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A STUDY OF THE AVERAGE ANNUAL PRECIPITATION AND THE REFLEXES ON THE STORED VOLUME AND TROPHIC STATE INDEX IN THE ACARAÚ MIRIM RESERVOIR IN THE MUNICIPALITY OF MASSAPÊ, CEARÁ

UM ESTUDO DA PRECIPITAÇÃO MÉDIA ANUAL E DOS REFLEXOS SOBRE O VOLUME ARMAZENADO E ÍNDICE DE ESTADO TRÓFICO NO RESERVATÓRIO ACARAÚ MIRIM NO MUNICÌPIO DE MASSAPÊ, CEARÁ

Vanessa Campos Alves
Researcher at the Semiarid Research and Extension Network/REPES-CNPq
vanessacampos1414@hotmail.com
https://orcid.org/0000-0002-4431-8198

Bruna Lima Carvalho
Master in Geography
https://orcid.org/0000-0003-3971-6885
brunanelore@gmail.com

João Rodrigues de Araujo Júnior
Master's student at PROGGEO/UVA
https://orcid.org/0000-0002-6320-1251
joaorodriguesjunior597@gmail.com

Patrícia Vasconcelos Frota
PhD Professor at Vale do Acaraú State University (UVA)
https://orcid.org/0000-0002-0237-2540
patricia_frota@uvanet.br

ABSTRACT
Dams play an important role in making it possible, among other functions, the storage of water for human supply and irrigation. Therefore, maintaining water quality through regular maintenance and monitoring the level of stored volume becomes essential to guarantee the population 's water security. The objective of this article is to describe the relationship between the average annual precipitation and the stored volume and quality of water in the Acaraú Mirim reservoir in the municipality of Massapê/CE. The materials and methods consisted of data collection on official websites such as FUNCEME, IPECE, IBGE, and subsequently synthesized into graphs and tables, followed by their respective analyses. The results showed that in the municipality of Massapê during the years 2012 to 2016, precipitation levels were below average, with rainfall around the average in 2017 and 2018. With the influx of rain from 2017 onwards, with an annual average above 800 mm, the behavior of the stored volume demonstrated a situation of stability and water security. However, it's important to establish an alert on the stored volume variation and the trophic state index, as the data analyzed in 2015 and 2016 demonstrated a predominance of water in a revolting state to meet priority demands associated with stored volumes of less than 50% in nearly all months and rainfall below the historical average.
Keywords: Stored volume; reservoir; water security;

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RESUMO

Os açudes possuem um papel importante ao tornar possível, dentre outras funções, o armazenamento de água para abastecimento humano e irrigação. Desta forma, manter a qualidade da água por meio de manutenções regulares e monitoramento de nível de volume armazenado torna-se essencial para garantir a segurança hídrica da população. O presente artigo traz como objetivo, descrever a relação entre a média de precipitação anual e o volume armazenado e qualidade da água do reservatório Acaraú Mirim no município de Massapê/CE. Os materiais e métodos consistiram na coleta de dados em sites oficiais como FUNCEME, IPECE, IBGE, e posteriormente sintetizados em gráficos e tabelas, seguido das suas respectivas análises. Os resultados apontaram que no município de Massapê durante os anos de 2012 a 2016 os níveis de precipitação ficaram abaixo da média, chuvas em torno da média nos anos de 2017 e 2018. Com o aporte das chuvas a partir de 2017, com média anual acima de 800 mm, o comportamento do volume armazenado demonstrou uma situação de estabilidade e segurança hídrica. Contudo é importante estabelecer um alerta sobre as variações de volume armazenado e o índice de estado trófico, pois os dados analisados nos anos de 2015 e 2016, demonstraram a predominância da água no estado indesejável para atendimento às demandas prioritárias associadas a volumes armazenados inferiores a 50% na maior parte dos meses e chuvas abaixo da média histórica.

Palavras-chaves: volume armazenado, reservatório, segurança hídrica

INTRODUCTION

Currently, integrated water resources management stands as one of the fundamental priorities of public policies, given the uncontrolled population growth, overwhelming water demand for various purposes, and the increasingly intense emergence of conflicts over limited water availability (VIEIRA, 2003).

