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RESEARCH ARTICLE

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PRECIPITATION TREND IN THE MUNICIPALITY OF CABACEIRAS (NORTHEAST OF BRAZIL)

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ABSTRACT

Introduction: The analysis of trends in historical rainfall series is important to verify the interannual and decadal climatic variability in order to identify how climate changes can modulate these temporal patterns of variability. **Objective:** The study aims to present a historical temporal distribution and future trend of rainfall in the municipality of Cabaceiras (Paraíba, Brazil), using a historical series. **Materials and methods:** The temporal distribution of the historical series and the rainfall trend was studied with linear regression and measures of central tendency and dispersion of the monthly and annual rainfall index. **Results:** It was verified that the median is the measure of central tendency most likely to occur. The rainy season occurs between February and July, with an average value of 278.9 mm (82.5% of the annual precipitation). The months of maximum rainfall occur between March and April and those with the lowest rainfall indexes center in the months of October and November. **Conclusion:** The trend of greater variability of precipitation is centered between the months of February to June, which has high rainfall rates for the region. The smaller pluviometry indexes are centered between the months of October and December, which has low rainfall indexes.

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INTRODUCTION

The importance of research that involves the study of the climate in the search for the construction of new parameters of knowledge and consequent application in the various human activities, agriculture, water retention, agriculture, economy, commerce and leisure are dependent on the data and increasingly concise information on rainfall, droughts, storms and extreme events with medium- and long-term information generated with a high degree of accuracy (Silva et al., 2021). The analysis of trends in historical rainfall series is important to verify the interannual and decadal climate variability so that they are identified as climate changes can modulate these temporal patterns of variability according to Lima et al. (2021). Medeiros (2012) performed a climatological analysis of precipitation in the municipality of Cabaceiras - PB in the period 1930 - 2011, as a contribution to the agroindustry and pointed out that rainfall indices are essential to agroindustrial sustainability. Several authors have evaluated the precipitation trend observed in the Brazilian Northeast (NEB) during the 20th century. Costa et al. (2021) made an analysis of rainfall over this region and highlighted the scarcity of perennial water resources and the threat of desertification. NEB. The study carried out by Santos and Britto (2007), using indexes of climatic extremes and correlating them with SST anomalies, also shows a trend of increase of annual total precipitation in the states of Paraíba and Rio Grande do Norte. Santos and Brito (2009) showed trends of precipitation increase for the state of Ceará, but studies carried out by Rolim et al. (2021) also show increase in the uncertainty of rainfall over the region. The distribution of rainfall in northeastern Brazil is quite irregular in time and space; in addition, rainy seasons occur differently, in quantity, duration and distribution (Britto et al., 2021).

The linear regression is a method to estimate the conditional (expected value) of a variable Y, given the values of some other variables x. Regression, in general, deals with the question of estimating an expected conditional value. In many situations, a linear relationship can be valid to summarize the association between the variables Y and X. Through the descriptive statistics, we can have essential characteristics for the histogram formation of relative frequencies of a sample of hydrological data according to the authors Naghettini and Pinto (2007). Therefore, the objective of this study is to present a historical temporal distribution and future trend of rainfall in the municipality of Cabaceiras - PB using a historical series of 86 years of data comprised between the period from 1926 - 2011.

MATERIAL AND METHODS

The municipality of Cabaceiras (Figure 1) is located in the Cariri Oriental and Borborema Meso-regions, bordering the municipalities of São João do Cariri, São Domingos do Cariri, Barra de São Miguel, Boqueirão and Boa Vista (AESA , 2011). Located at the latitude coordinates of latitude 7°30' to the south and longitude 36°17' west of Greenwich, with average altitude in relation to sea level of 390 meters, located in the lower area of the Borborema Plateau (CPRM, 2005). The study area is inserted in the Borborema, in the geomorphological unit denominated Plateau of Borborema of tabular and convex forms. The Borborema Plateau according to Souza et al. (2003), constitutes the most important geographic accident in the Northeast Region, exercising in Paraíba a role of particular importance in the overall relief and diversification of the climate.

