International Journal of Science and Research Archive

eISSN: 2582-8185

Cross Ref DOI: 10.30574/ijsra

Journal homepage: https://ijsra.net/

IJSRA

(Research Article)

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Climate oscillations and their trends for Lagoa Seca, Paraíba – Brazil

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International Journal of Science and Research Archive, 2022, 06(02), 162–173

Publication history: Received on 03 July 2022; revised on 09 August 2022; accepted on 11 August 2022

Article DOI: https://doi.org/10.30574/ijsra.2022.6.2.0164

Abstract

The objective is to analyze the fluctuations of temporal climate trends of precipitation and average temperature between the periods 1981-2020 for the municipality of Lagoa Seca, seeking possible damages of these oscillations in socioeconomic activities, helping decision makers regarding possible risks. Climatic precipitation data were provided by the Executive Water and Climate Agency of the State of Paraíba for the period from 1981 to 2020 and air temperature data were estimated by the Estima_T software for the same study period. Rainfall irregularities between 2000-2020 recorded ten years dry; six years very dry; three very rainy years and one rainy year, these rainfall irregularities lead us to conclude that climatic events and human actions may be contributing to the records of these scenarios on a local scale, the predominance of dry and very dry years has been causing impacts to fruit and vegetable producers which has been using longer times in irrigation. Studies with climate trends become more understandable when analyzing long time series which can be divided into sub-periods of at least 31 years. Rainfall irregularities between 2000-2020 recorded ten years dry; six years very dry; three very rainy years and two rainy years, these rainfall irregularities lead us to conclude that climatic events and anthropic actions may be contributing to the records of these scenarios on a local scale, the predominance of dry and very dry years has been causing impacts to fruit and vegetable producers which has been using longer times in irrigation.

Keywords: Rainfall and thermal indices; Climate variability and changes; Rainfall irregularities

1. Introduction

In the last two decades, scientific and academic communities have been debating climate change (IPCC, 2014; ANDRADE et al., 2014; NUNES, 2016; WANDERLEY et al., 2018). This has been happening due to changes in the scenarios of climate change that have taken place, which registers an increase of 2 °C in the average global temperature of the planet, covering major imbalances in ecosystems, such as expressive movements in the Amazon Forest affecting all its biodiversity, causing significant losses of glaciers. In the Andes and Himalayas, according to the study of the First National Assessment Report of the Brazilian Panel on Climate Change.

Penereiro et al, (2013) showed that spatial diagnoses of climate trends allow the observation of oscillations in the behavior of their alterations, providing clarification of subsidies of a certain variable in a region that has been allowing significant changes over time. Studying the climate changes that occurred in the past allows a better understanding of the variability induced in the present, in addition to subsidizing elements for investigation of the behavior of the future climate.

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Medeiros et al, (2018) studied rainfall variability for São Bento do Una (PE), a strong center of poultry production, due to the increase in water demand necessary for the full development of its activities. The study can be used as a tool for planning and actions aimed at managing water resources using water capture, storage and damming systems, avoiding the problem of water scarcity. They also emphasized that there is a need for policies and plans to capture and use rainwater, in addition to the efficient use of other natural resources in the region, so that socioeconomic development is not limited by low water availability.

Medeiros et al, (2017) used the monthly rainfall changes and verified their possible linear trend, identifying the greatest variability in rainfall in the municipality of Serra Talhada (PE) which occurred between January and April, recording high rainfall rates, its indices with lower values are found in the months of July to October. However, the authors stated that the local rainfall is quite irregular in space, time and quantity, its distribution and duration occur differently.

Priori (2014) showed that in areas of fragile and vulnerable ecosystems, such as the Brazilian semi-arid region, where climate change can cause high tides or severe storms in a short period of time, it will make it difficult for water to drain into the sea and cause an extension of floods, inundations and/or inundations causing health and socioeconomic problems to the local population. Silva et al, (2008) warned that economic damage to agriculture with partial or total losses could occur, affecting the water supply for the population caused by high rainfall irregularities, with predominance of intense and short-lived rains, causing strong social impact on the inhabitants of the region.

