RA'EGA
O ESPAÇO GEOGRÁFICO EM ANÁLISE
https://revistas.ufpr.br/raega

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V. 59, p. 102 – 126, 4/2024
http://dx.doi.org/10.5380/raega.v59i0.94992

Trends of climatic elements in the Semi-arid Region of Brazil: Case study of Cariri paraibano

Tendências de precipitação e temperatura na Região Semiárida do Brasil: estudo de caso no Cariri paraibano

Maria do Socorro Silva Salvador [*], **Daisy Beserra Lucena** [**], **Bartolomeu Israel de Souza** [***], **Tony Vinícius Moreira Sampaio** [****], **Inocencio de Oliveira Borges Neto** [*****]

[*] Departamento de Geografia, Universidade Federal do Paraná, maria.salvador6991@gmail.com
[**] Departamento de Geografia, Universidade Federal da Paraíba, daisy.beserra.lucena@academico.ufpb.br
[***] Departamento de Geografia, Universidade Federal da Paraíba, bartolomeuisrael@gmail.com
[****] Departamento de Geografia, Universidade Federal do Paraná, tony2sampaio@gmail.com
[*****] Departamento de Geografia, Universidade Federal do Paraná, iobngpb@gmail.com; santos.ufpr@gmail.com

http://dx.doi.org/10.5380/raega.v59i0.94992

Abstract

The Cariri region of Paraiba, located in the semi-arid region of Northeast Brazil, is a region characterized by high temperatures, great irregularity in the spatio-temporal distribution of precipitation, and long periods of drought. These conditions generally exert a strong influence on the local agriculture-based economy. With an expected increase in extreme events, it is crucial to study the distribution of precipitation and temperatures. Therefore, this study aims to analyze temporal patterns of precipitation and temperature in the municipalities of Monteiro and São João do Cariri, seeking to identify trends in the historical series. Precipitation and temperature data were used and the non-parametric Mann-Kendall, Sen's, and Pettitt tests were applied. The results indicated a statistically significant trend in the annual and monthly temperature data (in the months of May, April and June) for Monteiro, whereas this condition was not observed for the precipitation of the localities under analysis. As for the ruptures identified with Pettitt's method in the annual series of precipitation and temperature observed, these occurred, respectively, for Monteiro in the years 1999 and 1997 and in São João do Cariri in the years 2011 and 2009. Thus, although the municipalities present a similar climatic pattern, the trends identified were only detected in the temperature for Monteiro. Therefore it is of fundamental importance to carry out more studies covering the entire area of Cariri Paraibano, since comprehensive knowledge will facilitate the understanding of the specific needs of each municipality in the face of climate impacts.

Keywords:
Cariri paraibano, Extreme events, Precipitation, Temperature.

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V. 59, p. 102 – 126, 4/2024
http://dx.doi.org/10.5380/raega.v59i0.94992

Resumo

O Cariri paraibano, situado no Semiárido do Nordeste Brasileiro, é uma região caracterizada por altas temperaturas, com grande irregularidade na distribuição espaço-temporal da precipitação e com longos períodos de estiagem. Estas condições, geralmente, exercem forte influência na economia local baseada na agropecuária. Com o aumento previsto de eventos extremos, é crucial estudar a distribuição das precipitações e das temperaturas. Diante disto, este estudo tem como objetivo analisar padrões temporais de precipitação e de temperatura dos municípios de Monteiro e São João do Cariri, buscando identificar tendências na série histórica. Foram utilizados dados de precipitação e de temperatura e aplicados os testes não-paramétricos de Mann-Kendall, Sen's e Pettitt. Os resultados indicaram, tendência estatisticamente significativa nos dados de temperatura anual e mensal (nos meses de maio, abril e junho) para Monteiro. Essa mesma condição não foi observada para a precipitação das localidades em análise. Quanto as rupturas identificadas com o método de Pettitt na série anual de precipitação e temperatura observadas, estas ocorreram, respectivamente, para Monteiro nos anos de 1999 e 1997 e em São João do Cariri nos anos de 2011 e 2009. Desta forma, conclui-se que, apesar dos municípios apresentarem um padrão climático semelhantes as tendências identificadas foram apenas detectadas na temperatura para Monteiro. Desta forma, é de fundamental importância a realização de mais estudo abrangendo toda a área do Cariri Paraibano, uma vez que o conhecimento abrangente facilitará a compreensão das necessidades específicas de cada município diante dos impactos climáticos.

Palavras-chave:
Cariri paraibano, Eventos extremos, Precipitação, Temperatura.

I. INTRODUCTION

Climate change is causing economic, social, environmental, political and public health challenges in the 21st century. Due to the increase in greenhouse gas emissions, flooding, rainfall irregularities and rising sea levels, it has been difficult to determine the future effects of these changes on the environment (BARBIERI; FERREIRA; BARBI, 2018, p. 72; PEREIRA; NASCIMENTO, 2020, p. 14).

The special report, The Ocean and Cryosphere in a Changing Climate, published by the Intergovernmental Panel on Climate Change, assumes that global warming could change the patterns of rainfall totals, increasing the frequency and intensity of extreme weather events, such as droughts or excessive rainfall (IPCC, 2021, p. 15).

These extreme weather events, with significant deviations from normal behavior, can have a negative impact on everyday life and the balance of ecosystems (DANKELMAN et al., 2008, p. 5; GONÇALVES, 2013, p. 77; ASSIS et al., 2018, p. 413; TEODORO et al., 2021, p. 107). Studies indicate that South Asia and Europe are already facing consequences such as a decline in food security and an increase in deaths due to extreme events (BANDARA; CAI, 2014, p. 452; KRON; LÖW; KUNDZEWICZ, 2019, p. 77).

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V. 59, p. 102 – 126, 4/2024
http://dx.doi.org/10.5380/raega.v59i0.94992

Countries in Africa and South America, with incomes ranging from low to medium, suffer significant impacts, such as flooding events associated with climate change (CLARKE et al., 2022, p. 5). In Brazil, the occurrence of extreme events has caused deaths and socio-economic damage (TRAVASSO et al., 2021, p. 3). Cases such as the greater intensity of rainfall in southern Brazil, the drought in the Amazon in 2023 and the irregularity of rainfall in the Northeast have affected millions of people and harmed agriculture (MARENGO, 2009, p. 4; FERREIRA et al., 2017, p. 115; ALVALÁ et al., 2019, p. 1; G1, 2023; G1, 2023).

Thus, the Cariri region of Paraíba, located in the semi-arid region of northeastern Brazil, is characterized by high irregularity in the temporal and spatial distribution of rainfall, with low rainfall rates (the lowest in the state) and a daily water deficit of 60% or more (SUDENE, 2017). These conditions end up exerting a strong influence on part of the local economy, which is based on farming and cattle raising (DIAS et al., 2021, p. 21; SOUSA et al., 2022, p. 2).

According to Alves, Azevedo and Farias (2015), within the Cariri region of Paraíba, the average rainfall occurs differently, with the Oriental part of Cariri having a lower rainfall (on average 381.1 mm/year) than the Ocidental part (538.9 mm/year).

In view of the predicted increase in extreme events (IPCC, 2021), it is crucial to study the distribution of rainfall and temperature in the Cariri region of Paraiba, since information on these climatic elements on a more local level is essential for reformulating strategies aimed at the proper management of natural resources. It also enables sustainable planning, favoring the development of agricultural practices that have less impact on the environment.

Therefore, this research aims to analyze rainfall and temperature patterns and check for possible trends in the municipalities of Monteiro (Ocidental Cariri) and São João do Cariri (Oriental Cariri). These municipalities were chosen because they are both part of the Cariri region of Paraíba, and represent the localities well (in terms of altimetry and rainfall).

II. Materials and Methods

The study area is located in the semi-arid region of northeastern Brazil, more precisely in the state of Paraíba, in the area popularly known as Cariri Velhos, covering two municipalities: Monteiro (in the Ocidental part) and São João do Cariri (in the Oriental part) (Figure 1).

RA'EGA
O ESPAÇO GEOGRÁFICO EM ANÁLISE
https://revistas.ufpr.br/raega
ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V. 59, p. 102 – 126, 4/2024
http://dx.doi.org/10.5380/raega.v59i0.94992

