Chapter 196

Application of a collection model to estimate the revenue in the sub-basin of the Mamanguape river located on the coast of Paraíba state in Brazil territory

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ABSTRACT
The objective of this research is to estimate the collection of the Mamanguape sub-basin, located on the coast of Paraibano, with a mathematical model for charging for water use that considers volumes consumed, abstracted, transposed, and volumes of water used for effluent dilution. For this purpose, the main charging models adopted in Brazil were analyzed to finally define the best algorithmic basis, which considers the peculiarities of the sub-basin studied. With the chosen charging model research on water, pricing was carried out, to determine the optimal prices for consumption/capture and effluent discharge. Analyzing the results it was observed that the estimated collected resources do not provide a sustainable application of the real situation of the sub-basin analyzed, requiring more detailed studies to understand the peculiarities of the region, bearing in mind that the estimated collection is insufficient to provide the necessary infrastructure for the management system of the Mamanguape River/PB sub-basin. Therefore, the inaccuracy of the existing collection models to estimate the collection can compromise the investments and management, a situation that serves as a warning to the public water management agencies about the modeling to be used and the urgency of implementing the collection instrument, considering that it could improve the quality of the sub-basin studied.

Keywords: Water Resources, Management, Model, Charging.

1 INTRODUCTION

Water is one of the scarcest natural resources of recent times. A United Nations report (2006) points out that water consumption has grown exponentially due to population growth, industrial production, and food production. The tendency from now on is only to increase this scarcity since the pollution of the springs is out of control.

Bertoncini (2008) in turn, highlights key issues regarding the problems of misuse of water, the main ones that deserve to be highlighted are the lack of effluent treatment, as well as waste in irrigation, significant factors for this scenario of water scarcity. Ensuring water in quantity and quality is the great challenge of this century, in its absence, it can lead to major conflicts in the future, with this it is necessary that adequate planning and management of water occur and pressure public managers to invest in water infrastructure of watersheds.

With the need to complete the implementation of the Water Resources Management System (management instruments), provided for by Law 9,433/97, identified as an urgent matter, the growing management conflicts are brought to light. This management system is regulated by the National Water Resources Policy (PNRH), and its main objectives are: to manage water efficiently and strengthen the committees and agencies that aim to institute charges for water use as their main instrument in inhibiting bad use of water resources.

According to Forgiarini et. al (2007) in the 1990s, in Brazil, several innovative laws were approved concerning changes in water resource management paradigms. Such alterations mainly marked a new era, when the hydrographic basin was considered a management unit, and water was also considered a limited natural resource and endowed with economic value.

For a long time, water was considered a free good, and because it had a relative image of abundance, it did not have its aforementioned valuation, mainly because it is a renewable resource, not requiring economic valuation, only private costs derived from raising the resource itself. Since this good is in relative scarcity in different regions of the world, there has been a need to charge for its use, to guarantee water for future generations. The use of water, available in the environment, and its ability to assimilate waste, do not exactly constitute a good or service produced by the government, even if it is constituted by the public property, it is the simple fact that the public power itself effectively assumes the domain of water in the name of society, the exercise of its management, enabling the harmonization between the intentions of use and the availability in the environment (LANNA, 1995).

The implementation of the National Water Resources Management System (SNGRH) requires several rounds of negotiations between bodies at different levels of government, as well as users and organized civil society. These negotiations are managed by the basin committees to define the actions and public policies that directly affect the quantity and quality of water. It is perceived that the market alone would not be able to measure the transaction costs, the social costs that the individual decisions of each user of water resources impose on others (FORGIARINI, 2007).

In this sense, the need for public power intervention is notorious, through charging for the use of water, as a way of rationalizing the use of these resources, on the condition that they add and satisfy competing users with the right to use water. Ensuring the right to use water in quantity and quality is not an easy task, since there are countless variables to be taken into account when planning.

