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Rainfall Variability in São Bento Do Una Municipality, Pernambuco State, Brazil

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ABSTRACT

Precipitation is evaluated as a relevant factor for the development of various socio-economic and environmental activities, especially hydroelectric plants, industries, agribusiness, farming, poultry, fish farming, and contribution in increasing the levels of reservoirs for human supply. This work aims to evaluate the climatic trends of precipitation at a local level in the São Bento do Uma municipality, Pernambuco state, Brazil, for the period from 1920 to 2016, diagnosing its variations to provide subsidies to decision-makers. Daily precipitation provided by the Pernambuco Agency of Water and Climate, was used, and the Climap software was used to analyze the precipitation trend and the climate extremes indexes. The Mann-Kendall sequential test was applied to aim to verify the year in which the rainfall trends could start. The quarterly rainfall variabilities used in this study showed unsatisfactory behavior in characterizing the rainfall regime. The historical annual rainfall totals showed high spatial and temporal variation, with low rainfall rates in the wet season period. Irregular variability in rainfall and water availability was observed, a fact that is reflected in all human activities. It is essential to have a detailed knowledge of the historical behavior of precipitation, allied to technical and natural resources that provide subsidies for the development of the region. Policies and plans for capturing and using rainwater are needed so that there is a more efficient use of this natural resource and socioeconomic development is not limited by water availability.

INTRODUCTION

The pluvial instability added to the cyclical scarcity of rainfall, with poor spatial and temporal distribution, constitute an extraordinary definer of agricultural production. Socioeconomic, poultry, water storage, among so many others, occurring in the state, are affected by the production of crops, especially those cultivated by family farmers, with no irrigation, who have at their disposal few technological resources and are dependent on rainfall oscillations for their survival. These crops are greatly affected by rainfall fluctuations, appropriate for each cultivar. Rainfall rates below and/or above historical averages cause productivity problems for crops, especially food crops.

The Agreste region of Pernambuco state suffers from water scarcity, and any form that leads to a reduction in water consumption and consequent relief of the exploitation of water sources is welcome. The water supply is carried out by water trucks, and the scarcer the product, the greater the distances that the trucks have to travel to fetch water (OLIVEIRA, 2017).

Medeiros et al. (2015) performed an analysis of the climate and the availability of surface and groundwater resources in the municipality of São João do Cariri, Paraíba state, Brazil, and found that the climate and water resources do not provide water for the main activities of socio-economic importance when visualized through the water balance. The studied area needs rainwater storage since the groundwater is not sufficient and does not present satisfactory quality for domestic and other purposes.

Precipitation can be associated with extreme phenomena of various natures, depending on the pattern, intensity, and frequency of its rainfall regime. Souza (2011) stated that rainfall, considered a natural phenomenon, associated with the pattern of irregular urban occupation, has caused damage and losses to the environment, material and human, some identifiable and assessable, and others subjective and incalculable. It is judicious to analyze that global climate change can be intensified regionally and/or locally by its changes (Souza et al., 2009). For Kulkarni et al. (2013) rainfall has high importance in tropical regions and is considered as the point of convective processes that occur in the atmosphere.

According to Mendes (2015), the climatic variability of the Northeast of Brazil is greatly influenced by the El Niño phenomenon, associated with major drought events in the region, which causes great losses to the populations of this region.

The semi-arid Northeast region of Brazil has over the years been configured as an important laboratory, allowing several studies on its rainfall variability, given its spatial and temporal oscillations (Costa 2013).

Medeiros (2012) analyzed the climatology of precipitation in the municipality of Bananeiras, Paraíba state, Brazil, in the period 1930-2011, as a contribution to Agroindustry, and found that rainfall indices are essential to agro-industrial and agricultural sustainability.

Precipitation is a climatic element with the greatest spatiotemporal variability. For this reason, the study of extreme events of maximum annual daily precipitation is related to severe damage to human activities in all regions of the world, due to its potential to cause soil water saturation, runoff, and erosion (IPCC, 2007; Tammets et al., 2013).

This work aims to evaluate the climatic trends of precipitation at a local level in the São Bento do Uma municipality, Pernambuco state, Brazil, for the period from 1920 to 2016, diagnosing its variations to provide subsidies to decision-makers.

