for understanding and managing these ecosystems (AFONSO; FERNANDES; SERRANO, 2021; AMO et al., 2017; PACA et al., 2019; GHERMANDI et al., 2019; OLIVEIRA, 2020; ALMEIDA et al., 2020; ROMEIRAS et al., 2023; SAMBOU; DIOUF; SARR, 2023). By being part of this community, these countries share, based on their own cultures, the unique objective of caring for the environment, especially in the area of limnology.

In this study, the social aspect cannot be excluded from the discussion, as the current scenario of social inequalities, expressed by indicators such as Gross Domestic Product (GDP), Human Development Index (HDI), and low literacy rates in a country (IMF, 2022), may aid in understanding the effects of inequalities on the presence and consolidation of public policies.

Thus, the objective of this research is to examine scientific production in Portuguese-speaking countries, aligning the production with a comparative analysis of legislation. To this end, a survey of the main laws, regulations, and environmental policies in force was conducted using the official websites of each selected republic.

The data collection included the number of publications per year, and the analysis, therefore, covered the geographical distribution of research focusing on Portuguese-speaking countries.

In the case of legislation, the study explored its relation to Sustainable Development Goal (SDG) 6, which aims to ensure the availability and sustainable management of water and sanitation.

By 2030, SDG 6 seeks to achieve universal and equitable access to safe and affordable drinking water for all. The hypothesis of this investigation posits that limnological research in Portuguese-speaking countries has shown exponential growth in recent years, reaffirming the increasing value of the topic in the international scientific debate.

2 Material and Methods

To conduct this bibliographic survey, we used the ISI Web of Science (WoS) database (https://clarivate.com/academia-government/scientific-and-academic-research/research-discovery-and-referencing/web-of-science/web-of-science-core-collection/). The choice of a single platform was justified by the scope of the study. The aim was to identify limnological production in Portugal, Brazil, Angola, Mozambique, Cape Verde, Guinea-Bissau, Equatorial Guinea, São Tomé and Príncipe, and Timor-Leste.

The keywords were organised into three different groups, connected by "AND":
Aquatic Ecosystems: (Water resources OR reservoirs OR lakes OR rivers OR lagoon OR lake OR wetland OR dam OR lagoon OR stream OR floodplain);
Management and Conservation of Water Resources: (monitoring OR sanitation OR water security OR conservation OR sustainable OR legislation OR threats OR management OR global goals OR eutrophication); AND
Portuguese-Speaking Countries: (Portugal OR Brazil OR Angola OR Mozambique OR Cape Verde OR Guinea-Bissau OR São Tomé and Príncipe OR Equatorial Guinea).

The choice of the English language was made due to its broader reach for scientific publications. To ensure that only articles related to the theme were included in the analysis, additional filters were applied: "water resources, limnology, ecology, oceanography, fisheries".

For exclusion criteria, factors such as the "Origin of the Study," the "Main Topic of the Article," and "Availability of the Article" were considered. Inclusion, therefore, only occurred when it was confirmed that the article originated from Portuguese-speaking countries, had the main topic within the limnological context of CPLP, and the article was fully accessible (Table 1). After this stage, a survey was conducted on the legal framework and its relation to SDG 6. At this phase, a survey of the main laws, regulations, and environmental policies in force was carried out. For this, the official websites of each selected republic were accessed.

Table 1. Criteria for Inclusion and Exclusion of Articles in the Review.

CRITERIA	INCLUSION	EXCLUSION	JUSTIFICATION
Origin	CPLP	Outside CPLP	Sample Representation
Main Topic	Limnology/ CPLP	Outside the inclusion criteria	Maintaining the scope
Availability	Full Availability	Partial Availability	Ensuring Easy Access

The identification of the legislation discussed here established, as an inclusion criterion, the availability of legal norms on official websites of each republic, focusing exclusively on water or water resources legislation. All norms that exceeded this limit were excluded from the analysis, and only those dealing specifically with water resources were included.

Subsequently, the strategies and actions in each country were evaluated in relation to their orientation toward the implementation of SDG 6, which aims to ensure the availability and sustainable management of water and sanitation for all by 2030.

The topics related to water resources were categorised, including "water resources policies," "watershed management," "water use rights granting," and "hydrological yield control." Similarly, topics associated with SDG 6, such as "access to clean water and sanitation," "water use efficiency," and "protection of aquatic ecosystems," were also categorised for comparative analysis. In this stage, the comparative analysis was conducted considering the following aspects:

a) Coherence between Legislation and SDG 6: This involved assessing the alignment between each country's environmental legislation and the content of SDG 6, identifying how the goals and targets of SDG 6 are addressed in national legislation, and looking for evidence of compliance with laws and regulations related to water resources protection and SDG 6.

b) Social Participation: It was examined whether civil society and local communities participated in water resources protection policies and actions aimed at achieving SDG 6.

c) Management Instruments: The water resources management instruments adopted in each country were evaluated, as well as the strategies for implementing SDG 6, such as action plans, programs, and projects when suggested in the legal framework.

3 Results and Discussion

3.1. Articles Included in the Review

The process of identifying, excluding, and including articles is an essential step in scientific research, as discussed here, since it ensures the quality and relevance of the studies being analysed. In this case, a total of 4,674 articles were identified, representing a dataset that required careful screening.

The application of the exclusion process, as mentioned, resulted in a significant reduction of this number to 673 articles. This selection process proved to be crucial in ensuring that only studies relevant to the theme and meeting the inclusion criteria were considered in the analysis (Figure 1).