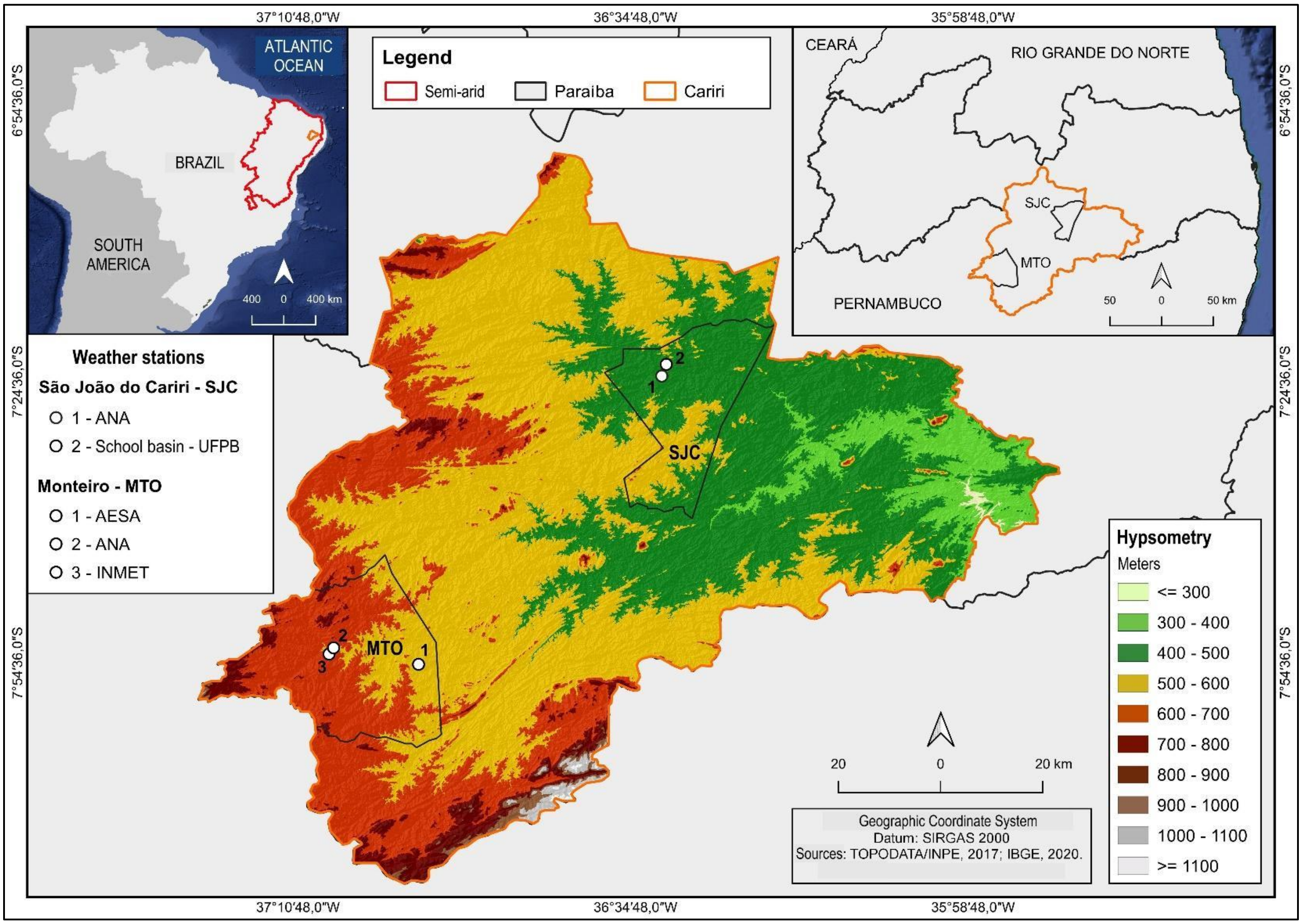


Figure 1- Location and hypsometry map of the area and municipality under study. Self- elaboration, 2022.

According to the Köppen-Geiger climate classification, the predominant climate in the Cariri region is of the hot semi-arid type (Bsh), with low average annual rainfall (around 400 mm), a dry season that can last up to 11 months, and average monthly temperatures of over 18°C (DANTAS et al., 2015; SANTOS et al., 2022, p. 217).

As for the predominant vegetation in the region, it is classified as xerophilous and hyperxerophilous Caatinga, and has distinctive characteristics; it is predominantly made up of small to medium-sized trees, with twisted trunks and a varied presence of herbaceous vegetation and thorny shrubs (SOUZA, 2008, p. 45; CÓRDULA; QUEIROZ; ALVES, 2010, p. 34; SILVA et al., 2017).

The relief present in both municipalities is defined by the Borborema Plateau. According to Costa et al. (2020, p. 190), a large part of the Borborema Plateau is made up of an arched crystalline massif that is distributed along the eastern-northeastern facade of Brazil (CORRÊA et al., 2010, p. 37; XAVIER et al., 2022, p. 42) (Figure 1).

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V. 59, p. 102 – 126, 4/2024
http://dx.doi.org/10.5380/raega.v59i0.94992

Database

For the study, daily rainfall series were used (Table 1), obtained free of charge from the National Water and Basic Sanitation Agency (ANA); Water Management Agency of the State of Paraiba (AESA); National Institute of Meteorology (INMET); and School Basin (located in the municipality of São João do Cariri), which belongs to the Federal University of Paraiba. Temperature data from INMET and the School Basin were also used for a 40 year period (1980-2019).

Table 1 – Weather stations used to obtain daily precipitation and temperature data.

WEATHER STATIONS						
Municipality	**Station type**	**Station code**	**Data origin**	**Latitude**	**Longitude**	**Altitude (m)**
Monteiro	Pluviometric	737014	ANA	7°52'60.0"S	37°07'00.0" W	590
Monteiro	Pluviometric	3855777	AESA	7°54'45.7"S	36°57'56.3"W	580
Monteiro	Pluviometric	82792	INMET	7°53'40.0"S	37°07'29.0" W	606
Monteiro	Temperature	82792	INMET	7°53'40.0"S	37°07'29.0" W	606
São João do Cariri	Pluviometric	736012	ANA	7°24'00.0" S	36°31'59.8"W	445
São João do Cariri	Pluviometric	Ebsjc	School basin	7°22'45.1"S	36°31'47.2"W	468
São João do Cariri	Temperature	Ebsjc	School basin	7°22'45.1"S	36°31'47.2"W	468

Source: Self-elaboration, 2022.

After organizing the data, gaps were found in the historical series for precipitation and temperature: For the municipality of Monteiro these gaps amounted to 20.20% (precipitation) and 27.70% (temperature); and in São João do Cariri the percentage was 11.88% (precipitation) and 42.08% (temperature). In order to work with a more complete and longer series of data, methodologies were used to fill in these gaps, with estimation based on Xavier, King and Scanlon (2016) and based on Cavalcante, Silva and Souza (2006). The Xavier, King and Scanlon (2016) methodology provides estimates of precipitation and temperature data for a time scale from 1980 to mid-2017, which can be obtained free of charge from the website: https://utexas.app.box.com/v/Xavier-etal-IJOC-DATA.

The estimation methodology of Cavalcante, Silva and Souza (2006) estimates data from 1950 to 2019. This estimation method is a model developed in the Visual Basic computer language for the Windows environment. Its purpose is to estimate the air temperature for Northeast Brazil, using quadratic functions for the average, maximum and minimum temperatures of the region as a function of the values of the geographical coordinates latitude, longitude and altitude of the location to be estimated. The Estima_T software is available

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V. 59, p. 102 – 126, 4/2024
http://dx.doi.org/10.5380/raega.v59i0.94992

on the website (http://app.dca.ufcg.edu.br/estimat/estimat.htm) of the Department of Atmospheric Science of the Federal University of Campina Grande, free of charge.

To begin, Spearman's correlation test was used to determine which of these methodologies would be the best to apply to this work. This test was applied because the data was not normal, since normal data has a bell-shaped curve. The correlation test was carried out using the original precipitation and temperature data from the stations, with the data estimated using the R Studio software, i.e. the months without data were not used.

Theory/Calculus

Non-parametric tests were used to analyze the trends Mann-Kendall, Sen's, and Pettitt (MANN, 1945; SEN, 1968; KENDALL, 1975; PETTITT, 1979). The tests were carried out using the R Studio software for the annual and monthly scales, corresponding to the period from 1980 to 2019. For annual precipitation and temperature data, the accumulated and average data were used respectively, and the monthly data corresponded to the month-by-month grouping.

The Mann-Kendall statistic (MANN, 1945; KENDALL, 1975) is a test for detecting trends in environmental, climatic and hydrological data series. It is widely used globally and recommended by the World Meteorological Organization (WMO), due to its robustness for deviations from normality and non-stationarity of the data in the historical series (BLAIN, 2011; ADEYERI et al., 2022; JAVED et al., 2022; ZEYBEKOĞLU, 2023).

The test compares each value in the time series with the remaining values, always in sequential order. The number of times the remaining terms are greater than the analyzed values is counted (SENA, 2013, p. 1406). The statistical variable S for a series of n data in the Mann-Kendall test is calculated from the sum of all the counts present in the following way:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sng\ (x_j - x_k) \quad (1)$$

Where sng (x) is obtained by:

$$Sng(x) = \{\ 1; se\ x_j > x_i\ 0; se\ x_j = x_i\ -1; se\ \ x_j < x_i \quad (2)$$

Kendall (1975) reports that S is normally distributed with mean E (S), and variance Var(S), for a situation in which there can be equal values of x, is calculated by the following expression:

RA'EGA O ESPAÇO GEOGRÁFICO EM ANÁLISE
https://revistas.ufpr.br/raega
ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V. 59, p. 102 – 126, 4/2024
http://dx.doi.org/10.5380/raega.v59i0.94992

$$E(S) = 0 \quad (3)$$

$$Va\,Var(S) = \frac{n(n-1)(2n+5) - \sum_{j=1}^{p} tj(t_j - 1)(2t_j + 5)}{18}$$

Where p is the number of tied groups in a data set and t_j is the number of data points in the j-ésismo tied group. Based on the results of S and Var(S), the Z Index was estimated, according to the sign of S, using the following equation:

$$Z = \left\{ \frac{S-1}{\sqrt{Var(S)}};\ se\ S > 0\ 0;\ se\ \ S = 0\ \frac{S+1}{\sqrt{Var\ (S)}};\ se\ S < 0 \right\} \quad (4)$$

The Z result is used to check whether there is a statistically significant trend. For trend analyses, a positive Z value indicates an upward trend and when Z shows a negative value, the trend is downward.

The level of significance α adopted for this test corresponded to α= 0.05 = 5%; if the probability of p in the test is less than the level α, p < α, a statistically significant trend exists, while if p is greater than the level of α, p > α, an insignificant trend is confirmed. For more details on the methodology, please consult Mann (1945), Kendall (1975) and Pohlert (2015).

The Sen's Slope test is used to calculate the magnitude of the trends in the Sen's curvature. This test was first proposed by Sen (1968) and improved by Hirsch et al. (1982) for computing. The method is insensitive to outliers and missing data and is more rigorous than linear regression curvature, providing a truer measure of trends in time series (ALCÂNTARA et al., 2019, p. 133).

To calculate the Sen's Slope, all pairs of values presented in the series are computed x1, x2, x3,..., xn, according to the following equation (FERRARI; VECCHIA; COLABONE, 2012, p. 32):

$$S_e = \frac{x_j - x_i}{j\ - i} \quad (5)$$

In which S_e corresponds to the estimated value of the Sen's slope, i.e. the increase or decrease as a function of time given by the equation $f(t) = S_e\ t\ + B$, where B is the constant.

