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Water Availability and Precipitation Indicators in the Muriaé River Basin, Southeast Brazil

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Abstract

This study investigated the relationship between precipitation indicators and water availability in the Muriaé River Basin (MRB), Southeast Brazil, using rainfall and streamflow series from 1961 to 2020. Monthly mean precipitation (MMP), the total annual precipitation (PRCPTOT), the Rainfall Anomaly Index (RAI), and the Q95 low flow parameter were analyzed to evaluate hydrological variability and drought conditions. Trend analyses were performed using the Mann–Kendall test and Sen's slope estimator, and Pearson correlation analysis was applied to assess the relationship between precipitation and low flow availability. The results showed marked temporal variability in precipitation and hydrological conditions throughout the basin. Although statistically significant increasing trends in annual precipitation were identified at Carangola and Patrocínio do Muriaé, no generalized long-term reduction in precipitation was observed in the MRB. In contrast, Q95 exhibited reductions at all monitored stations, with decadal decreases ranging from approximately 31% at Carangola to 56% at Itaperuna. The RAI analysis indicated predominance of very dry and extremely dry events during the most recent decade, coinciding with reduced low flow availability. The results indicate that changes in water availability are linked to the temporal distribution and persistence of dry anomalies. These findings can influence decisions in hydrological monitoring and water resource management strategies in the basin.

Keywords: northwest region of the state of Rio de Janeiro; drought; rainfall anomaly index; low flow

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1. Introduction

Changes in precipitation and temperature patterns directly affect water availability by influencing aquifer recharge, river flows, and evaporation—processes essential for human supply, productive activities, and the maintenance of ecosystems [1]. The growing demand for water presents significant challenges to water security, especially in densely populated areas or regions with high industrial development [2].

In situations of drought, or any other imbalance between water supply and demand that leads to consumption restrictions, water security is compromised [3]. Additionally, water security involves access to water, efficient risk management, and the resolution of conflicts related to its use [4].

Drought is defined as an anomaly characterized by a prolonged period of below-average precipitation [5]. One example is the 2014–2015 drought, considered one of the most severe ever recorded in Southeast Brazil, which drastically affected the reservoirs

supplying the region's main cities [6]. The event was associated with a deficient rainy season combined with rising average temperatures, resulting in prolonged water deficits and compromising the water security of millions of people [7].

Climate change impacts precipitation dynamics through changes in the intensity and frequency of rainfall events [8]. However, it also alters the water resources of a basin [9], affecting the ability of river basins to satisfy water demands [8,10]. In Brazil, water availability is represented by a low flow with a 95% guarantee (Q95), which reflects the water demand [11]. The integration of climate indicators with hydrological time series enables more accurate forecasts of future water availability [12].

According to [13], monthly mean precipitation (MMP) calculated from historical series allows the analysis of seasonal rainfall behavior. Similarly, the authors of [14] state that the distribution of monthly average precipitation provides insights into the seasonal behavior of a basin.

In their assessment of climate trends in the State of Rio de Janeiro [15] used total annual precipitation (PRCPTOT), which represents the total annual precipitation recorded on wet days [16].

According to [17], the Rainfall Anomaly Index (RAI) is another relevant indicator for monitoring extreme events [18], in a study on the Central Amazon, used the RAI to analyze interannual and interdecadal rainfall events. As defined by [19], the RAI detects anomalies relative to historical averages, classifying periods as extremely dry or excessively wet.

The identification of seasonal trends in precipitation and river flow is crucial for understanding climate variability and is essential for developing hydrological models and managing water resources. However, there is limited knowledge on how the spatial and temporal patterns of rainfall have changed or are changing, as well as their effects and impacts on water resources [20–22].

This study will analyze the trends of historical precipitation and streamflow series in the Muriaé River Basin (MRB), located between the states of Rio de Janeiro and Minas Gerais, in Southeast Brazil, to allow the information obtained to be used by decision-makers to implement adaptive strategies, including infrastructure planning and water resource management.

2. Materials and Methods

The MRB spans the eastern region of the state of Minas Gerais and the Northwest and Northern regions of the state of Rio de Janeiro, covering a total drainage area of 8126 km^2 (Figure 1). According to [23], the Northwest Region of the State of Rio de Janeiro is one of the driest and most environmentally degraded areas, facing severe limitations in water supply for both human and animal consumption. The Muriaé River is a main left-bank tributary of the Paraíba do Sul River [23]. Rainfall distribution within the basin is strongly influenced by topography; the headwater regions record the highest rainfall, exceeding 1400 mm, whereas in lowland regions near the river's mouth, annual totals drop significantly, reaching minimum values around 900 mm [24].

Precipitation and streamflow data were obtained from Hidroweb, a platform integrated into the Brazilian National Water Resources Information System (SNIRH) [25]. The criterion was to select stations with daily records with no or minimal missing data (less than 5%) for the study period (1961–2020). Tables 1 and 2 summarize the characteristics of the selected monitoring stations.