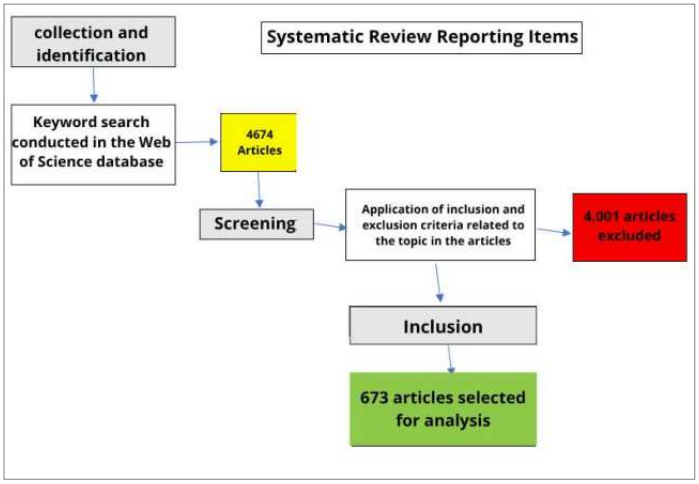


Figure 1. Process of Including Articles on Limnology Published in the CPLP Member States.

It is interesting to note that, after the exclusion process, the 673 articles were distributed among the 9 member countries of the Community of Portuguese Language Countries (CPLP). This aspect highlights the geographical scope of the research, addressing different realities and contributions from each nation to the body of knowledge analysed.

Figure 2, which represents this distribution, serves as a tool for understanding how the articles are spread across the member countries. This representation of geographically diverse approaches not only enriches the research but also provides insight into the different perspectives and contributions within the CPLP.

The analysis of these 673 articles can reveal trends, research gaps, and areas of prominence in each country.

Moreover, the diversity of cultural, social, and economic contexts present in the member countries may influence the research findings, offering a multifaceted reading of the subject under analysis.

Thus, the process of identifying and excluding articles, combined with the geographical distribution of the 673 articles across the 9 member countries, enriched the research by incorporating perspectives from the CPLP on limnological production. This contributes to a better understanding of the subject, benefiting both the academic community and those interested in the themes addressed.

Of the 673 articles identified, 285 were from Brazil, 338 from Portugal, 36 from Mozambique, 7 from Cape Verde, and 4 from Angola. In São Tomé and Príncipe (2) and Guinea-Bissau (1), the number of studies remained below 2, while Equatorial Guinea and Timor-Leste had no publications during the period analysed (Figure 2).

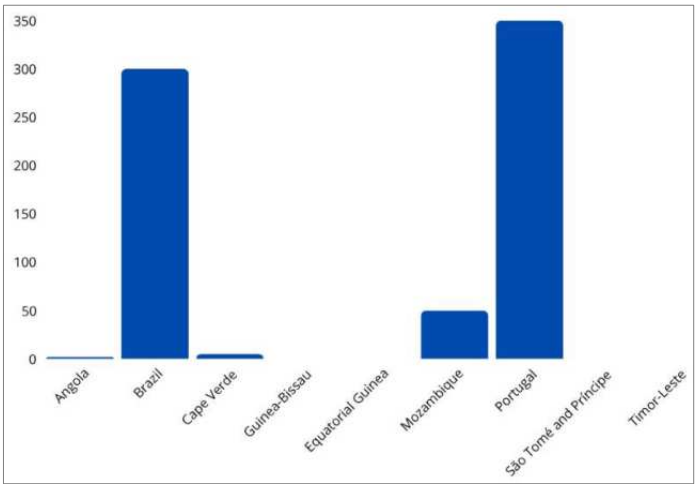


Figure 2. Distribution of Limnology Publications by CPLP Member States.

The distribution of limnology publications among the member states of the Community of Portuguese Language Countries (CPLP) revealed a growing trend over time, highlighting the interest and engagement of these nations in research within this specific field. An analysis of the period from 2006 to 2014 showed a remarkable increase in the number of studies conducted.

In 2006, the number of published studies was initially identified, marking the beginning of this analysis period. However, it was from 2009 onward that a significant increase was observed, with 31 articles published annually, representing considerable growth compared to previous years. Based on the results, it can be concluded that this notable rise in scientific output suggests growing interest and research activity in limnology among CPLP Member States.

The peak of this growth occurred in 2011, when 31 articles were again published. This period stood out for the continued consolidation of interest among these nations in the field of limnology. However, between 2012 and 2013, a decline in the number of publications was observed, with both years presenting 24 articles, indicating possible stabilisation or variation in scientific production during this timeframe.

Surprisingly, in 2014, the scientific output on limnology showed exponential growth compared to previous years. The number of articles published doubled that of 2013, totalling 43 publications in that year. This remarkable increase indicates a revitalisation of interest and renewed engagement from CPLP member states in limnology research (Figure 3).

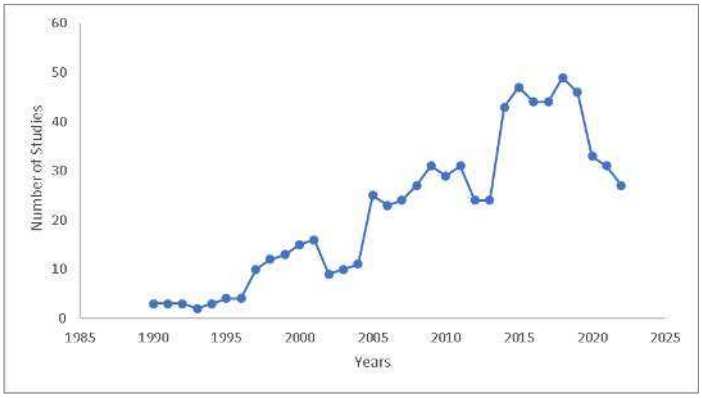


Figure 3. Number of Limnology Studies Over Time by CPLP Member States.

Thus, the analysis of the results reveals a growth trend in the number of published articles over the years, as catalogued by the ISI Web of Science database. Since the beginning of the cataloguing, the maximum number recorded in a single year was 31 articles. However, in the six subsequent years, the number ranged between 43 and 49 articles, with 2018 being the year of the highest output, totalling 49 articles.

A comparison between the year 1996, which recorded only 6 articles, and 2018, with its 49 articles, shows an increase of 817% over this period. This substantial growth not only illustrates the evolution of research in the field but also indicates a growing interest in the subject over time, as previously noted by Amo et al. (2017).

This increase in article production suggests greater awareness and involvement of the academic community, supporting argument from Oliveira (2020) that there has been a growing and sustained interest in the investigation and dissemination of knowledge related to the field of limnology worldwide.