PAHO (2014) clarified that the speed and magnitude of changes could cause the extinction of many species (fauna and flora), resulting in environmental changes that will lead to the aggravation of disasters such as increased socioeconomic and cultural impact, population growth, urbanization, industrialization, consumption of natural resources and demand on biogeochemical cycles. The increase in the concentrations of greenhouse gases in the atmosphere, which are intensified by human activities (GHINI et al., 2008), caused by the sum of the actions produced by the concentrations of greenhouse gases (SANTOS, 2006).

Santos Neto et al, (2014) stated that understanding the behavior of the seasonal trend of rainfall indexes serves as an option to solve multiple problems of urban and rural planning, water resources, agricultural, industrial and horticultural, disaster alert services and conditioning daily life of local human activities.

Medeiros et al, (2016) analyzing the behavior of rainfall and thermal trends in climatological conditions in Bom Jesus - PI, pointed out that the future scenario is pessimistic, suggesting a reduction of up to 20% in precipitation and a 4 ºC increase in air temperature.

Studies that showed possible temporal trends in mean temperature (MEDEIROS et al., 2018) and studies about precipitation (GROPPO et al., 2008; AMAZON et al., 2012; KARMESHU, 2012; WANDERLEY et al., 2018; YANG et al., 2010; CHIERICE et al., 2014; ISHIHARA et al., 2014; NÓBREGA et al., 2015; LAI et al., 2016 and ZHIJIA et al., 2016). (FARIAS et al., 2012; DUARTE et al., 2015) worked with extreme precipitation events using the Quantile technique for the state of Pernambuco in order to relate them to disasters resulting from temporal trends

Lagoa Seca - PB has as one of the source of human survival the development of fruit and vegetable productivity, this article intends to draw attention to the municipal and state governmental decision-making powers to carry out better projects aimed at the occurrence of effects or occurrences of extreme events that could happen causing damage to vegetables and socioeconomic conditions.

The objective is to analyze the fluctuations of the temporal climatic trends of precipitation and average temperature between the period 1981-2020 for the city of Lagoa Seca (PB) looking for possible damages of these oscillations in the socioeconomic activities and providing subsidies to decision makers regarding the risks possible.

2. Material and methods

The municipal is located at latitude 07º10'15''S; longitude of 35º51’13’’W and altitude of 634 meters are located in the Microregion of Lagoa seca and Mesoregion of Agreste Paraibano. It is limited to: Campina Grande, Massaranduba, Matinhas, São Sebastião de Lagoa de Roça, Montadas, Puxinanã and Esperança. (Figure 1).

Source: Medeiros (2022)

Figure 1 Area of the municipality of Lagoa Seca within the state of Paraíba

According to [19; 20] the climate is of type "As" (hot and humid Tropical rainy). Studies such as the one by [2] corroborate the type of climate studied. The climate classification [41; 42] is sub-humid, megathermic dry (C_1ADa'), with little or no excess of water and evapotranspiration with 29.66% of the potential annual evapotranspiration concentrated in the lowest quarter. Hottest of the year (November, December and January). Thermal amplitudes vary according to latitude, altitude and degree of continentality (effects of mountains, orography, valleys, hills, etc.).

Lagoa Seca is part of the isohyets range (line joining the same amount of precipitation) rom 1,100 mm.year1 to 1,200 mm.year1. [28]. the rains begin around the second half of March, increasing in volume in the first days of April and continue until August, with the wettest quarter between May and July. In the municipality specifically studied, the rains are fundamental for the good development of the regime of perennial rivers, streams, streams, levels of lakes and ponds, as well as for the occupation of the soil, being essential to the planning of any activity the knowledge of its dynamics. The complementation of the factors causing rain in the municipality are formation of squall lines on the coast and transported to the interior by the northeast trade winds, development of convective clusters, from the heat stored on the surface and transferred to the atmosphere, orography, contributions from the formations of the cyclonic vortices, and having as main system the positioning of the Intertropical Convergence Zone. Normally the rains have moderate intensity followed by irregularities due to the failures of the active meteorological systems. The occurrence of summer periods (occurrences of several consecutive days without rain during the rainy season) in the rainy four months (April to July) was possible and varies from year to year. Its magnitude varies depending on the season and meteorological factors. Occurrences with summer periods of more than 17 days per month have been recorded in the time interval elapsed within the four-month period. [28].