The Brazilian Semiarid comprises a region formed by nine states in the Northeast region and part of the Southeast region, including the north of Minas Gerais, comprising the states of Alagoas, Bahia, Ceará, Maranhão, Minas Gerais, Paraíba, Pernambuco, Piauí, Rio Grande do Norte, Sergipe, and Minas Gerais (SUDENE, 2017). According to data from the National Semiarid Institute (INSA, 2023), this area is characterized as the most densely populated semiarid region on the planet, with 28 million inhabitants, of which 62% (17,360,000) live in urban areas and 38% (10,640,000) reside in rural areas.

The Semiarid region is primarily characterized by water scarcity as an environmental factor. Historically, there have been records of various actions aimed at solving the problems resulting from drought, even before the political-geographical delimitation of the region, among which the construction of reservoirs stands out, known as damming policy.

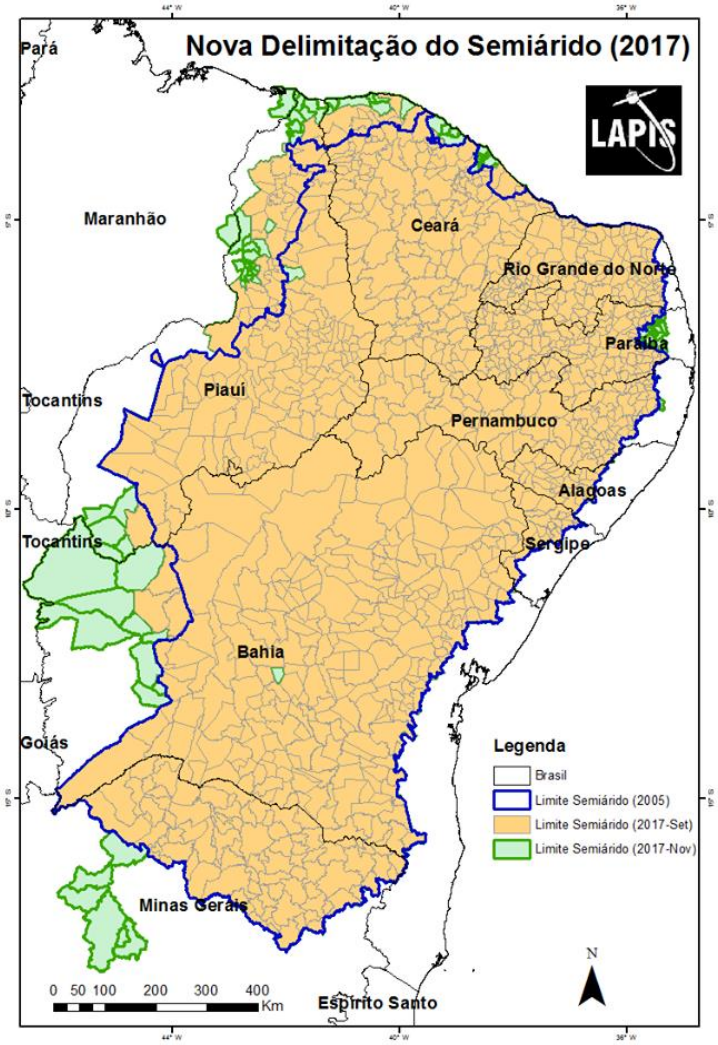
Reservoirs play an important role by enabling, among other functions, water storage for multiple uses, prioritizing human consumption and animal watering. Thus, maintaining water quality through regular maintenance and monitoring of stored volume levels becomes essential to ensure the water security of the population benefiting from its waters.

When the Semiarid is mentioned, it is common to convey an image through digital and mass media, stereotyping the region for its lack of water. The vegetation with dry tones and the sky marked by a striking blue with little presence of clouds signaling the possible arrival of rain. However, in technical terms, the characterization is given by the irregularity in annual precipitation and high evapotranspiration rates (INSA, 2023). The delimitation of semiarid areas has long been defined based on annual precipitation, so that areas with precipitation equal to or less than 800 millimeters per year would be classified as semiarid

However, in 2017 there were changes in the semi-arid delimitation criteria, the criteria were approved by the Resolutions of the Sudene Deliberative Council No. 107, of 07/27/2017 and No. 115, of 11/23/2017:

- Average annual rainfall equal to or less than 800 mm;
- Thornthwaite Aridity Index equal to or less than 0.50;
- Daily percentage of water deficit equal to or greater than 60%, considering all days of the year.

Figure 1 - New delimitation of the Brazilian Semiarid



Source: Mundogeo, 2017.