In this context, the year 2018, in particular, stands out as a significant milestone, indicating a peak in academic activity and a strong commitment to research.

This growth can also be interpreted as an indicator of the field's maturity and consolidation, as pointed out by Romeiras et al. (2023). This idea is reinforced by the increasing awareness of the importance of research in the area over time, as demonstrated by the results presented here. Furthermore, it is important to highlight that the dissemination of information and advances in technology may have contributed to the expansion of scientific output, reflecting the dynamism and vitality of the academic community.

3.2. Impact of COVID-19 on Scientific Publication Output

However, in 2019, a series of changes occurred in the global scientific landscape, notably driven by the COVID-19 pandemic (INOMATA et al., 2021). These changes contributed to a decline in production during the subsequent years—2019, 2020, 2021, and 2022—with the largest drop observed in 2022, when only 22 articles were published.

The global event of the COVID-19 pandemic not only triggered a worldwide health crisis but also caused significant shifts in the scientific environment. Inomata et al. (2021), when discussing the pandemic's influence on scientific article publication, highlights the complexity of challenges faced by the scientific community amid the unexpected and widespread changes in living conditions, work, and social interactions.

Cruz et al. (2021), addressing the topic, emphasise that the transformations imposed by the pandemic presented significant challenges to the world of science. Rapid adaptation to new realities, restructuring of research methodologies, and the pursuit of innovative solutions became imperative in response to the restrictions and uncertainties introduced by the health crisis.

The citation by Cruz et al. (2021) highlights that the changes caused by the pandemic are not limited to the scientific realm but also affect living conditions, work, and social interactions. The widespread impact of these changes inevitably reflects on the production and dissemination of scientific knowledge.

It is crucial to recognise that the temporal scope of the pandemic may extend for a substantial period, as warned by Cruz et al. (2021). This prolongation suggests that the effects of COVID-19 on contemporary science and society will not be fleeting.

On the contrary, its influence may last for a long time, demanding continuous adaptations and resilient strategies from the scientific community.

The challenge imposed by the pandemic, however, also opens opportunities for innovation and collaboration among researchers, institutions, and countries. The pursuit of effective solutions and a deeper understanding of the impacts of the global crisis may result in significant advances in scientific knowledge.

Contributing to the discussion of the data presented here, the analysis by Inomata et al. (2021) and the reflections by Cruz et al. (2021) emphasise the challenges faced by the scientific community amid the COVID-19 pandemic. Understanding the complexity of these transformations is essential to shaping effective strategies and promoting adaptable and resilient science, capable of addressing current and future challenges arising from this global event.

3.3. Socioecological Approach and Article Publication in the CPLP

Among the citations by country, Brazil and Portugal stand out (≥ 80%), while the others (Mozambique, Cape Verde, and São Tomé and Príncipe) show a low publication rate (less than 15%). Sambou, Diouf and Sarr (2023) argued that "countries located on the African continent have historically invested less in research in the fields of limnology and water resources, impacting the development of public policies for water supply as well as treatment to maintain quality" (SAMBOU; DIOUF; SARR, 2023).

According to Berger (2022), the Human Development Index (HDI) can aid reflection on the relationship between investment and public policy development since it "provides an overview of the effectiveness of regulatory and public value distribution instruments, their goals, and outcomes" (BERGER, 2022, p. 8). The author also notes that the HDI measures the level of development of a society in terms of education, health, and income, and thus its use in socioecological analysis can be an evaluation tool for development beyond economic aspects.

The correlation between the Human Development Index (HDI) and investments in crucial sectors such as education and health has been the subject of study and analysis by several researchers (PACA et al., 2019; BERGER, 2022; OLIVEIRA, 2020; ALMEIDA et al., 2020). According to these authors, there is a direct relationship between countries with higher HDI—exemplified here by Portugal and Brazil—and their substantial efforts to invest in these fundamental areas.

The assertion that nations with higher HDI, such as Portugal and Brazil, tend to invest more in education represents a connection between human development and public policies in these countries. This prioritisation creates a foundation for scientific development, as education is an essential pillar for social and economic progress.

The results presented here reinforce this trend by placing Portugal at the top of the analysed countries, boasting an HDI of 0.866, followed by Brazil in second place with an HDI of 0.754. In light of the theoretical framework discussed, these figures may indicate the promotion of an environment conducive to scientific development.

Table 2, mentioned below, provides an overview of the research results, allowing for analysis of how the HDI relates to investment in education. The arrangement of this tabular data is important not only to understand the relative positions of the countries but also to identify patterns and nuances that may contribute to understanding this interconnection.

Table 2. GDP, HDI, and Literacy Rate of CPLP Member States.

COUNTRY	GDP	HDI	LITERACY
Angola	$198,821	0,586	73,5%
Brazil	$3.388,962	0,754	90,4%
Cape Verde	$3,983	0,662	81,2%
Guinea-Bissau	$3,385	0,483	44,8%
Equatorial Guinea	$28,410	0,596	94,2%
Portugal	$328,252	0,866	95,4%
Mozambique	$38,679	0,446	56,1%
São Tomé and Príncipe	$726	0,618	84,9%
Timor-Leste	$6,470	0,607	50,1%

According to Ghermandi et al. (2019), populations with access to quality education are more likely to engage in scientific and research activities, contributing to the production and dissemination of knowledge. In this context, Portugal ranks first with 95.4% of its population being literate, followed by Brazil with 90.4%. At the bottom of the ranking are Guinea-Bissau, with a literacy rate of 44.8%, and Timor-Leste, with 50.1%, both showing the lowest numbers of scientific publications.

The study reveals a correlation between the Human Development Index (HDI), investment in education, and scientific output, highlighting the importance of these factors in a nation's development. Countries such as Portugal and Brazil, with higher HDI scores, demonstrate a significant commitment to education, which is reflected in the increase in scientific publications.

The positive influence of HDI on scientific development is evident when analysing the considerable number of articles published by these nations. Portugal, with an HDI of 0.866, has 338 published articles, while Brazil, with an HDI of 0.754, has 285. This association suggests that investing in social indicators and quality of life creates a favourable environment for scientific advancement.