Rainfall data were acquired from the Executive Water and Climate Agency of the State of Paraíba [1], referring to the period from 1981 to 2019. The average air temperature data for the studied area were estimated by the Estima_T software for the same period of rainfall data [5;6]. Since the aforementioned municipality does not have the equipment to carry out such an observation. Estima_T is a software to estimate air temperatures in the Northeast Region of Brazil (NEB). The coefficients of the quadratic function were determined for the monthly average temperatures as a function of the local coordinates: latitude, longitude and altitude [5] given by:

$$T = C0 + C1\lambda + C2\emptyset + C3h + C4\lambda 2 + C5\emptyset 2 + C6h2 + C7\lambda\emptyset + C8\lambda h + C9\emptyset h$$

On what:

C0, C1,..., C9 are the constants;

λ, λ2, λ Ø, λ h longitude;

Ø, Ø2, λ Ø latitude; h, h2, λ h,

Ø h height.

They also estimated the temperature time series, adding to it the temperature anomaly of the Tropical Atlantic Ocean [39].

Tij = Ti + AATij i= 1, 2, 3,..., 12 j= 1950, 1951, 1952,....2020

Where: i=1, 2, 3,...,12;

j= 1950, 1951, 1952, 1953,..., 2020.

The worked data have 34 years of continuous observations and according to the World Meteorological Organization [45] the climate of a given area or region is characterized by a minimum period of 30 years with continuous observations, because the longer the data period, the longer the data. The greater the credibility of the climate distinction of the studied region. These have long enough historical series to be classified in terms of climate variability, and are evenly distributed across the municipality under study.

The data were prepared in electronic spreadsheets by Microsoft Office Excel (2016), generating graphs and tables, carried out their analyzes for precipitation, average temperature and trend occurrence by using the mentioned parameters.

Precipitation data were totaled annually and then quantiles were calculated similarly to those used by [37; 46 and 47], referring to probabilities ($Q_{0.15}$), ($Q_{0.35}$), and ($Q0_{.65}$) and (Q0.85), so that, for each year, rainfall data were considered (Table 1). And in (Table 2) there are the calculations of the monthly quantiles and their relative probabilities.

Table 1 Classification, probability and average range of annual rainfall (mm) of rainfall regimes between 1981 and 2020 in Lagoa Seca - Paraíba

Classification	**Probability**	**Average rainfall interval (mm)**	
		Minimum	**maximum**
Very dry	P < Q(0,15)	-	922,90
Dry	Q(0,15)≤P< Q(0,35)	922,90	1083,25
Normal	Q(0,35)≤P<Q(0,65)	1083,25	1210,79
Rainy	Q(0,65)≤P<Q(0,85)	1210,79	1294,79
very rainy	P>Q(0,85)	1294,79	-

Source: [46].

Table 2 Classification, probability and average range of monthly rainfall (mm) of rainfall in the period from 1981 to 2020 in the municipality of Lagoa Seca – Paraíba

Classification	**Probability**	**Average rainfall interval (mm)**	
		Minimum	maximum
Very dry	P < Q(0,15)	< 306,9	307,0
Dry	Q(0,15)≤P<Q(0,35)	307,1	361,1
Normal	Q(0,35)≤P<Q(0,65)	361,2	403,6
Rainy	Q(0,65)≤P<Q(0,85)	403,7	431,6
very rainy	P>Q(0,85)	431,7	<431,8

Source: Adapted by Medeiros (2022)

3. Results and discussion

Table 3 shows the annual rainfall fluctuations, their classification according to the quantile intervals for each year, the years classified as “dry” were: 1980; 1991; 1995; 1997 to 1999; 2001-2003; 2005; 2008; 2010; 2013; 2014; 2018 and 2019.

