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Climate Change Scenarios and Water Implications at the Epitácio Pessoa Dam – Paraíba

Cenários de Mudanças Climáticas e as Implicações Hídricas na Barragem de Epitácio Pessoa – Paraíba

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Abstract: This article analyzes the effects of climate change on the water resources of the Epitácio Pessoa Dam, located in the semiarid region of Paraíba. The study focuses on changes in hydrological cycles, the increase in extreme events, and changes in precipitation patterns, primarily due to prolonged periods of drought. The methodology included, in addition to a review of national and international literature, the analysis of time series graphs, divided into two time periods: the first spanning thirty years (1993-2023) for time series data, and the second spanning eleven years (2012-2023) for seasonality, forecast, trend, and stationary data extracted from official AESA databases. The statistical models ARIMA and SARIMA were also applied, along with the Dickey-Fuller test to assess stationarity and the Mann-Kendall test to identify trends. This study highlights water vulnerability and the implications for water systems in semiarid regions, compromising the future climate scenario. In this sense, the results show significant climate variations, which affect water availability and quality, evaporation, and seasonality, aspects that directly affect long-term water supply.

Keywords: Climate Change; Statiscal models; Semiarid.

Resumo: Este artigo tem como objetivo analisar os efeitos das mudanças climáticas nos recursos hídricos da barragem Epitácio Pessoa, localizada no semiárido paraibano. O estudo se concentra nas alterações nos ciclos hidrológicos, no aumento de eventos extremos e nas mudanças nos padrões de precipitação, principalmente devido a períodos prolongados de seca. A metodologia incluiu, além da revisão de literatura nacional e estrangeira, a análise de gráficos de séries temporais, dividida em dois recortes temporais: o primeiro de trinta anos (1993-2023), para dados de séries temporais, e o segundo de onze anos (2012-2023), para dados de sazonalidade, previsão, tendência e séries estacionárias que foram extraídas de bases de dados oficiais da AESA. Foram aplicados, ainda, os modelos estatísticos de ARIMA e SARIMA e testes Dickey-Fuller, para avaliar a estacionaridade, e Mann-Kendall, para identificar tendências. O presente estudo destaca a vulnerabilidade hídrica e as implicações nos sistemas hídricos nas regiões semiáridas, comprometendo o cenário climático futuro; nesse sentido, os resultados mostram variações climáticas significativas, as quais afetam a disponibilidade e a qualidade da água, a evaporação e a sazonalidade, aspectos que implicam, diretamente, no abastecimento d`água a longo prazo.

Palavras-chave: Mudanças Climáticas; Modelos Estatísticos; Semiárido.

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1. Introduction

Climate change is associated with the influence of natural factors and anthropogenic and atmospheric actions, including the average increase in Earth's global temperature, driven by greenhouse gas emissions into the atmosphere. Climate instabilities, over time, present a set of statistical variations with trends regarding changes in the climate system and the tools to combat them, depending on their intensity during the studied time series.

When it comes to the consequences of climate change, we find that they affect various areas, producing both direct and indirect impacts at global and local levels, affecting human well-being in both urban and rural areas. This is because they interfere with health, food security, agricultural crops, and the production system, which can consequently lead to a series of environmental disruptions such as increased heatwaves, floods, landslides, and prolonged droughts (IPCC, 2023).

In this context, according to Teixeira (2025), such factors can be measured through statistical analyses that relate changes to climatic factors over short or extended time periods, potentially resulting in extreme impacts and risks, such as prolonged droughts, floods, and landslides—events identified in historical meteorological and rainfall data, which are highly relevant for shaping perspectives on public policies for water resource management.

Furthermore, in smooth or monotonic (increasing or decreasing) changes in climatic phenomena that affect resilience, mitigation, and adaptation processes, average values of these historical rainfall and temperature series are highlighted over medium and long terms. These can occur, depending on the geographical scale, in specific or broader regions, and are confirmed by trends in time series data (IPCC, 2023).

The discussion surrounding climate change is a recurring theme in environmental and academic debates, environmental policies, and scientific studies, given that the data on the frequency of severe events are alarming. This signals the need to revise development models towards sustainability, with the goal of achieving future progress. This issue began to be discussed in the 1970s, specifically in 1972, during the United Nations Conference on the Human Environment held in Stockholm (Sweden). However, it was only in 1987 that the UN established the United Nations Environment Commission, when the premises for sustainable development for future generations were defined (MORAIS et al., 2022).

It is worth noting that climatic factors significantly influence large-scale environmental disasters, which result mainly from extensive geographic and hydrological conditions. The resources of hydrographic basins and their water sources—each with a hydrological function of supply, capture, storage, and distribution (both quantitatively and qualitatively)—are subject to assessments regarding the effects of climate change, considering both water utilization and distribution losses. The increase in evapotranspiration creates water vulnerability in reservoirs, compromising the availability of quality water in various Brazilian regions, particularly in the Northeast, worsening climate scenarios by substantially increasing temperatures and decreasing rainfall levels, thus resulting in prolonged droughts (JIMÉNEZ CISNEIROS et al., 2014).