Furthermore, the correlation between limnological research output and the number of Higher Education Institutions (HEIs) underscores the role of education in scientific production. Countries with a higher number of HEIs—Figure 4—such as Brazil (2,595 HEIs) and Portugal (123 HEIs), appear more likely to generate scientific knowledge, corroborating the findings of Ghermandi et al. (2019).

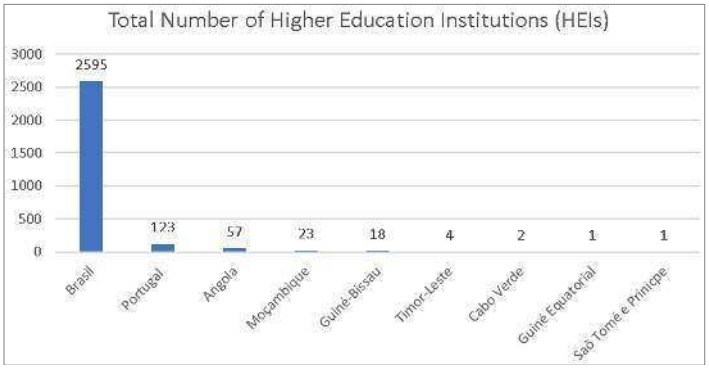


Figure 4. Distribution of Higher Education Institutions among CPLP Member Countries.

However, it is essential to recognise that communities with low social indicators face significant challenges in implementing structural public policies, such as those proposed by the Sustainable Development Goals (SDGs). SDG 6, for example, emphasises the need to ensure access to water and sanitation for all—something that may be hindered in societies with limited resources and infrastructure.

When analysing other countries such as Angola, Mozambique, Guinea-Bissau, Timor-Leste, Cape Verde, Equatorial Guinea, and São Tomé and Príncipe, it becomes evident that the reduced number of Higher Education Institutions (HEIs) may negatively influence scientific output. These nations could benefit from additional investments in education to boost research and contribute to global scientific advancement.

The results discussed here show that the relationship between HDI, investment in education, and scientific production is clear and highlights the need for public policies that prioritise these factors. Countries with higher human development tend to lead in scientific research, while those facing social challenges encounter significant barriers.

Investing in education and quality of life is crucial to stimulate scientific progress and, consequently, promote sustainable and equitable development.

3.4. Publication of Legal Norms and Comparative Law within the CPLP

Investigating a legal interpretation aimed at minimizing the effects of the global environmental crisis is an urgent matter (GOMES, 2018; GOMES; LANCEIRO, 2018). Thus, discussing and comparing the legislation of the nine member countries seeks to address the urgency of how each nation particularly understands the value of discourse surrounding SDG 6.

Unlike determining the number of article publications by country, the objective here is not to show the number of laws in each member state but to identify legal norms in each republic exclusively related to strategies and actions directed toward the implementation of SDG 6, correlating them with limnological research in Portuguese-speaking countries.

In this context, discussing comparative legislation is very useful for environmental debate, as it involves the challenge of putting on the table, at least, the urgency of ensuring the availability and sustainable management of water for all by 2030, and how to seek convergence between legislation and SDG 6 within the CPLP (SANTOS et al., 2022).

The concept of development has evolved, gradually incorporating a more comprehensive approach that inseparably includes notions of socioeconomic growth, as highlighted by Santos et al. (2022, p. 12). This broadened vision is also expressed in the legal compendiums governing the nations, and its understanding becomes essential to analyse the legislation of the nine countries belonging to the Portuguese-speaking bloc.

In this regard, this research not only quantified legal provisions but also organised them into specific themes, providing a more detailed and contextualised view of the legislation. The identified themes include “National Water Resources Policy in Portuguese-speaking Countries” (Table 3), “Management of Watersheds” (Table 4), “Granting of Water Use Rights” (Table 5), and “Water Yield Control” (Table 6).

The careful allocation of legislation within these specific themes offers a simplified understanding of the approaches adopted by member countries regarding water resource management. Each table represents a distinct facet of the legislation, allowing for more specific analyses and an overview of how countries address critical water-related issues.

Table 3. National Water Resources Policy in Portuguese-speaking Countries.

COUNTRY	REGULATION	SUMMARY
Portugal	PENSAAR/20	2020 Strategic Plan for Water Supply and Wastewater Sanitation
Cape Verde	Law Nº 115/99	Authorises the Government to amend the Water Code
Mozambique	Law Nº16/91	Establishes the country's Water Law.
Guinea-Bissau	Dec. Nº 5A/92	Establishes legal regulations for the use of water in the country
Equatorial Guinea	Law Nº 7/03	Establishes legal regulation for water quality
Brazil	Law Nº 9433/97	Establishes the legal framework for water use in the country
Angola	*	*
São Tomé and Príncipe	*	*
Timor-Leste	*	*

*Although this research identified environmental regulations, none met the inclusion criteria established in the methodology of this investigation.

Table 4. Management of Watersheds.

COUNTRY	REGULATION	SUMMARY
Portugal	Dec Nº 2000/60	Establishes criteria for the governance of water policy
Cape Verde	Law Nº 115/99	Suggests regulations for watershed management
Mozambique	Dec. Nº 46/97	Establishes rules for the granting of water use licenses
Guinea-Bissau	*	*
Equatorial Guinea	*	*
Brazil	Law Nº 9433/97	
Angola	*	*
São Tomé and Príncipe	*	*
Timor-Leste	*	*

*Although this research identified regulations related to the environment, none met the inclusion criteria established in the methodology of this investigation.

Table 5. Granting of Water Use Rights.

COUNTRY	REGULATION	SUMMARY
Portugal	Dec Nº 2000/60	Establishes criteria for the governance of water policy
Cape Verde	Law Nº 115/99	Suggests regulations for watershed management approaches
Mozambique	Dec. Nº 46/97	Establishes rules for the granting of water use licenses
Guinea-Bissau	*	*
Equatorial Guinea	*	*
Brazil	Law Nº 9433/97	Establishes the National Water Resources Policy and creates the National Water Resources Management System
Angola	*	*
São Tomé and Príncipe	*	*
Timor-Leste	Law Nº 4/04	Establishes guidelines for water distribution

*Although this research identified environmental regulations, none met the inclusion criteria established in the methodology of this study.