The years classified as “very dry” were 1981; 1982; 1993; 2006; 2007; 2012; 2015 and 2017. The years classified as “normal rainfall” were: 1983; 1984; 1990 and 1996. The years of 1987; 1988 and 2009 behaved as a “rainy” year. A “very rainy” category was registered for the years: 1985; 1986; 1992; 1994; 2000; 2004 and 2011.

Table 3 Years, annual total rainfall, and classification according to quantile intervals for the municipality of Lagoa Seca - PB in the period 1981-2020

Year	Total Annual	Rank	Year	Total Annual	Rank
1981	856,0	Very dry	2001	1042,5	Dry
1982	867,0	Very dry	2002	1010,8	Dry
1983	1091,1	Normal	2003	998,7	Dry
1984	1182,2	Normal	2004	1697,7	Very rainy
1985	1657,0	Very rainy	2005	971,5	Dry
1986	1522,4	Very rainy	2006	783,1	Very dry
1987	1236,7	Rainy	2007	844,2	Very dry
1988	1251,5	Rainy	2008	1078,7	Dry
1989	928,5	Dry	2009	1256,4	Rainy
1990	1088,8	Normal	2010	971,4	Seco
1991	1078,0	dry	2011	1797,1	Very rainy
1992	1433,4	Very rainy	2012	748,4	Very dry
1993	607,5	Very dry	2013	994,5	Dry
1994	1667,5	Very rainy	2014	1010,6	Dry
1995	955,4	Seco	2015	807,1	Very dry
1996	1202,0	Normal	2016	809,3	Very dry
1997	961,1	Dry	2017	856,4	Very dry
1998	586,0	Dry	2018	938,7	Dry
1999	817,7	Dry	2019	1077,0	Dry
2000	1584,4	Very rainy			

Source: Medeiros (2022).

[30] Explained that disorderly urban expansion can be considered as one of the causes of the worsening of this situation, such as the expansion of natural disasters (prolonged droughts, floods, floods, inundation, flooding, and erosion, among other phenomena). According to the author, actions aimed at sustainability can help with necessary improvements in the socioeconomic and environmental spheres and in the affected cities for the stabilization of the climate. This statement corroborates the discussions presented here.

Table 3 shows the years, their monthly classifications according to the quantile intervals (Table 2) for the municipality of Lagoa Seca - PB in the period 1981-2019. Taking into account the quantile class intervals, four (4) types of classifications were determined. The classification “very dry” (MS) prevailed in most months, in June 1994 and January 2004 rainfall was between normality (N), the months of May and July 2011 were classified as “very rainy” (MC) and the month of July 2015 was classified as “dry (S). Such variability resulted from the active atmospheric systems, the local and regional contributions that were not necessary and sufficient to cause rains above the quantile average. Studies such as [24 and 23] have contributed to the results discussed in this article.

The climatology of the extreme events of the maximum monthly rainfall shows that the highest absolute frequencies of the Quantiles of heavy rain, concentrated between the months of March to September. In the months from October to December, there was a lower record of monthly rainfall, very strong (15<X<35 mm)

Table 4 Years and their monthly classifications for rainfall

ANO	JAN	FEV	MAR	ABR	MAI	JUN	JUL	AGO	SET	OUT	NOV	DEZ
1981	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
1982	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
1983	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
1984	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
1985	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
1986	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
1987	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
1988	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
1989	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
1990	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
1991	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
1992	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
1993	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
1994	MS	MS	MS	MS	MS	N	MS	MS	MS	MS	MS	MS
1995	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
1996	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
1997	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
1998	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
1999	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
2000	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
2001	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
2002	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
2003	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
2004	N	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
2005	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
2006	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
2007	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
2008	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
2009	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
2010	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
2011	MS	MS	MS	MS	MC	MS	MC	MS	MS	MS	MS	MS