In Brazil, the projected increase in temperature (from 1°C to 6°C) may be attributed to greenhouse gas emissions, which intensify the surface evaporation process and provoke alterations in the water balance of both natural vegetation and agricultural crops. These factors, combined with population growth, unequal spatial distribution, and lack of proper management, highlight a long-standing problem that challenges water resource management: the universal guarantee of access to water. This issue is particularly severe in regions dominated by subsistence agriculture, such as the semi-arid Northeast (JACOBI; NASCIMENTO, 2016).

Throughout the 21st century, some projections indicate that both surface and underground water resources will decrease in most dry subtropical regions, intensifying competition for water among sectors. These risks are linked both to reduced supply of untreated water and to the distribution of potable water, whose quality becomes compromised—despite conventional treatment—due to rising temperatures, sedimentation, nutrient concentration, and pollutant loads from intense rainfall (JACOBI; NASCIMENTO, 2016).

Thus, this study aims to analyze the effects of climate change on water resources in the Epitácio Pessoa reservoir, located in the semi-arid region of Paraíba. The research is based on the premise that hydrological cycles have been altered by the natural and cyclical phenomena of El Niño and La Niña, which are becoming increasingly frequent and intense due to climate change. This results in prolonged extreme drought events, interfering with rainfall patterns and water volume during the time series defined in the study.

2. Methods

For the execution of this study, a quantitative research approach was employed, with data collected from AESA, considering a 30-year time interval (from January 1993 to September 2023). The objective was to identify the rainfall index in time series of precipitation and water volume at the Epitácio Pessoa reservoir. Additionally, for the period between

2012 and 2023, annual percentage data on trends, seasonality, and volumes were analyzed, according to the Executive Water Management Agency of the State of Paraíba (AESA).

Further sources included academic journals from CAPES, which provided theoretical support for the theme of statistical variation analysis. These sources specified time series for rainfall indices, water volume, supply, hydric capacity, and environmental and climatic anthropogenic factors that occurred over the three decades in question.

Regarding the location of the municipality that hosts the reservoir, we used QGIS software and the statistical program R, which facilitates data collection and analysis by producing combined time series graphs. These graphs assign annual percentage averages for volume, trends, seasonality, and series profiles. For the analysis of the annual volume data of the Epitácio Pessoa reservoir (part of the Paraíba River Basin), as made available by AESA, we applied the SARIMA statistical model (Seasonal Autoregressive Integrated Moving Average Model).

Finally, we used the Mann-Kendall and Dickey-Fuller tests, whose functions assist in identifying non-stationary time series, allowing for the detection of trends within the time series. These methods are better suited for incorporating statistical equation functions for volume orders, seasonality, climatic cycles, and variations near reservoirs, corresponding to the period marked by intense climatic phenomena over the past 11 years (from January 2012 to December 2023).

2.1 Study área

The Epitácio Pessoa reservoir is located in the municipality of Boqueirão, geographically situated in the Borborema mesoregion, 46.6 km from Campina Grande and 146 km from João Pessoa, the state capital. Also known as the "City of Waters," it is part of the Paraíba River Basin, as it hosts the Epitácio Pessoa Reservoir—the second largest water reservoir in the state—with a storage capacity of 400 million cubic meters of water.

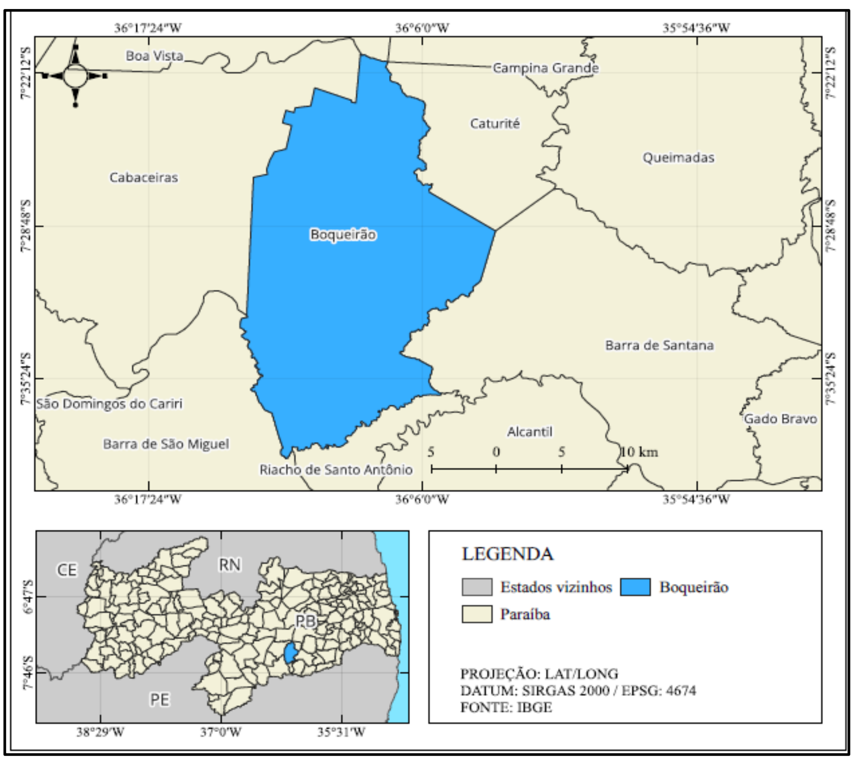

Figure 1: Location map of the municipality of Boqueirão, Paraíba (PB).
Source: IBGE (2022).