Table 6. Water Yield Control.

COUNTRY	REGULATION	SUMMARY
Portugal	Dispatch Nº 2339/07	Approval of the Strategic Plan for Water Supply and Wastewater Sanitation.
Cape Verde	Law Nº 115/99	Establishes a Strategic Plan for the Development and Implementation of the National Water Information System.
Mozambique	Dec. Nº 46/97	Establishes rules for the granting of water use licenses.
Guinea-Bissau	Dec. Nº 5A/92	Establishes legal regulations for the use of water in the country.
Equatorial Guinea	Law Nº 3/07	Establishes legal regulations for the use of water in the country.
Brazil	Law Nº 12334/10	
Angola	Res. Nº 08/05	Establishes sanitation service fees.
São Tomé and Príncipe	Law Nº 07/18	
Timor-Leste	Dec. Nº 48/12	Regulates the operation of the Ministry of Public Works, especially related to water resources.

The distribution of legislation among the countries studied, as presented in Figure 5, provides a visual summary of the results. This graphical representation facilitates the identification of patterns and trends in the regulatory approaches of each nation concerning water resources, without delving into legal hermeneutics, since this is not the aim of this investigation. Visualisation through graphs contributed to a comparative understanding of the legislation, enabling the analysis of its diversity and convergence.

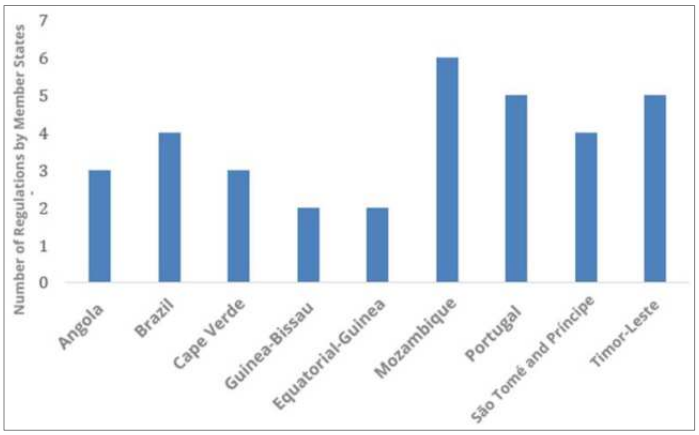


Figure 5. Distribution of Regulations by CPLP Member States.

Overall, the research highlights the importance of a comprehensive approach when analysing the legislation of member countries of the Portuguese-speaking bloc, especially in the context of water resources. Studying legal instruments, even in a general way as performed in this investigation, is important to understand how these countries consider the importance of sustainable natural resource management, reinforcing the ongoing need for a panoramic perspective on socioeconomic development.

The result of the comparative analysis of the themes categorised as "access to drinking water and basic sanitation," "efficiency in water use," and "protection of aquatic ecosystems" indicated that Mozambique was the member state with the highest number of regulations and the greatest adherence to the themes categorised in the methodology of this study.

According to Law 16/91 of the Republic of Mozambique, for example, it is recorded that:
"The State shall progressively implement, in the regions defined as priority intervention areas, a water management policy aimed at achieving the following objectives: Better use of available water for all purposes through its rational and planned utilization, with a view to meeting the needs of the population and national economic development" (Art. 8, Clause a of Law 16/91, REPÚBLICA DE MOÇAMBIQUE, 1991).

The cited law aligns with SDG 6 by proposing a water management policy, advocating the use of available water for all, and adhering to the commitment to economic development, encompassing the three aspects indicated in the methodology of this study: coherence between legislation and SDG 6, encouragement of social participation, and highlighting management instruments. Thus, it can be affirmed that the legislation is aligned with SDG 6, including the mention of support and strengthening of local community participation to improve water and sanitation management (Santos et al., 2022), as indicated in target 6.B of the goal.

On the other hand, Guinea-Bissau was the CPLP member with the lowest number of legal norms specifically addressing water issues, yet it did not fail to contribute to the debate. Law 1/2011 from Republic of Guinea-Bissau, in its Article 10, expresses concern with maintaining water quality through the preservation of its reservoirs, where it states:

The discharge of polluting effluents, solid waste, or any products or species that alter the characteristics of the waters or make them unsuitable for their various uses shall be subject to special legislation (Art. 10 of Law 1/2011, REPÚBLICA DA GUINÉ-BISSAU, 2011).

The concern with the "discharge of polluting effluents" that may alter water characteristics to the point of making them unsuitable also aligns with SDG 6, as it supports targets 6.2 and 6.3—both aiming to achieve access to sanitation and reduce pollution by eliminating discharges and minimizing the release of hazardous chemicals and materials, as reminded by the indicators of the Brazilian National Water and Sanitation Agency (ANA, 2019), still advocating for a legal framework.

The creation of a legal framework for water use involves several stages and considerations that are also related to the aforementioned socio-ecological aspects (ADAMS et al., 2020). This is because, initially, it is essential to clearly define the rights and responsibilities of the various users, whether individuals, companies, or governmental entities. Thus, it is “essential to clearly define rights and responsibilities” (ADAMS et al., 2020, p. 7). This position can be identified in Directive No. 2000/60 of the Council of the European Parliament in Portugal, which established “a framework for community action in the field of water policy” (Art. 4, Directive 2000/60, EUROPEAN UNION, 2000).

Similarly, the Assembly of the Republic of Mozambique, through Law No. 16/91 since 1991, established that country’s Water Law with strong protection of the natural resource; Guinea-Bissau, for its part, promulgated Decree No. 5A/92 establishing the legal regulation for water use in the country.

In all these examples taken from the results of this investigation, rights and responsibilities are aligned with SDG 6 through targets 6.4 and 6.5, respectively, of that goal.