Atmospheric Systems Operating in the Semiarid Region

It is known that climate is marked by its dynamism, such that distinct climatic dynamics can affect the climatic configuration of different regions. In the Brazilian Semiarid, the dynamics of abnormal warmings and coolings in the Pacific and Atlantic oceans represent events that create anomalous behaviors and interannual variations in precipitation values. According to Kayano and Andreoli (2009), this region is characterized as one of the main ones in South America, where the signals of intraseasonal variability are most evident.

According to Marengo (2011), the most important system in rainfall production in the region is the Intertropical Convergence Zone (ITCZ), which represents the axis of the equatorial trough and its variations in position and intensity that are directly related to changes in the positions and intensities of the subtropical highs of the North and South Atlantic. The ITCZ is formed by the convergence of the trade winds from the North and South, located in the ascending portion of the Hadley cell, marked by low pressures, cloudiness, and abundant rainfall, and preferably follows the regions where the sea surface temperature (SST) is higher.

Uvo and Nobre (1989) reiterate the influence of the ITCZ, attributing its approach to the northern region of the Northeast (NNE) as the main responsible for generating rainfall. This fact is observed when considering that the peak precipitation over the NNE (March and April) occurs exactly when the ITCZ reaches its southernmost positions.

Thus, in the northern portion of the Northeast, precipitation is caused by the action of the ITCZ, as its action is conditioned by a series of other climatic elements, such as variations in the sea surface temperature of the Pacific and Atlantic oceans, which may present unfavorable conditions for rainfall, such as El Niño in the Pacific or positive dipole in the Atlantic, as well as a favorable configuration for the occurrence of rainfall with La Niña in the Pacific or negative dipole in the Atlantic.

According to Araujo Junior (2022), the great difficulty in predicting climatic dynamics is due to the fact that atmospheric and oceanic configurations are complex and continually changing. Thus, the occurrence of climatic extremes such as drought and historical rainfall accumulations may be difficult to predict, but in the historical occurrence in the semiarid region, drought occurs more frequently, putting at risk the supply and provisioning in the region that is characterized as the most inhabited Semiarid in the world.

Therefore, this article aims to describe the relationship between the average annual precipitation and the stored volume of a reservoir, as well as the factors that influence its integrity as an ecosystem, water resource, and human supply capacity.

This is a case study in the municipality of Massapê, where the object of study is a specific reservoir belonging to the Acaraú watershed, in the state of Ceará, where the set of environmental characteristics that shape its landscape and way of life, developed under a seasonal precipitation regime, intensify considerable challenges in water resources management hídricos (Alves *et al* 2024..

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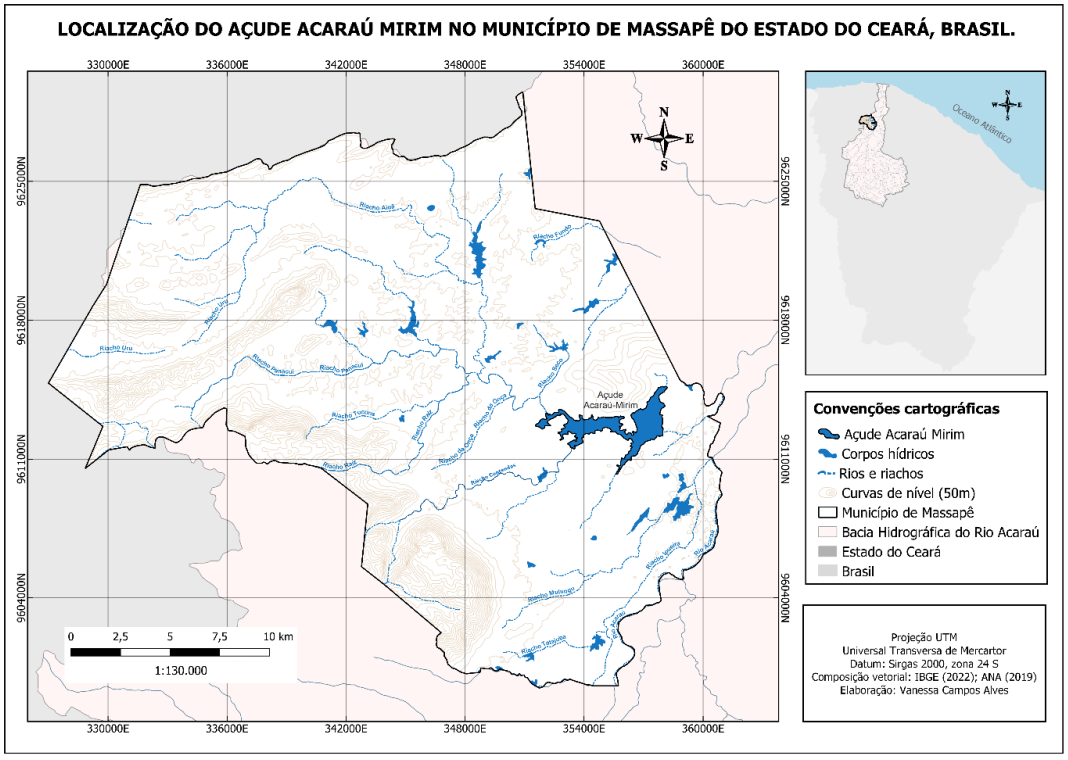
The Acaraú watershed is located in the northwest portion of the state of Ceará, covering an area of 14,444 km² with 15 reservoirs monitored by the Water Resources Management Company. Of these 15 reservoirs, Acaraú-Mirim was chosen for this research, with its contribution area being the municipality of Massapê, precisely in the district of Ipaguaçu Mirim, at coordinates 355000.30 m E and 9612600.35 m N.