Identified in blue in Figure 1, Boqueirão is responsible for supplying water to more than 1.8 million inhabitants, distributed across 19 municipalities in the metropolitan region of Campina Grande, Paraíba (IBGE, 2022).

2.2 Historical Time Series Data Collection

According to Teixeira (2025), historical time series are defined and classified into three categories of unobservable components: Trend (Tt), Seasonality (St), and random variation or White Noise (Ɛt). Once the mathematical model is selected and the relational criteria for adding the cited components are defined (Zt = Tt x St x Ɛt), a logarithmic transformation is applied, converting the multiplicative model into a log-linear one, which ultimately results in a historical time series equation.

Each time series model must be assigned a condition, considering stationary and non-stationary series, as this determines the most appropriate model for the study. A non-stationary model should be used when the series fluctuates around a mean and then shifts to a new level (series differencing). When a trend is established, converting it to a stationary series requires a second differencing. In such cases, the ARIMA model is indicated due to recurring seasonality across multiple periods, and is classified within a stochastic component (MORETTIN; TOLLOI, 1985; 2004; 2006).

Thus, a time or historical series requires a time interval associated with a sequence of data collected over time. For this, the parameters of the time series must be based on the climatic phenomenon under study, from which the analysis will provide a description of the series' behavior and its estimated means, considering a cause-and-effect relationship. According to Yin (2001), this aligns with the SARIMA family model, which is the most appropriate for forecasting and estimating model representations, diagnostics of series profiles, residuals, forecasts, trends, and estimates.

The historical series analyzed in this study were obtained from AESA's Hydrometeorological Data System (SEIRA). For the Epitácio Pessoa reservoir, time series data were collected for two intervals: 30 years and 11 years. These series contain annual values of water volume levels, seasonality, forecasting, and trends.

2.3 Statistical Analysis of Historical Time Series

According to Box et al. (2008), the statistical modeling of SARIMA is determined by a time series: z1, z2,...,zN, in which observations occur at equally spaced time intervals. The backshift operator B is defined as Bzt = zt−1, that is, Bmzt = zt−m; in seasonal time series, the period uses the operator BSzt = zt−S. Additionally, the difference operator ∇ is defined as ∇zt = zt − zt−1 = (1 − B)zt (first-order difference), and the seasonal difference operator ∇S is defined as ∇Szt = zt − zt−S = (1 − BS)zt (seasonal difference of orders). In this regard, Morettin (2006) suggests the use of seasonal autoregressive integrated moving average models (SARIMA).

The author also notes that the time series is defined by S (seasonality), for example, for monthly data, while ΦP(BS) and ΘQ(BS) are polynomials in BS of degrees P and Q, respectively; Φp(B) and θq(B) are polynomials in B of degrees p and q, respectively: ∇S = 1 − BS and ∇ = 1 − B. Given the respective orders of seasonal and regular differencing, εt is a series of random shocks or white noise, and the series model is referred to as being of order (p, d, q) × (P, D, Q)s.

Thus, the construction of this model is linked to a time series, followed by an organized strategy with an interactive process in which the model structure is selected based on the data itself. The modeling phases consist of specifying the general class of models, identifying those supported by autocorrelation and partial autocorrelation analyses estimated from verification parameters, and analyzing model residuals in order to achieve the lowest forecasting error.

In this context, the SARIMA modeling methodology was adopted. According to Morettin and Toloi (2006) and Diggle (1992), it is the most effective method for calculating the means of stationary and non-stationary time series with seasonality in the water volumes of the Epitácio Pessoa reservoir. Through comparative analysis, forecasting models were identified for the time series monitoring of the reservoir, resulting in time-based seasonal graphs, profiles of stationary and non-stationary volume series (%), and forecasts of the behavior of volume level series (%) of the reservoir for the next 12 months.

It is important to emphasize that one of the core principles of SARIMA modeling lies in observations that fit the replicated models in the study: stationarity and non-stationarity. These are applied in both the Mann-Kendall test—used to assess trends in time series under the assumption of independent series that may show a monotonic trend over time—and the Dickey-Fuller test, applied to autoregressive series that do not reject the null hypothesis of non-stationarity, i.e., the series is non-stationary.

The application of the Mann-Kendall (MK) test in the present study is based on Sneyers (1975), who noted the presence of trends in the variables of monthly time series, with a prevalence of ARIMA. The dependent variable reflects the conditions of hydrological, climatic, and meteorological seasonality, prevailing in the samples and data analyzed (above a 5% probability threshold) for the Epitácio Pessoa reservoir, with volume measurements in percentage and precipitation in millimeters, over the 30-year and 11-year time periods, respectively. Therefore, the method proved to be the most appropriate, as it enables more accurate climate forecasting analyses and allows for the detection and localization of trends, considering the assumptions of historical series.

According to Teixeira (2025), the Dickey-Fuller stationarity test is the most suitable for this research, as it tests the null hypothesis of a unit root in the series: when not rejected, the series is said to have a unit root and is generally considered non-stationary. However, to avoid autocorrelation in the residuals, the Augmented Dickey-Fuller (ADF) test is used, which incorporates lagged terms to eliminate residual autocorrelation problems.