In this case, the connection between the legislation studied and SDG 6 lies in the alignment of the laws with targets that, in theory, achieve the goal possible. It is important to remember that target 6.4 aims to substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and freshwater supply to address water scarcity and substantially reduce the number of people suffering from water scarcity; and target 6.5 seeks to implement integrated water resources management at all levels, including through transboundary cooperation as appropriate.

The analysis of the summaries presented in Table 3 reveals a legally aligned scenario among various countries, which, despite their peculiarities, converge on a crucial point: the preservation of water resources. By observing the legislations of Brazil (Law 9433/97), Cape Verde (Law 115/V/99), Guinea-Bissau (Decree 5A/92), Angola (Law 5/98), São Tomé and Príncipe (Law 07/18), Timor-Leste (Law 42/20), and Equatorial Guinea (Law 03/2007), it is possible to identify a shared concern to ensure the availability and sustainable management of water, as well as to promote basic sanitation, aiming to meet present needs and preserve this vital resource for future generations, as highlighted by Santos et al. (2022).

The theme of water resource preservation is addressed in the analysed norms, reflecting a shared commitment to environmental sustainability and responsible development. The explicit mention of “ensuring availability and sustainable management of water and sanitation for future generations” is a point of convergence among the legal texts selected by the methodology, highlighting the importance attributed to responsible water resource management.

According to Adams et al. (2020), socio-ecological analysis can aid in interpreting the triad of fact, value, and norm, especially when normative convergences established by different people are envisaged (ADAMS et al., 2020). This normative convergence among the studied countries not only highlights the global relevance attributed to the preservation of water resources but also reinforces the interconnection between national legislations and the Sustainable Development Goals (SDGs), particularly SDG 6, which aims to ensure clean water and sanitation for all by 2030.

By aligning these countries’ regulations with SDG 6, the data reveals an implicit international cooperation in seeking shared solutions to water-related challenges.

This convergence strengthens the legal foundation of each nation and contributes to building a more robust and cohesive global normative framework for the preservation of water resources (SANTOS et al., 2022).

The analysis of the legislative summaries shows a unified commitment to addressing water challenges, demonstrating that despite geographical and cultural differences, the preservation of water resources is a shared priority among various countries, notably aligning with the principles established by the Sustainable Development Goals.

The 2030 Agenda stipulates in SDG 6 the availability and sustainable management of water and sanitation for all, constituting the most important objective of that proposal. According to the authors, "within the scope of this goal, it is still necessary to verify which target makes sense for the local reality, and only after this is it possible to verify the implementation of actions in that territory" (SANTOS et al., 2022).

Cape Verde, Mozambique, and Brazil recorded well-defined targets related to watershed management aligned with the reality of these nations and their local contexts. The same does not apply to Portugal, Guinea-Bissau, Angola, São Tomé and Príncipe, and Timor-Leste, for which no regulations on watershed management were identified (Table 4).

According to Roma (2019), efficient management of river basins is a fundamental element to ensure the preservation and sustainable use of water resources in different countries. According to the author, by analysing the policies and regulations adopted by various nations, one can find a variety of approaches and strategies. The data obtained in this research corroborates this theory, as can be seen in the following lines.

Portugal, for example, stood out among the countries studied by establishing specific criteria for water management through Directive No. 2000/60. This directive serves as a fundamental guide for implementing water policies in the country, providing clear guidelines and standards for the effective management of river basins.

Cape Verde, in turn, addresses the issue of river basin management through Law No. 115/99. This legislation establishes general rules to guide the country's approach to its river basins, recognizing the importance of sustainable practices for the conservation of this vital resource.

Mozambique, through Decree No. 46/97, focuses on rules and regulations for granting water use licenses.

This regulatory approach aims to balance the use of water resources, ensuring their long-term preservation and promoting fair distribution among different sectors.

Brazil, with its vast territorial extension and rich hydrographic diversity, adopted Law No. 9433/97. This legislation not only establishes the National Water Resources Policy but also creates the National Water Resources Management System, seeking an integrated and comprehensive approach to water management in the country.

However, when analysing Guinea-Bissau, Angola, São Tomé and Príncipe, Timor-Leste, and Equatorial Guinea, there is an absence of norms that meet the inclusion criteria established in the methodology of this research. Although these countries have various environmental legal norms in force, none fit the specific parameters defined in the methodology applied in this investigation.

This discrepancy highlights the diversity of legal approaches and developments among countries, emphasizing the importance of evaluating each nation's particularities when addressing crucial issues such as river basin management. The research identifies the ongoing need for the development and improvement of regulations to guarantee the sustainable management of water resources worldwide.

Granting licenses (*outorga*) is also an important theme concerning SDG 6. The granting of water use rights is a technical term that refers to the process by which competent authorities issue legal permissions for individuals, companies, or entities to use water resources in a regulated manner (ROMA, 2019).

This concession is important to ensure that water use is carried out sustainably, equitably, and in compliance with environmental standards, which aligns with SDG 6 through its target 6.6, aimed at protecting and restoring water-related ecosystems by controlling their use.

Upon analysing the legislation of the studied countries, it is observed that in the documents from Portugal, Guinea-Bissau, Angola, São Tomé and Príncipe, and Timor-Leste, the term "granting of water use rights" is not explicitly mentioned in their laws and regulations related to water resources (Table 5).

According to Souza and Silva (2021), "it is essential to have special care in how this resource (water) is used, keeping in mind the objectives and foundations of the National Water Resources Policy (PNRH), as it is a resource that requires attention to avoid further depletion" (SOUZA; SILVA, 2021, p. 22).

The National Water Resources Policy is a topic of great importance for all countries and is considered fundamental to ensuring proper management of water resources, promoting access to potable water, sustainable development, and the preservation of aquatic ecosystems (BORSOI; TORRES, 2017).

Among the countries studied, Angola and São Tomé and Príncipe were the only ones identified as not explicitly incorporating the importance of the National Water Resources Policy in their legislation (Table 6).

Environmental legislation plays a vital role in promoting scientific research on environmental and sustainability issues. Countries with strict environmental regulations can encourage research focused on the preservation and sustainable management of natural resources.