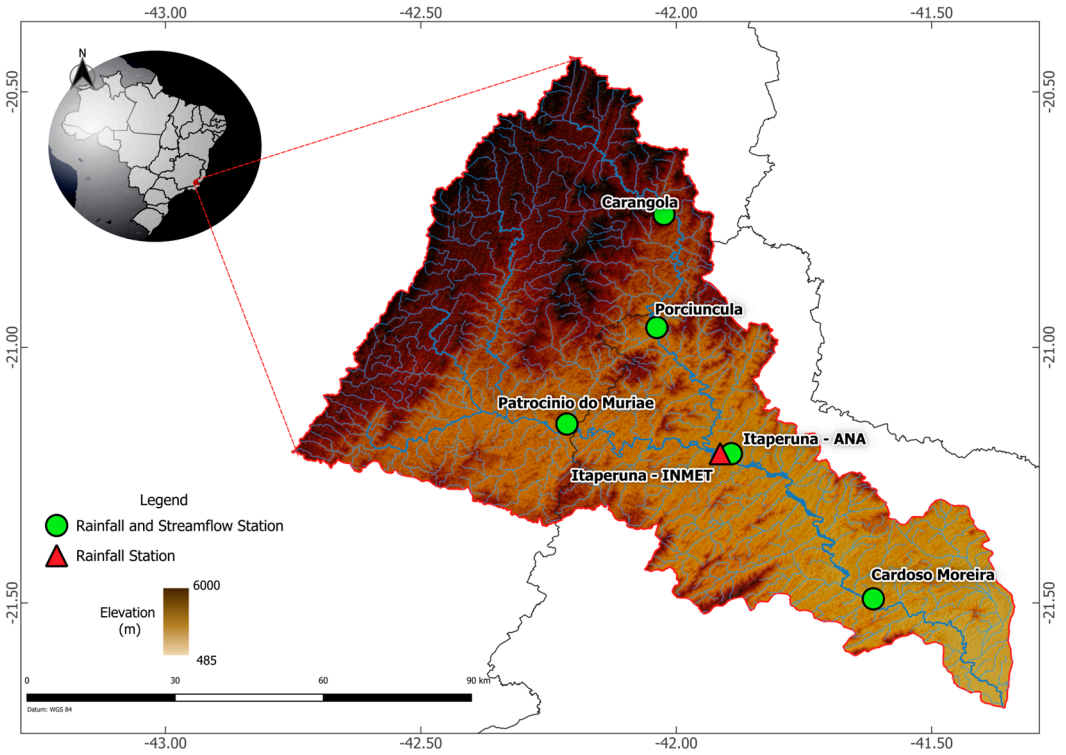


Figure 1. Location of the Muriaé River Basin (MRB) in Southeast Brazil and spatial distribution of the selected rainfall and streamflow monitoring stations used in this study.

Table 1. Selected streamflow monitoring stations.

Station Code	Station Name	River	Drainage Area (km^2)	Latitude	Longitude
58930000	Carangola	Carangola	773	−20.740	−42.024
58934000	Porciúncula	Carangola	1340	−20.961	−42.038
58920000	Patrocínio do Muriaé	Muriaé	2660	−21.150	−42.214
58940000	Itaperuna	Muriaé	5800	−21.208	−41.892
58960000	Cardoso Moreira	Muriaé	7210	−21.492	−41.614

Table 2. Selected rainfall monitoring stations.

Station Code	Station Name	Monitoring Agency	Latitude	Longitude
2042000	Carangola	ANA	−20.740	−42.024
2042027	Porciúncula	ANA	−20.961	−42.038
2142002	Patrocínio do Muriaé	ANA	−21.150	−42.214
2141004	Itaperuna	ANA	−21.208	−41.892
83695	Itaperuna	INMET	−21.208	−41.914
2141003	Cardoso Moreira	ANA	−21.492	−41.614

The streamflow monitoring stations presented no missing data. However, limited missing records were identified in the Itaperuna ANA rainfall series, mainly concentrated in the early 1980s. This gap was completed using monthly data from the Itaperuna station operated by the National Institute of Meteorology (INMET; station 83695), after verification of statistical agreement between the two series through Pearson correlation and linear regression analyses [26,27], and the results are presented in the Results and Discussion Section.

To support this procedure, the nearest available rainfall station was identified based on spatial proximity, considering a maximum search radius of 3 km [28]. The Itaperuna

INMET station (83695), located 2.2 km from the corresponding ANA station (2141004), was the only station meeting this criterion.

Regarding streamflow data, daily quality-controlled series obtained from Hidroweb were used for the study period (1961–2020). The long-term mean flow (QLTM) and the Q95 flow were analyzed using the flow continuity method, which compares the discharge of a station with that of other stations, located upstream or downstream of it [26,29].

To evaluate climate variability in the MRB from 1961 to 2020, three indicators were analyzed: monthly mean precipitation (MMP), total annual precipitation (PRCPTOT), and the RAI.

For the RAI calculation, Equations (1) and (2) were used to classify the magnitude of positive and negative precipitation anomalies [19]:

$$RAI_{positive} = (3 \times (N - N_1))/(M - N_1) \quad (1)$$

$$RAI_{negative} = -(3 \times (N - N_1))/(X - N_1) \quad (2)$$

where N is the observed annual precipitation for the year in which the RAI will be calculated (mm); N_1 is the historical series annual mean precipitation (mm); M is the average of the 10 highest annual precipitation values in the historical series (mm); and X is the average of the 10 lowest annual precipitation values in the historical series (mm). Table 3 presents the RAI classification, according to [19].

Table 3. RAI classification. Adapted from [17].

RAI	Rainfall Classification
Greater than 4	Extremely Wet (EW)
Between 2 and 4	Very Wet (VW)
Between 0 and 2	Wet (W)
0	Neither Wet nor Dry
Between 0 and −2	Dry (D)
Between −2 and −4	Very Dry (VD)
Less than −4	Extremely Dry (ED)

The final step of the methodology involved estimating water availability, represented by the Q95 flow, defined as the streamflow equaled or exceeded 95% of the time during the observation period [30].

To estimate Q95, daily streamflow records from each station were ordered and used to construct the flow duration curve, which represents the frequency distribution of streamflow magnitudes over time [31]. The exceedance probability was calculated using Equation (3):

$$P = 100 \times (m/(n + 1)) \quad (3)$$

where P is the exceedance probability (%); m is the rank position of the streamflow value in the ordered series; and n is the total number of observations in the historical series. The Q95 value was obtained as the streamflow associated with a 95% exceedance probability.

Long-term trends in annual PRCPTOT and Q95 series for the period 1961–2020 were evaluated using the non-parametric Mann–Kendall test, while Sen's slope estimator was used to quantify the magnitude and direction of detected trends. The relationship between annual PRCPTOT and Q95 was assessed using Pearson correlation coefficients. Statistical significance was assessed at the 5% level ($p < 0.05$). Data processing and statistical analyses were performed using Microsoft Excel 2021 and Python 3.11.

3. Results and Discussion

The hydrological behavior of the monitored stations in the MRB was initially characterized using the QLTM and Q95 calculated from the complete daily streamflow series (1961–2020), as presented in Table 4.

Table 4. Long-term mean flow (QLTM) and Q95 low flow values calculated from the complete daily streamflow series (1961–2020) for the monitored stations in the Muriaé River Basin (MRB).

Station	Drainage Area (km^2)	QLTM (m^3/s)	Q95 (m^3/s)
Carangola	773	3.54	1.38
Porciúncula	1340	5.18	2.14
Patrocínio do Muriaé	2660	13.76	7.65
Itaperuna	5800	22.69	10.18
Cardoso Moreira	7210	26.60	12.15

It can be observed that the flows increased from upstream to downstream due to the increase in the drainage area, allowing us to infer that there are no problems regarding flow continuity analysis. The results also indicate substantial differences between mean and low flow conditions across the basin, highlighting the reduction in water availability during dry periods.