Meanwhile, according to Arêdes and Pereira (2008) apud Santos (2015), the most appropriate test for use is that of stationarity analysis in time series, considering that the results of the autocorrelation and partial autocorrelation coefficients are constructed from their respective correlograms: ACF (Autocorrelation Function) and PACF (Partial Autocorrelation Function), resulting in graphical inspections of lags.

There are various classes of autocorrelation models suggested and proposed by Box and Jenkins (1970), who laid out the theoretical foundations for the formulation of autoregressive and moving average components in time series modeling. These rely on two basic methodological principles in model construction: parsimony, which seeks to use the fewest possible parameters to represent the climatic phenomenon, and interactivity, which balances theory and practice to achieve a satisfactory result. In this context, empirical material is analyzed with theoretical support, and the outcomes of the stages and climatic phenomena throughout the time series interval are determined and tested through successive iterations until reaching an ideal model, whose representation is explained by a statistical equation:

$$yt = a0 + a1yt-1 + \cdots + apyt-p + \varepsilon t + \beta 1\varepsilon t-1 + \cdots + \beta q\varepsilon t-q$$

In the equation, the term a_0 is represented by a constant in the estimated model (a_1 to a_p), which are the parameters that define the past values Y_t from the immediately preceding moment to the most distant one, as defined by p. The term ε_t represents the portion controlled in the model (referred to as white noise), which applies when the series does not exhibit stationarity. Furthermore, the parameters β_1 to βq, correspond to a series derived from the function of past shocks. In summary, each ε_t is assumed to follow a normal distribution, with a mean of zero, constant variance, and no autocorrelation (SANTOS, 2015).

Given this, we identify that the most appropriate model to be applied in this study is one that accounts for variable adjustments in the series of seasonality and climatic variables applied to the Epitácio Pessoa reservoir. This model uses the Akaike Information Criterion – AIC, the Bayesian Information Criterion – BIC, and the Mean Squared Error – MSE for forecasting, as defined by Priestley (1989). These methods offer the most precision, with a minimal error margin, thereby making the process more efficient and feasible and improving the accuracy of the parameters and, consequently, the results.

In the scenario analyzed, it is evident that the greater the vulnerability index of the population, the greater the impacts of natural disasters. However, the incidence of these phenomena is related to a series of factors, among which is the irregularity in rainfall indices across different regions (FARIAS, 2020).

3. Results and Discussion

Considering the 30-year historical interval analyzed (January 1993 to September 2023), it was found that the most critical periods of water crisis in the state, caused by climatic interferences from the El Niño phenomenon in the Epitácio Pessoa reservoir, occurred primarily between the years 1997–2000 and 2012–2018. In this scenario, both anthropogenic and natural factors, combined with a worsening trend in precipitation volume indices, led to regional-scale climate variations. These resulted in difficulties in water supply for the population, as well as for industrial and irrigation services—issues that were exacerbated by water waste, contamination, and high evapotranspiration, ultimately leading to water supply collapse in the Paraíba River basin reservoirs and water rationing in the metropolitan region of Campina Grande.

Other relevant factors observed in the results include the joint actions of public agents from the Federal and State Governments, especially the National Water Agency (ANA), the Paraíba River Basin Committee, and the Executive Water Management Agency of the State of Paraíba (AESA), all of which actively participated in decision-making processes in response to the issue. Notable actions include the arrival of water from the São Francisco River Transposition Project (PISF) to the Paraíba River Basin in 2017, which significantly increased the water volume levels of the Epitácio Pessoa reservoir, along with the negotiated water allocation and the management of reservoir usage.

Next, Figure 2 presents the time series of the water volume percentage in the Epitácio Pessoa reservoir from January 1993 to September 2023:

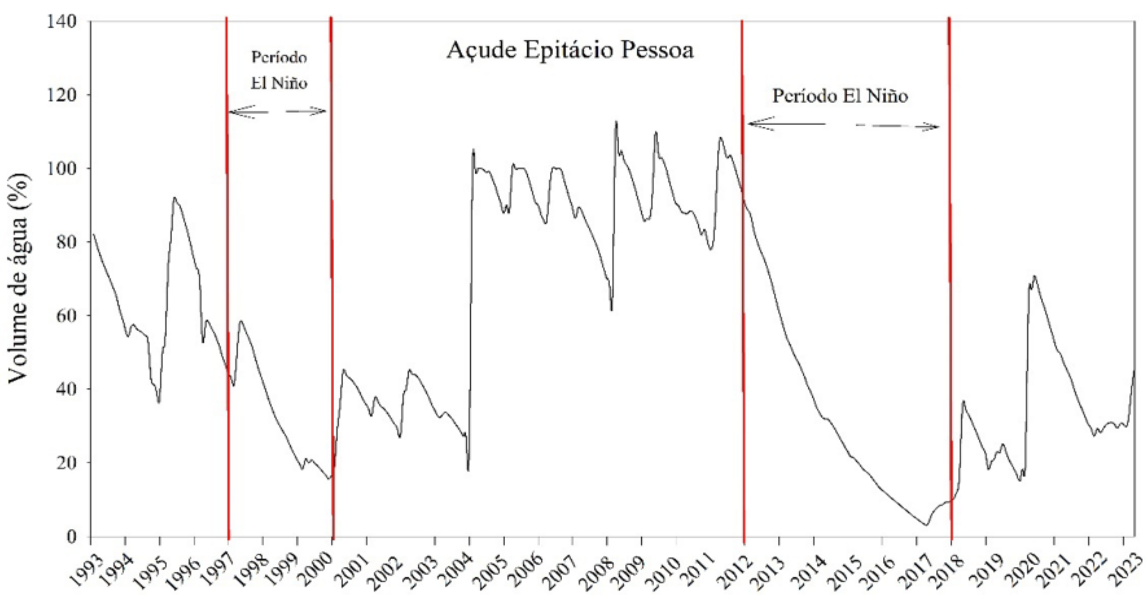

Figure 2: Time series graph of the water volume in the Epitácio Pessoa reservoir.
Source: AESA (2025).