The Pettitt test (1979) is used to identify the only point of discontinuity in hydrological and climatic series with continuous data. It tests the hypothesis H_o: O T variables that follow one or more distributions that have the same location parameter (no change), against the alternative hypothesis that there is point one of change

O ESPAÇO GEOGRÁFICO EM ANÁLISE
https://revistas.ufpr.br/raega
ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V. 59, p. 102 – 126, 4/2024
http://dx.doi.org/10.5380/raega.v59i0.94992

(POHLERT, 2015), in addition to evaluating whether two samples, $Y1$,..., Yt e Yt+1,..., YT, belong to the same population.

In view of this, the statistics $U_{t,T}$ will count the number of times in which the value of the first sample is greater than the value of the second, thus making it possible to detect possible changes in the series studied. This statistic is represented by the following equation (FERREIRA; PENEREIRO; FONTOLAN, 2015, p. 55):

$$U_{t,T} = U_{t-1T,} + \sum_{j=1}^{T} sng\,(y_{i\,-}\, y_j\,) \text{ para t= 2,....,T} \tag{6}$$

The statistics of $U_{t,T}$ are considered for values 1 < t < T, and the test statistic k(t) provides the maximum absolute value of $U_{t,T}$, using the equation (PETTITT, 1979):

$$k_{T=\frac{max}{1<i<T}}|U_{t,T}| \tag{7}$$

The statistics of K_T locates the point at which the abrupt change in the time series occurred, and its significance can be calculated using the following equation:

$$p \backsimeq 2\,exp\{-6k_t^2/(T^3 +\, T^2\} \tag{8}$$

Further details of the methodology can be found at Pettitt (1979) and Pohlert (2015).

In order to verify the relationship between the years of ruptures (obtained in the Pettitt test) and the El Niño-Southern Oscillation (ENOS) phenomenon, we used information obtained from the National Oceanic and Atmospheric Administration (NOAA) - Physical Sciences Laboratory website (https://psl.noaa.gov/enso/), which provides data from previous years of ENOS that will be fundamental for analysis.

The El Niño-Southern Oscillation (ENOS) cycle involves variations in the surface temperature of the Equatorial Pacific Ocean, resulting in a neutral phase and two extremes: El Niño and La Niña. Under normal conditions, the trade winds move warm waters into the western Pacific. In El Niño, there is abnormal warming due to a reduction in the winds, while in La Niña, there is cooling due to an increase in the speed of the trade winds (ARAÚJO, 2012).

According to Dias et al. (2020), the index signals the El Niño phenomenon when it remains above +0.5°C for at least five consecutive months. On the other hand, the presence of La Niña is characterized when the index remains below -0.5°C for five consecutive months.

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V. 59, p. 102 – 126, 4/2024
http://dx.doi.org/10.5380/raega.v59i0.94992

III. RESULTS

With the organization of annual and monthly precipitation and temperature data (Figure 2), gaps were observed in the historical series. Becker et al. (2011, p. 290) explains that the absence of data during this period was due to a crisis in the network of the Superintendence for the Development of the Northeast (SUDENE), which was responsible for monitoring and maintaining the rainfall network in the Northeast.

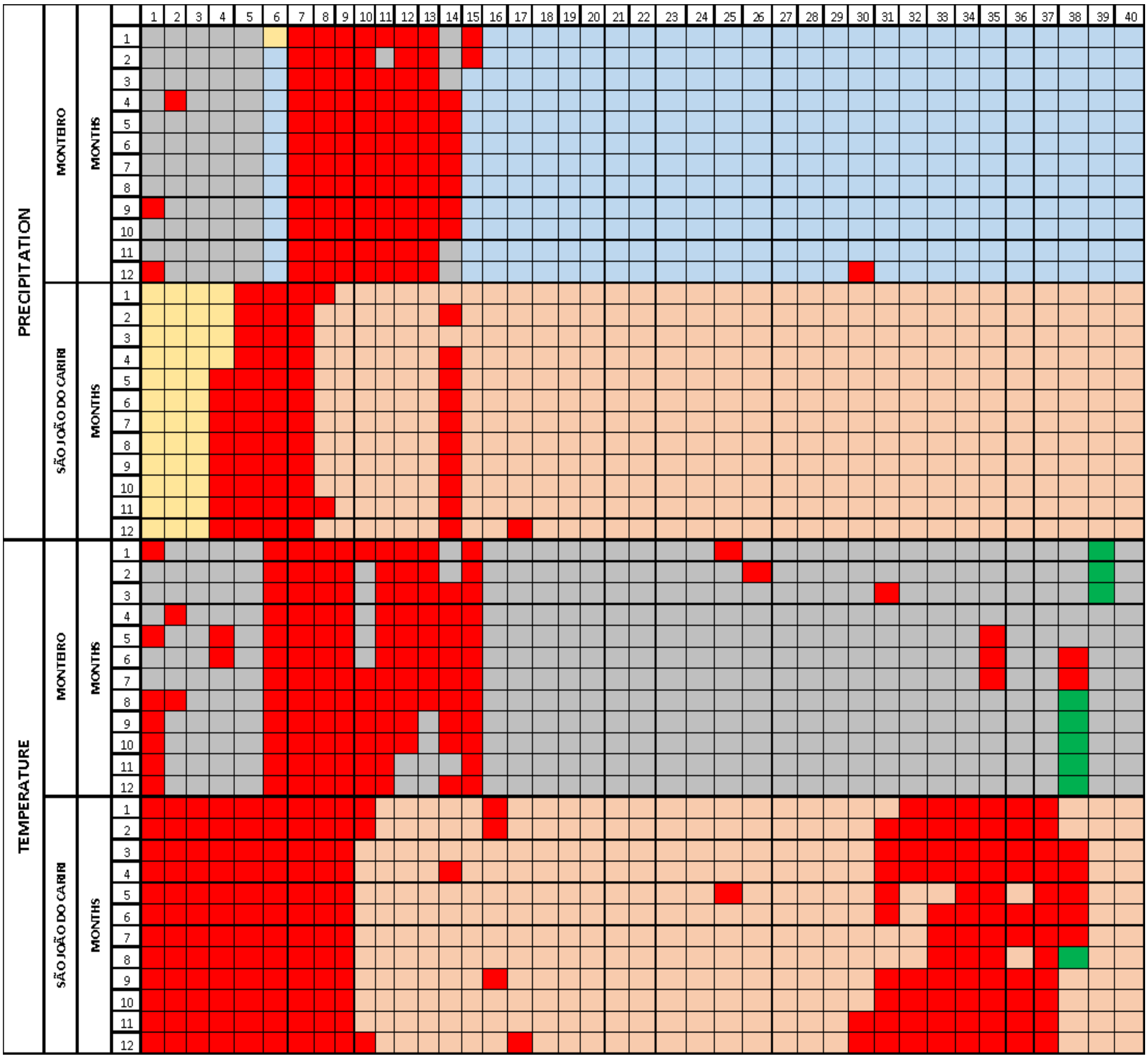


Figure 2 – Precipitation and daily temperature data that made up the time series (1980 to 2019) for Monteiro and São João do Cariri. Legend: The institutions that provided precipitation and temperature data are represented by the colors: gray = INMET; yellow = ANA; blue = AESA; orange = School basin; red = data estimated by the Xavier et al. (2016); and green = data estimated by the Cavalcante et al. (2006). The vertical numbering from 1 to 12 indicates the months (January to December). The numbers 1 to 40 refer to the years from 1980 to 2019, i.e. 1 = 1980, 2 = 1981 and so on. Source: ANA, AESA, INMET and School basin. Self elaboration, 2023.

RA'EGA O ESPAÇO GEOGRÁFICO EM ANÁLISE
https://revistas.ufpr.br/raega
ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V. 59, p. 102 – 126, 4/2024
http://dx.doi.org/10.5380/raega.v59i0.94992

The methodologies used to estimate missing data, when compared with the data from the institutions using the Spearman Correlation Test, showed a correlation of 0.80 for rainfall and 0.97 for temperature in the municipality of Monteiro, using the methodology of Xavier, King and Scanlon (2016). In the case of the municipality of São João do Cariri, correlations of 0.84 were observed for rainfall and 0.78 for temperature. The Estima_T methodology, in turn, indicated temperatures equivalent to 0.83 and 0.73 for Monteiro and São João do Cariri respectively. In view of these results, it was decided to work with the estimate by Xavier, King and Scanlon (2016) and use the Estima_T methodology to finish estimating the months with no temperature after covering the estimate by the first methodology by Xavier, King and Scanlon (2016).

Using the Mann-Kendall test, the municipalities of Monteiro and São João do Cariri showed an upward trend in annual rainfall data, but not a statistically significant one, since the Z_MK was positive and the calculated p-value was higher than the α significance level of 5% (0.05).

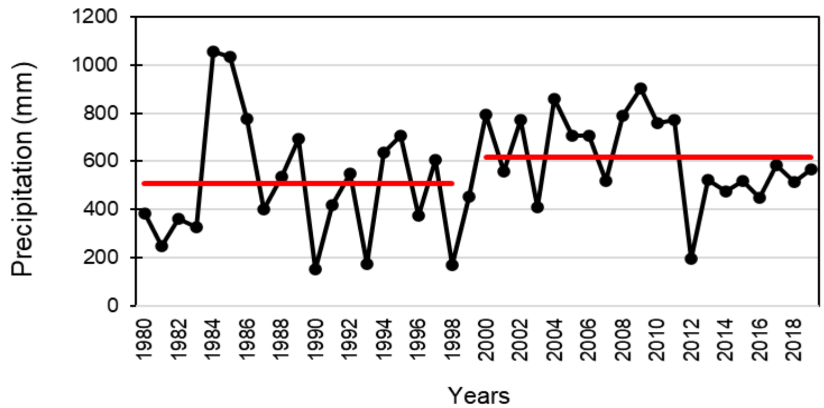
Based on the Sen's curvature method, it can be seen that the municipality of Monteiro had a positive magnitude of 3.55 for the rainfall data, while São João do Cariri had a positive magnitude of 0.56 (Figure 3). The Pettitt test, on the other hand, showed an abrupt change in precipitation for the municipalities, with Monteiro showing a change in 1999, and São João do Cariri in 2011.