MATERIALS AND METHODS

São Bento do Una municipality is located in the mesoregion Agreste and in the micro-region of the Ipojuca Valley of the State of Pernambuco, Brazil, bordering Belo Jardim to the north, Jucati, Jupi, and Lajedo to the south, Cachoeirinha to the east, and Capoeiras, Sanharó, and Pesqueira to the west (Figure 1).

Figure 1 - Location of the municipality of São Bento do Una in the state of Pernambuco.

Source: Medeiros (2021).

The municipal area is 719.15 km^2 and represents 0.72% of the State of Pernambuco. The municipal seat has an altitude of 614 meters above sea level and is located at the geographical coordinates of 08°31'22" south latitude and 36°06'40" west longitude.

São Bento do Una is inserted in the geoenvironmental unit of the Borborema Plateau, formed by massifs and high hills, with altitudes varying from 650 to 1,000 meters. It occupies an arched area that extends from the south of Alagoas to Rio Grande do Norte. The relief is generally rolling, with deep and narrow dissected valleys. Concerning soil is quite varied, with some predominance of medium to high fertility.

The area of the unit is cut by perennial rivers of small flow and its groundwater potential is low. The vegetation is formed by Subcaducifolic and Caducifolic Forests, typical of the harsh areas.

According to the climate classification by Köppen (1928), São Bento do Una has the climate As Tropical Rainy, with dry summer. This classification is in agreement with Medeiros et al. (2018) and Alvares et al. (2014). The rainy season starts in February with pre-season rains, rains that occur before the rainy season, and ends at the end of August and can last until the first half of September. The rainy quarter is centered in May, June, and July and its dry months occur between October, November, and December. The factors that cause the rains in the municipality are the contribution of the Intertropical Convergence Zone (ITCZ), the formation of cyclonic vortices of high levels (HVCAS), the contribution of the northeasterly trade winds in the transport of steam and moisture which condense and form clouds, the formation of lines of instability, orography and their local and regional contributions forming clouds and causing moderate to heavy rains (Medeiros, 2016).

To evaluate the precipitation patterns that can adapt to the climatic variations of a given region, it is necessary to work with data series for a minimum period of thirty years (WMO, 1989). To determine climate variability, it is essential to investigate the daily, monthly, and annual behavior of the rainfall regime in the area to be studied.

For the development of this article, were analyzed the daily precipitation data of the municipality of São Bento do Una, Pernambuco state, Brazil, acquired through the Pernambuco Agency for Water and Climate (APAC, 2016), for the period from 1920 to 2016, comprising 105 years of observed data.

The rainfall series were used, made homogenization and consistency of the gaps, being filled to make the analysis more reliable. The data were organized in electronic spreadsheets where simplified statistical calculations were performed as monthly and annual averages for each month and year of the series. Graphs were produced being plotted to aid in the interpretation of the information. The rainfall indices and their graphic visualizations were processed in the Climap 3.0software, generating specific information about the variability in the rainfall regime of the studied area.

Climap is an application with a graphic interface that helps the analysis of meteorological data series of rainfall and air temperature, with the association of information and the creation of graphs. According to Salvador (2014), the application was developed as part of the academic activities in the postgraduate course in Meteorology at the Universidade Federal de Campina Grande (UFCG). The programming language employed for its development was Python 2.7.6, with the graphical interface creation resources of the Tkinter library, which is a native Python resource (Rossum, 1996).

The Climap 1.1 application was used to obtain the following indexes:

I. Monthly, quarterly, and annual rainfall totals;

II. SPD: Standard deviation of the precipitation of monthly, quarterly and annual totals. PPD= (total-average)/standard deviation;

III. Pr1: Number of days per year with precipitation ≥ 10 mm;

IV. Pr10: Number of days with precipitation ≥ 20mm;

V. Per95p: Number of days with precipitation ≥ the 95th percentile of significant rainfall;

VI. Per99: Number of days with precipitation ≥ the 99th percentile of significant rainfall;

VII. Prmax1d: Highest precipitation occurring on one day per year (mm).

Through the Climap 1.1 application, the Mann-Kendall sequential test (MK) was performed to complement the analysis with the correlation and prognosis of the test initially proposed by Sneyers (1975), used to test the hypotheses concerning the trends of certain historical data series. According to Goossens et al. (1986), using the Mann-Kendall test, it is possible to detect an approximately find the starting point of a given trend line. In Climap, the variables considered in the MK test are the standard deviation and the variance, and the significance (p-value) is defined when it ranges from ≤ 0.05 to 0.5.