Based on the graph above, it can be observed that in two distinct periods, the impact of climatic phenomena on the hydrological cycles of the Epitácio Pessoa reservoir directly influenced the significant drops in reservoir volume between 1997–2000 and 2012–2018. During these intervals, the reservoir reached 14% of its capacity in December 1999 and a historic low of 3.18% in April 2017, considered the most critical period in the reservoir's historical time series. This marked the lowest volume ever recorded, resulting in a regional water supply collapse. However, following this event, there was an exponential increase in water volume, mainly due to the arrival of water from the São Francisco River Transposition Project (PISF). Since then, the reservoir has received increased attention in terms of long-term water resource planning by both federal and state authorities.

Between 2004 and 2005, there was a significant increase in the reservoir's volume, rising from 20% in 2004 to 100% the following year. Another notable period was between 2008 and 2009, when the annual average levels exceeded 100%, due to a period of intense rainfall that began in 2004, associated with the La Niña phenomenon, which lasted until 2011 and reappeared only in 2020, when the reservoir reached over 60% of its capacity. The influence of climatic phenomena on the reservoir aligns with the findings of Gomes and Lima (2021), who confirmed the influence of climate variability and precipitation on reservoir water volumes in Northeastern Brazil between 1986 and 2018.

It is important to highlight that, as stated by Morais and Barbosa (2022), the increase in the average estimated reservoir volume is closely linked to long-term time series trends, which serve as a basis for statistical parameters related to trends, seasonality, stationarity, and predictability. These parameters inform climate scenario analyses for the Epitácio Pessoa reservoir.

Next, Figure 3 presents the monthly and annual seasonality graph of the Epitácio Pessoa reservoir volume, covering the period from January 2012 to December 2023, based on AESA's measurement data:

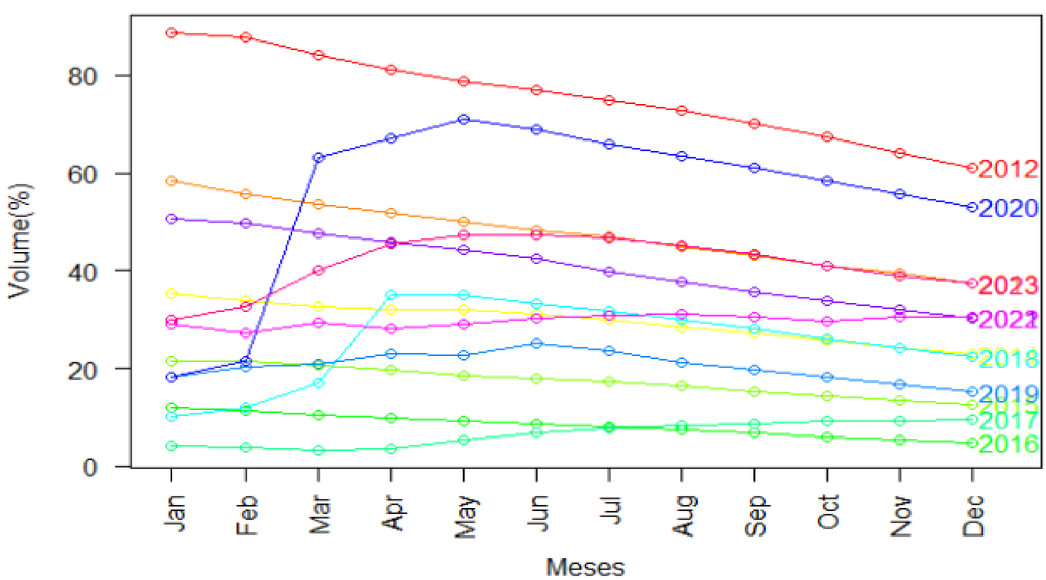

Figure 3. Monthly seasonality of the water volume (%) in the Epitácio Pessoa reservoir between 2012 and 2023. Source: AESA (2025).

The image shows that, over the eleven-year interval (January 2012 to December 2023), the Epitácio Pessoa reservoir experienced a reduction in water volume due to seasonality. Initially, the reservoir was at 86% of its capacity, which decreased to 65% by December 2014 and later dropped to 30%, leading to the implementation of water rationing policies in the metropolitan region of Campina Grande and in the 19 municipalities supplied by the reservoir. This situation persisted until 2018. It is noteworthy that the 2016/2017 biennium was considered the most critical in the seasonal series, when the average water volume fell below 10%, mainly due to climatic factors associated with the El Niño phenomenon.

Amid climatic fluctuations, in April 2017, the Epitácio Pessoa reservoir began a recovery process following the arrival of water from the São Francisco River Transposition Project through the eastern axis into the Paraíba River section. This raised the reservoir's water level from 2.3% in April to 10% by December of the same year. In January 2020, the increase was even more significant, from 18% to 62% in just five months.