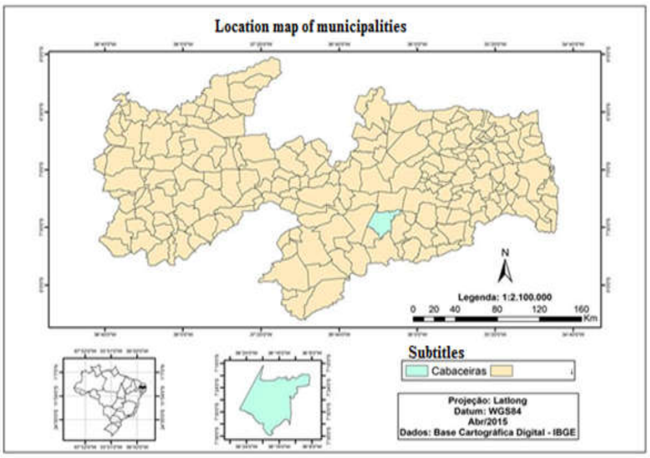


Figure 1. Location of the study area

The climate of Cabaceiras - PB according to Köppen (1928) classification is considered of type "Bsh" - Semiarid hot, precipitation predominantly, below 600 mm.year^{-1}, and lower temperature due to the effect of altitude (400 to 700 m). The municipal rainfall regime has an irregular spatial and temporal distribution, which is a characteristic of the Brazilian Northeast, due to its seasonal precipitation concentrates almost all its volume during the five months in the rainy season according to Silva (2004). The methodology used mean monthly and annual climatological rainfall data acquired from the database of the Northeast Development Superintendency (SUDENE, 1990) and the Executive Agency for the Management of Waters of the State of Paraíba (AESA, 2022) for the period from 1926 - 2011. The average monthly climatological data were grouped in 86 years, characterizing a period of normal climatology where electronic spreadsheets were used to extract the values of the monthly and annual averages of the precipitation. For this study, measures of central tendency and dispersion were calculated. Using the measures of central tendency and dispersion we can verify the parameters analytically, and observe if the samples are different or similar. The Mann-Kendall test was applied to the monthly totals of the study area.

RESULTS AND DISCUSSION

In the statistical analysis using the Mann-Kendall test, the coefficient of determination (R^2) of 0.13 was obtained, with a small variation explained by the variable and thus demonstrating that this test has no significance for the study area. A large variability in the above and below average distributions is observed in Figure 2, with an increase in annual rainfall index.

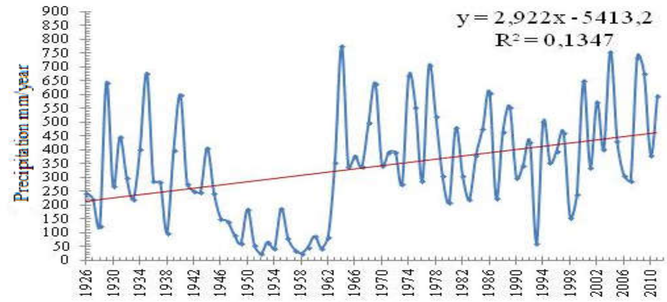


Figure 2. Mann-Kendall test of precipitations from the period 1926 - 2011 in Cabaceiras (Paraíba, Brazil)

The distribution of rainfall values of the annual average, based on historical data from 1926 to 2011, showed a marked variation in precipitation (Figure 3). The highest rainfall indices registered in the city for the series of 86 years of data were observed in the years 1964, 1974, 1977, 2004 and 2008 with the respective indices 775.5mm; 721.1 mm; 704.5mm; 755.8mm and 736.8mm, and the lowest rainfall recorded in 1952 (23.8mm); 1954 (43.2mm); 1957 (38.1mm); 1958 (25.5mm) and 1962 (25.9mm). Meteorological systems of large scales are known to cause variabilities in yearly or decade scale (are due to the operating in those years (Barlow et al., 2019). For the municipality of Cabaceiras, there is no long-term trend, only interdecadal variability occurs, with drier decades preceded by rainier decades and vice versa.