2 STATE OF ART

The practices of organizing water billing processes emerged some time ago in Western countries, especially in Germany, France, England, and Wales. According to Silva and Pruski (2005), the Basin Associations, in Germany, were the first to be created, and date back to the beginning of the 20th century.

be resolved by its users, in this sense, the Government is only responsible for establishing norms and guidelines aimed at ordering and ensuring the forwarding of solutions, financial resources from its members, allocations from the treasury, and another financing.

For Ramos (2007), Germany was the first country to have a basin agency - the Rhur Agency - dating from the beginning of the 20th century. Becoming representative because it is the centralized management of water resources with the application of charges for capturing water and for releasing effluents to finance the management system, but with relative decentralization in basin organizations. France, on the other hand, stands out for having decentralized management of the basin, with the application of charges for the use of water and for the emission of effluents to finance the management system and pollution control works. Silva and Pruski (2005) report that, in the 1930s, the creation of the Tennessee Valley Authority (TVA) as the first Watershed Superintendence acted in line with cost-effectiveness. However, as its performance was always executive, it caused many problems of conflict with municipal governments in the United States.

In England and Wales, the management of water resources began in 1974 with the creation of the National Water Council, composed of the State and Environment Secretariats and the Ministry of Agriculture, Fisheries and Supply, where, at the time, there were 1200 water supply and sewage systems. It was only in 1983 that administrative decentralization took place, given the creation of ten Regional Basin Superintendencies that began to build, operate and maintain all hydraulic works, financially independent, becoming a private company, with attributions to manage the quality and quantity of water resource uses. (SILVA et al., 2005).

Thus, little by little, society became aware of problems related to the use and handling of water, due not only to the debates and innovations in recent decades but above all to the ecological disasters resulting from the pollution of watercourses. In this way, expressions such as management of water resources, water management, and rational use of water, became part of people's daily lives and the media. Even realizing that the way water resources are being treated is gradually changing, especially regarding conservation, not only for ourselves but especially for future generations. According to Bertoncini (2008), in Brazil, water management attempts began in 1934, with the Water Code, but only from 1997, with the enactment of Law 9.433/97, the year that instituted the charge for water use. of water, which consolidated the concept of "user pays" and "polluter pays" so that those who waste and pollute pay more.

days et. al (2010) point out that from the 1980s onwards, awareness began to form about the need to preserve natural resources. The Management of Water Resources can be evaluated as an instrument that guides not only the government but also society, mainly concerning the use and monitoring of environmental, natural, sociocultural, and economic resources. In this case, the area covered by a sub-basin, promotes sustainable development in the region, mainly because, with the increase in the human population, the accelerated growth of cities, industrialization, and irrigated agriculture caused the qualitative and quantitative scarcity of this resource, generating serious conflicts of use, since consumption, waste and, consequently, pollution are increasing, causing a series of problems that, until recently, did not receive due concern. This critical approach plays a very important role, characterizing the problem of water resources management as an area of knowledge in evolution whose values vary over time.

Grigg (1996) defines water resources management as the application of structural and non-structural measures to control water resources, natural and artificial, for human benefit and meeting environmental objectives. Thus, structural actions are those that require the construction of structures, to obtain controls over the flow and quality of water, such as the construction of water treatment plants, etc. Non-structural actions are programs or activities that do not require the construction of structures, such as land occupation zoning, and regulations against water waste, among others.

3 METHODOLOGY

The present work can be classified as exploratory and descriptive since it involves bibliographical research, case study, and mathematical-statistical inferences. The observations will be established directly since instruments are used to obtain specific data.

According to Silva; Menezes (2001) the main objective of descriptive research is to describe the characteristics of a given population or phenomenon and to establish relationships between variables, using data collection or any modality of treatment or disclosure in the study.

As for the development of the research, the hypothetical-deductive method was chosen. This option is justified because the chosen method allows the researcher to propose a hypothesis and departs, through deduction, for its confirmation or not.