By the end of 2020, the reservoir stabilized at an average between 40% and 45% during the 2021–2023 triennium, due both to the transposition waters and to regular seasonal rainfall at the Paraíba River headwaters, driven by La Niña effects. This improved the reservoir's volume by more than 40% over a four-year period. Figure 4 below presents the annual time series profile—both stationary and non-stationary—of the Epitácio Pessoa reservoir volume, based on AESA's measurements from January 2012 to December 2023:

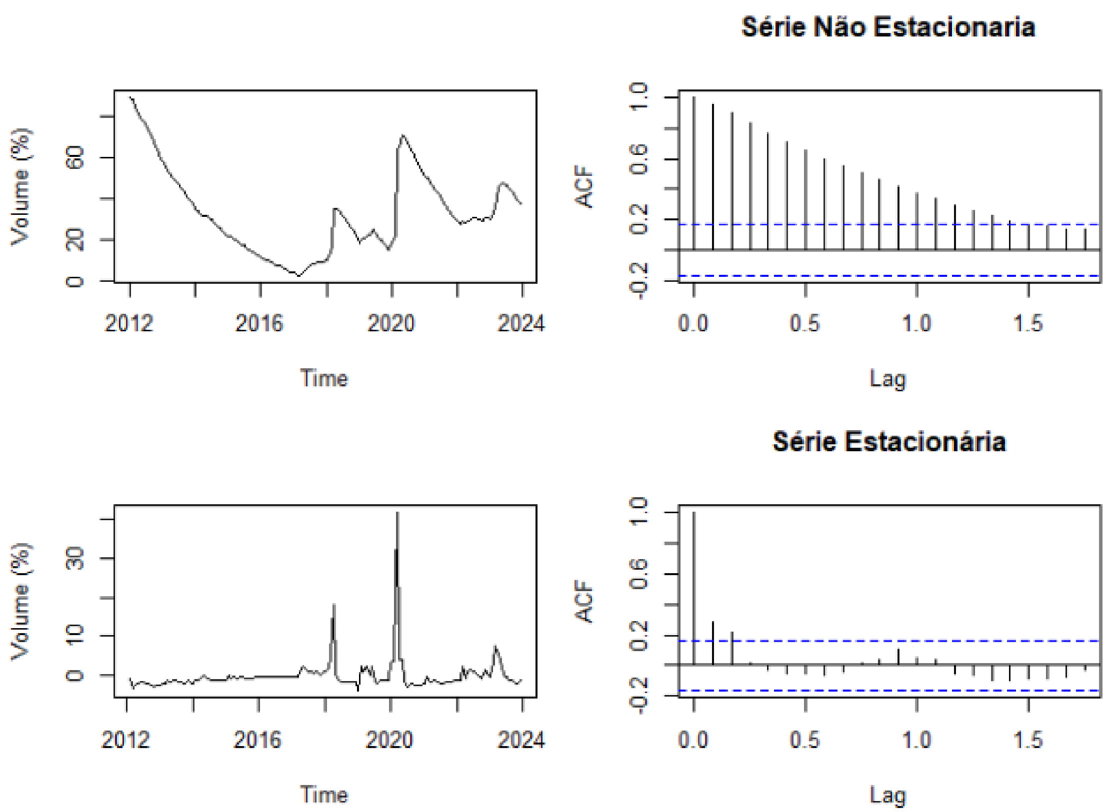

Figure 4. Profile of stationary and non-stationary series of the water volume (%) in the Epitácio Pessoa reservoir between 2012 and 2023.

Source: AESA (2025).

Through the profile of stationary and non-stationary time series of the water volume, it was possible to identify a sharp drop in reservoir levels between 2012 and 2017, when the volume drastically decreased from 86% to 2.13% in April 2017. This situation required the use of the reservoir's technical reserve, marking the most critical period in the historical series since its inauguration in 1957. This was caused by a prolonged drought linked to the El Niño phenomenon, highlighting a hydroclimatic scenario of extreme seasonal climate events, in alignment with the study by Almino and Rufino (2021).

However, one of the key observations in the stationary and non-stationary series profiles of the Epitácio Pessoa reservoir was the steady recovery of water levels. In the first half of 2018, the volume was around 10%, and by the second half of 2019, it had reached 25% of its capacity. This 15% recovery in less than two years is largely attributed to the arrival of water from the São Francisco River Transposition Project. This occurred in a context marked by significant historical water losses due to severe droughts, driven by El Niño and high evapotranspiration rates in the upper and middle sections of the Paraíba River since 2012.

The arrival of water from the eastern axis of the São Francisco River transposition project in April 2017, combined with intense rainfall in the upper headwaters of the Paraíba River—at a time when the reservoir's volume had reached the critical level of 2.13%—led to a significant increase of approximately 58% over a four-year period, bringing the reservoir to 60% of its capacity.

In conducting technical analyses of the graphs depicting the Epitácio Pessoa reservoir series profiles, it is essential to note that stationarity and non-stationarity are interconnected with the mathematical models underpinning the Mann-Kendall test, which aims to identify trends in time series under a given hypothesis. It is crucial to understand that the sample must be independent and identically distributed, with "series observations showing a stationary monotonic trend over time." Thus, the function of the Dickey-Fuller test is applied when the null hypothesis of non-stationarity is not rejected, indicating the series is non-stationary.