RESULTS AND DISCUSSION

Figure 2 shows the variability of historical monthly averages of precipitation where fluctuations of the increasing trend are observed between December to April, with their maximum values in March and April flowing between 80 and 90 mm. The months of September and October with lower rates (>20mm); the months of May, June, and July registered rainfall variability of 60 to 80 mm.

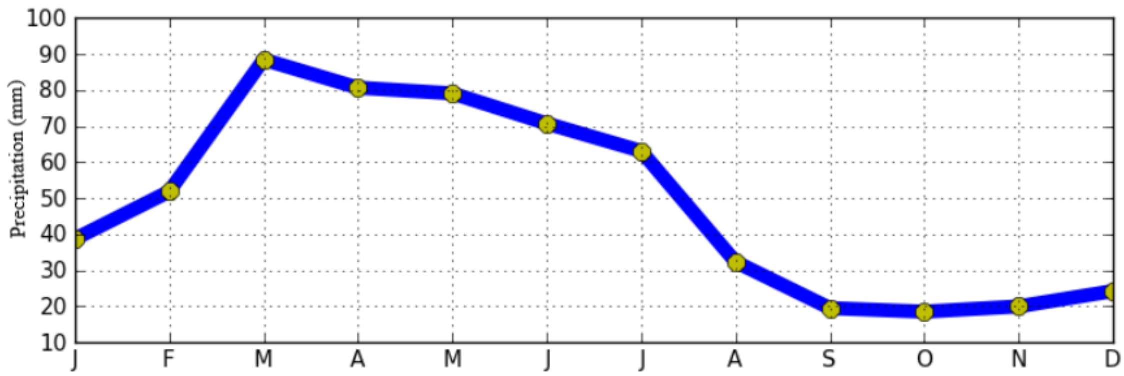

Figure 2 - Variability of historical monthly precipitation averages in São Bento do Una municipality, Pernambuco state, Brazil.

Source: Medeiros (2021).

Figure 3 shows the quarterly rainfall averages. In the quarter January, February, March (JFM), February, March, April (FMA), March, April, May (MAM), April, May, June (AMJ), May, June, July (MJJ), and June, July, August (JJA), their indexes flow between 115 to 250 mm; In the quarter July, August, September (JAS) the sum of the rainfall index was 107.8 mm; in the quarter August, September, October (ASO) 60 mm is recorded; in September, October, November (SON), and October, November and December (OND) the quarterly variability was 50 mm, fluctuations between 90 and 110 mm are observed in the quarter November, December, January (NDJ) and December, January, and February (DJF) respectively.

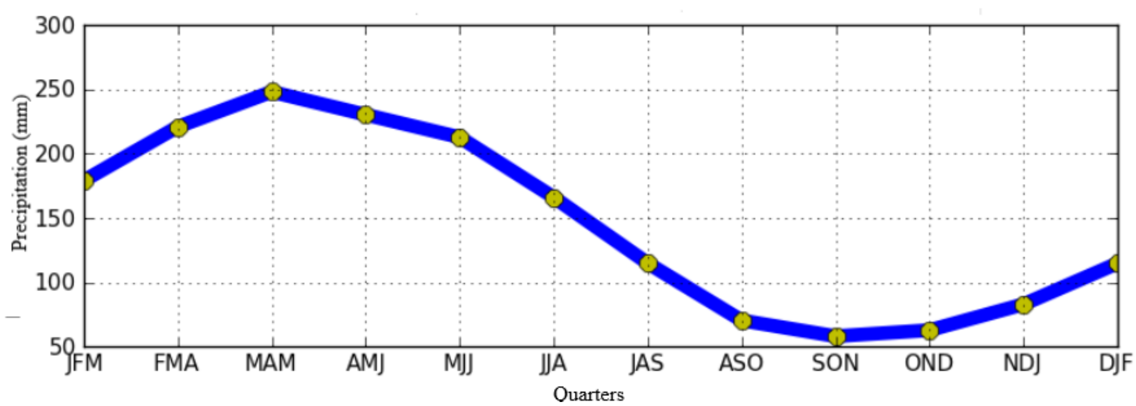

Figure 3: Variability of quarterly average rainfall in São Bento do Una municipality, Pernambuco state, Brazil.

Source: Medeiros (2021).