The documented and collected material, as well as the respective analyzes of the results, will be organized in the form of a final report. According to Poper, K. apud Gil (1994), knowledge alone is insufficient to explain a given situation and the difficulties of the problem, so hypotheses are formulated that infer the consequences to be falsified or to confirm the hypothesis, which is the case of the hypothetical -deductive.

3.1 COLLECTION AND ANALYSIS OF RESULTS

For Neves (1996), the approach of research methods can be classified as quali-quantitative, since they present contrasting characteristics in terms of form and emphasis, although they are not mutually exclusive. This classification does not mean that one should choose one or the other.

The researcher can, when developing his study, use both, enjoying, on the one hand, the advantage of being able to explain all the steps of the research and, on the other hand, the opportunity to prevent the interference of his subjectivity in the conclusions obtained. Based on this context, the information that can be collected and analyzed regarding the charging for the use of water: articles, books, and websites, among others.

To put the proposed specific objectives into action, initially bibliographic and exploratory research will be carried out to understand the concepts of charging for water use and to raise the main charging models, available in the literature, to measure the collection in the Mamanguape River sub-basin -PB taking into account the representation of the dynamics of each region.

Thus, the following hypothesis was inferred: Through the water use charging model, it is possible to estimate a fair collection for the Mamanguape River sub-basin, located on the Paraíba coast of Brazil, to sustain the local management system ?".

To find out if this hypothesis is true or false, a detailed study will be made of each charging model available in the literature, taking into account variables such as consumption, collection, dilution, and transposition of flows (if any).