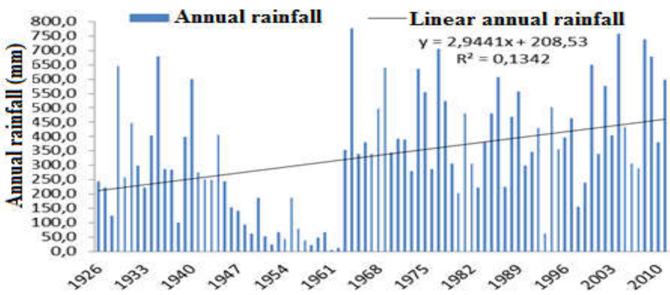
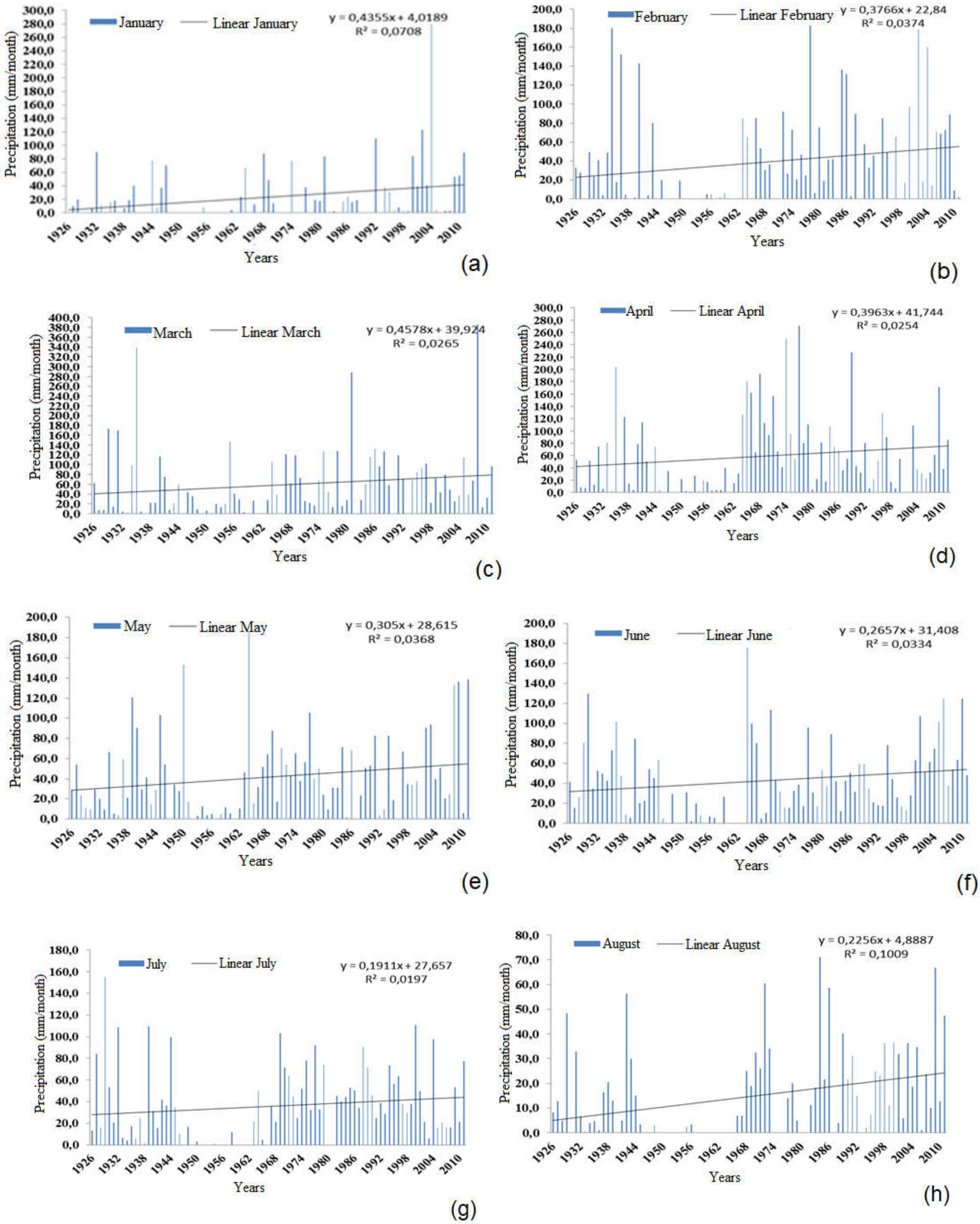