2012	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
2013	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
2014	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
2015	MS	MS	MS	MS	MS	MS	S	MS	MS	MS	MS	MS
2016	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
2017	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
2018	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
2019	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS

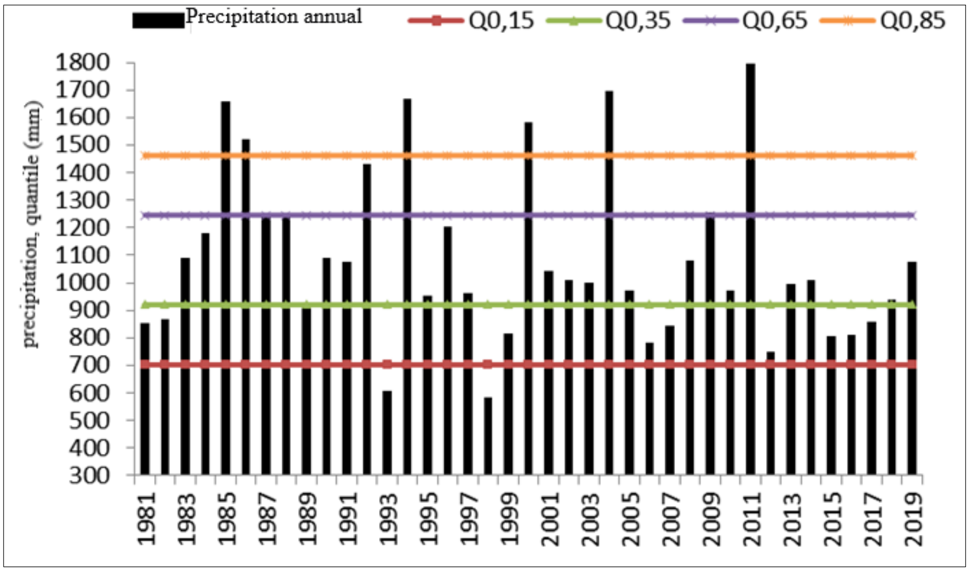
Caption: MS - Very rainy, dry (S), Very rainy (MC), Normality (N). Source: Medeiros (2022).

[29] with data corresponding to the historical series from 1980 to 2009 of the Empresa de Pesquisa Agropecuária do Rio Grande do Norte - EMPARN, in the region of the lower course of the Apodi-Mossoró river, using the Quantis technique, through the proposed methodology per [37; 46 and 47], the approximate monthly amount of rainfall was 642.8 mm, and the intervals established for each extreme class indicated values below 299.2 mm, which corroborate the results shown, in Table 4.

[44] Observed higher daily volumes of precipitation recorded between 1961 and 2016 in Recife, however, these data were different from what was achieved in this study, the rainy season for the municipality under study was reduced due to the beginning of the dry period.

Figure 2 shows the annual rainfall fluctuation, climatological average for the period 1981-2019 and its quantile values $Q_{(0.15)}$, $Q_{(0.35)}$, $Q_{(0.65)}$ and $Q_{(0.85)}$, to the city of Lagoa Seca - PB. The classifications of rainfall years were performed according to Table 1, taking into account the classifications and probabilities for the average rainfall intervals in relation to the quantiles.