This change in the average behavior of precipitation divided the series into two periods in the municipalities, in which, in Monteiro, the first period was between 1980-1998, with an average of 503.04 mm and in the second period (2000-2019) an average of 618.56 mm. The difference between this split in the rainfall series corresponded to an increase of 22.96%. During the period 1980-1998, the municipality of Monteiro experienced three extreme drought events, concentrated in the years 1980 to 1983, 1990 to 1993 and another in 1998.

In São João do Cariri, the first period before this change took place between 1980-2010, corresponding to an average value of 503.32 mm; shortly after the change, the average rainfall behavior for the second period, 2012-2019, changed to 285.12 mm. The difference between this split in the rainfall series corresponded to a decrease of 43.35% (Figure 3 - A and B).

RA'EGA
O ESPAÇO GEOGRÁFICO EM ANÁLISE
https://revistas.ufpr.br/raega
ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V. 59, p. 102 – 126, 4/2024
http://dx.doi.org/10.5380/raega.v59i0.94992

MONTEIRO			(A)
Z_{MK}	P-Valor	Sen' s	Pettitt
1.04	0.30	3.55	1999



SÃO JOÃO DO CARIRI			(B)
Z_{MK}	P-Valor	Sen' s	Pettitt
0.19	0.85	0.56	2011

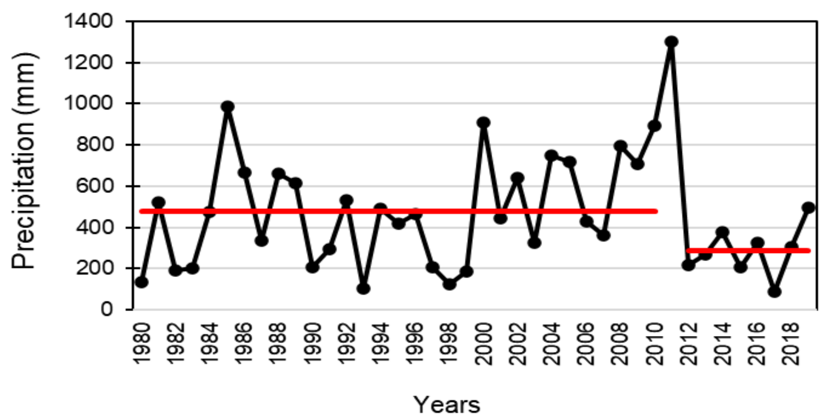


Figure 3 - Precipitation trends for Monteiro (A) and São João do Cariri (B). Note: red line = average. Source: Self elaboration, 2023.

Figure 4 shows the behavior of temperature using the same tests applied to precipitation. For Monteiro and São João do Cariri, these showed the presence of an upward trend (Mann-Kendall), but only the first municipality stood out as having a statistically significant trend.

The Sen's slope showed a positive magnitude of 0.02 for Monteiro and 0.00 for São João do Cariri (Figure 4 - A and B). The Pettitt test for temperature showed an abrupt change for the two municipalities in different years, both in relation to the precipitation variable and the temperature variable between the locations.

Monteiro's abrupt change occurred in 1997, while São João do Cariri's change occurred in 2009. Before that, the municipality of Monteiro had an average of 24.06 °C in the period 1980-1996, and in the second period

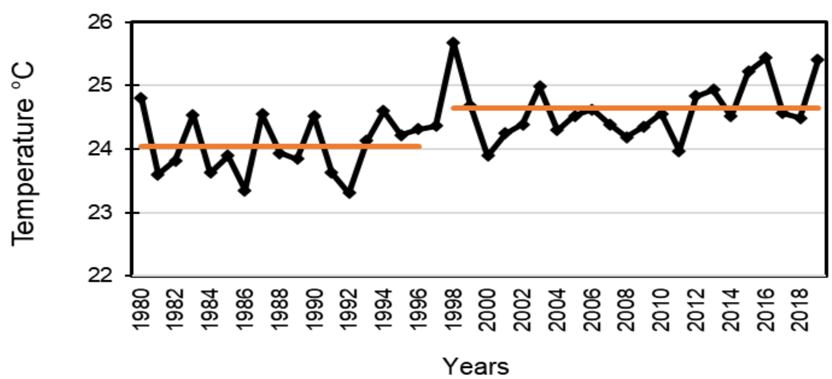
RA'EGA
O ESPAÇO GEOGRÁFICO EM ANÁLISE
https://revistas.ufpr.br/raega

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V. 59, p. 102 – 126, 4/2024
http://dx.doi.org/10.5380/raega.v59i0.94992

(1998-2019) it had an average of 24.64 °C. This difference between the divisions in the temperature series corresponded to an increase of 2.41%. Meanwhile, in São João do Cariri, the first period (1980-2008) had an average of 24.91 °C, and the second period (2010-2019) had an average of 25.13 °C. The difference between this split in the temperature series corresponded to an increase of 0.88%.

MONTEIRO (A)

Z_{MK}	P-Valor	Sen' s	Pettitt
3.57	0.00	0.02	1997



SÃO JOÃO DO CARIRI (B)

Z_{MK}	P-Valor	Sen' s	Pettitt
0.02	0.98	0.00	2009

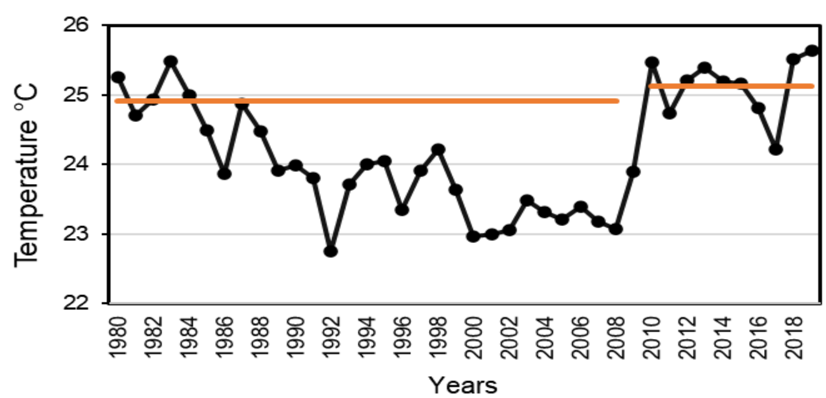


Figure 4 - Temperature trend for Monteiro (A) and São João do Cariri (B). Note: orange line = average. Source: Self elaboration, 2023.

Given that the annual results for rainfall and temperature were not statistically significant (with the exception of temperature for Monteiro), we investigated whether these conditions also occur on a monthly scale. The trend test was then applied to the precipitation and temperature variables, where a grouping of each month over 40 years was analyzed.

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V. 59, p. 102 – 126, 4/2024
http://dx.doi.org/10.5380/raega.v59i0.94992

The evaluation of the Mann-Kendall test procedure for the two locations studied, in a monthly analysis (as shown in Table 2), revealed no significant trend for rainfall. However, there is variation over the months: In Monteiro, the months of January, February, May, June, July and December showed an upward trend, while the other months had a downward trend.

Similarly, when analyzing the rainfall data for São João de Cariri, there was an upward trend in the months of January, April, May, June, July, October and December, while February, March, August, September and November showed a downward trend.

The Pettitt test for the precipitation variable for the monthly analysis showed a strong presence of ruptures in the years 1983, 1993, 1998 and 2011 for both municipalities, the latter being favored by the high occurrence of precipitation. The first three were marked as years with high temperature indices and low precipitation indices.

Table 2 – Monthly precipitation trends for the municipalities of Monteiro and São João do Cariri.

Months	MONTEIRO			SÃO JOÃO DO CARIRI		
	Z_{MK} / Statistical significance	P-Value	Pettitt	Z_{MK} / Statistical significance	P-Value	Pettitt
January	1.10 (NS)	0.27	2008	0.76 (NS)	0.45	1999
February	0.12 (NS)	0.91	1999	-0.13 (NS)	0.90	2001
March	-0.08 (NS)	0.94	1983	-0.65 (NS)	0.51	2011
April	-0.12 (NS)	0.91	1989	0.82 (NS)	0.41	2004
May	1.15 (NS)	0.37	1993	0.44 (NS)	0.66	2011
June	0.82 (NS)	0.41	1998	0.07 (NS)	0.94	2013
July	0.06 (NS)	0.95	1983	0.66 (NS)	0.51	1983
August	-1.23 (NS)	0.22	1998	-0.30 (NS)	0.76	2011
September	-1.63 (NS)	0.10	1993	-0.37 (NS)	0.71	2004
October	-1.49 (NS)	0.48	1993	0.70 (NS)	0.49	1996
November	-1.29 (NS)	0.20	1995	-0.62 (NS)	0.54	1997
December	0.63 (NS)	0.53	1997	0.53 (NS)	0.59	1998

Note: NS = No statistical significance. Source: Self elaboration, 2023.

Figure 5 presents the monthly rainfall variability for Monteiro and São João do Cariri, which shows that the highest rainfall values vary from January to May. It is also possible to see the variability of rainfall over the course of each month belonging to the grouping of 40 years.