Figure 3. Time-space distribution and linear regression analysis of rainfall from the period 1926 – 2011

There is a high spatial and temporal variability of rainfall in the months of January to July, (Figures 4 - a, b, c, d, e, f). The lowest rainfall totals were concentrated in the months of August to December. The pluviometric indexes increase from the month of January with the pre-season rains and extends until the month of July, having rainier months for the months of March to June. There is a negative trend in the months of October to November (Figures 4 - j, l), and the use of the spatial mean of rainfall totals may have smoothed trends. Figure 4a shows the variability of the rainfall indices for January of the period 1926-2011. It is noteworthy that between the years 1926 to 2015 the annual rainfall records were below 90 mm, except for the years 1992, 2003, 2005, which rained above 100 mm. Figure 4b shows the rainfall irregularity in February months throughout the study, in which it is observed a positive rainfall trend and R^2 of low significance. In 1927, 1931, 1933, 1936, 1939, 1939, 1941, 1942, 1943 to 1963, 1969, 1971-1973, 1975, 1977, 1980, 1982, 1985, 1988, 1997, 2000-2002, 2005, 2006, 2008 and 2011 rained below 40 mm, in the other years fluctuations of its indices registered between 42 and 190 mm.


January
Linear January
y = 0,4355x + 4,0189
R² = 0,0708
Precipitation (mm/month)
Years
(a)
February
Linear February
y = 0,3766x + 22,84
R² = 0,0374
(b)
March
Linear March
y = 0,4578x + 39,924
R² = 0,0265
(c)
April
Linear April
y = 0,3963x + 41,744
R² = 0,0254
(d)
May
Linear May
y = 0,305x + 28,615
R² = 0,0368
(e)
June
Linear June
y = 0,2657x + 31,408
R² = 0,0334
(f)
July
Linear July
y = 0,1911x + 27,657
R² = 0,0197
(g)
August
Linear August
y = 0,2256x + 4,8887
R² = 0,1009
(h)