The consistency analysis between the Itaperuna ANA and INMET rainfall series was performed using aggregated monthly precipitation totals through Pearson correlation and linear regression, as illustrated in Figure 2.

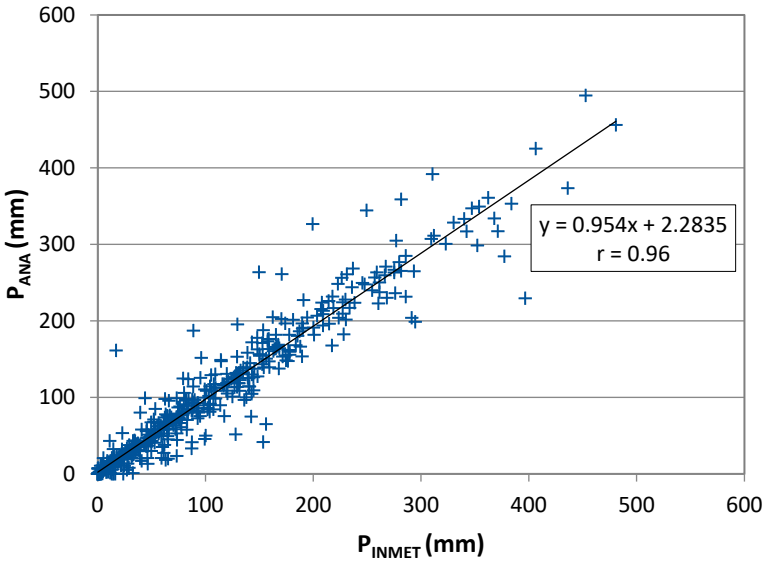


Figure 2. Correlation between monthly mean precipitation (MMP) recorded at the Itaperuna ANA and Itaperuna INMET stations.

A strong statistical agreement was observed (r = 0.96), with the regression equation given by:

$$P_{ANA} = 0.954P_{INMET} + 2.2835 \rightarrow r = 0.96 \quad (4)$$

This high correlation supported the use of the INMET series to complete the limited missing records in the ANA rainfall dataset.

Regarding water availability, Figure 3 illustrates the temporal variability of decadal Q95 values across the monitored stations in the MRB, where Q95 was calculated from the daily streamflow records within each 10-year period. A general reduction in Q95 was

observed during the 2011–2020 decade compared with previous decades, reflecting lower low flow availability across all analyzed stations.

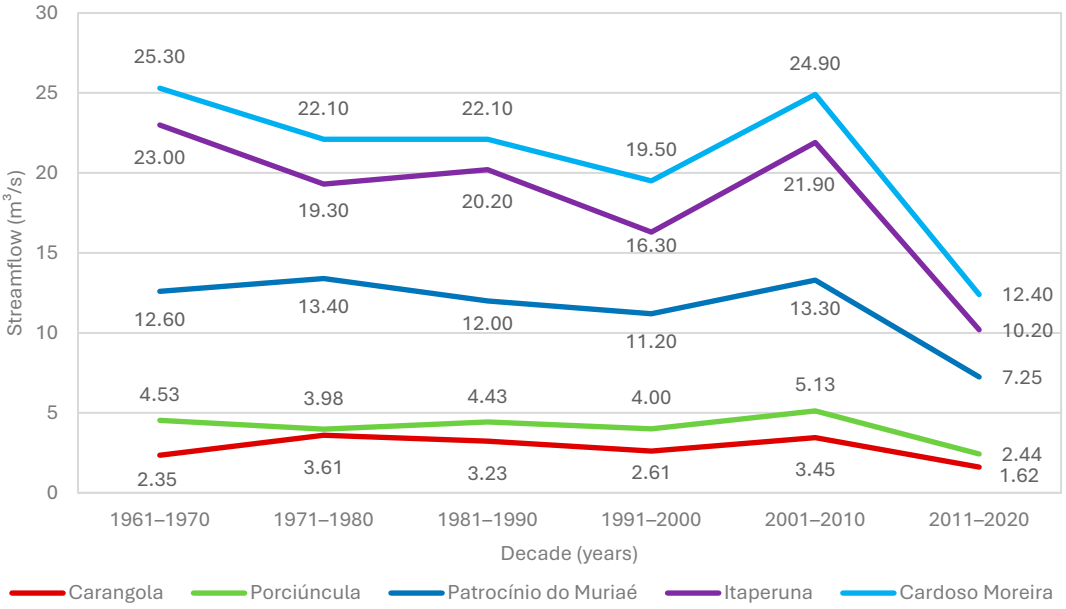


Figure 3. Decadal variation in Q95 low flow for the monitored stations in the Muriaé River Basin (MRB) during the period 1961–2020.

The reductions ranged from 31.1% at Carangola to 55.7% at Itaperuna, with substantial decreases also observed at Porciúncula (46.2%), Patrocínio do Muriaé (42.5%), and Cardoso Moreira (51.0%). The most pronounced reductions were observed at the stations located along the main Muriaé River channel, indicating a marked decline in low flow water availability in recent decades.

This reduction is consistent with observations reported by [32], who identified average flows at the Itaperuna and Cardoso Moreira stations below the historical monthly mean for July between 2014 and 2019. Similarly, the Monitoring Room of the Lower Paraíba do Sul and Itabapoana River Basin Committee [33] estimated a Q95 value of 12.22 m^3/s for the Cardoso Moreira station for the 2012–2022 period, suggesting increasing pressure on water availability in recent years.

Regarding precipitation seasonality, Figure 4 presents the monthly mean precipitation (MMP) and corresponding seasonal behavior of Q95 for the period 1961–2020 across the monitored stations.

The results indicate a well-defined seasonal hydrological regime. January, February, and March correspond to the rainy season. The transition period begins in April, marked by a gradual decrease in rainfall and the onset of the dry season, which extends from May to September. In October, a new transition toward the rainy season begins, with rainfall intensifying during November and December.

From the analysis of Figure 4, it is observed that the decrease in Q95 begins with the transition to the dry season (April) and extends until the return of the rainy season (October).

The findings are consistent with those of [34], who reported that streamflow patterns in Brazilian basins strongly reflect the seasonality of precipitation across the country. Similarly, refs. [35,36] noted that streamflow variability generally follows the variation in monthly average precipitation, reflecting the regional meteorological seasonal pattern.