Studying climate variables in a semi-arid climate is a task that demands a lot of work. This is due to the low periodicity of climatic phenomena and the poor distribution of rainfall, either temporally or spatially, that occurs in these regions.

The interannual rainfall variability is irregular. The years 1940 with 1000 mm, 1969 with 1100 mm, 1986 and 2010 close to 1000 mm, the years 1930 and 1935 with approximately 300 mm, 1998 with 250 mm, and 2012 and 2016 as atypical and below normal rainfall (Figure 4). With a positive trend line and an R^2 of low significance, it is difficult to say whether rainfall increases or decreases will occur.

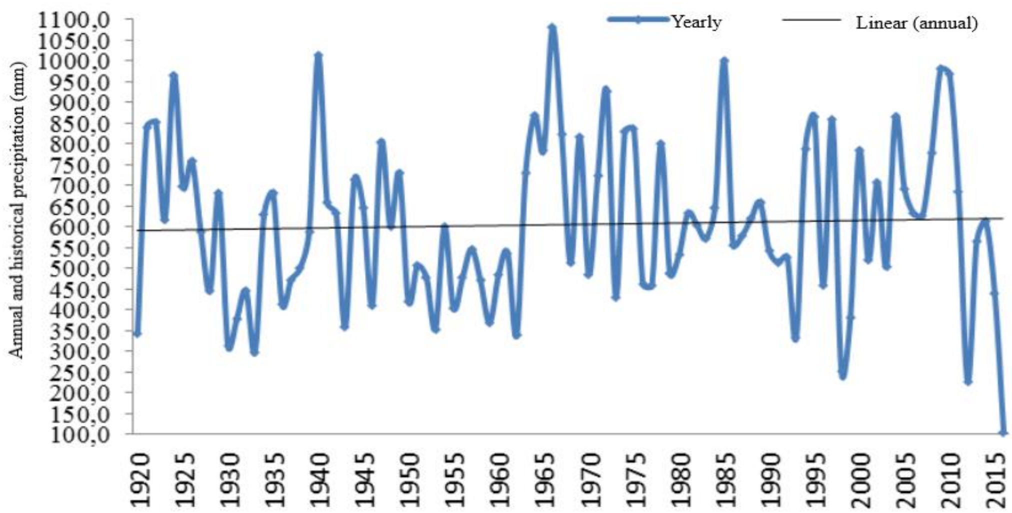

Figure 4 - Annual variability of precipitation and trend line in the period from 1920 to 2016 for the São Bento do Una municipality, Pernambuco state, Brazil.

Source: Medeiros (2021).

The interannual rainfall variability shows a linear trend with a small increase in precipitation patterns. The largest average fluctuations achieved in the period studied occur between 1965-1979 and 1996-2010, corroborating this trend line, always occurring after rainy years with reduced precipitation about the previous or subsequent year. This frequency may be related to the various meso and micro-scale meteorological elements independent of the positive linear trend. The least rainy years were: 1930, 1992, 1994, 1999, and 2016. A study developed by Santos et al. (2009), who analyzed the trends of rainfall indices in the Ceará state, Brazil, using the climatological series for the period 1935 to 2006 through the RClimDex module, corroborates the results discussed here. Related studies are in agreement with Holanda et al. (2016), demonstrating that meso, microscale phenomena, and local contributions are favorable to rainfall variability.

According to Marengo et al. (2011) in the Brazilian semiarid region this climate variability, particularly those related to drought, has always been synonymous with hardship for the rural populations of the interior of the region and has been an object of concern for society and government sectors over the years. According to the same authors, intense climatic events, associated with soil degradation, can lead to desertification scenarios.

In the climatological series of precipitation (1920-2016), high variability is perceived about the total of the quarter January, February, and March (JFM). In Figure 5a, there were 35.42% of the years with above-average rainfall, 43.75% with below-average rainfall, and 20.83% with normalized rainfall. The quarterly average was 180.1 mm. The total indices of quarterly rainfall vary from 6.5 mm in the year 1920 to 162.2 mm in the year 2004.