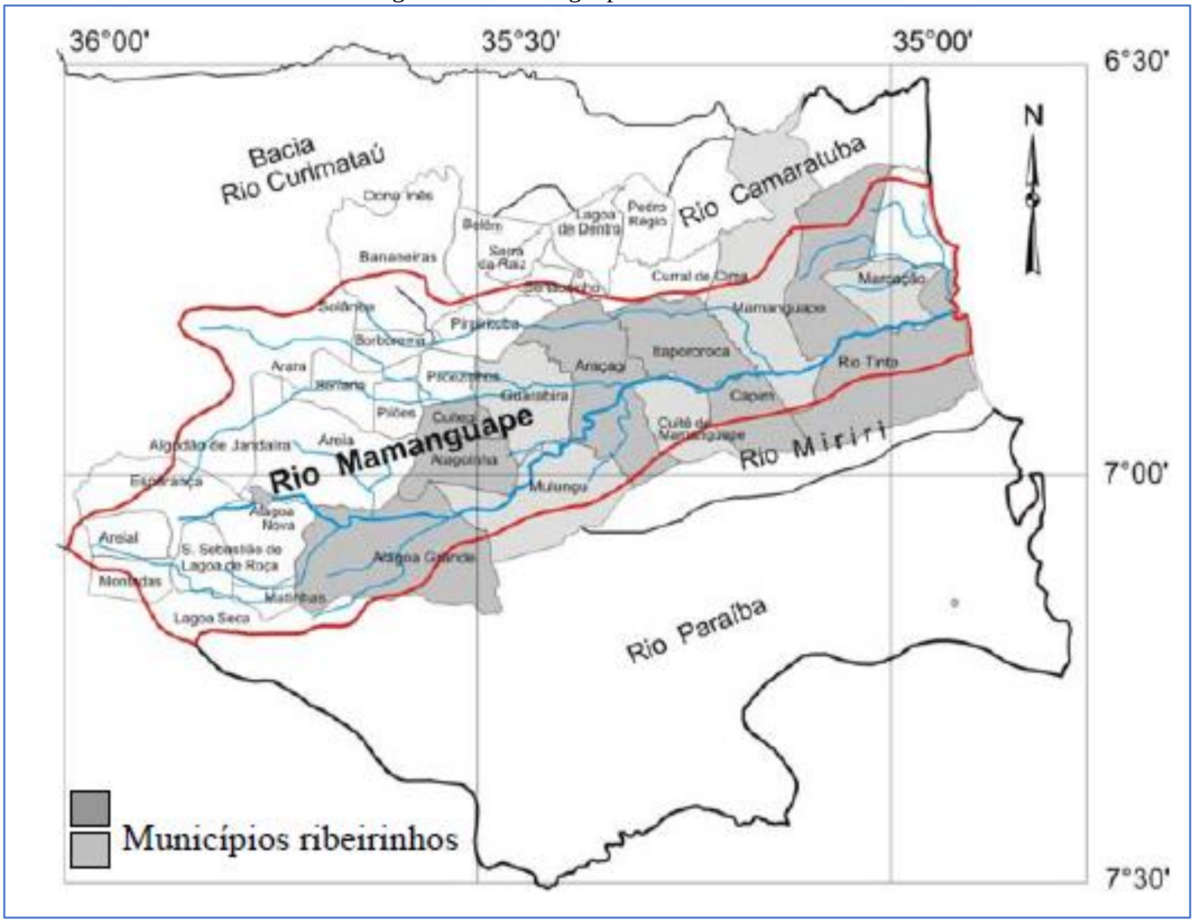
3.2 STUDY AREA DESCRIPTION

The Mamanguape River hydrographic sub-basin is located in the extreme east of the State of Paraíba, between latitudes 6°41'57" and 7°15'58" south and longitudes 34°54'37" and 36° west of Greenwich. It is limited to the north by the Curimataú River basin, to the west by the Curimataú and Paraíba basins, to the south by the Paraíba River, and to the east by the Atlantic Ocean.

Its main river is the intermittent Mamanguape, which rises in the micro-region of Agreste da Borborema and flows into the Atlantic Ocean in the municipality of Rio Tinto. It receives contributions from watercourses such as the Guariba, Guandu, Araçagi, and Saquaiba rivers and the Bloqueio Creek.

The Mamanguape River sub-basin drains an area of 3,525.00 km². Within this basin, 42 municipalities are completely and partially distributed, of which we can say that 10 are located in areas considered at risk of riverside flooding because they are close to the Lower and Middle Courses of the Mamanguape River and the Araçagi River: Alagoa Grande, Araçagi, Cuité de Mamanguape, Cuitegi, Guarabira, Itapororoca, Mamanguape, Marcação, Mulungu, Rio Tinto, as shown in Figure 1. The average monthly flow and precipitation, respectively, are Qm = 148.10 m3/s and 782.2 mm. Concerning annual evapotranspiration, it is approximately 2,000.00 mm.

Figure 01: Mamanguape River Watershed.



Source: Barbosa e Santos (2005).

3.3 STRUCTURES OF BILLING MODELS

Ribeiro and Lana (2001) established four basic criteria for water use that are subject to charges. They are: • Raw water is considered a production factor or a final consumption good; • The use of services for capturing, transporting, regulating, treating, and distributing water; • The use of treatment, transport, and destination of effluents; • The use of available water as a receiving body.

According to Thomas (2002), the charge for water use is determined by the product of the calculation base, the unit price, and the coefficients. In this way, the price is defined according to the collection objectives and the calculation basis will quantify the volume of water used for use, collection, consumption, or dilution.

Coefficients

Generally, the coefficients used in the charging mechanisms must take into account the type of user, type of use, efficiency of use, seasonality, discount, classification of water bodies, water availability, the vulnerability of aquifers, distance from launch, and treatment of effluents ;

Calculation basis

For Thomas (2002) the uses of water can be characterized directly or indirectly. When characterized directly, the flow rate is used as a parameter. As for indirect, other parameters are used, such as the pollutant load released, the irrigated area, or the energy produced.

Unit price

There are numerous methodologies for determining the unit price. And there is already a consensus on which methods to adopt for price formation, among which we can highlight: the theory of price determination with the objective of financing and the theory of price determination with the objective of economic optimization.

4 RESULTS AND DISCUSSION

To obtain a better understanding of this estimated collection in the studied sub-basin, three scenarios were idealized and simulated, considering the data presented and the components (capture, consumption, and release), and with classification class II, according to the Resolution of CONAMA, 357/05.