……….Continue

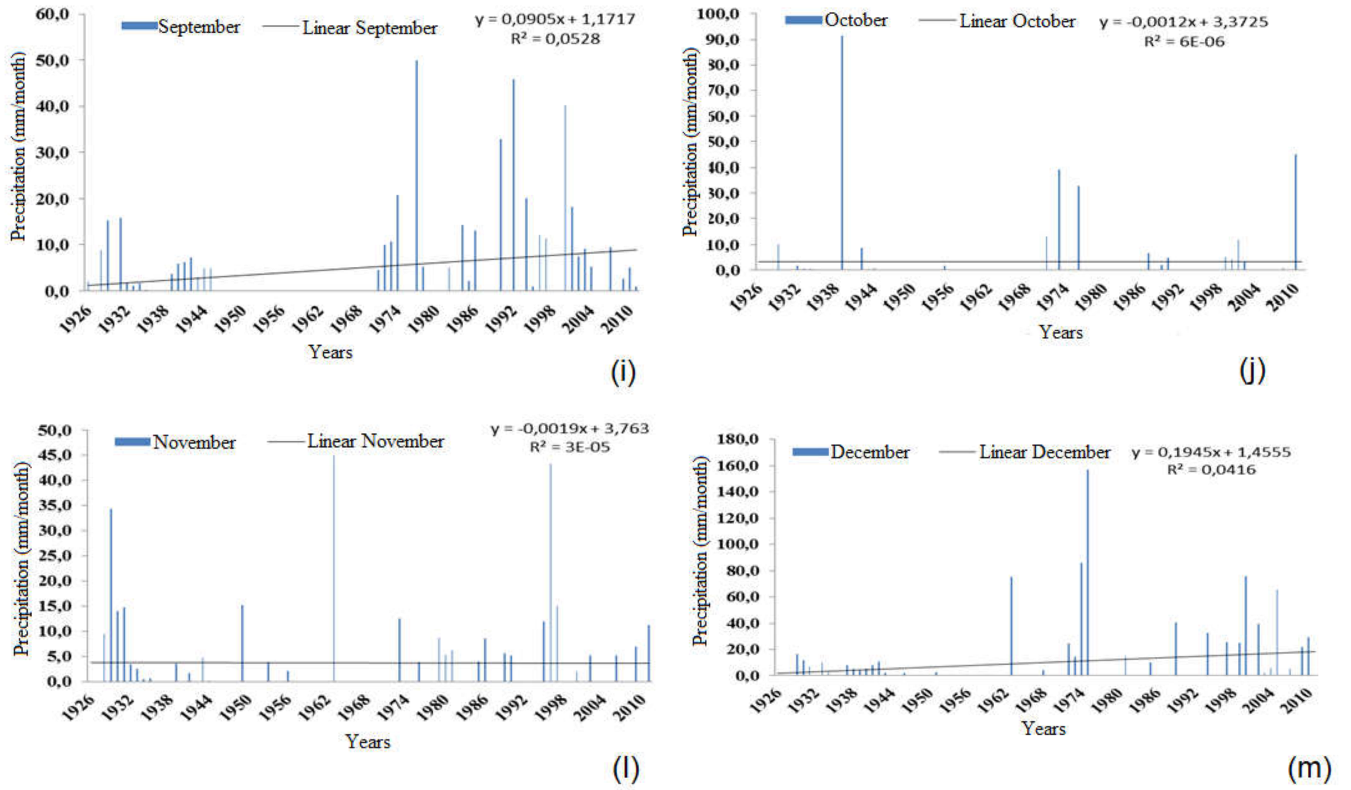


Figure 4. Monthly precipitation and its trend line from the period 1926-2011. a) January; b) February; c) March; d) April; e) May; f) June; g) July; h) August; i) September; j) October; l) November; m) December

The rainfall irregularities recorded in March for the period 1926-2011 (Figure 4c). XXX states that rainfall irregularities can be caused by the variability of the large, meso, and microscale atmospheric systems with local and regional contributions . Monthly indexes range from 0 to 400 mm. The slope coefficient of the equation of the line is positive and its R^2 represents low significance. In the month of April, rainfall values ranged between 0 to 290 mm. Between the years of 1946 and 1963, the monthly totals did not exceed 40 mm, while in 1964 to 1973 years, the rainfall index 15 to 270 mm in April months. Between 1974 and 2011, it was observed fluctuations ranged 120 and 280 mm (Figure 4d). The month of May presents a trend line with a positive angular coefficient and R^2 with a low significance. The tendency is for the rainfall index to remain in the range that is occurring except when large-scale extreme events, such as El Niño, occur. The pluviometric fluctuation oscillated from 0 to 180 mm, and the magnitude were better between the years of 1963 to 2011. The month of June, considered as rainy in the study region, presents irregularity that flow between 0 to 175 mm.