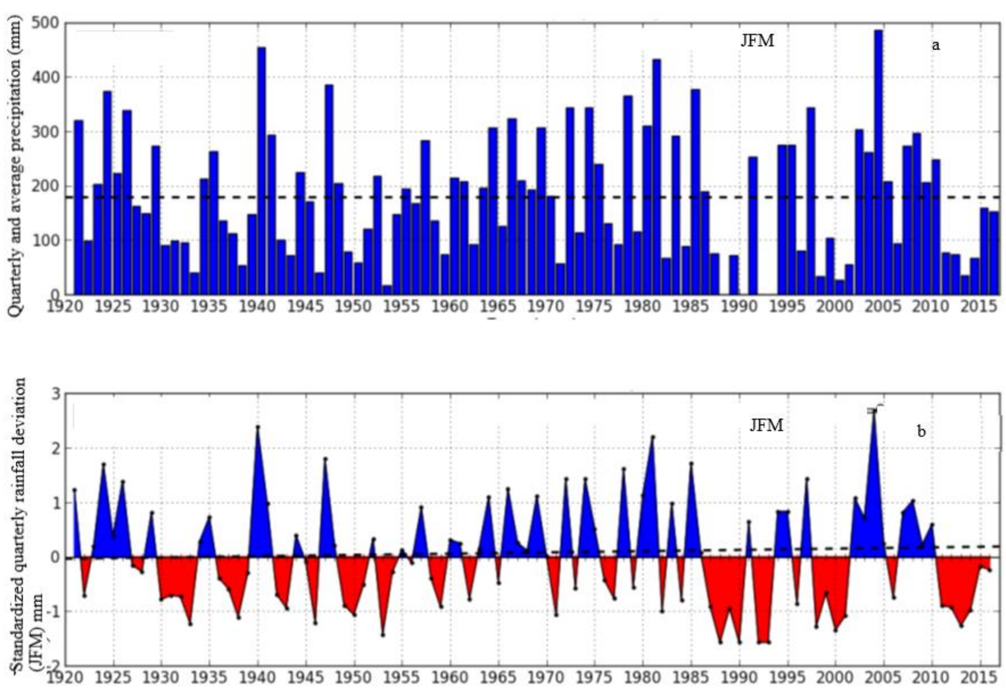

Figure 5 - Total rainfall of January, February, and March quarter (a) and its respective standard deviation (b) of the average rainfall in São Bento do Una municipality, Pernambuco state, Brazil.

Source: Medeiros (2021).

In the standard deviation (Figure 5b), the variability of the increasing and decreasing linear trend over time, oscillated between positive and negative rates stands out. In the period 2011-2016 the standard deviation presented a negative trend; between 2000-2004 showed a positive trend but the rainfall rates were not sufficient to improve the storage and water contribution; between 1965-1985 the standard deviation stands out because its positive variability is accentuated when compared to negative fluctuations. In the period 1930-1950, the standard deviation fluctuations were intense negatively which did not contribute to the normalization of the rainfall indices registered in the studied area. The standard deviation reflects the measure of the dispersion of the values of the normal distribution of rainfall about the mean, and the variability recorded in the figure is a representation of the poor distribution of rainfall over the months and years in the region.

Silva et al. (2011) stated that the rainy season in the Northeast region of Brazil (NEB) coincides with the time of year when the Intertropical Convergence Zone (ITCZ) is positioned south of the equator, which corresponds to March, April, and May (rainy quarter). The ITCZ is more significant over the oceans and therefore, the Sea Surface Temperature (SST) is a determining factor in its position and intensity (FUCEME, 2017). This study corroborates with the results found in this paper.

Figure 6 shows the variability of the total rainfall for the quarter of April, May, and June (AMJ) (6a) and its respective standard deviation (6b) of the average rainfall in São Bento do Una. It is noteworthy that the linear trend represented in the figure corroborates with the shaping trend in Figure 6, which exposes the historical averages of precipitation. The figures point to a positive disposition of the amount of rainfall in the area studied, although their changes are not perspicacious to imply a significant change in the pattern of the series. The results show 45.83% of rainfall below the climatological average; 23.96% with rainfall recorded between normal; and 30.21% of rainfall above the historical average for the quarter April, May, and June.