For the Capture Component, the Qcap value refers to the annual volume of water abstracted (m^3/year) and is associated with the grant data and the type of user foreseen in the state plan for water resources of Paraíba (PERH/PB, 2021). Due to the lack of consistent data, current and future demands with losses in the watercourse of 40% of the estimated volume were considered as catchment flow. About PUBcap, it was decided to use those measured by ANA, practiced in other interstate basins, with the same peculiarities, with values from the year 2011, referring to the type of use, which in turn were updated taking into account inflation average of 6.06% per year. Kclass is the coefficient that takes into account the classification of the water body, in this case, Class II was considered.

For the analysis of the Effluent Release Component, only domestic effluents were considered, the collection was estimated based on the Biochemical Oxygen Demand (BOD5.20) and is associated with the amount of organic matter contained in the effluent, an average of 350 mg/l adopted by the Basic Sanitation Company of the State of São Paulo - SABESP. As for Irrigation, an average concentration of 50 mg/l was adopted.

The Consumption component, in this scenario, refers to the annual payment for water consumption, that is, the measured value. 70% of the volume of current and future demands were considered for urban and rural supply and industry, and 80% of this volume was for other uses. PUBs were updated considering system losses and average inflation for the year. The constant Kcons is associated with the Kgarantia, and this coefficient considers the scarcity of water, which is characteristic of the region and is established by priority for the type of use.

It is important to add in this scenario that charging for the discharge of effluents is seen as a way of forcing the polluter to replace the expenses with the treatment of effluents and that even paying for the discharge of effluents, they are still obliged to meet the established discharge standards. by the environmental agency during licensing (ANA, 2014). Thus, three scenarios were established, with demand projections, referring to the analyzed sub-basin, which shows the demands of urban/rural supply, irrigation, industry/commerce, animal watering, and aquaculture for the years 2021, 2026, 2031, 2041, years which, in turn, served as the basis for the projection of the charge, the subject of this study.

4.1 TREND SCENARIO

Based on the estimated demands for these scenarios, considering the classification class II, the basic unit price updated by average inflation, water supply system losses, management coefficient equal to 1, and an average return coefficient of 0.8 based on the expected demands, the following table 01 of the collection was obtained, as follows:

Table 01: Collection by components in the trend scenario.

YEAR	Withdrawal (Capture + Consumption)	Launch
2021	123.890.597,31	173.446.836,23
2026	194.679.126,01	272.550.776,42
2031	261.273.974,20	365.783.563,88
2041	406.905.186,06	569.667.260,48

Source: Survey data (2022).

Table 01, observe that the collection for collection, consumption, and release tripled in the year 2041, since the water demand tripled, evidencing the future pressure on water volumes in the studied sub-basin. The total collection for the trend scenario is shown in Table 02.

Table 02: Total collection in the trend scenario for the studied sub-basin.

	YEAR	TOTAL COLLECTION
MAMANGUAPE RIVER SUB-BASIN	2021	297.337.433,54
	2026	467.229.902,43
	2031	627.057.538,08
	2041	976.572.446,54

Source: Survey data (2022).

4.2 CRITICAL SCENARIO

In this type of scenario, the demands were also estimated, but considering extreme weather events such as drought, classification class II was also considered, the basic unit price updated by average inflation, water supply system losses, management coefficient equal to 1, and an average return coefficient of 0.8 based on the expected demands, the following Table 03 of the collection was obtained, as follows:

Table 03: Collection by components in the critical scenario.

ANO	Withdrawal (Capture + Consumption)	Launch
2021	123.392.405,27	172.749.367,37
2026	154.078.970,84	215.710.559,17
2031	168.576.193,12	236.006.670,37
2041	174.923.778,93	244.893.290,50

Source: Survey data (2022).

Table 03, observe that the collection when considering the withdrawal, consumption, and release components practically doubled in the year 2041 when compared to 2021, since the water demand decreased, evidencing the drop in collection in the sub-basin studied. The total collection for the critical scenario is shown in Table 04.