These variabilities are interrelated to the precipitating factors and/or rainfall inhibitors acting on the macro scale and region of study. It is observed that between 1964 and 2011 the rainfall intensity was better distributed than between the period from 1926 to 1963. July months have a straight line equation with a positive angular coefficient of low significance. The future trend is a monthly increase of around 0.3 to 1 mm/year, depending on the meteorological factors. It is noteworthy that between the year interval between 1946 and 1961, the lowest rainfall incidences occurred. Fluctuations with rainfall above 50 mm occurred in isolated months and had contributions from the trade winds in the transport of moisture, low solar incidence, increase in cloud cover. In the month of August, a transition period between the end of the rainy season and the beginning of the dry season, the pluviometric events flowed from 0 to 70 mm. Irregular fluctuations between the studied years were noticed. It can highlighted that the years 1929, 1932, 1942, 1973, 1984, 1986, 1989, 2009 and 2011 presented above normal rainfall volume. The equation of the trend line presented positive angular coefficient and R^2 of low significance. The future trend is that the month will continue with anomalous rains and will not exceed 80 mm. The rainfall irregularities occurred in the month of September for the study period (Figure 4i), when the rainfall index flowed from 0 to 50 mm. Between the years 1928 to 1935, the pluviometric oscillations ranged between 0.3 and 18 mm. In the interval from 1938 to 1945, precipitation was recorded between 3.5 to 10 mm. Between 1945 and 1971, rainfall variability did not exceed 0.3 mm. The irregularity of major fluctuations occurred between the years 1972 to 2011, in which it was related to local, regional and mesoscale atmospheric activities such as upward vertical movements, heat exchange and humidity. Figure 4j shows the pluviometric oscillations referring to the month of October where, in most of the months, they did not exceed 10 mm. In the period from 1926 to 2011, the rainfall ranged from 0 to 90 mm. In 1939, rainfall of approximately 90 mm was related, while in 1974, 1978 and 2011, rainfall of 40 mm, 34 mm and 45 mm, respectively, were observed. These pluviometric anomalies of these years are related to local, regional effects and transient systems that carried steam and humidity above normal. The month of November (figure 4l), considered as the low rainfall index, presented anomalies in its indices with rainfall above 10 mm in the years of 1927-1932, 1950, 1963, 1974, 1987, 1988, 1989 and 2011. In the other years, the November month showed rainfall below the 10 mm and the trend line had negative angular coefficient and R^2 of very low significance. Figure 4m represents the variability of the pluviometric indices occurred in the month of December of the 1926-2011 series. It is highlighted that the years of 1963, 1972, 1975, 1976, 1989, 1995, 1998, 1999, 2000, 2003, 2006 and 2011 showed rainfall above 20 mm, considered anomalous due to local transient factors. In the series of precipitation studied, the rainfall regime is very complex being quite diversified seasonally presenting great interannual and interdecadal variability. Divergences of climate change patterns is still uncertain over the world. Some climate projections suggest an increase in the rainfall and others indicate a decrease (Lamboni et al., 2019).

Annual and monthly future trends: Table 1 shows that the best regression determination coefficients (R^2 = 0.0708 and 0.1009) for the months of January and August and the worst regression coefficients were for the months of October and November respectively ($R^2 = 6x10^{-6}$ and $3x10^{-3}$). Higher values indicate the degree of approximation of the model to the means. Conversely, lower value indicate the degree of distance of the model to the means.

Table 1. Linear equation, coefficient of determination of the regression (R^2), historical average monthly and total annual precipitation of the period from 1926 to 2011 in Cabaceira (Paraíba, Brazil)

Month	Linear equation	R²	Average rainfall
January	0.4355x + 4.0189	0.0708	23.0
February	0.3766x + 22.840	0.0374	39.2
March	0.4578x + 39.924	0.0265	59.8
April	0.3963x + 41.744	0.0254	59.0
May	0.3049x + 28.624	0.0368	41.9
June	0.2701x + 30.896	0.0343	42.6
July	0.1190x + 27.750	0.0197	36.0
August	0.2256x + 4.8887	0.1009	14.7
September	0.0905x + 0.0528	0.0528	5.1
October	-0.0012x + 3.2725	6x10-6	3.3
November	-0.0045x + 4.1364	3x10-5	3.9
December	0.1945x + 1.4555	0.0416	10.9

It can be observed in Figure 5 that the highest monthly average precipitation indexes were recorded in March and April, with an average value of 118.8 mm, corresponding to 35.1% of the annual precipitation. The months with the lowest rainfall indexes oscillate between September and December, corresponding to 6.5% of the annual total, showing, over time, a spatial variability characteristic of the NEB region.