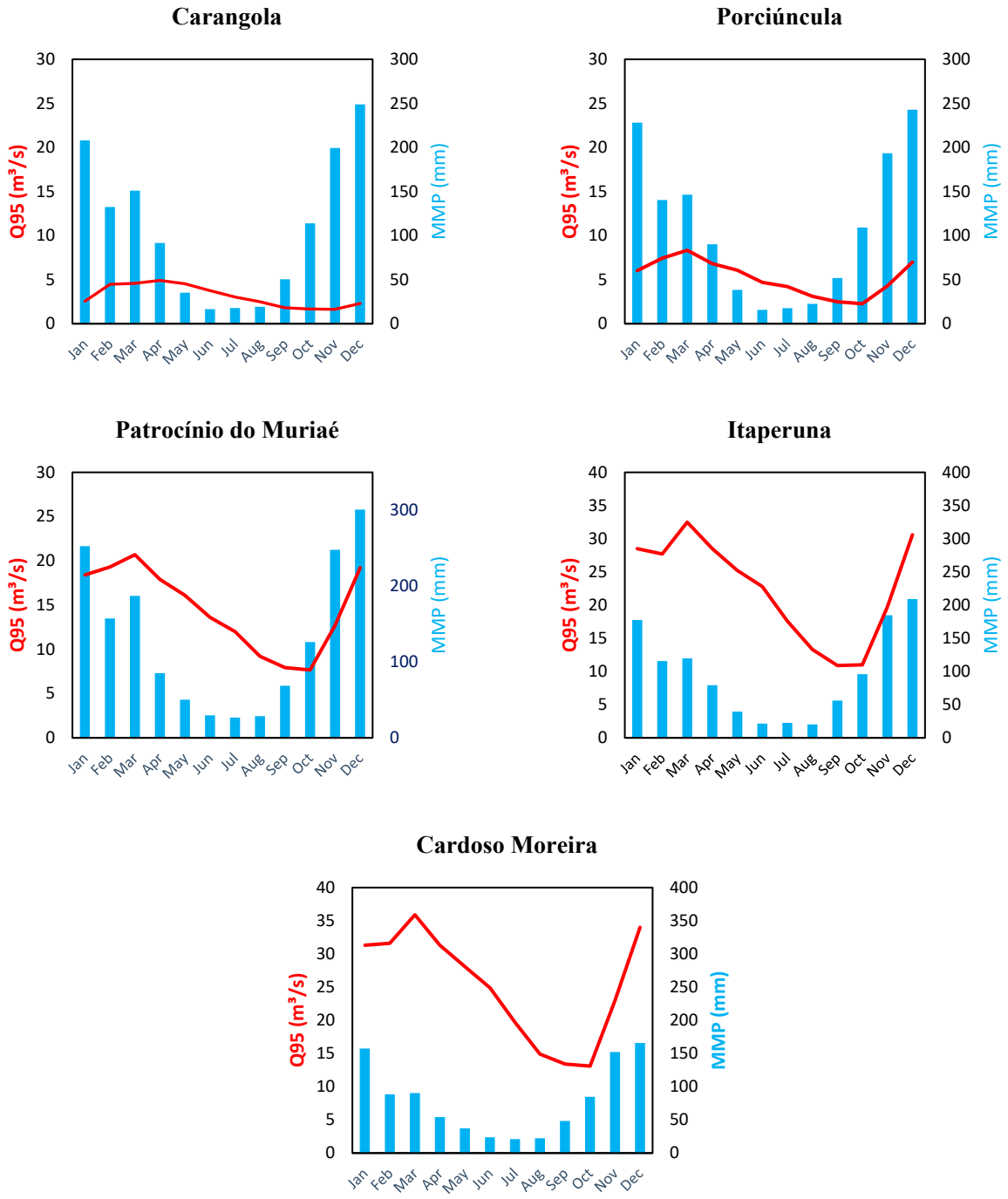


Figure 4. Sazonal variation in Q95 low flow as a function of monthly mean precipitation (MMP) for the monitored stations in the Muriaé River Basin (MRB) during the period 1961–2020.

For the analysis of PRCPTOT, Figure 5 presents the temporal variability of annual precipitation totals for each monitored station, together with the corresponding trend lines for the period 1961–2020. The statistical results of the trend analysis are summarized in Table 5.