Table 04: Total collection in the critical scenario for the studied sub-basin.

	YEAR	**TOTAL COLLECTION**
MAMANGUAPE RIVER SUB-BASIN	2021	296.141.772,64
	2026	369.789.530,01
	2031	404.582.863,49
	2041	419.817.069,43

Source: Survey data (2022).

4.3 OPTIMISTIC SCENARIO

In the optimistic scenario, the demands were estimated considering above-average precipitation events, that is, great rainy periods, classification class II was also considered, the basic unit price updated by average inflation, losses in the water supply system, coefficient management equal to 1 and an average return coefficient of 0.8 based on the expected demands, the following Table 05 of the collection was obtained, as follows:

Table 05: Collection by components in the optimistic scenario.

ANO	Withdrawal (Capture + Consumption)	Launch
2021	123.575.401,30	173.005.561,82
2026	207.743.362,22	290.840.707,10
2031	300.454.090,66	420.635.726,93
2041	540.217.589,13	756.304.624,78

Source: Survey data (2022).

Table 05, observe that the collection when considering the withdrawal, consumption and release components increased by four times the collection in the year 2041 when compared to the year 2021, since the demands show an excellent scenario. Since the total collection for the optimistic scenario is presented in Table 06.

Table 06: Total collection in the critical scenario for the studied sub-basin.

	YEAR	TOTAL COLLECTION
MAMANGUAPE RIVER SUB-BASIN	2021	296.580.963,11
	2026	498.584.069,32
	2031	721.089.817,60
	2041	1.296.522.213,91

Source: Survey data (2022).

4.4 TOTAL COLLECTION

The costs considered in this assessment are related to expenditures resulting from the implementation of the actions foreseen in the Plan. These costs involve activities related to studies, projects, improvement works, recovery and implementation of water infrastructure. Complementary costs are also included for the implementation, operation and maintenance of water supply systems which, although not part of the list of actions foreseen in the plan is essential for its economic viability. The evaluation was carried out in local currency and quotation based on 2003. The budget considered in the economic evaluation is presented as follows: Costs arising from the 24 programs included in the Plan: R$ 330 million, of which R$ 44.1 refers to studies and projects, R$ 262.2 refers to works and acquisitions and R$ 23.7 refers to operation and maintenance; Costs arising from additional actions, not included in the plan, but necessary for its economic viability: R$ 127.4 million, of which R$ 17.3 million refer to works and R$ 110.1 refer to the operation and maintenance of the systems. In Table 1, below, the direct costs of the Plan are presented and broken down by action programs.

Table 01: Investment cost per program for the State of Paraíba (2006).

Item	Program	Value (R$)
01	Support for the Creation and Operation of Basin Committees and Water User Associations	1.506.000,00
02	Institutional Articulation of the Integrated System of Planning and Management of Water Resources	159.000,00
03	Elaboration and Updating of Watershed Master Plans	2.330.000,00
04	Grant Management Computerization System	264.000,00
05	Billing Policy for the Use of Raw Water	241.000,00
06	Water Use Inspection System	250.000,00
07	Information System on Water Resources	264.000,00
08	Hydrometeorological Monitoring	3.460.000,00
09	Water Quality Monitoring	2.950.000,00
10	Environmental Education for the Protection of Water Resources	14.100.000,00
11	Training in Water Resources	869.000,00
12	Integrated Reservoir Operation Planning	420.000,00
13	Insertion of the State in the Management Model of the Integration Project of the São Francisco River with Hydrographic Basins of the Northern Northeast - Basins of the Paraíba and Piranhas Rivers in the State of Paraíba	2.200.000,00
14	Regulation of Water Use in Irrigation	197.000,00
15	Raw Water Macro Measurement	4.540.000,00
16	Recovery and Maintenance of Weirs	23.360.000,00
17	Rational Exploitation of Small Reservoirs	1.900.000,00
18	Implementation of Water Infrastructure Works	256.893.000,00

19	Use of the Crystalline Aquifer System for the Development of the Semiarid Region	2.115.000,00
20	Rational Exploration of Groundwater from Sedimentary Formations and Alluvial Spots	2.740.000,00
21	Flood Risks and Flood Control	620.000,00
22	Urban Demand Management (Water Supply)	2.194.000,00
23	Wastewater Reuse	3.170.000,00
24	Environmental Preservation of Springs	3.635.000,00
TOTAL COST		330.377.000,00

Source: PERH/PB (2006).