RA'EGA
O ESPAÇO GEOGRÁFICO EM ANÁLISE
https://revistas.ufpr.br/raega
ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V. 59, p. 102 – 126, 4/2024
http://dx.doi.org/10.5380/raega.v59i0.94992

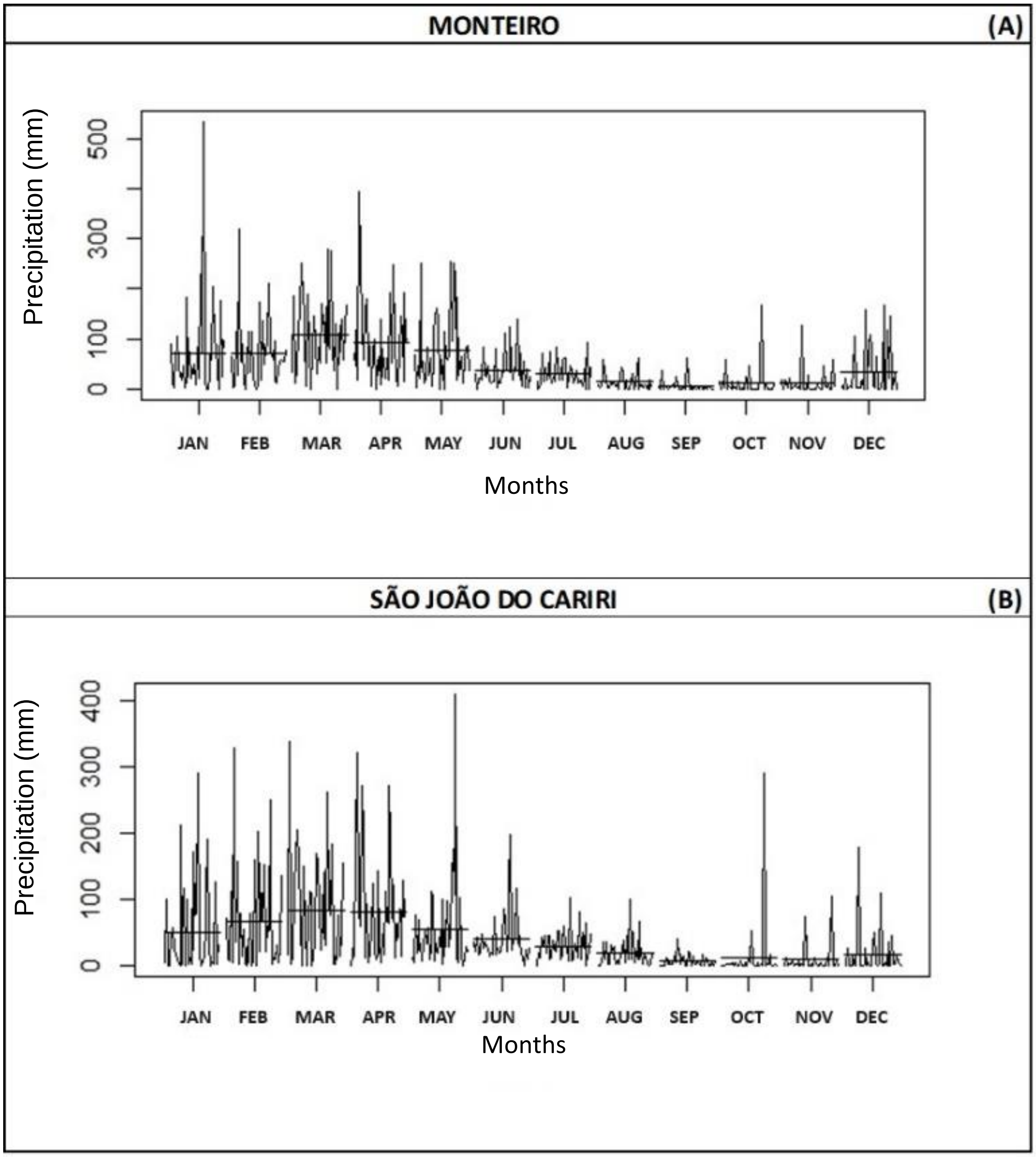


Figure 5 - Monthly precipitation in the municipalities of Monteiro (A) and São João do Cariri (B). Source: Self elaboration, 2023.

Unlike the monthly rainfall trend test, the temperature test showed some months with a statistically significant trend for the municipality of Monteiro, as pointed out in the annual trend test. For São João do Cariri, this analysis was not significant, but it did show months with an upward trend (February, March, April, May, June, November and December) and those with a downward trend (January, July, August, September and October).

With regard to the presence of a trend in the temperature series for both locations, it was found that Monteiro's temperature showed an upward trend in all months, being statistically significant in the fall, winter

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V. 59, p. 102 – 126, 4/2024
http://dx.doi.org/10.5380/raega.v59i0.94992

and spring seasons, i.e. in the months of April, May, June, July, September, October and November (Table 3). Pettitt's monthly test showed that the years 1996 and 1997 presented more abrupt changes for Monteiro, as these two years preceded the drought period of 1998.

For the municipality of São João do Cariri, the most notable years containing a month with a break in the monthly analysis were 2008 and 2009, which were very wet years, thus allowed the temperature to drop. Of the months analyzed, the ones with breaks in 2008 were March, May, November and December. For 2009, the months that showed a break were February, April, June, August and October (Table 3).

Table 3 - Monthly temperature trends for the municipalities of Monteiro and São João do Cariri.

Months	MONTEIRO			SÃO JOÃO DO CARIRI		
	Z_{MK} / Statistical significance	P-Value	Pettitt	Z_{MK} / Statistical significance	P-Value	Pettitt
January	0.54 (NS)	0.59	2002	0.02 (NS)	0.98	2010
February	1.04 (NS)	0.30	1987	0.57 (NS)	0.57	2009
March	1.50 (NS)	0.13	2008	0.34 (NS)	0.74	2008
April	3.25 (S+)	0.00	1997	-0.31 (NS)	0.75	1999
May	3.24 (S+)	0.00	1997	-1.34 (NS)	0.18	1991
June	3.70 (S+)	0.00	2009	-0.68 (NS)	0.50	1991
July	3.73 (S+)	0.00	1997	-0.09 (NS)	0.93	2011
August	1.76 (NS)	0.08	2010	-0.17 (NS)	0.86	2009
September	2.33 (S+)	0.02	1996	0.13 (NS)	0.90	2009
Octuber	2.20 (S+)	0.03	1993	-0.40 (NS)	0.69	2009
November	2.39 (S+)	0.02	1996	-0.52 (NS)	0.60	2008
December	1.81 (NS)	0.07	1992	0.48 (NS)	0.63	2008

Note: S+ = Significant upward trend. NS = No statistical significance. Source: Self elaboration, 2023.

When looking at the monthly temperature data (Figure 6 - A and B), it can be seen that, like rainfall, there is monthly and temporal variability for the two municipalities. The temporal observation of the data showed that the months with the highest temperatures vary from October to March.

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V. 59, p. 102 – 126, 4/2024
http://dx.doi.org/10.5380/raega.v59i0.94992

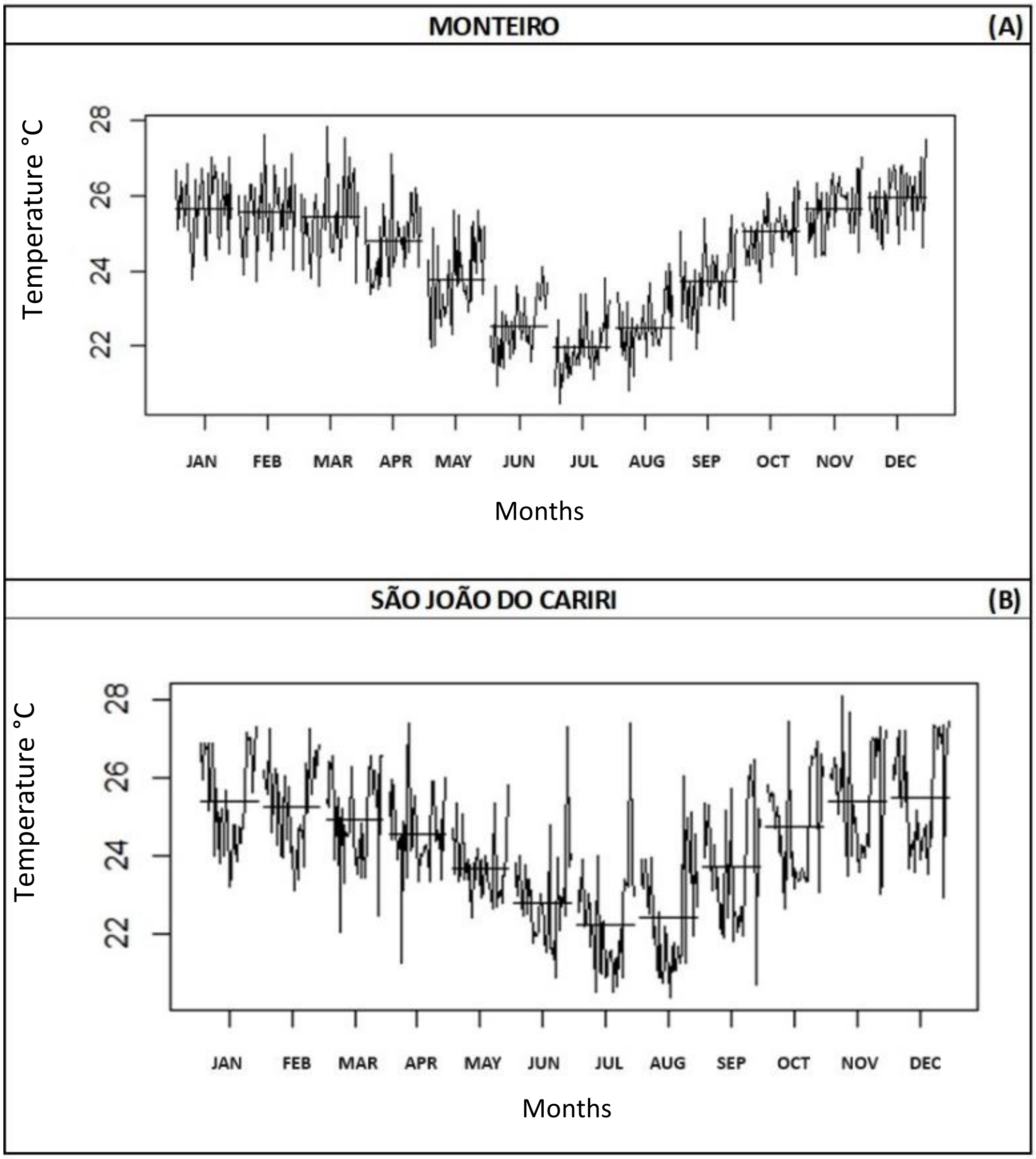


Figure 6 - Monthly temperature behavior in the municipalities of Monteiro (A) and São João do Cariri (B). Source: Self elaboration, 2023.