Following this, Figure 5 presents the ARIMA residual graph for the annual stationary and non-stationary series, based on the autocorrelation model of the Epitácio Pessoa reservoir volume, according to AESA measurements from January 2012 to December 2023:

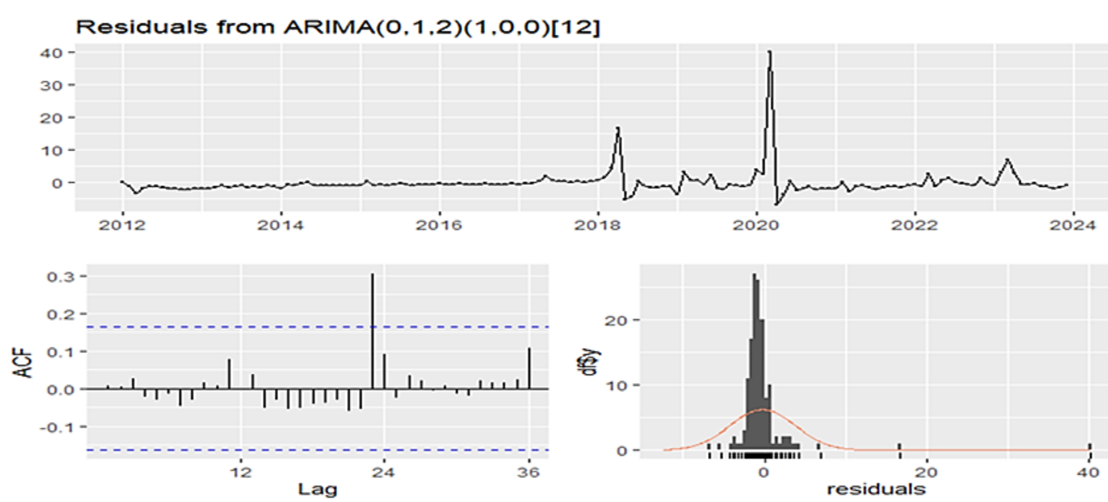

Figure 5. ARIMA residual model graph for p.d.q values (0,1,2)(1,0,0) of the Epitácio Pessoa reservoir, covering the time series period from 2012 to 2023.
Source: AESA (2025).

The illustration highlights features of the ARIMA residual model for the reservoir in question, based on the autocorrelation function of the ARIMA modeling, defined by p.d.q values of (0,1,2)(1,0,0). These values support the interrelationships observed in the eleven-year time series, illustrating the reservoir's behavior during a period marked by strong climatic and meteorological variability, driven by the El Niño phenomenon between 2012 and 2018.

Thus, considering stationarity between 2012 and 2017 in the time series as defined by the Mann-Kendall static model, we analyzed both monthly and annual series, in which the water volume variable remained stationary over the first six years. However, the graph shows that the residual ACF (Autocorrelation Function) values represent graphical inspections of lags in the highest volume values at lag 24, indicating an exponential increase in water volumes after the year 2020. Another relevant contributing factor to this trend was the arrival of waters from the eastern axis of the São Francisco River transposition project at the Epitácio Pessoa (Boqueirão) reservoir in April 2017.

Figure 6 below presents the forecasted volume of the Epitácio Pessoa Reservoir, estimated using the ARIMA model based on past and future annual time series data from AESA, highlighting the projected annual average for the year 2025:

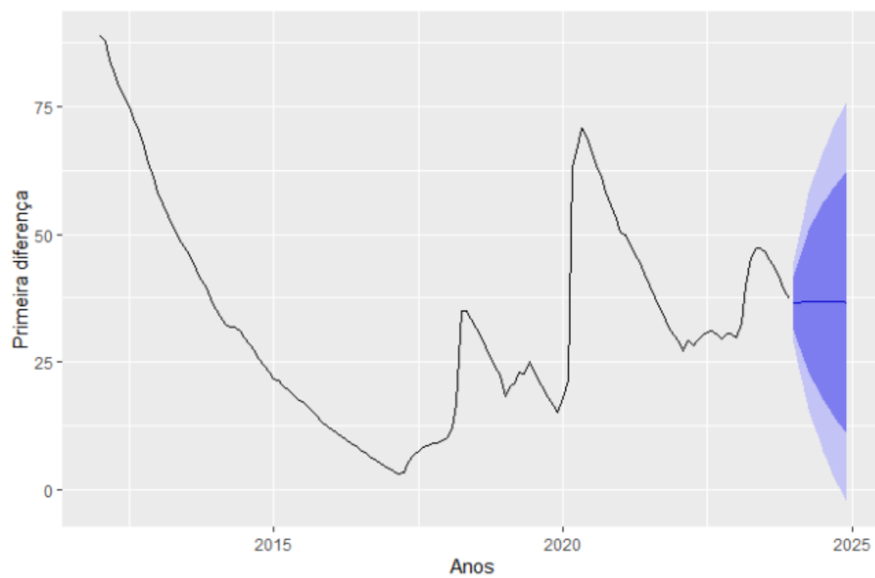

Figure 6. Temporal variation forecast graph of the water volume (%) for the Epitácio Pessoa reservoir in 2025.
Source: AESA (2025).