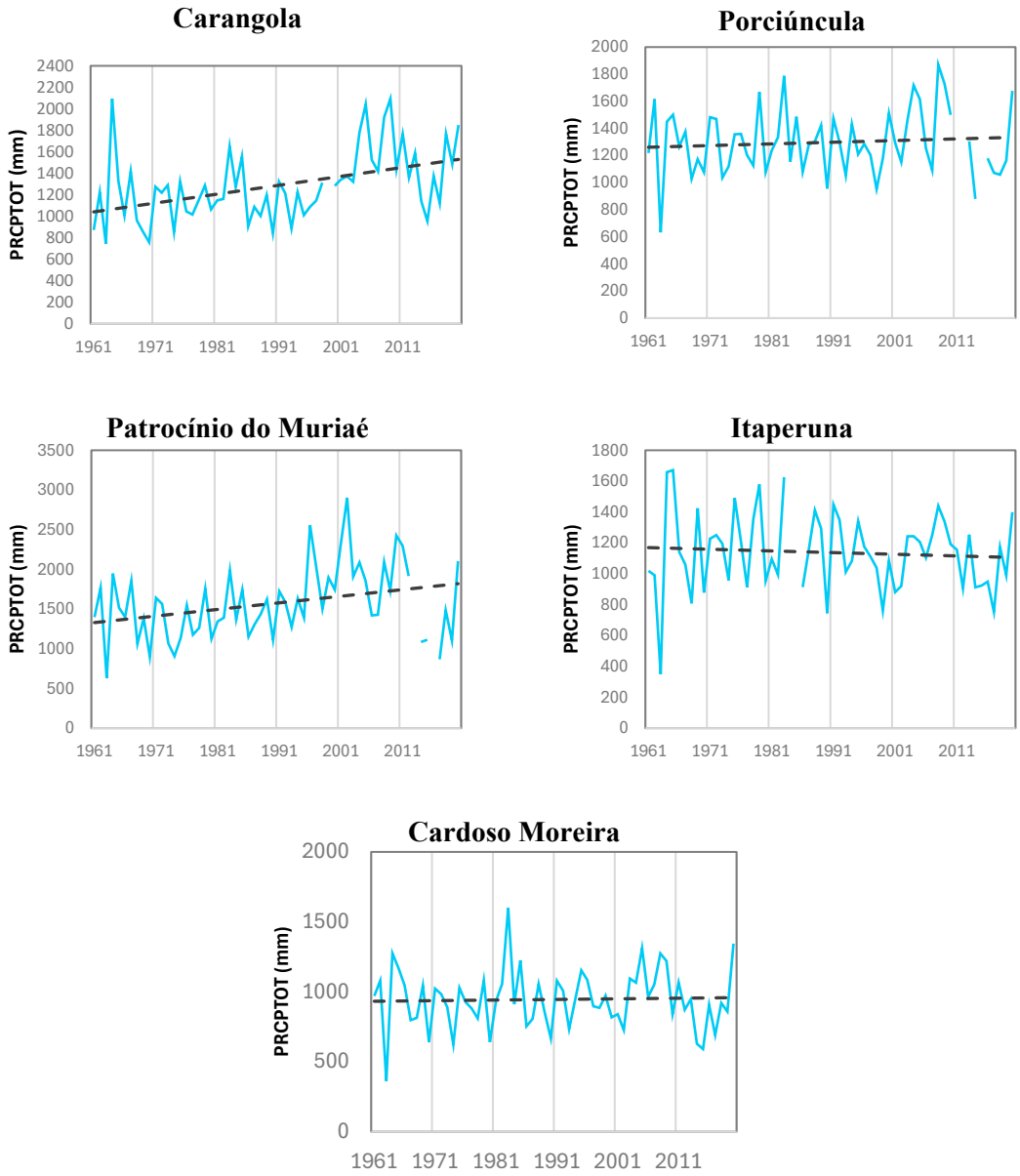


Figure 5. Temporal variability of total annual precipitation (PRCPTOT) and corresponding trend lines for the monitored stations in the Muriaé River Basin (MRB) during the period 1961–2020.

Table 5. Mann–Kendall trend test and Sen's slope estimates for PRCPTOT during the period 1961–2020.

Station	N	S (MK)	Z (MK)	*p*-Value	Sen's (mm per Year)	Trend
Carangola	59	579	3.78	0.0002	9.13	Significant increase
Porciúncula	57	34	0.23	0.820	0.40	No significant trend
Patrocínio do Muriaé	58	364	2.44	0.015	9.42	Significant increase
Itaperuna	58	−92	−0.61	0.542	−1.19	No significant trend
Cardoso Moreira	60	−10	−0.06	0.954	−0.14	No significant trend

The statistical analysis of PRCPTOT (Table 5) indicated distinct trends among the evaluated stations. Carangola and Patrocínio do Muriaé exhibited statistically significant increasing trends ($p < 0.05$), with estimated annual increases of 9.13 mm yr^{-1} and 9.42 mm yr^{-1}, respectively. In contrast, Porciúncula, Itaperuna, and Cardoso Moreira did not present statistically significant trends throughout the analyzed period ($p > 0.05$).

Although Porciúncula exhibited a slight positive slope, Itaperuna and Cardoso Moreira presented negative slopes without statistical significance.

These results were compared with the findings reported by [15,37,38]. The study conducted by [37], which evaluated precipitation extreme trends in the Paraíba do Sul River Basin between 1982 and 2011, identified increasing PRCPTOT trends at the Itaperuna and Cardoso Moreira stations. Similarly, ref. [15], in an assessment of climate indicators for the State of Rio de Janeiro, using rainfall series from 1961 to 2012, reported mean PRCPTOT values ranging between 1000 and 1300 mm in the region corresponding to the Itaperuna stations, associated with decreasing trends. Since the authors provided only the spatial location of the stations without nominal identification, the comparison was limited to the Itaperuna–ANA and Itaperuna–INMET stations. Likewise, ref. [38], in an analysis of rainfall-related climate extremes in the State of Rio de Janeiro, reported mean PRCPTOT values ranging from 943 to 1177 mm in the Itaperuna region, associated with increasing trends.

The results of the present study indicate that the mean PRCPTOT values observed at Itaperuna are consistent with those reported by [15,38]. However, unlike these studies, no statistically significant trend was identified for this station during the period 1961–2020.

For the analysis of annual Q95, Figure 6 presents the temporal variability of low flow availability at each monitored station for the period 1961–2020, together with the corresponding trend lines. The statistical results of the Mann–Kendall test and Sen's slope estimator are summarized in Table 6, allowing the evaluation of the magnitude, direction, and statistical significance of changes in water availability over time.

Table 6. Mann–Kendall trend test and Sen's slope estimates for annual Q95 during the period 1961–2020.

Station	N	S (MK)	Z (MK)	*p*-Value	Sen's (m^3/s per Year)	Trend
Carangola	60	−320	−2.04	0.042	−0.021	Significant decrease
Porciúncula	60	−134	−0.85	0.396	−0.014	No significant trend
Patrocínio do Muriaé	60	−239	−1.52	0.129	−0.055	No significant trend
Itaperuna	60	−294	−1.87	0.062	−0.138	No significant trend
Cardoso Moreira	60	−211	−1.34	0.180	−0.115	No significant trend

The statistical analysis of Q95 (Table 6) indicated negative slopes at all evaluated stations, according to the negative values of Sen's estimator. However, only the Carangola station exhibited a statistically significant trend ($p < 0.05$), with an estimated reduction of 0.021 m^3/s per year. The Porciúncula, Patrocínio do Muriaé, Itaperuna, and Cardoso Moreira stations also presented negative slopes, although without statistical significance throughout the analyzed period.

Although only Carangola exhibited a statistically significant trend, all stations showed reductions in Q95 throughout the historical series. On a decadal basis, reductions between 1961–1970 and 2011–2020 ranged from approximately 31% at Carangola to 55% at Itaperuna, highlighting a substantial reduction in low flow water availability during recent decades.

Considering the influence of precipitation variability on low flow water availability, the relationship between annual PRCPTOT and Q95 was evaluated for the monitored stations in the MRB. Figure 7 presents the relationship between annual precipitation totals and annual Q95 values, while the statistical results of the Pearson correlation analysis are summarized in Table 7.