According to IBGE (2022), the municipality has a total of 37,697 inhabitants over a territorial area of 567.780 km². With a capacity of 36.71 hm3, the reservoir supplies the city of Massapê, the districts of Mumbaba, Ipaguaçu Mirim, and localities of Salgadinho through the Water and Sewage Company of the State of Ceará (CAGECE).

Its waters are used for human consumption, fish farming activities, irrigation of agricultural crops, animal watering, and recreation, where the presence of resorts and bars is noticeable. These activities have impacts on both the volume of stored water and the quality of its waters, which decrease mainly during periods when the reservoir has low storage levels. The main rivers that feed the reservoir are Contendas and Raiz, both originating from the Serra da Meruoca, traversing the municipality, and having their waters impounded by the Acaraú Mirim dam.

Map 1 - Location of the Acaraú Mirim-CE dam



Source: IBGE (2022); ANA (2019). Elaboração: ALVES (2022).

MATERIALS AND METHODS

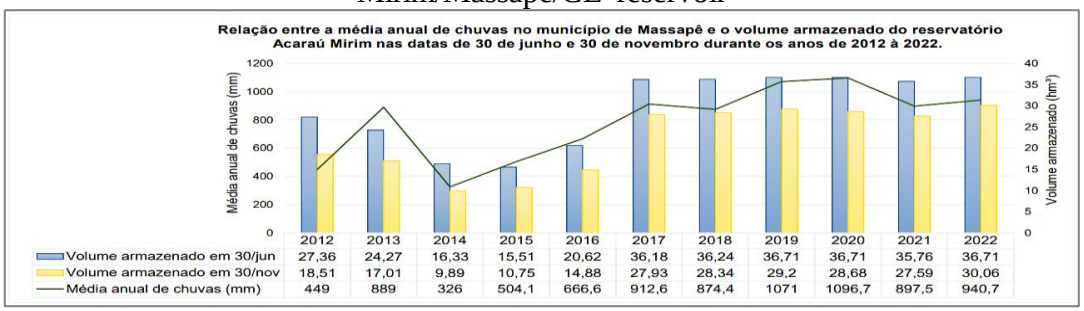
Initially, we sought to relate the average annual precipitation in the municipality of Massapê to the amount of stored volume in the Acaraú Mirim reservoir. Thus, precipitation data were collected from the virtual platform of the Ceará Foundation for Meteorology and Water Resources

- FUNCEME, where parameter values are defined as follows: from 0 to 684.9 mm (below average); from 684.9 mm to 940.7 mm (around average); and values above 940.7 mm (above average). Data regarding the reservoir were collected from the monitoring platform Portal hidrológico do Ceará, with the temporal cut-off chosen as June 30th and November 30th for the assessment of the stored volume of the Acaraú Mirim reservoir at the end of the rainy season (June 30th) and at the end of the dry season (November 30th) during the years from 2012 to 2022. After the data collection, graphs were created using Microsoft Excel spreadsheet software to represent the collected data and facilitate the proposed analysis. In the second phase, the role of this reservoir in municipal water security and an assessment of the state of its water quality were addressed.