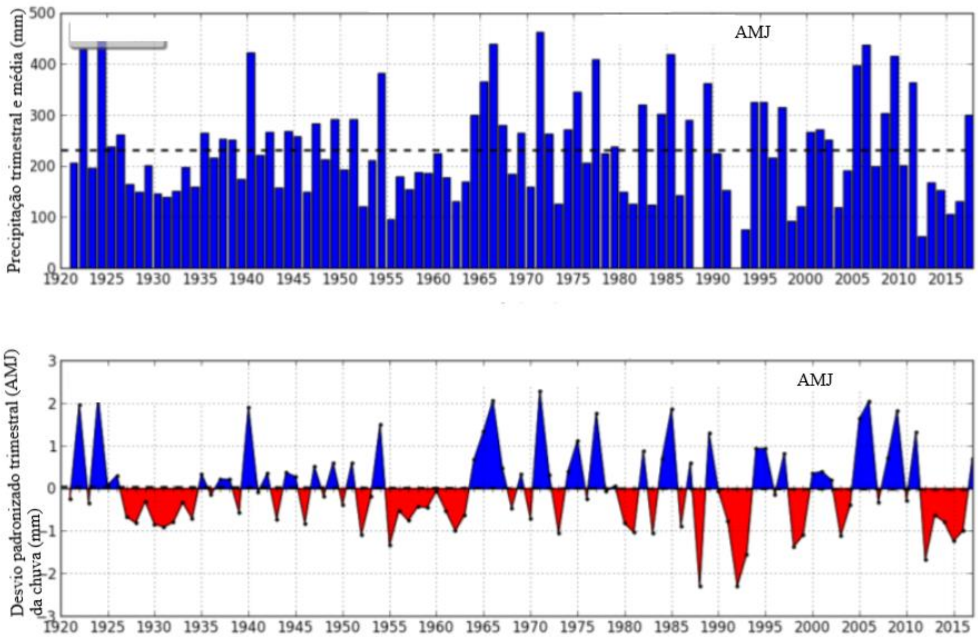

Figure 6. Total precipitation of the quarter April, May, and June (a) and its respective Standard Deviation (b) of the average rainfall in São Bento do Una municipality, Pernambuco state, Brazil.

Source: Medeiros (2021).

The fluctuations of the quarterly standard deviations (April, May, and June) in the period 1920-2016 presented with intensenegatively variabilities in their fluctuations, mainly between the three decades. These fluctuations may be interconnected with the seasonalities of extreme phenomena acting in the local and regional atmospheric circulation which did not contribute to the normalization of rainfall indices, recorded in the studied area, reflecting the measure of the dispersion of the values of the abnormal distribution of rainfall about the average, and their recorded variabilities (Figure 6b).

Figure 7a shows an average of 114.9 mm for the quarter of July, August, and September, with 43 years of above-average rainfall. These variabilities are by Marengo et al. (2011) and Silva et al. (2011).

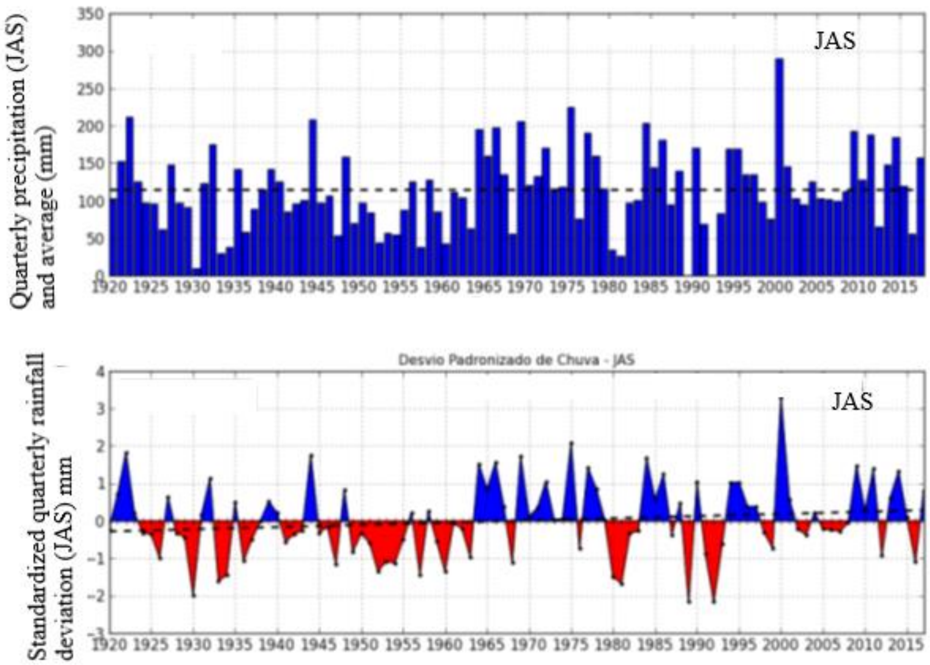

Figure 7. Total rainfall of the quarter July, August, and September (a) and its respective Standard Deviation (b) of the average rainfall in São Bento do Una municipality, Pernambuco state, Brazil.