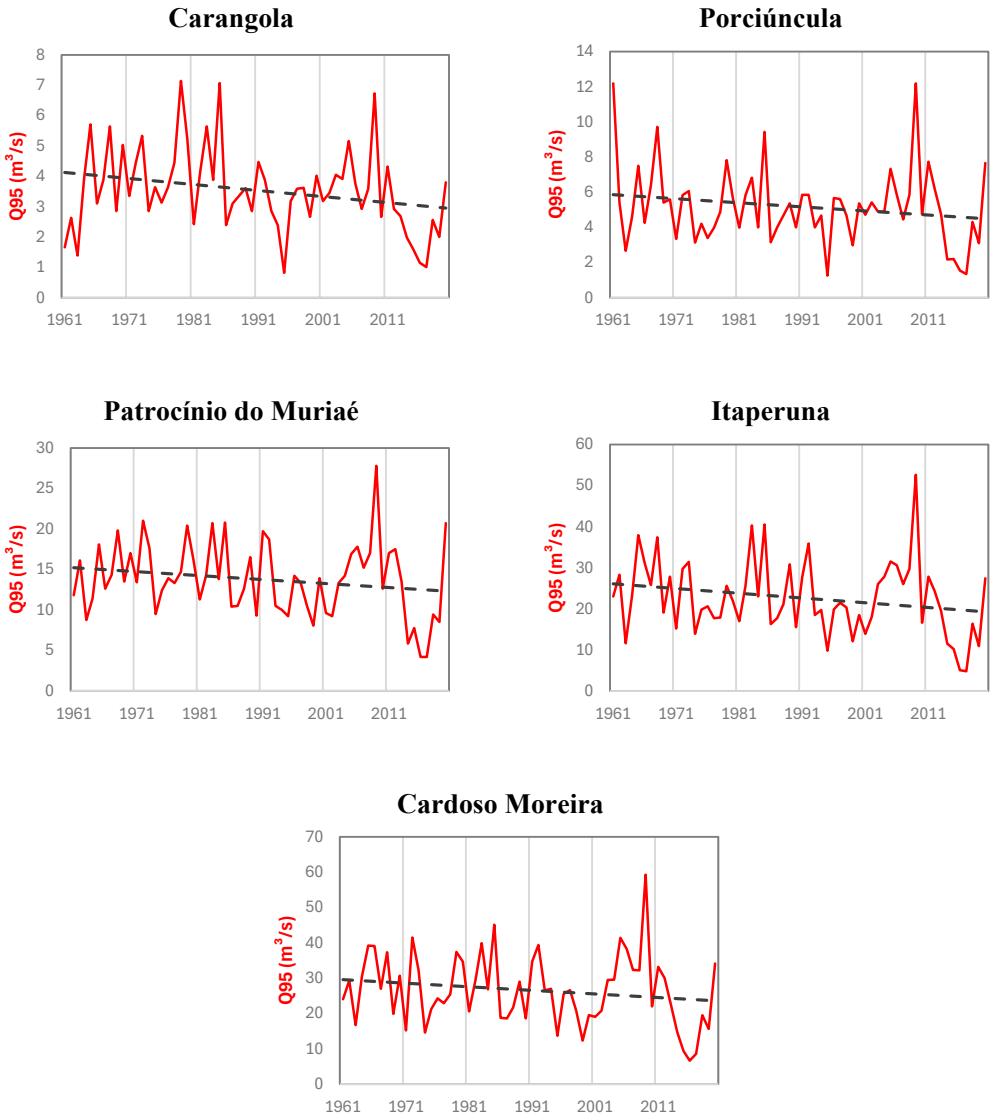


Figure 6. Annual Q95 variability and corresponding linear trend lines for the streamflow monitoring stations in the Muriaé River Basin (MRB) during the period 1961–2020. The figures illustrate the temporal behavior of observed trends in water availability at Carangola, Porciúncula, Patrocínio do Muriaé, Itaperuna, and Cardoso Moreira stations.

Table 7. Pearson correlation coefficients (r), *p*-values, and correlation strength classification between PRCPTOT and Q95 for the monitored stations in the Muriaé River Basin (MRB) during the period 1961–2020.

Station	Pearson r	*p*-Value	Correlation Strength
Carangola	0.356	0.0056	Positive moderate
Porciúncula	0.435	0.0007	Positive moderate
Patrocínio do Muriaé	0.252	0.0564	Positive weak
Itaperuna	0.481	0.0001	Positive moderate
Cardoso Moreira	0.548	<0.0001	Positive strong moderate

The strength of the Pearson correlation coefficients was interpreted according to the classification proposed by [39].

The Pearson correlation analysis between annual PRCPTOT and Q95 indicated positive associations at all monitored stations, demonstrating that years with higher annual precipitation totals were generally associated with greater low flow water availability. Correlation coefficients ranged from 0.252 at Patrocínio do Muriaé to 0.548 at Cardoso Moreira. Statistically significant correlations ($p < 0.05$) were observed at all stations except Patrocínio

do Muriaé. According to the adopted classification, the observed relationships ranged from weak positive to moderately strong positive correlations.