RESULTS AND DISCUSSIONS

The information collected showed that in the municipality of Massapê during the years 2012, 2014, 2015 and 2016 precipitation levels remained below average, with the exception of an intensification of rainfall in 2013 with an average level of 889 mm presenting around the average and decreasing again in the following years, with an improvement occurring in 2017 and 2018 with values appearing around the average and finally in 2019 the amount of precipitation exceeds the average accounting for a total of 1071 mm, in 2020 the average had a small increase reaching 1096.7, in 2021 and 2022 the levels returned to remain around the average. As shown in graph - 1 the following data:

Graph 1 – Average annual precipitation and stored volume of the Acaraú Mirim/Massapê/CE reservoir



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Volume armazenado em 30/jun	27,36	24,27	16,33	15,51	20,62	36,18	36,24	36,71	36,71	35,76	36,71
Volume armazenado em 30/nov	18,51	17,01	9,89	10,75	14,88	27,93	28,34	29,2	28,68	27,59	30,06
Média anual de chuvas (mm)	449	889	326	504,1	666,6	912,6	874,4	1071	1096,7	897,5	940,7

Source: Rain calendar – FUNCEME (2023); graphic organized by the authors

This period is related to the occurrence of the El Niño phenomenon, responsible for years of drought associated with high temperatures and wind speeds, leading to increased insolation rates in the environment and drastically impacting the water balance of reservoirs due to the loss of water volume through evaporation. Thus, despite a higher concentration of rainfall throughout the period, the volume stored in the Acaraú Mirim reservoir for the month of June showed values below its total capacity from 2012 to 2016, reaching its capacity only from 2017 to 2019, differing from the results of November, when there was a decrease in precipitation from 2012 to 2019.

As a result, the volume did not reach its capacity, decreasing significantly compared to June. Furthermore, according to data from IPECE (2017), the municipality of Massapê

had a total of 7,601 active connections in 2016, which means serving approximately 34,204.5 inhabitants. In 2014, the population was more affected by the stored water volume, causing concerns about scarcity. In 2020, as precipitation values were above average, it led to an increase in the reservoir's level.

The trophic state index is an important assessment of the ecological balance of monitored reservoirs. According to Macedo and Sipaúba-Tavares (2010), this phenomenon results in an increase in primary productivity, being intrinsically related to the excessive increase in biomass of primary producers, such as microalgae, macrophytes, and cyanobacteria. The methodology for classifying trophic status was based on Paulino, Oliveira, and Avelino (2013), and the description of each of the classes can be seen in Table 1.

Table 1 – Trophy states and their meanings

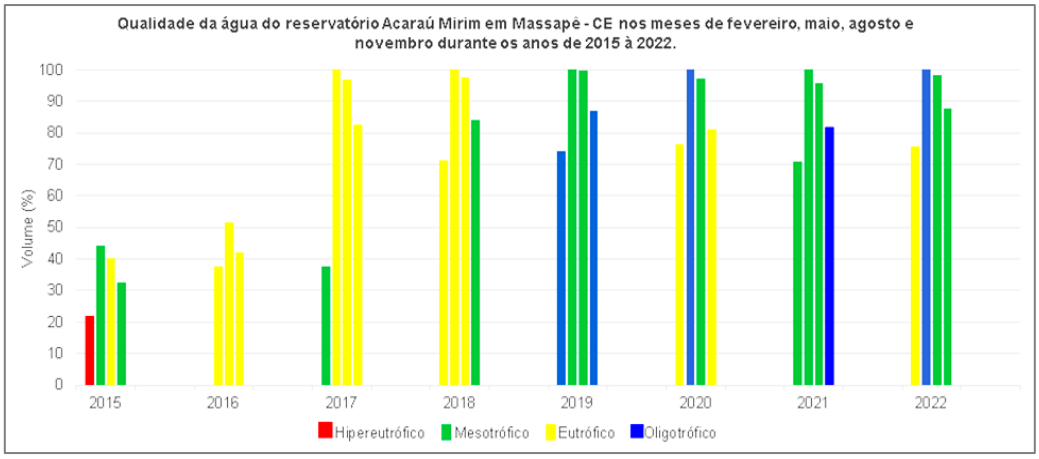
Estado de trofia	Significado
Oligotrófico	Possuem águas limpas, de baixa produtividade, em que não ocorrem interferências indesejáveis sobre os usos da água, decorrentes da presença de nutrientes.
Mesotrófico	São águas com produtividade intermediária, com possíveis implicações sobre a qualidade da água, mas em níveis aceitáveis, na maioria dos casos.
Eutrófico	São os corpos de água com alta produtividade, com redução da transparência, em geral afetados por atividades antrópicas, nos quais ocorrem alterações indesejáveis na qualidade da água e interferências nos usos múltiplos.
Hipereutrófico	Águas afetadas significativamente pelas elevadas concentrações de matéria orgânica e nutriente, com comprometimento acentuado nos seus usos, associado a episódios de florações de algas ou mortandade de peixes, com comprometimento acentuado nos seus usos.