Considering the results obtained by the monthly trend test for the municipalities, it was noted that for the rainfall variable, the months analyzed over the 40 years did not contribute to the significance of the annual trend test, because they showed the same results.

As for the monthly trend test for the temperature of the two municipalities, it was found that for Monteiro the months of April, May and July of 1997 contributed to the annual break, since they were statistically significant. The same condition was not observed for São João do Cariri, as the months analyzed were not significant.

RA'EGA
O ESPAÇO GEOGRÁFICO EM ANÁLISE
https://revistas.ufpr.br/raega
ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V. 59, p. 102 – 126, 4/2024
http://dx.doi.org/10.5380/raega.v59i0.94992

In the context of the ENOS phenomena that coincided with years of breaks in the series, the annual analysis of precipitation in the municipalities of Monteiro and São João do Cariri revealed the presence of the La Niña phenomenon. With regard to temperature variations, it was found that these breaks occurred in both municipalities during the neutral phase of ENOS.

In the years in which there were breaks in the monthly tests, the precipitation data for Monteiro showed the incidence of three El Niño events (in 1983, 1995 and 1998), three La Niña events (1989, 1999 and 2008), and two years in which the phenomenon was in a neutral phase. In São João do Cariri, there were two ruptures during the El Niño phase (1983 and 1998), two during the La Niña phase and four in the neutral period (1996, 1997, 2001 and 2004).

As for the ENOS phenomena recorded in the years of monthly temperature breaks, for the municipality of Monteiro, we identified three years with the El Niño phenomenon (1987, 1992, 2010), one year in the La Niña phase in 2008, and five years in the neutral phase (1993, 1996, 1997, 2002, 2009). In São João do Cariri, one year was observed in the El Niño phase (2010), two years in the La Niña phase (2008 and 2011), and the neutral phase in 1991 and 2009.

IV. Discussion

The tests (Mann-Kendall, Sen's, and Pettitt) revealed that over the 40 years analyzed, temperature was the only statistically significant index for Monteiro. Another study carried out in the area covering all the municipalities in the Cariri region on a shorter time scale (16 years) obtained a positive and significant trend for the rainfall series (SENA; LUCENA, 2013, p. 1410).

The abrupt change found in rainfall in 1999 for the municipality of Monteiro may be linked to the occurrence of the El Niño phenomenon in 1998, which probably amplified the incidence of droughts in the region, resulting in a decrease in rainfall (DINIZ et al., 2020; FARIAS; XAVIER, 2023, p. 3).

In the 2000s, the municipality of São João do Cariri experienced high rates of precipitation and a reduction in temperature. This situation was correlated with an increase in La Niña events (SENA; MORAIS NETO; LUCENA, 2017). After the 2000 period in the municipality of São João do Cariri, low rates of precipitation and an increase in temperature were observed, but were not significant. The occurrence of rising temperatures was something predominant not only for the locality studied, but for the entire Brazilian semi-arid region (COSTA et al., 2021, p. 7; DIAS; PESSOA; TEIXEIRA, 2021, p. 24; SANTOS; CUNHA; RIBEIRO, 2019, p. 95).

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V. 59, p. 102 – 126, 4/2024
http://dx.doi.org/10.5380/raega.v59i0.94992

However, for both municipalities, there was a strong presence of ruptures in the years 1983, 1993 and 1998, using the Pettitt test. These years were considered in the literature to be years of severe drought, with high temperature indices and low rainfall indices (MACEDO et al., 2010, p. 212; BURITI; BARBOSA, 2018, p. 137-138). The first months (January to June) of 1983 were marked by little rainfall, and those that did occur were sporadic and only in a few locations in the state of Paraíba. This situation further aggravated the critical peasant situation in the Cariri region of Paraíba (FARIAS, 2018, p. 33).

According to Moraes Neto, Barbosa and Araújo (2007), the decrease in rainfall in 1983, 1993 and 1998 in the Cariri region was the result of the El Niño mega-event. In 1983, this phenomenon caused a severe drought of longer duration in the municipality of Monteiro. According to Macedo et al. (2010), in addition to the phenomenon at work, one of the reasons that probably intensified the drought was the formation of steep terrain in the surrounding area, which may have hindered the action of transient systems.

According to Buriti and Barbosa (2018), the severe drought that occurred in 1993 did not cause any deaths in the Cariri region, but it did affect around 2 million people due to the lack of adequate public policy planning.

The year 1998, on the other hand, was classified by Silva et al. (2018, p. 53) as extremely dry. The authors observed that, during this year, only the months of January and February did not follow the climatic variability within the rainy season, showing lower than expected rainfall values. During 1998, which preceded the break in precipitation for the municipality of Monteiro, the El Niño phenomenon caused several consequences for the Cariri region, such as a drop in production in almost all agricultural sectors (MORAES NETO; BARBOSA; ARAÚJO, 2007, p. 64).

In order to solve the impacts of the 1998 drought, the government implemented palliative measures such as distributing basic food baskets, opening work fronts, and water tankers that were used to supply rural and urban communities with water (SOUSA, 2007, p. 90), however the measures adopted were of an emergency nature. After periods of drought, the population returned to cultivating the land with limited resources, due to decapitalization and the constant struggle for survival.

The last drought that affected the region from 2012 to 2017 was intensified by the warming of the Tropical North Atlantic Ocean, which favored an abnormally northerly position of the Intertropical Convergence Zone (ITCZ) and reduced precipitation in the Brazilian Northeast (NEB) (MARENGO et al. 2018, p. 1975).

The drought from 2012 to 2017 highlighted the communities' lack of preparation to deal with the consequences of the lack of rainfall. During this period, there was a significant drop in the production of various

RA'EGA
O ESPAÇO GEOGRÁFICO EM ANÁLISE
https://revistas.ufpr.br/raega
ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V. 59, p. 102 – 126, 4/2024
http://dx.doi.org/10.5380/raega.v59i0.94992

temporary crops, including grains such as corn and beans, tubers such as manioc, as well as a significant reduction in livestock (MARTINS; MAGALHÃES, 2015, p. 120; MARTINS; MAGALHÃES; FONTENELE, 2017, p. 33).

Alencar et al. (2007, p. 19) reported that this vulnerability in agriculture is due to the lack of a more effective infrastructure to mitigate the effects of drought, and the lack of assistance. Faced with the seriousness of this situation, it is vital to reconsider the economic model employed in environmentally delicate areas.

In the analysis of behavior over the 40 years, rainfall showed great variability in both municipalities. However, this was not enough for the phenomenon to show a significant trend. The absence of a significant trend in the rainfall series, as pointed out by the authors Sena and Lucena (2013, p. 1411), may have been caused by the large variation in pluviometric totals.

In the monthly analysis, focusing on temperature data from Monteiro, statistical significance was observed in both the annual and monthly data. The monthly data played a crucial role in the break in the annual series in 1997, due to the breaks identified in 1996, which was a year of high rainfall peaks, in contrast to 1998 (MORAIS NETO; BARBOSA; ARAÚJO, 2007, p. 63).

The monthly temperature tests for the municipality of São João do Cariri, although not statistically significant, were concentrated in 2008 and 2009, which are respectively considered to be years of severe and extreme rainfall for the Semi-Arid region. The occurrence of extreme precipitation for the region lasted until 2011 (NASCIMENTO; MEDEIROS, 2022, p. 13).

During the course of this study, some noteworthy limitations were identified. Initially, challenges were faced related to the scarcity of data from meteorological stations, so it was decided to supplement this with observed data from other sources and, if this was not possible, there were wo other ways: one by statistical modeling (CAVALCANTE; SILVA; SOUZA, 2006) and the other based on interpolation (XAVIER; KING; SCANLON, 2016), and despite the results being consistent with local characteristics, especially with regard to comparison with other studies carried out in the region and/or for the locality itself.

It should be noted that the Pettitt test applied points to only a single point-of-change in the series, and in the municipality of Monteiro it is clear that in 2012 there was another break linked, probably, to the great drought that hit the northeast region, which lasted around 5 years (AQUINO; ALVES; VIDAL, 2020). São João do Cariri could also reflect the existence of a slump in 2000. Perhaps to reinforce this discussion it would be interesting to first use other sources of data for filling in, for example, reanalyses, and then apply other statistical techniques/methods to determine whether there are significant differences between the means of three or more independent groups, such as an analysis of variance (ANOVA).

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V. 59, p. 102 – 126, 4/2024
http://dx.doi.org/10.5380/raega.v59i0.94992

V. Conclusion

Analysis of the annual trends for rainfall and temperature in the municipalities of Monteiro and São João do Cariri revealed statistical significance only in the Monteiro temperature data series. When examining the monthly trends for the precipitation variable, it was found that the lack of statistical significance in the months analyzed was reflected in the absence of significance in the annual test. With regard to monthly temperature, it was observed in Monteiro that the months of May, April and July 1997 contributed to an annual break, unlike São João do Cariri, where such a condition was not identified.

Based on the verification of the impacts of climatic conditions on agriculture in the municipalities, observing the years that presented precipitation breaks, it is understood that the development of this economic activity requires adequate sustainable planning due to the environmental conditions.

Based on these results, understanding the climate profile of the municipalities of Monteiro and São João do Cariri suggests the need to expand studies on climate variability to all the municipalities in the Cariri region, using new methodologies and strategies for filling in data, such as the use of satellite data and reanalyses that better investigate the impacts of climate change on environmental conditions in the region. In addition, the use of statistical techniques that better investigate and detail the annual behavior and averages of climatic elements is of great importance to corroborate this preliminary analysis. This broader approach is crucial, considering the distinct manifestation of climatic behavior in each location. Expanding the research will enable a more comprehensive understanding of the specific needs of each municipality in the face of climate impacts, contributing to more effective adaptive strategies.