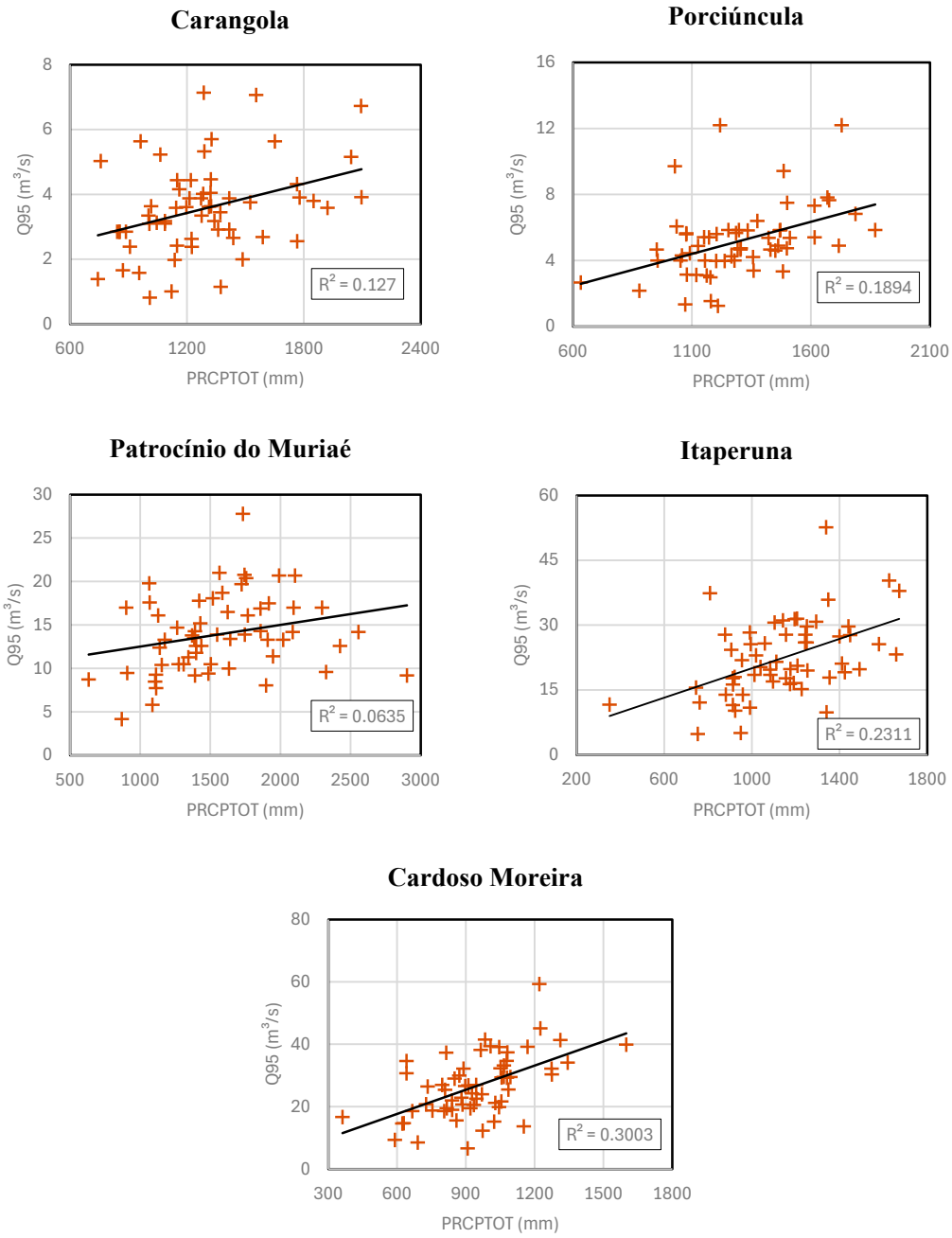


Figure 7. Scatterplots showing the relationship between total annual precipitation (PRCPTOT) and Q95 low flow for the monitored stations in the Muriaé River Basin (MRB) during the period 1961–2020.

To evaluate the temporal variability of wet and dry conditions in the Muriaé River Basin (MRB), the annual Rainfall Anomaly Index (RAI) was analyzed for the monitored stations over the period 1961–2020. Figure 8 presents the annual RAI values for each station, allowing the identification of periods with predominance of positive anomalies (wet conditions) and negative anomalies (dry conditions). The analysis of RAI complements the evaluation of PRCPTOT and Q95 by highlighting the occurrence and persistence of anomalously wet and dry years throughout the historical series.

