Climatological diagnosis and precipitation trend in Cabaceiras - PB, Brazil

Romildo M. Holanda*, Raimundo M. de Medeiros**

*Prof. Dr. Federal Rural University of Pernambuco, UFRPE, PE, Brazil, e-mail: romildomorant@gmail.com

**Prof., Post Doc, Dr. Adelmar Furtado Faculty, Teresina, Piauí – Brazil, E-mail: mainarmedeiros@gmail.com

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Abstract

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. We analyzed the temporal distribution of the historical series and the rainfall trend for the municipality of Cabaceiras - PB and a study with linear regression and measures of central tendency and dispersion of the monthly and annual rainfall indices. Based on the 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, corresponding to 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; It was verified in the linear regression analysis of the historical series of precipitation of the period from 1926 to 2011, the trend of greater variability of precipitation is centered between the months of February to June, which has high rainfall rates for the region and the smaller ones Pluviometric indexes is centered between the months of October and December, which has low rainfall indexes.

Keywords: Variability timeline, trend, linear regression.

1. Introduction

Nowadays, 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 (Viana, 2010).

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 Soriano (1997).

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 found 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. Haylock et al. (2006) made an analysis of rainfall over South America and observed a

trend of increasing annual rainfall over NEB. The study 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. Still Santos and Brito (2009) showed trends of precipitation increase for the state of Ceará.

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.

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.

2. 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 (AESAs, 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 map of the study area.

The climate of Cabaceiras - PB according to Köppen 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) and the Executive Agency for the Management of Waters of the State of Paraíba (AESAs) 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.

3. 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 indice.

Figure 2- Mann-Kendall test of the period 1926-2011.

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). These variabilities are due to the meteorological systems of large scales operating in those years. 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.

The Figure 4a shows the variability of the rainfall indices for the month of 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 4a - Precipitation of the month of January and its trend line for the period of 1926-2011.

Figure 4b shows the rainfall irregularity of the study period. Observes 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 in the months of February.

Figure 4b - Precipitation of the month of February and its trend line for the period of 1926-2011.

The rainfall irregularities recorded in March for the period 1926-2011 (Figure 4c) were 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.

The month of April of the pluviometric series of the period of 1926-2011 presents with oscillations between 0 to 290 mm. Between the years of 1946 and 1963 the monthly totals did not exceed 40 mm, between the years of 1964 to 1973 in the great majority of the month of April the rainfall index 15 to 270 mm,

between 1974 and 2011 it is the years 1975, 1978, 1989 and 2009 with fluctuations between 120 and 280 mm (Figure 4d).

Figure 4c - Precipitation of the month of march and its trend line for the period of 1926-2011.

Figure 4d - Precipitation of the month of abril and its trend line for the period of 1926-2011.

The month of May presents a trend line with a positive angular coefficient and R^2 with a low significance (Figure 4e). 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 19663 to 2011.

Figure 4e - Precipitation of the month of may and its trend line for the period of 1926-2011.

The month of June for being considered as rainy presents irregularity that flow between 0 to 175 mm (Figure 4f). 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.

O mês de julho tem equação de reta com coeficiente angular positivo e de baixa significância, a tendência futura é aumento mensal por volta de 0,3 a 1 mm/ano, dependendo dos fatores meteorológicos atuantes. Destaca-se que entre o intervalo de ano

compreendido entre 1946 a 1961 ocorreram as menores incidências pluviométricas (Figure 4g). As flutuações com índices pluviométricos superiores a 50 mm ocorreram em meses isolados e tiveram contribuições dos ventos alísios no transporte de umidade, baixa incidência solar, aumento da cobertura de nuvem.

Figure 4f - Precipitation of the month of June and its trend line for the period of 1926-2011.

Figure 4g - Precipitation of the month of July and its trend line for the period of 1926-2011.

The month of August as being a transition between the end of the rainy season and the beginning of the dry season, the pluviometric events flowed from 0 to 70 mm (Figure 4h). Irregular fluctuations between the studied years stand out, highlight the years 1929, 1932, 1942, 1973, 1984, 1986, 1989, 2009 and 2011 with rains above normal. 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.

Figure 4h - Precipitation of the month of August and its trend line for the period of 1926-2011.

The rainfall irregularities occurred in the month of September for the study period as recorded in Figure 4i, where the rainfall index flowed from 0 to 50 mm. Between the years 1928 to 1935 the pluviometric oscillations flowed between 0.3 and 18 mm. In the interval of years between 1938 and 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 was related to local, regional and mesoscale atmospheric activities such as upward vertical movements, heat exchange and humidity.

Figure 4i - Precipitation of the month of September and its trend line for the period of 1926-2011.

The 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 pluviometric buoyancy ranged from 0 to 90 mm. The years: 1939 rained 90 mm, 1974, 1978 and 2011 rained respectively 40 mm, 34 mm and 45 mm, these pluviometric anomalies of these years are related to local, regional effects and transient systems that carried steam and humidity above normal.

Figure 4j - Precipitation of the month of October and its trend line for the period of 1926-2011.

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, for the other months of November Of the mentioned years the pluviometric fluctuations were below the 10 mm, the trend line has negative angular coefficient and R^2 of very low significance.

Figure 4l - Precipitation of the month of November and its trend line for the period of 1926-2011.

The Figure 4m represents the variability of the pluviometric indices occurred in the month of

December of the 1926-2011 series. We highlight that the years of 1963, 1972, 1975, 1976, 1989, 1995, 1998, 1999, 2000, 2003, 2006 and 2011 that rained above 20 mm, considered anomalous and its anomaly is due to local transient factors.

Figure 4m - Precipitation of the month of december and its trend line for the period of 1926-2011.

In the series of precipitation studied it is that the rainfall regime is very complex being quite diversified seasonally presenting great interannual and interdecadal variability.

Annual and monthly future trends

The 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 ($R^2 = 6 \times 10^{-6}$ and 3×10^{-3}). Meaning that when the value is higher, indicates the degree of approximation of the model to the means, and when the value is smaller indicates the degree of distance of the model to the means.

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.

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.

Month	Linear equation	R^2	Mean
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	$-0.0012x + 3.2725$	6×10^{-6}	3.3
November	$-0.0045x + 4.1364$	3×10^{-5}	3.9
December	$0.1945x + 1.4555$	0.0416	10.9

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

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, according to results found by Almeida and Pereira (2007).

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

Months	Average	Deviation	Medium	Variation	maximum	minimum
	(mm)	(mm)	(mm)	(%)	(mm)	(mm)
January	23,0	40,9	4,2	1,78	279,2	0,0
February	39,2	48,6	19,4	1,24	183,8	0,0
March	59,8	70,2	37,4	1,17	386,0	0,0
April	59,0	62,3	39,4	1,04	271,2	0,0
May	41,9	39,7	31,1	0,94	184,8	0,0
June	42,6	36,4	36,0	0,84	176,0	0,0
July	36,0	33,9	29,0	0,92	154,8	0,0
August	14,7	17,8	7,0	1,19	71,0	0,0
September	5,1	9,9	0,0	1,90	50,0	0,0
October	3,3	12,4	0,0	3,62	91,4	0,0
November	39,0	8,4	0,0	2,23	45,0	0,0
December	10,0	23,0	0,0	2,46	157,0	0,0
Yearly	338,1	200,7	230,9	0,60	775,5	0,0

4. 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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