IV. References

ADEYERI, O. E.; LAUX, P.; ISHOLA, K. A.; ZHOU, W.; BALOGUN, I. A.; ADEYEWA, Z. D.; KUNSTMANN, H. Homogenising meteorological variables: Impact on trends and associated climate indices. Journal of Hydrology, v. 607, p. 127585, 2022. https://doi.org/10.1016/j.jhydrol.2022.127585.

ALVALÁ, R. C. S.; CUNHA, A. P. M. A.; BRITO, S. S. B.; SELUCHI, M. E.; MARENGO, J. A.; MORAES, O. L. L.; ALCÂNTARA, L. R. P.; COSTA, I. R. A.; BARROS, V. H. O.; SANTOS NETO, S. M.; COUTINHO, A. P.; ANTONINO, A. C. D. Análise de tendência para dados pluviométricos no município de Toritama-PE. In: Journal of Environmental Analysis and Progress, v. 04 n. 02, 2019, p. 130-139.

ALENCAR, M. L. S.; BARBOSA, M. P.; SOUSA, R. F. Efeitos do El Niño De 1997/1998 na produção agropecuária na Bacia do Rio Sucuru - Cariri Paraibano. In: Caminhos de Geografia Uberlândia, v. 8, n. 24. 2007, p. 15 – 21.

ALVES, T. L. B.; AZEVEDO, P. V.; FARIAS, A. A. Comportamento da precipitação pluvial e sua relação com o relevo nas microrregiões do Cariri Oriental e Ocidental do estado da Paraíba. Revista Brasileira de Geografia Física, v. 8, n. 6, p. 1601-1614, 2015.

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V. 59, p. 102 – 126, 4/2024
http://dx.doi.org/10.5380/raega.v59i0.94992

AQUINO, J. R.; ALVES, M. O.; VIDAL, M. F. Agricultura familiar no Nordeste do Brasil: um retrato atualizado a partir dos dados do censo agropecuário 2017. Revista Econômica Do Nordeste, 51(Suplemento Especial), 31–54.

ARAÚJO, P. H. C. Eventos climáticos extremos: os efeitos dos fenômenos El Niño e La Niña sobre a produtividade agrícola nas regiões Nordeste e Sul do Brasil. Dissertação (Mestrado em Economia Aplicada), Universidade Federal de Viçosa, Viçosa, Minas Gerais, Brasil, 2012.

ASSIS, J. M. O.; SOUZA, W. M. S.; KOCH, H.; SOBRAL, M. C. M. Influência dos oceanos pacífico e atlântico tropicais sobre os índices climáticos da precipitação na Bacia do submédio São Francisco. In: Revista Brasileira de Climatologia, Ano 14 – Vol. 23, 2018. http://dx.doi.org/10.5380/abclima.v23i0.

BANDARA, J. S.; CAI, Y. The impact of climate change on food crop productivity, food prices and food security in South Asia. Economic Analysis and Policy, v. 44, n. 4, p. 451-465, 2014.

BARBIERI, M. D.; FERREIRA, L. C.; BARBI, F. Governando as mudanças climáticas. Ideias, as estratégias políticas de Brasil e China. In: IDÉIAS, v.9 N.2, 2018. Disponível em:https://periodicos.sbu.unicamp.br/ojs/index.php/ideias/article/view/8655192. Acesso em: 25 de abr. 2021.

BECKER, C. T.; MELO, M. M. M. S.; COSTA, M. N. M.; RIBEIRO, R. E. P. Caracterização Climática das Regiões Pluviometricamente Homogêneas do Estado da Paraíba. In: Revista Brasileira de Geografia Física, 2011.

BLAIN, G. C. Considerações estatísticas relativas a seis séries mensais de temperatura do ar da Secretaria de Agricultura e Abastecimento do Estado de São Paulo.In: Revista Brasileira de Meteorologia. v. 26, n. 2, 2011, p. 279-296.

BURITI, C. O.; BARBOSA, H. A. Um Século de secas: Por que as políticas hídricas não transformaram o Semiárido brasileiro?. In: Chiado Editora, 1 Ed. 2018.

CAVALCANTI, E. P.; SILVA, V. P. R.; SOUSA, F. A. S. Estima_T Estimativa da Temperatura do Ar. In: Departamento de Ciência Atmosférica, 2006. Disponível em: http://app.dca.ufcg.edu.br/estimat/estimat.htm. Acesso em: 17 de janeiro de 2024.

CLARKE, B.; OTTO, F.; STUART-SMITH, R.; HARRINGTON, L. Extreme weather impacts of climate change: an attribution perspective. Environmental Research: Climate, v. 1, n. 1, 2022, p. 012001.

CARVALHO, M. A. Drought monitoring in the Brazilian Semiarid region. In: An Acad Bras Cienc, 2019.

CORRÊA, A. C. B.; TAVARES, B. A. C.; MONTEIRO, K. A.; CAVALCANTI, L. C. S.; LIRA, D. R. Megageomorfologia e morfoestrutura do planalto da Borborema. Revista do Instituto Geológico, São Paulo, 31 (1/2), 2010, p. 35-52.

COSTA, L. R. F.; MAIA, R. P.; BARRETO, L. L.; CLAUDINO-SALES, V. C. Geomorfologia do Nordeste Setentrional Brasileiro: uma Proposta de Classificação. In: Rev. Bras. Geomorfol. (On-line). São Paulo, v.21, n.1, (Jan-Mar), 2020. https://doi.org/10.20502/rbg.v21i1.1447.

COSTA, S. A. T.; BEZERRA, A. C.; ARAÚJO, A. M. Q.; SILVA, M. F.; ALVES, R. M.; SOUZA, L. S. B. Dinâmica espaço-temporal das anomalias de precipitação em uma região semiárida, Nordeste do Brasil. Revista de Gestão de Água da América Latina, 2021. https://doi.org/10.21168/rega.v18e14.

CÓRDULA, E.; QUEIROZ, L. P.; ALVES, M. Diversidade e Distribuição de Leguminosae em uma Área Prioritária para a Conservação da Caatinga em Pernambuco- Brasil. In: Revista Caatinga. 2010. v. 23, p. 33-40.

DANKELMAN, I.; ALAM, K.; AHMED, W. B.; GUEYE, Y.D.; FATEMA, N.; MENSAH-KUTIN, R.; 2008. Gender, Climate Change and Human Security: Lessons from Bangladesh, Ghana, and Senegal. WEDO with ABANTU for

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V. 59, p. 102 – 126, 4/2024
http://dx.doi.org/10.5380/raega.v59i0.94992

Development in Ghana, ActionAid Bangladesh and ENDA Senegal, 2008. https://hdl.handle.net/2066/72456.

DANTAS, J. C.; SILVA, M. A.; SILVA, R. M.; VIANNA, P. C. G. Simulação vazão erosão usando o modelo swat para uma grande bacia da Região Semiárida da Paraíba. Geociências, v. 34, n. 4, p. 816-827, 2015

DIAS, E. M. S.; PESSOA, Z. S.; TEIXEIRA, R. L. P.; SILVA, L. C. S. Mudanças climáticas e agropecuária: vulnerabilidades da região semiárida. In: Revista do Desenvolvimento Regional - Faccat - Taquara/RS - v. 18, n. 3, 2021. https://doi.org/10.26767/2118.

DIAS, G. F. M.; GOMES, D. J. C.; SERRÃO, E. A. O.; LIMA, A. M. M.; MIRANDA, S. B. A.; SILVA JUNIOR, J. A.; SOUSA, A. M. L. Associação entre eventos de ENOS e distribuição espaço-temporal da precipitação na bacia hidrográfica do rio Capim (MA-PA). Revista Brasileira de Climatologia, v. 26, n. 16, p. 521 –540, 2020.

DINIZ, R. R. S.; ALENCAR, M. L. S.; MEDEIROS, S. A.; GUERRA, H. O. C.; SALES, J. C. R. Índice de anomalia de chuvas da Microrregião do Cariri Ocidental Paraibano. Revista Brasileira de Geografia Física, v. 13, n. 6, p. 2628-2640, 2020.

FARIAS, A. A.; XAVIER, R. A. Extreme Droughts Events in the Sucuru River Hydrographic Sub-basin, Cariri Paraibano. Revista Brasileira de Meteorologia, 2023. http://dx.doi.org/10.1590/0102-77863810087.

FARIAS, R. B. S. A grande "seca" de 1979-1983: estado, oligarquias, frentes de emergência e resistência camponesa em São João do Cariri-PB. Trabalho de 90 Conclusão do Curso em Educação do Campo. Universidade Federal de Campina Grande, Campus Sumé, 2018, p. 1 - 88.

FERREIRA, P. S.; GOMES, V. P.; GALVÍNCIO, J. D.; SANTOS, A. M.; SOUZA, W. M. Avaliação da tendência espaço-temporal da precipitação pluviométrica em uma região semiárida do estado de Pernambuco. In: Revista Brasileira de Climatologia. Ano 13 – Vol. 21, 2017. DOI: http://dx.doi.org/10.5380/abclima.v21i0.45895.

FERREIRA, D. H. L.; PENEREIRO, J. C.; FONTOLAN, M. R. Análises estatísticas de tendências das séries hidro-climáticas e de ações antrópicas ao longo das sub-bacias do Rio Tietê. Holos, v. 2, p. 50-68, 2015.

FERRARI, A. L.; VECCHIA, F. A. S.; COLABONE, R. O. Tendência e variabilidade anuais da temperatura e da pluviosidade em Pirassununga-SP. Revista Brasileira de Climatologia, v. 6, n. September, p. 494–501, 2012.