By analysing these indicators together, it is possible to outline a panorama of scientific production in Portuguese-speaking countries. However, it is worth noting that these factors are interrelated and mutually influence each other; a conducive environment for scientific research requires not only financial resources but also investments in education, adequate legislation, and broad commitment to sustainable development (GHERMANDI et al., 2019).

Strengthening these pillars can enhance scientific production and contribute to the advancement of knowledge and innovation in these countries.

4 Conclusions

Considering that the objective of this work was to examine the scientific production in Portuguese-speaking countries and analyse the environmental legislation related to Sustainable Development Goal (SDG) 6 of the member states of the bloc, and also considering that the hypothesis admitted was that limnological research in Portuguese-speaking countries has shown exponential growth, confirming the growing importance of the theme in the international scientific debate, it is concluded that the objective was achieved and the hypothesis proven based on the following description.

This study provided an overview of limnological scientific production over an extensive period, from 1996 to 2022, focusing specifically on the community of Portuguese-speaking countries. The analysis revealed a remarkable increase in the publication of scientific articles related to Limnology and Water Resources until 2021, showing growing recognition of the importance of these areas for sustainable development and the preservation of water resources.

However, an intriguing aspect emerged in 2022, with a reduction in scientific production. The possible association of this decline with the post-COVID-19 pandemic scenario highlights the challenges faced by the global scientific community. The pandemic brought restrictions, logistical limitations, and changes in work patterns, directly impacting knowledge production.

The analysis of bibliographic data from the ISI Web of Science (WoS) database provided a solid and well-founded approach to understanding the evolution of research in Limnology and Water Resources within the CPLP. Furthermore, the survey of laws, regulations, and policies (which included the quantification of Higher Education Institutions in each Republic) enriched the analysis by establishing connections between scientific production and relations with Sustainable Development Goal (SDG) 6.

It is concluded that this study not only documented the significant growth in scientific production over the past decades but also highlighted the sensitivity of the scientific landscape in the face of significant global events, such as the COVID-19 pandemic.

This reflection is crucial to guide future research and policies, adapting to emerging challenges and promoting the continued advancement of science in the field of Limnology and Water Resources, which are fundamental for environmental sustainability.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

J. Da Silva: Conceptualisation, Data Curation, and Project Administration; G.H. Palmeira: Methodology and Writing; R.C.L.S. Silva: Formal Analysis and Review; A.L.S.S. Gomes: Writing and Review; J. Da Silva Júnior: Review, Validation, and Translation.

DECLARATION OF INTEREST

The authors disclose that they have no known competing financial interests or personal relationships that could have appeared to influence the study reported in this manuscript.

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REFERENCES

ADAMS, C.; BORGES, Z.; MORETTO, E.M.; FUTEMMA, C. Governança ambiental no Brasil: acelerando em direção aos objetivos de desenvolvimento sustentável ou olhando pelo retrovisor? **Cadernos Gestão Pública e Cidadania**, v. 25, n. 81, p. 1-13, 2020. Available from: https://doi.org/10.12660/cgpc.v25n81.81403

AFONSO, S.D.J.; FERNANDES, L.A.; SERRANO, L.R.P. Evaluation Microbiological of the Water of the City of Huambo, Angola. **Ingeniería Agrícola**, v. 11, n. 2, p. 33-38, 2021. Available from: https://revistas.unah.edu.cu/index.php/IAgric/article/view/1362. Accessed on: 25 Apr. 2025.

ALMEIDA, A.; FORMIGO, N.E.; SOUSA-PINTO, I.; ANTUNES, S.C. Contribution of zooplankton as a biological element in the assessment of reservoir water quality. **Limnetica**, v. 39, n. 1, p. 245-261, 2020. Available from: http://doi.org/10.23818/limn.39.16

AMO, V.E.; SILVA, J.E.; PINHA, G.D.; RAGONHA, F.H.; MORMUL, R.P. Factors affecting assemblage attributes of freshwater Oligochaeta in Neotropical shallow floodplain lakes. **Acta Limnologica Brasiliensia**, v. 29, article e114, 2017. Available from: https://doi.org/10.1590/S2179-975X8717

ANA (Agência Nacional de Águas). **ODS 6 no Brasil:** Visão da ANA sobre os indicadores. Brasília: ANA, 2019. Available from: https://www.gov.br/ana/pt-br/centrais-de-conteudos/publicacoes/ods6. Accessed on: 15 Apr. 2025.

ANDRADE, L.; FREITAS, L. Socio-ecological approach as a basis for local and neighborhood scale to promote urban and community resilience to climate change. **arq.urb** [Revista do Programa de Pós-Graduação *stricto sensu* em Arquitetura e Urbanismo da Universidade São Judas Tadeu], n. 32, p. 69–81, 2021. Available from: http://doi.org/10.37916/arq.urb.vi32.548

BERGER, L. **Relação entre gastos com educação versus IDEB e o IDH versus IDEB:** Um estudo nos municípios da Serra Gaúcha. 2022. 24 f. Trabalho de Conclusão de Curso (Bacharelado em Ciências Contábeis) — Universidade de Caxias do Sul, Caxias do Sul, 2022. Available from: https://repositorio.ucs.br/11338/10907. Accessed on: 10 May 2025.

BORSOI, Z.M.F.; TORRES, S.D.A. A política de recursos hídricos no Brasil. **Revista do BNDES**, v. 4, n. 8, p. 143-165, 2017. Available from: https://web.bndes.gov.br/bib/jspui/handle/1408/11774 . Accessed on: 10 May 2025.

CRUZ, R.M.; BORGES-ANDRADE, J.E.; DE ANDRADE, A.L.; MOSCON, D.C.B.; VISEU, J.; MICHELETTO, M.R.D.; KIENEN, N.; ESTEVES, G.G.L.; DELBEN, P.B.; DE CARVALHO-FREITAS, M.N. Production and dissemination of scientific knowledge in times of the COVID-19 pandemic. **Revista Psicologia Organizações e Trabalho**, v. 21, n. 1, p. 1-2, 2021. Available from: http://dx.doi.org/10.5935/rpot/2021.1.editorial

EUROPEAN UNION. Diretiva 2000/60/CE. Água de boa qualidade na Europa (Diretiva Água da UE). **EUR-Lex:** Brussels, 22 Oct. 2000. Available from: https://eur-lex.europa.eu/legal-content/pt/LSU/?uri=CELEX:32000L0060. Accessed on: 16 Apr. 2025.