In the forecast presented in Figure 6, a declining trend in the water volume for 2025 is observed. However, a stationary pattern in the average volume levels of the Epitácio Pessoa reservoir is also expected, indicating a monotonic trend of water volume stationarity for the following year, as seen in the first difference shown in the graph. This homogeneous stationarity around 40% of the reservoir's volume is explained by the SARIMA method, which measures the prevalence of volume values in the time series through the Dickey-Fuller test. This test adopts a 5% significance level, supporting the assumption of a stationary ARIMA model.

This forecasted trend of stationarity is confirmed by the Dickey-Fuller test, which defines the ARIMA mathematical model as the basis for predicting future average water levels for 2025. These values are derived from climatic and meteorological variables and verified by the Dickey-Fuller stationarity test (unit root), for which the null hypothesis was rejected, resulting in the predominance of a stationary ARIMA (IRA) model.

Next, Figure 7 presents the annual trend graph of the water volume in the Epitácio Pessoa reservoir, based on the ARIMA model and AESA measurement data for the decade 2012–2023:

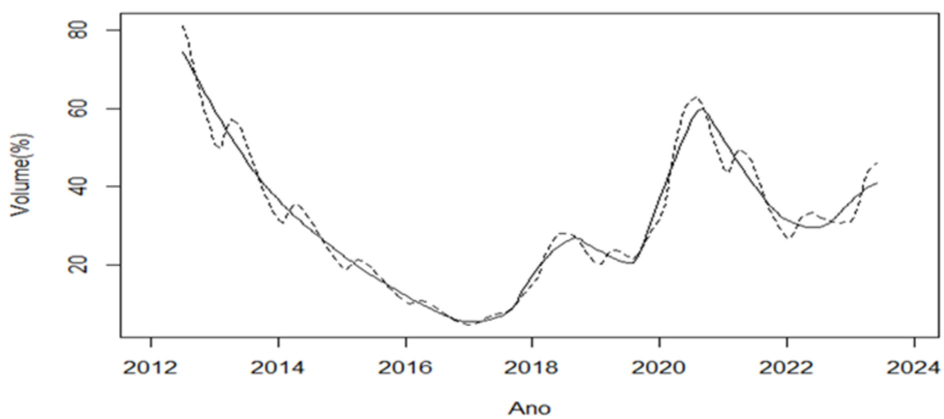

Figure 7. Annual water volume (%) trend graph of the Epitácio Pessoa reservoir, for the period between 2012 and 2023.
Source: AESA (2025).

In the image above, a rapid decline in the reservoir's water volume can be observed between 2012 and 2017, falling from 80% to 2.3%, which represents a loss of 77.7 percentage points over a five-year interval. Following this episode, only with the arrival of water from the eastern axis of the São Francisco River transposition project did a significant recovery occur, from 15% to 60%—a rising trend of 45% over a three-year span.

In this sense, the present study reaffirmed—through simple mean comparison tests and statistical analyses of time series—that during the defined time frame, the Epitácio Pessoa reservoir experienced intense hydro-climatic cycle alterations. These changes were due not only to the interference of climatic phenomena such as El Niño and La Niña, whose effects resulted in drastic reductions in precipitation and water volume, but also to the reservoir's location in a semi-arid region, where high evapotranspiration rates contribute to water loss.

Moreover, the study confirms the importance of promoting actions focused on predictability, trend analysis, and seasonality, along with public policies for water resource management aimed at risk mitigation and climate adaptation. This calls for more efficient and flexible allocation systems, as well as greater investment in infrastructure and environmental policies to ensure both access to water resources and the reduction of damages caused by climate change. Such measures can be supported through validated simple comparison tests and statistical modeling and analyses—specifically, trend analysis (Mann-Kendall) and stationarity tests (Dickey-Fuller). These confirmed, through the highlighted time series data, that climatic cycles directly influence hydrological cycles, especially as extreme natural events have altered precipitation and volume patterns, notably during prolonged drought periods such as those experienced by the Epitácio Pessoa reservoir.

3. Final Considerations

The study revealed a consistent trend in the forecasted water volume levels for the Epitácio Pessoa Public Reservoir in 2025, with an estimated probability of approximately 40% in volume elevation. This is considered a significant projection, especially since the increase in 2024 was only 5%. The average water volume in the reservoir over the past 11 years, according to the ARIMA autoregressive model, supports the forecast for 2025, with variation values evaluated using the Mann-Kendall parametric trend test, reaching a significance level of 5% (p-value < 0.05).

Through the application of SARIMA and ARIMA statistical models, supported by descriptive analyses of trend tests (Mann-Kendall) and stationarity tests (Dickey-Fuller), the 2025 water volume projections proved effective for monitoring time series of hydrological systems. This allows for the implementation of feasible measures by public management in response to climate change and its impacts on the Epitácio Pessoa reservoir, particularly during periods of extreme climatic events, enabling the establishment of water distribution strategies aligned with governmental planning actions.

Thus, the studies developed using statistical models of volume and rainfall for the Epitácio Pessoa reservoir demonstrated that climatic fluctuations directly influence changes in rainfall regimes as well as water volumes in reservoirs. Therefore, it is possible to determine that the time series indices analyzed reaffirm these effects on the socio-environmental context of the reservoir's water resources during the evaluated time series period.

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