Subsequently, to ascertain the return on investments, the investment plan was considered, to determine the costs in the Mamanguape/PB River sub-basin, based on the information contained in the Executive Summary of the State Water Resources Plan of the State of Paraíba - PERH/PB (BRASIL, 2006). The area of the State of Paraíba equals 56,585 km² and respecting the principle of isonomy, these investments in the State were apportioned by Basin, therefore, this apportionment was calculated from the percentage of the sub-basin area, which with 3,523 km² corresponds to 6.23% of the state's total area.

Percentage of invested amount $p=\frac{3.523}{56.585}=0,623*100\%=6,23\%$

Based on this geographic percentage, average inflation and expected investment costs for the State of Paraíba, the following cost-benefit analysis and forecast year were obtained, as shown in Table 07.

Table 07: Analysis of the cost and benefit of the State of Paraíba and the sub-basin studied.

MAMAGUAPE RIVER SUB BASIN AREA - (Km³)	3.523,00
AREA OF THE STATE OF PARAIBA - (Km³)	56.585,00
APPROVAL PERCENTAGE - (%)	6,23%
STATE INVESTMENT COST - (AESA - 2006) - (BRL)	330.377.000,00
UPDATED STATE INVESTMENT COST (BRL) - YEAR 2021	5.256.102.847,23
COST OF INVESTMENT IN THE SUB BASIN - (BRL) - YEAR 2021	327.246.625,97
UPDATED STATE INVESTMENT COST - (BRL) - YEAR 2026	7.008.137.129,64
COST OF INVESTMENT IN THE SUB BASIN - (BRL) - YEAR 2026	436.328.834,63
UPDATED STATE INVESTMENT COST - (BRL) - YEAR 2031	8.760.171.412,05
COST OF INVESTMENT IN THE SUB BASIN - (BRL) - YEAR 2031	545.411.043,29
UPDATED STATE INVESTMENT COST - (BRL) - YEAR 2041	12.264.239.976,86
COST OF INVESTMENT IN THE SUB BASIN - (BRL) - YEAR 2041	763.575.460,61

Analyzing the updated investment costs and estimating the collection by scenario, it is observed that the collection model used in the year 2021 overestimates the total collection and underestimates it in the year 2041 when compared to the trend scenario. This same situation can be observed when compared with the other scenarios and an in-depth assessment of the accuracy of these charging models available in the literature becomes evident, when a representation close to reality is desired.

5 CONCLUSION

As evidenced, the instrument of charging for the use of water is necessary when one wishes to invest in a given hydrographic basin, aiming to stimulate the production of water and the management of the system. It also has as one of its main objectives to reduce waste and pollution of water sources.

Therefore, this work was based on the search for a collection model that considers the peculiarities of the region and provided knowledge of the annual collection of current and future demands of the Mamanguape River Sub-basin, consequently alerting public managers to the urgency of implementation of the collection instrument, considering that what is allowed to be collected could substantially improve the studied sub-basin.

Therefore, it was observed that the collection model used to estimate the collection in the studied sub-basin is inaccurate, since in moments of analysis it underestimates and overestimates the collection, showing that the hypothesis is false.

However, the inaccuracy of the existing charging models to estimate the collection can compromise investments and management, a situation that serves as a warning to public water management bodies about the modeling to be used and the urgency of implementing the instrument of collection, bearing in mind that it could improve the quality of the infrastructure of the hydrographic sub-basin studied.

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