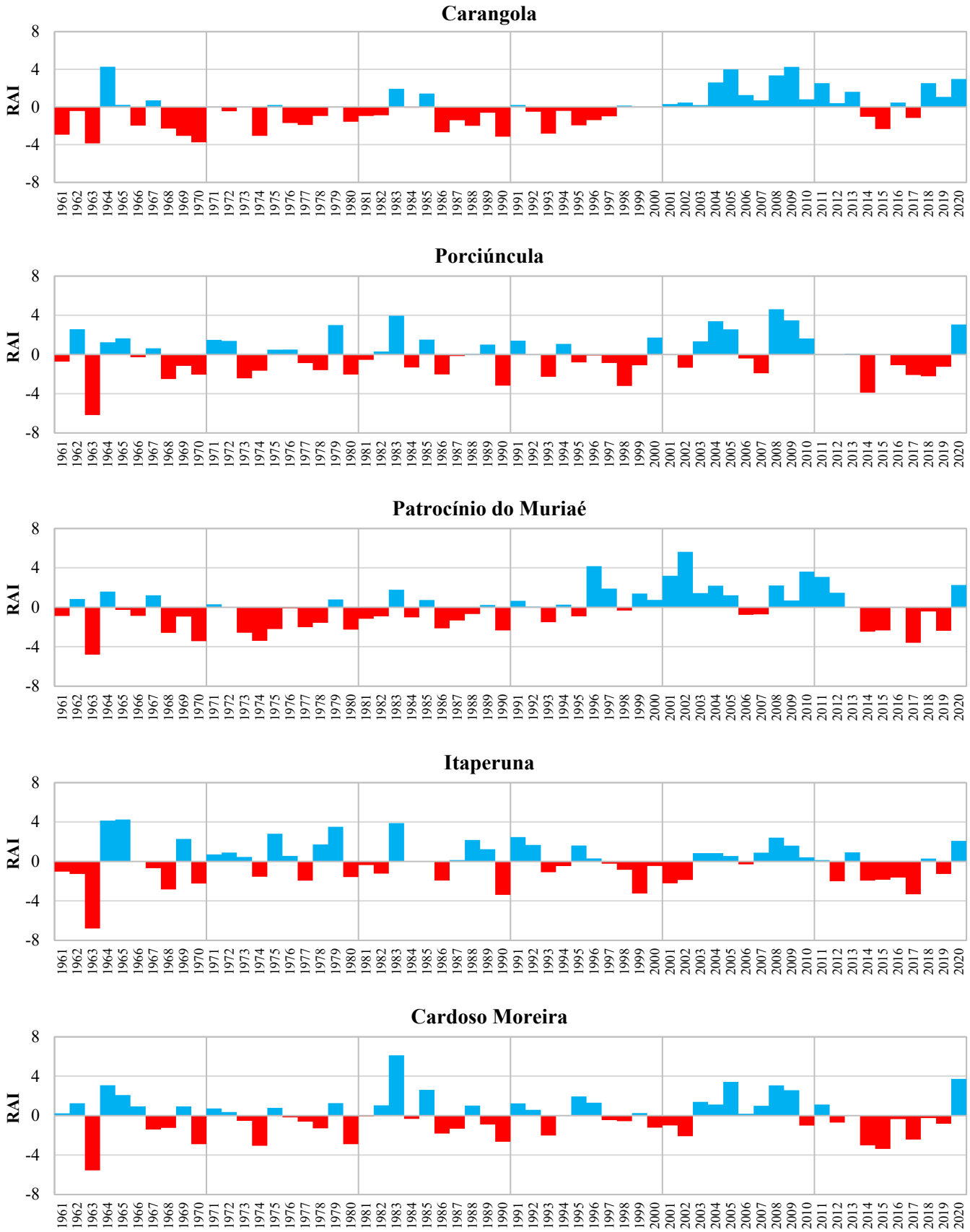


Figure 8. Annual Rainfall Anomaly Index (RAI) for the monitored stations in the Muriaé River Basin (MRB) during the period 1961–2020. Positive values (blue bars) indicate wet conditions, whereas negative values (red bars) indicate dry conditions.

The RAI results indicate marked temporal variability between wet and dry conditions across the monitored stations in the MRB during 1961–2020. In general, all stations exhibited alternation between positive and negative anomalies throughout the historical series, reflecting the climatic variability of the basin. The frequency analysis of RAI classes showed relative balance between the intermediate wet (W) and dry (D) conditions across the evaluated decades, with variations in the predominance of these classes over time. However, greater differences were observed for the more intense anomalies, particularly due to the predominance of very dry (VD) and extremely dry (ED) events over very wet (VW) and extremely wet (EW) events throughout the historical series.

The frequency analysis of the RAI classes by decade (Table 8) showed that the period 2001–2010 presented the highest occurrence of wet conditions and the lowest frequency of severe dry anomalies. This behavior is consistent with the increase in Q95 observed during the same period, indicating greater low flow water availability associated with wetter climatic conditions.

Table 8. Frequency of RAI classes by decade considering all monitored stations in the Muriaé River Basin (MRB) during the period 1961–2020. EW = Extremely Wet; VW = Very Wet; W = Wet; D = Dry; VD = Very Dry; ED = Extremely Dry.

Decade	EW	VW	W	D	VD	ED
1961–1970	1	2	17	14	7	4
1971–1980	0	0	21	17	8	4
1981–1990	0	1	17	23	5	2
1991–2000	0	1	19	19	6	4
2001–2010	1	2	33	12	1	1
2011–2020	0	0	19	14	8	5

Conversely, the decade 2011–2020 exhibited an increase in very dry and extremely dry conditions, coinciding with the reduction in Q95 observed during the same period. Among the analyzed years, 1963 was identified as one of the driest years in the historical series, while 1983, 2008, and 2009 were associated with strong positive anomalies at several stations.

Most stations exhibited predominance of negative anomalies during the second half of the last decade, reflecting a pronounced drought period across the MRB. In contrast, Carangola showed a less persistent dry pattern during this interval, suggesting spatial variability in precipitation anomalies within the basin.

Overall, the RAI analysis suggests alternating wet and dry phases throughout the historical series, with the most recent decade characterized by predominance of dry anomalies and reduced low flow availability across most monitored stations. These findings are consistent with the reduction in Q95 observed during the last decade and corroborate the drought conditions reported for the Southeast region by [32,33].

4. Conclusions

The analysis of hydrological and climatic indicators in the Muriaé River Basin (MRB) for the period 1961–2020 revealed marked temporal variability in precipitation and low flow water availability. Although reductions in the Q95 were observed across all monitored stations, the precipitation analysis did not indicate a generalized drying trend in the basin over the last 60 years. On the contrary, statistically significant increasing trends in the PRCPTOT were identified at Carangola and Patrocínio do Muriaé, while the remaining stations did not present significant trends.

Despite the absence of widespread reductions in the PRCPTOT, the results demonstrated that the occurrence of severe dry anomalies during the most recent decade had

a substantial impact on water availability. The RAI analysis showed a predominance of very dry and extremely dry events over very wet and extremely wet conditions throughout the historical series, with the decade 2011–2020 presenting the highest frequency of severe dry conditions.

This behavior was directly reflected in the Q95 results, which exhibited expressive reductions during the last decade. Decadal Q95 reductions ranged from approximately 31% at Carangola to 55% at Itaperuna between 1961–1970 and 2011–2020, demonstrating the sensitivity of low flow availability to the occurrence and persistence of dry periods, even in the absence of long-term reductions in the PRCPTOT.

Conversely, the decade 2001–2010, characterized by higher frequencies of wet conditions and fewer severe dry anomalies, presented increased Q95 values across the monitored stations, reinforcing the influence of precipitation variability on hydrological behavior in the basin.

Some limitations should also be considered in the interpretation of the results. The Patrocínio do Muriaé station presented missing precipitation records during part of the last decade, which may have influenced the increasing precipitation trend identified for this station. This aspect becomes particularly relevant considering that the most recent decade was characterized by predominance of very dry and extremely dry anomalies across most monitored stations.

In addition, the results highlight the importance of future seasonal analyses of precipitation and streamflow variability in the MRB. The occurrence of rainfall concentrated in short periods, irregular rainfall distribution during dry seasons, or the persistence of low flows during wetter months may significantly affect the Q95 behavior and water availability. Future studies should therefore investigate the seasonal distribution of wet and dry periods and their impacts on low flow conditions, particularly during critical dry-season months such as July and August. Such analyses could also consider the influence of additional factors that may affect water availability in the MRB, including land-use changes, water withdrawals, evapotranspiration dynamics, groundwater storage, baseflow contributions, and potential delayed hydrological responses to precipitation.

Overall, the integrated analysis of the MMP, PRCPTOT, Q95, and RAI proved effective in identifying hydrological variability and drought conditions in the MRB. The results indicate that changes in water availability are linked to the temporal distribution and persistence of dry anomalies. These findings can influence decisions in hydrological monitoring and water resource management strategies in the basin.

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Data Availability Statement: Publicly available datasets were analyzed in this study. This data can be found here: Daily and Monthly Rainfall and Discharge Series (https://www.snirh.gov.br/hidroweb/publico/medicoes_historicas_abas.jsf, accessed on 4 October 2024), Daily Rainfall Series (https://bdmep.inmet.gov.br/, accessed on 4 October 2024).

Conflicts of Interest: The authors have no relevant financial or non-financial interests to disclose.

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