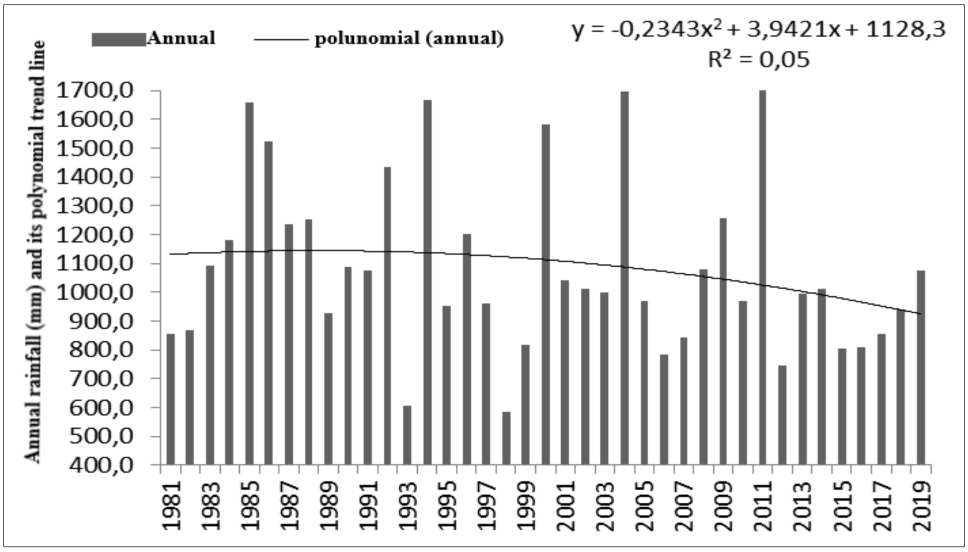
For $Q_{(0.15)}$ there are two years with annual values below (1983, 1998); for $Q_{(0.35)}$ show the years below this 1981, 1982, 1990, 1991, 1999, 2006, 2007, 2015 to 2017. In $Q_{(0.65)}$ the years 1983, 1984, 1991 were recorded, 1991, 1996, 2001 to 2003, 2005, 2008, 2010. With rainfall rates above $Q_{(0.85)}$ were the years 1985, 1986, 1994, 2000, 2004 and 2011. The years that were below $Q_{(0.85)}$ were dried according to quantile distributions presented by [46].



Source: Medeiros (2022).

Figure 2 Annual rainfall distribution and its quantile values $Q_{(0.15)}$, $Q_{(0.35)}$, $Q_{(0.65)}$ and $Q_{(0.85)}$, for the municipality of Lagoa Seca - PB

The polynomial curvature (Figure 3) of precipitation demonstrates the well-defined dry and rainy years, in addition to showing that in recent years between 2010-2018 the reduction in rainfall is more specific given the irregularities recorded, except for the years 2011 and 2014. The polynomial trend curve has a negative angular coefficient and R3 of low significance where it cannot be said that there is an increase or decrease in rainfall.

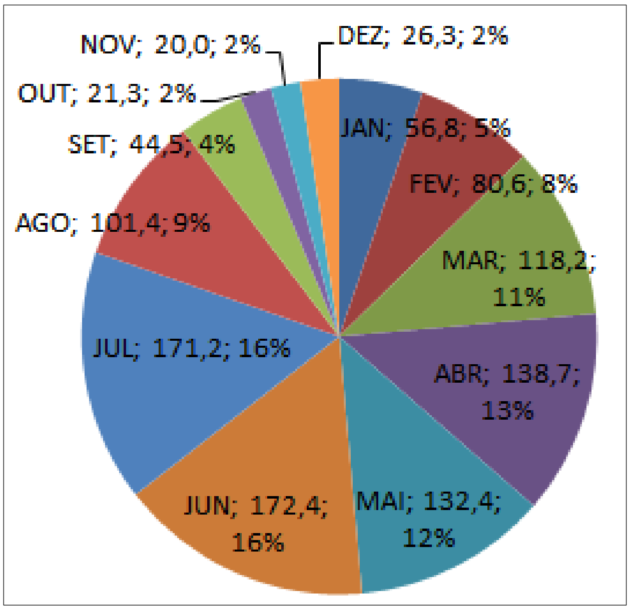


Source: Medeiros (2022).

Figure 3 Annual rainfall (mm) and its polynomial trend line, for the period 1981-2020 in the municipality of Lagoa Seca - PB

[23] Stated that the intertropical convergence zone (ITCZ) is the important rainfall-causing atmospheric system in the northeastern region of Brazil, which is represented by the equatorial trough axis and its different variations in position and intensity that are correlated to the subtropical highs of the North and South Atlantic.