Source: Medeiros(2021).

The fluctuations of the standard deviations presented themselves with intense negative variability fluctuations in the quarters of July, August, and September comprised between the years 1930-1932, 1950-1955, 1980, and 1981. These fluctuations may be interconnected with the seasonalities of extreme phenomena acting in the local and regional atmospheric circulation which did not contribute to the normalization of rainfall indices recorded in the studied area, reflecting the measure of the dispersion of the values of the abnormal distribution of precipitation about the average, and their variabilities recorded in Figure 7b.

Figure 8 shows the quarter of October, November, and December with an average of 62.7 mm (Figure 8a). Between the years 1920 and 1930 five years with above-average rainfall values were recorded. From 1931 to 1960 there were 10 years with above-average rainfall. Between 1961 and 1990 there were 11 years with above-average rainfall, and between 1991 and 2016 rainfall was above or close to average in six years. These variabilities were due to the acting meso and microscale systems and the factors that provoked and/or inhibited rainfall in the study area, as stated by Medeiros (2016), Marengo et al. (2011), and Silva et al. (2011).

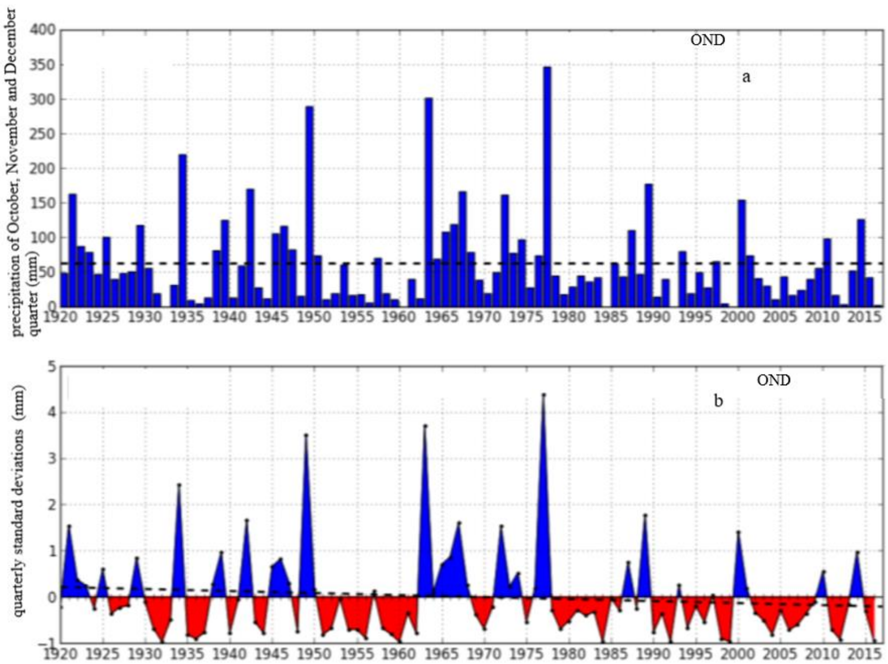

Figure 8. Total precipitation of October, November, and December quarter (a) and its respective Standard Deviation (b) of the average rainfall in São Bento do Una municipality, Pernambuco state, Brazil.

Source: Medeiros (2021).

The fluctuations of the quarterly standard deviations (October, November, and December) in the period 1920-2016 appeared with intense negative variability in their fluctuations, mainly between the last six decades. In the decades from 1920 to 1960, were registered irregularities in the standard deviations and their negative oscillations predominated. These fluctuations may be interconnected with the seasonality of extreme phenomena acting in the local and regional atmospheric circulation which did not contribute to the normalization of rainfall recorded in the area studied, reflecting the measure of the dispersion of the values of the abnormal distribution of rainfall about the average, and their variability recorded in Figure 8b.