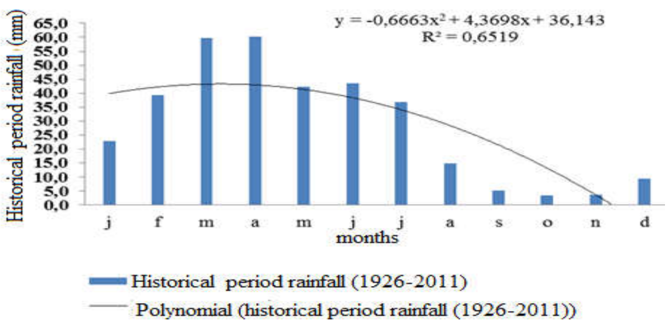


Figure 5. Histogram of historical pluviometric mean and polynomial trend for the period from 1926 to 2011

Table 2. Measures of central tendency and dispersion according to the statistical analysis of historical data from 1931 to 2010

Months	Minimum rainfall (mm)	Average rainfall (mm)	Deviation standard (mm)	Maximum rainfall (mm)	Variation (%)
January	0,0	23.0	40.9	279.2	1.78
February	0,0	39.2	48.6	183.8	1.24
March	0,0	59.8	70.2	386.0	1.17
April	0,0	59.0	62.3	271.2	1.10
May	0,0	41.9	39.7	184.8	0.94
June	0,0	42.6	36.4	176.0	0.84
July	0,0	36.0	33.9	154.8	0.92
August	0,0	14.7	17.8	71.0	1.19
September	0,0	5.1	9.9	50.0	1.90
October	0,0	3.3	12.4	91.4	3.62
November	0,0	39.0	8.4	45.0	2.46
December	0,0	10.0	23.0	157.0	0.60

Statistical analysis: Table 2 shows that the mean and median values were unrelated, showing that discordant extreme values were present in the sample. The highest rainfall index, ie, the maximum occurs in the month of March (386mm), while the minimum occurred in all the months being registered 0.0mm. It should be noted that the maximum values occurred in all months had a variation greater than the annual average, indicating a dispersion in the rainfall index. In the standard deviation we observe the influence of the smaller deviations in the months of September and November (9.9 and 8.4mm), the month of March being the one with the greatest deviation (70.2), showing the strong dispersion of the data. The average monthly variability indicates that this measure of central tendency may not be the most likely value to occur in this type of distribution. It is also notable that the monthly averages exceed the median values. Thus, the monthly rainfall distribution models are asymmetrical, with a positive asymmetry coefficient. With this, the median is more likely to occur than the average.

CONCLUSIONS

Based on the results it is concluded that the median is the measure of central tendency most likely to occur; the rainy season lasts six months (February to July) with an average value of 278.9mm, corresponding to 82.5% of the annual precipitation. In 86 years of observed rainfall its historical average is of 338.1mm. The total annual precipitation showed a gradual increase in its indices of the studied series, being able to be related to the elevation of the temperature and a higher evaporative index. There was no long-term trend, that is, there was no decrease or increase in annual rainfall, only interdecadal variability. It should be noted that there is a possibility of extreme events in the rainfall indices of rainfall of high magnitudes and in a short interval of time. According to the linear regression analysis of the historical series of precipitation from 1926 to 2011, the trend of greater rainfall variability is centered between February and June, which has high rainfall rates for the region and the lowest rainfall is centered between the months of October and December, which has low rainfall indexes.

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