GHERMANDI, A.; OBURA, D.; KNUDSEN, C.; NUNES, P.A.L.D. Marine ecosystem services in the Northern Mozambique Channel: A geospatial and socio-economic analysis for policy support. **Ecosystem Services**, v. 35, p. 1-12, 2019. Available from: https://doi.org/10.1016/j.ecoser.2018.10.009

GOMES, C.A. **Direito internacional do ambiente:** Uma abordagem temática. Lisboa: AAFDL Editora, 2018. Available from: https://livraria.aafdl.pt/pt/direito-do-ambiente/762-direito-do-ambiente-direito-internacional-do-ambiente-uma-abordagem-tematica-9789726292319.html. Accessed on: 15 Apr. 2025.

GOMES, C.A.; LANCEIRO, R.T. O acesso à informação ambiental no direito internacional e no direito da União Europeia. **Revista Argumentum** [Argumentum Journal of Law], v. 19, v. 2, p. 583-613, 2018. Available from: https://ojs.unimar.br/index.php/revistaargumentum/article/view/629. Accessed on: 26 Apr. 2025.

IMF (International Monetary Fund). **World Economic Outlook Database:** October 2022 Edition. 2022. Available from: https://www.imf.org/en/Publications/WEO/weo-database/2022/October. Accessed on: 17 Aug. 2023.

INOMATA, D.O.; SILVA JUNIOR, C.L.; SAMPAIO, T.B.; SILVA, M.F. Divulgação científica em tempos de pandemia: Podcast Biblioquê? Presente. **Cidadania em Ação: Revista de Extensão e Cultura**, v. 5, n. 2, p. 107-119, 2021. Available from: http://doi.org/10.5965/2594641205022021107

OLIVEIRA, T.M. **Influência da atividade humana nos ecossistemas aquáticos:** Uma análise cienciométrica e um estudo de caso. 2020. 88 f. Dissertação (Mestrado em Ambiente e Sociedade) — Universidade Estadual de Goiás, Campus Sudeste, Anápolis, 2020. Available from: http://www.bdtd.ueg.br/handle/tede/600. Accessed on: 10 May 2025.

PACA, J.M.; SANTOS, F.M.; PIRES, J.C.M.; LEITÃO, A.A.; BOAVENTURA, R.A.R. Quality assessment of water intended for human consumption from Kwanza, Dande and Bengo rivers (Angola). **Environmental Pollution**, v. 254, part. B, 2019. Available from: https://doi.org/10.1016/j.envpol.2019.113037

REPÚBLICA DA GUINÉ-BISSAU. Lei nº 1/2011. Aprovada a Lei de Bases do Ambiente. **Boletim Oficial:** Bissau, 2 Mar. 2011, nº 9. Available from: https://faolex.fao.org/docs/pdf/gbs118164.pdf. Accessed on: 16 Apr. 2025.

REPÚBLICA DE MOÇAMBIQUE. Lei nº 16/1991. Aprova a Lei de Águas. **Boletim da República:** Maputo, 3 Aug. 1991, nº 31. Available from: https://www.aquashare.org.mz/wp-content/uploads/2022/06/Lei-16_1991-Lei-de-guas.pdf. Accessed on: 16 Apr. 2025.

ROMA, J.C. Os objetivos de desenvolvimento do milênio e sua transição para os objetivos de desenvolvimento sustentável. **Ciência e Cultura**, v. 71, n. 1, p. 33-39, 2019. Available from: http://dx.doi.org/10.21800/2317-66602019000100011

ROMEIRAS, M.M.; GOMES, I.; CATARINO, S.; FORTES, A.; FERREIRA, V.; DUARTE, M.C. Flora and Natural Resources of Cabo Verde Islands. Lisboa: Universidade de Cabo Verde e Universidade de Lisboa — ISAPress, 2023. Available from: http://hdl.handle.net/10400.5/27733. Accessed on: 28 May 2025.

SAMBOU, S; DIOUF, R.N.; SARR, J. Water Control, Impacts and Sub-Regional Cooperation Around a Transboundary Hydrological System - The Case of the Kayanga/Geba Catchment Area: (Guinea, Senegal and Guinea-Bissau). In: RAY, R.L.; PANAGOULIA, D.G.; ABEYSINGHA, N.S. (Ed.). **River Basin Management:** Under a Changing Climate. London: IntechOpen, 2023. Available from: http://doi.org/10.5772/intechopen.105698

SANTOS, C.I.; LEITE, M.D.S.; MEDEIROS, A.C.; MAGALHÃES, T.S.S.A.; De LAVOR, F.I.G.; SOUSA NETO, O.L.S.; PIRES, B.C.B.; GONÇALVES, A.J.N.; SAMPAIO, R.L.; MEDEIROS, E.C.C.; SILVA FILHO, V.G.; BANDEIRA, P.S.R.S.; SANTOS, K.L.A.; ALMEIDA, K.E.L.; NOBRE, K.M.R.; VICTOR, J.T.S.; SILVA, G.I.C.M.; De OLIVEIRA, S.N.; MARQUES, A.T.; MENDES, J.R.L. Agenda 2030: um estudo de caso sobre os desafios da implementação do ODS 6 para o município de Pombal-PB. **Research, Society and Development**, v. 11, n. 4, article e20311425386, 2022. Available from: https://doi.org/10.33448/rsd-v11i4.25386

SOUZA, M.V.K.; SILVA, H.P. Política Nacional de Recursos Hídricos (PNRH): Um estudo comparativo sobre arrecadação e desembolso das bacias hidrográficas interestaduais no Brasil. **Caderno PAIC**, v. 22, n. 1, p. 659-684, 2021. Available from: https://cadernopaic.fae.edu/cadernopaic/article/view/477. Accessed on: 10 May 2025.