Figure 9a shows the variability of quarterly rainfall (December, January, and February) with a quarterly average of 115.4 mm. The quarterly fluctuations occur between 0.5 to 440 mm. It stands out the period 1941-1950 with low quarterly rainfall rates and the periods 1921-192, 1970-1972, 1981-1983, 200-2002, and 2007-2009 with higher quarterly fluctuations recorded. These variabilities are due to the activities of the acting meso and micro-scale climatic factors aided by local effects.

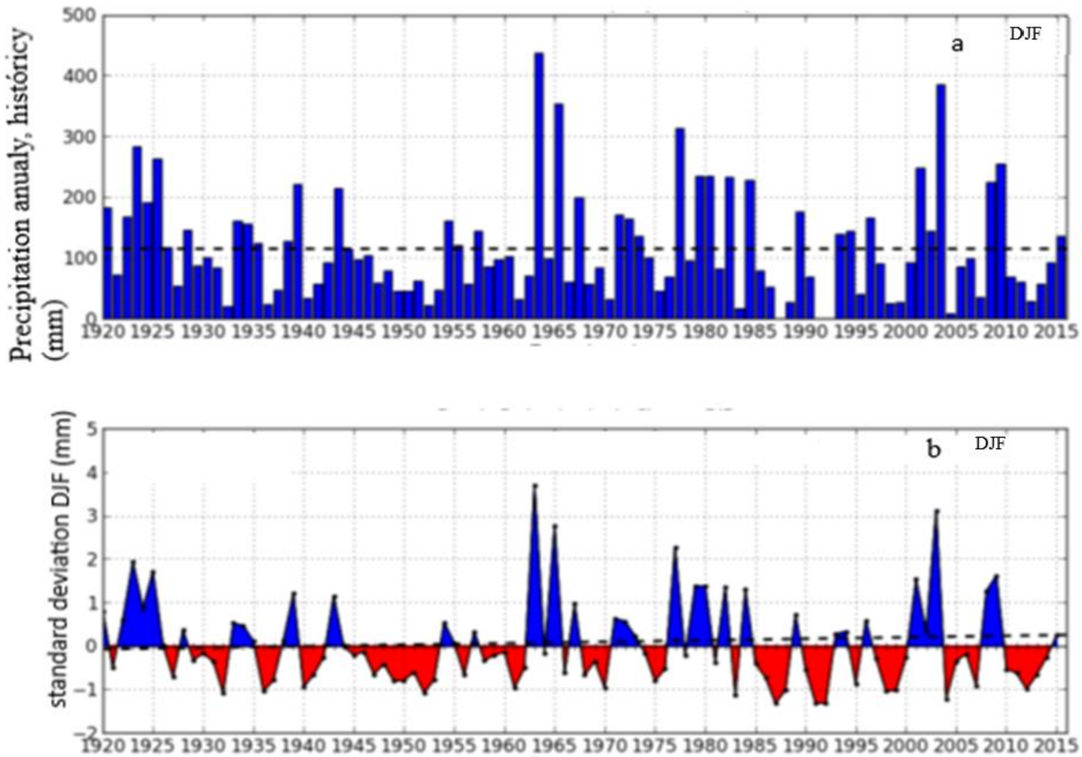

Figure 9. Total rainfall of December, January, and February quarter (a) and its respective Standard Deviation (b) of the average rainfall in São Bento do Una municipality, Pernambuco state, Brazil.

Source: Medeiros (2021).

Figure 9b shows that the largest negative fluctuations of the standard deviation were registered between 1940-1950, followed by the years: 1961, 1070, 1981, 1985, 1988, 1989, 2000, and 2011. It is also noteworthy that the trend line does not present slope and significance.

The elongated periods of extreme drought, influenced by El Niño (HASTENRATH, 2012; Cavalcanti, 2012), can have caused irreparable damage to the population of the semiarid region, especially those who lived off the livelihood of rainfed agricultural activity, especially family farming (RODRIGUEZ et al., 2015). These studies corroborate the results discussed here.

CONCLUSION

The quarterly rainfall variabilities used in this study showed unsatisfactory behavior in characterizing the rainfall regime.

The historical annual rainfall totals showed high spatial and temporal variation, with low rainfall rates in the wet season period.

Irregular variability in rainfall and water availability was observed, a fact that is reflected in all human activities. It is essential to have a detailed knowledge of the historical behavior of precipitation, allied to technical and natural resources that provide subsidies for the development of the region.

Policies and plans for capturing and using rainwater are needed so that there is a more efficient use of this natural resource and socioeconomic development is not limited by water availability.

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