G1. Rio Negro tem pior seca da história ao atingir 13,59 metros em Manaus. Disponível em: https://g1.globo.com/am/amazonas/noticia/2023/10/16/manaus-registra-a-pior-seca-da-historia-com-nivel-do-rio-negro-em-1359-metros.ghtml. Acesso: 12 de dezembro 2023.

G1. Chuvas no Sul causam mortes e enchentes deixam desabrigados. Disponível em: https://g1.globo.com/meio-ambiente/noticia/2023/11/18/chuvas-no-sul-causam-mortes-e-enchentes-deixam-desabrigados.ghtml Acesso: 12 de dezembro 2023.

GONÇALVES, N. M. S. Impactos pluviais e desorganização do espaço urbano em Salvador. In: MENDONÇA, F.; MONTEIRO, C. A. F. (Org.). Clima urbano. 2. ed. São Paulo: Contexto, 2013.

HIRSCH, R. M.; SLACK, J. R.; SMITH, R. A. Techniques of trend analysis for monthly water quality data. Water Resourses Research. v. 18, n. 1, 1982, p. 107-121.

IPCC, 2021: Climate Change 2021 - the Physical Science Basis, Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, In Press, Published: 9 August 2021.

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V. 59, p. 102 – 126, 4/2024
http://dx.doi.org/10.5380/raega.v59i0.94992

JAVED, S.; SHAHZAD, M. I.; ABBAS, S.; NAZEER, M. Long-Term Variability of Atmospheric Visual Range (1980–2020) over Diverse Topography of Pakistan. Remote Sensing, v. 15, n. 1, pág. 46, 2023. https://doi.org/10.3390/rs15010046.

KENDALL, M. G. Rank correlation Methods. 4.ed. Londres: Charles Griffin, 1975.

KRON, W.; LÖW, P.; KUNDZEWICZ, Z. W. Changes in risk of extreme weather events in Europe. Environmental Science & Policy, v. 100, p. 74-83, 2019.

MACEDO, M. J. H.; GUEDES, R. V. S.; SOUZA, F. A. S.; DANTAS, F. R. C. Analysis of the standardized precipitation index for the Paraíba state, Brazil. Ambi-Água, Taubaté, v. 5, n. 1, 2010, p. 204 -214.

MANN, H. B. Non-parametric tests against trend. Econometria, v. 13, 1945, p. 245-259.

MARTINS, E. S. P. R.; MAGALHÃES, A. R. A seca de 2012-2015 no Nordeste e seus impactos. In: Revista Parcerias Estratégicas, Edição Especial, v. 20, n. 41, 2015, p. 107-128.

MARTINS, E. S. P. R.; MAGALHÃES, A. R.; FONTENELE, D. A seca plurianual de 2010-2017 no Nordeste e seus impactos. In: Revista Parcerias Estratégicas, Brasília-DF, v. 22, n. 44, 2017, p. 17- 40.

MARENGO, J. A.; ALVES, L. M.; ALVALÁ, R. C. S.; CUNHA, A. P.; BRITO, S.; MORAES, O. L. L. Climatic characteristics of the 2010–2016 drought in the semiarid northeast Brazil region. Anais da Academia Brasileira de Ciências, 90(2), supl 1. 2018. https://doi.org/10.1590/0001-3765201720170206.

MARENGO, J. A. Impactos de extremos relacionados com o tempo e o clima–Impactos sociais e econômicos. Boletim do Grupo de Pesquisa em Mudanças Climáticas–GPMC, Edição Especial, 2009. http://mudancasclimaticas.cptec.inpe.br/~rmclima/pdfs/newsletters/Boletim_No8_Port.pdf.

MORAIS NETO, J. M.; BARBOSA, M. P.; ARAÚJO, A. E. E. Efeito dos eventos ENOS e das TSM na variação pluviométrica do semi-árido paraibano. Revista Brasileira de Engenharia Agrícola e Ambiental, v. 11, p. 61-66, 2007. https://doi.org/10.1590/S1415-43662007000100008.

NASCIMENTO, M. B. Avaliação espaço-temporal da variabilidade pluviométrica na região geográfica imediata de Monteiro-PB. Caderno Prudentino de Geografia, v. 4, n. 44, p. 72-90, 2022.

PEREIRA, L. H. NASCIMENTO, P. S. S. Avaliação das normais climatológicas em municípios do Nordeste brasileiro no período de 1961 a 2010. In: Brazilian Journal of Development. Curitiba, v. 6, n. 1, 2020. p. 13 - 27. DOI:10.34117/bjdv6n1-002.

PETTITT, A. N. A non-parametric approach to the changepoint problem. Applied Statistics, London, v. 28, n. 2, 1979, p. 126 - 135.

POHLERT, T. Non-Parametric Trend Tests and Change-Point Detection. 2015.

SANTOS, M. P. A.; SOUSA, J. H. S.; NASCIMENTO, A. A.; NASCIMENTO RIBEIRO, G.; PRADO JÚNIOR, L. S.; OLIVEIRA NETO, J. N. Volume hídrico por processamento digital de imagens de açude público em Sumé, Paraíba. Revista Verde de Agroecologia e Desenvolvimento Sustentável, v. 17, n. 3, p. 215-220, 2022. DOI: https://doi.org/10.18378/rvads.v17i3.9622.

SANTOS, S. R. Q.; CUNHA, A. P. M. A.; RIBEIRO NETO, G. G. Avaliação de dados de precipitação para o monitoramento do padrão espaço-temporal da seca no Nordeste do Brasil. In: Revista Brasileira de Climatologia, ano 15, Vol. 25, 2019.

SANTOS JUNIOR, E. P.; BLAIN, G. C.; XAVIER, A. C. F. Avaliação dos Dados de Reanálise do Climatic Research Unit

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V. 59, p. 102 – 126, 4/2024
http://dx.doi.org/10.5380/raega.v59i0.94992

(CRU) e do 5th Generation of European Reanalisis (ERA5) no Monitoramento Probabilístico Padronizado da Seca. Revista Brasileira de Meteorologia, v. 37, p. 243-260, 2022.

SENA, J. P. O.; LUENA, D. B. Identificação de tendência da precipitação na Microrregião do Cariri Paraibano. In: Revista Brasileira de Geografia Física, v.6, n.5, 2013, p. 1400 -1416.

SENA, J. P. O.; MORAIS NETO, J. M.; LUCENA, D. B. Variabilidade da precipitação por década e a relação com os eventos extremos. Revista Brasileira de Climatologia, v. 20, 2017.

SEN, P. K. Estimates of the regression coefficient based on Kendall's tau. Journal of the American Statistical Association. v. 63, 1968, p. 1379 -1389.

SILVA, J. M. C.; BARBOSA, L. C. F.; LEAL, I. R.; TABARELLI, M. The Caatinga: Understanding the Challenges. In: Caatinga: The Largest Tropical Dry Forest Region in South America.Springer International Publishing, 2017, p. 3-19.

SILVA, G. S.; SILVA, W. S.; SILVA, A. L.; ALMEIDA, N. V.; ARAÚJO, L. E. Análise da Precipitação da Microrregião do Cariri Oriental Paraibano. In: REGNE, Vol. 4, Nº 1, 2018.

SOUSA, R. F. Terras agrícolas e o processo de desertificação em municípios do Semiárido paraibano. 2007, p.180. In: Tese (Doutorado Engenharia Agrícola) – UniversidadeFederal de Campina Grande, Centro de Tecnologia e Recursos Naturais. Campina Grande, 2007.

SOUSA, V. D.; FARIAS, M. S. S.; GUIMARÃES, J. P.; PEREIRA, J. S. Soil hydrododynamics in a degraded area in the Cariri region of Paraíba. Research, Society and Development, [S. l.], v. 11, n. 1, p. e27311124937, 2022. DOI: 10.33448/rsd-v11i1.24937.

SOUZA, B. I. Cariri Paraibano: Do silêncio do lugar a desertificação. Tese Programa de Pós-Graduação em Geografia. Universidade Federal do Rio Grande do Sul. 2008.

SUDENE. Superintendência de Desenvolvimento do Nordeste. 2017 Resolução nº107 de 27 de julho de 2017. https://www.lex.com.br/legis_27508570_RES OLUCAO_N_107_DE_27_DE_JULHO_DE_ 2017

TRAVASSOS, L.; TORRES, P. H. C.; DI GIULIO, G.; JACOBI, P. R.; FREITAS, E. D.; SIQUEIRA, I. C.; AMBRIZZI, T. Why do extreme events still kill in the São Paulo Macro Metropolis Region? Chronicle of a death foretold in the global south. International Journal of Urban Sustainable Development, v. 13, n. 1, p. 1-16, 2021.

TEODORO, A. L.; CÁSSIA SOUZA, C.; MAMMOLI, M.; MELLO TORRES, J. G. Gestão de riscos de desastres na Rodovia dos Tamoios em eventos extremos. South American Development Society Journal, v. 7, n. 21, p. 94, 2021.

XAVIER, A. C.; KING, C. W.; SCANLON, B. R. BrazilMetData_1980-2013. Disponível em: https://utexas.app.box.com/v/Xavier-etal-IJOC-DATA. Acesso em: 17 de janeiro de 2024.

XAVIER, R. A.; SOUZA, B. I.; CARDOSO, E. C. M.; SEABRA, V. S. Padrões de relevo da Área de Proteção Ambiental do Cariri Paraibano: uma contribuição à cartografia geomorfológica semiárida. Revista Ciência Geográfica, v. 26, n. 01, p. 34-50, 2022.

ZEYBEKOĞLU, U. Temperature series analysis of the Hirfanli Dam Basin with the Mann-Kendall and Sequential Mann-Kendall tests. Turkish Journal of Engineering, v. 7, n. 4, p. 306-313, 2023. https://doi.org/10.31127/tuje.1145716.

RA'EGA
O ESPAÇO GEOGRÁFICO EM ANÁLISE
https://revistas.ufpr.br/raega
ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V. 59, p. 102 – 126, 4/2024
http://dx.doi.org/10.5380/raega.v59i0.94992