Figure 4 shows the distributions of monthly rainfall (mm) and their percentage values for the period 1981-2019 in the municipality of Lagoa Seca - PB. Between the months of March and August, the rainfall indexes represent 77% of the annual value and between the months of September and February, 23%. For [21] about 90% of the rainfall in the region occurs between the months of January and May and over the years these precipitations have been reducing due to the climatic effects that have occurred and occur on a regional scale, which contradicts the study by [21].

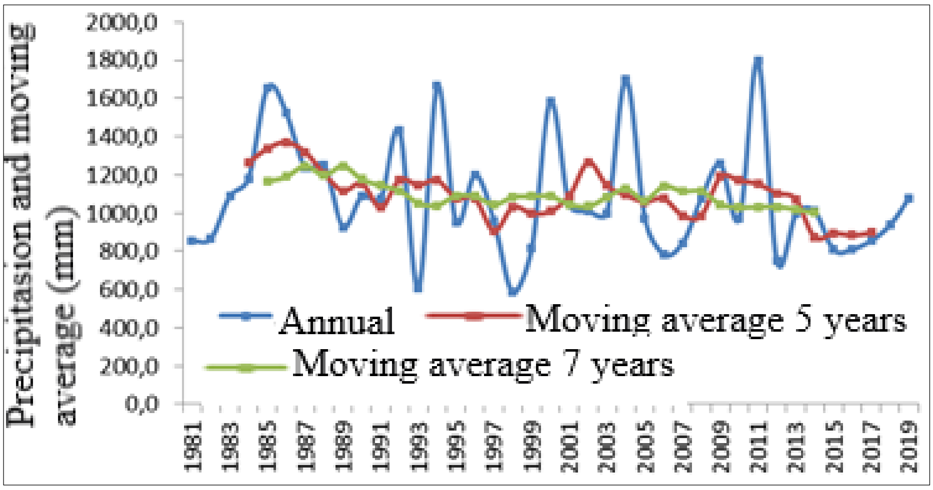


Source: Medeiros (2022).

Figure 4 Distribution of monthly rainfall (mm) and its percentage values in the period 1981-2020 in the municipality of Lagoa Seca - PB

[31] Analyzed the fluctuation and trends in rainfall extremes in Pernambuco using data for the period from 1978 to 2010. [8] Observed seasonal and annual trends in extreme rainfall rates for the City of Campina Grande, from 1975 to 2011. This statement corroborates the results of this article.

Figure 5 represents the observed precipitation and its precipitation trends estimated by moving averages for 5 and 7 years for the study area. The estimates of the moving averages of 7 years present values of greater significance than for the 5 years. Similar studies were carried out by [11] on the precipitation of the São Francisco River for (some upper and middle sector of the river course).



Source: Medeiros (2022).

Figure 5 Annual precipitation and its moving average trend lines for 5 and 7 years in the period 1981-2020 in Lagoa Seca - PB

[25] Showed that when computing the moving averages for São Bento do Una (PE), the 10-year moving average estimates present values of greater significance. Extreme events occurred in many cases due to the simultaneous occurrence of several time scales that are responsible for rainfall anomalies, corroborating [4, 12, 7]

4. Conclusion

It was found that in the assessment of climate trends, the meteorological systems that cause high intensity rains and in short time intervals are the formation of instability lines, isolated pulse of the ITCZ and the contribution of local effects that contribute to rainfall irregularities.

Rainfall irregularities between 2000-2019 recorded ten years dry; six years very dry; three very rainy years and one rainy year, these rainfall irregularities lead us to conclude that climatic events and human actions may be contributing to the records of these scenarios on a local scale, the predominance of dry and very dry years has been causing impacts to fruit and vegetable producers which has been using longer times in irrigation.

Studies with climate trends become more understandable when analyzing long time series which can be divided into sub-periods of at least 30 years.

The irregularity in the quantity and temporal distribution of rainfall are limiting factors for the development of agricultural and horticultural production in the study area.

The time series consisting of the monthly rainfall totals recorded each year between 1981-2019 does not represent significant components of serial correlation, temporal trends or periodicities.

Compliance with ethical standards

Disclosure of conflict of interest

All authors had equal participation in the development of the article.

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