Source: ANA (2015), with adaptations.

According to Falcão Sobrinho (2020, p.100), "The variation in rainfall and dry seasons are the most important factors, combined with shallow soil in the landscape of the sertão surface." Deforestation, coupled with traditional agricultural practices in the areas surrounding the reservoirs, leaves large areas of soil unprotected, increasing surface runoff towards water bodies and the accumulation of sediments and nutrients.

For the analysis of the trophic state index, the period between 2015 and 2022 was selected. In this temporal scope, it is possible to identify the correlation between water quantity and quality in the years 2015 and 2016, which were marked by stored volumes below 50% and bodies of water with high productivity. In the years 2017 and 2018, the reservoir with significant input due to rainfall already shows an improvement in water quality in the following years, from 2019 to 2022, as shown in graph 2.

Graph 2 – Quality of stored water



MESES	ANOS							
	2015		2016		2017		2018	
	VOLUME (%)	QUALIDADE	VOLUME (%)	QUALIDADE	VOLUME (%)	QUALIDADE	VOLUME (%)	QUALIDADE
FEVEREIRO	21,9	Hipereutrófica	-	-	37,68	Mesotrófica	71,38	Eutrófica
MAIO	44,2	Mesotrófica	37,5	Eutrófica	100	Eutrófica	100	Eutrófica
AGOSTO	40,1	Eutrófica	51,4	Eutrófica	96,75	Eutrófica	97,56	Eutrófica
NOVEMBRO	32,4	Mesotrófica	42	Eutrófica	82,66	Eutrófica	84,25	Mesotrófica

MESES	ANOS							
	2019		2020		2021		2022	
	VOLUME (%)	QUALIDADE	VOLUME (%)	QUALIDADE	VOLUME (%)	QUALIDADE	VOLUME (%)	QUALIDADE
FEVEREIRO	74,36	Oligotrófica	76,56	Eutrófica	70,9	Mesotrófica	75,6	Eutrófica
MAIO	100	Mesotrófica	100	Oligotrófica	100	Mesotrófica	100	Oligotrófica
AGOSTO	99,68	Mesotrófica	97,1	Mesotrófica	95,6	Mesotrófica	98,2	Mesotrófica
NOVEMBRO	87,17	Oligotrófica	81,1	Eutrófica	82	Oligotrófica	87,8	Mesotrófica

Source: COGERH (2023); graph and table prepared by the authors.

Reservoirs with large volumes of water have a greater capacity for dilution and dispersion of these nutrients, contributing to the reduction of eutrophication risks, especially during seasons of higher rainfall. On the other hand, reservoirs with low water volumes become more susceptible to conditions that lead to eutrophication. Other factors influencing this dynamic are related to land use in nearby areas through erosion and watershed management practices, such as monitoring and conservation practices of water resources.

CONCLUSIONS

Based on the research, it is evident that the water from the Acaraú Mirim reservoir is the primary water source for the municipality of Massapê. Thus, below-average volumes directly impact the supplied population. Besides human consumption, the reservoir serves other purposes such as irrigation of crops and animal watering. In the influence area of the Acaraú Mirim reservoir, pasture areas are also prominent. Consequently, when the reservoir's volume is low, it affects the entire region, and activities depend on this water. Therefore, water supply is contingent upon precipitation and accumulation during the rainy season, which typically ranges from February to May. Although rain may occur outside this period, it's sporadic, and when it does, it often doesn't accumulate significantly.

Thus, although the reservoir ensures the supply of essential water for basic needs and for subsistence activities by its population, during drought situations, the population's water supply becomes compromised due to the sharp reduction in annual precipitation, resulting in an inability to supply water. Unfortunately, climatological predictions of drought

events still cannot offer the desired precision for implementing mitigating policies to alleviate the effects of such climatic adversity.

Therefore, the adoption of practices and policies aimed at the use and conservation of available water resources in the semiarid region is necessary, avoiding wastage and adopting more appropriate practices for seasonal and interannual variations of water resources in the Brazilian Semiarid region.

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