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Thermal Oscillations in Lagoa Seca Municipality, Paraíba, Brazil

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Raimundo Mainar de Medeiros*[1], Manoel Viera de França[1], Romildo Morant de Holanda[1], Luciano Marcelo Fallé Saboya[3], Wagner Rodolfo de Araújo[2], Fernando Cartaxo Rolim Neto[1]

1 Universidade Federal Rural de Pernambuco, Brasil

2 Universidade Estácio de Sá, Brasil

3 Universidade Federal de Campina Grande, Brasil

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ABSTRACT

A climatic variability is a fundamental tool for understanding the atmospheric phenomena that directly affect human life, such as climatic extremes that have been occurring all over the world. The objective of the present work is to analyze the annual thermal oscillations of the maximum, average, and minimum temperatures, between 1981-2019, for the city of Lagoa Seca, Paraíba state, Brazil. The maximum, average, and minimum temperature data were estimated by the estima_T software, for the studied period, using basic statistical parameters. The coefficients of the quadratic function were determined for monthly average temperatures as a function of local coordinates latitude, longitude, and altitude. The temperature time series were also estimated, adding to it the temperature anomaly of the Tropical Atlantic Ocean. Among the temperatures studied, the minimum temperature is the one that remarkably presents the greatest increase and spatial consistency. The increase in the average temperature is related to the strong tendency to increase the minimum temperature. The three temperatures show higher values in the most recent period 1980-2009 than in 1950-1979, being more evident for the minimum and average temperatures. It is possible to make a delimitation of the climatic behavior in the studied area, using maximum, average, and minimum temperature data and providing its delimitations of a hot and/or cold period, serving as a warning to authorities and decision-makers, for better agricultural and agribusiness planning.

INTRODUCTION

In the agricultural production system, meteorological conditions represent exogenous factors that affect the growth, development, and productivity of plants and animals. During its cycle, the plant responds directly to meteorological conditions, which form a combination of factors whose effects can vary from favorable to unfavorable to plant growth and productivity.

Temperature fluctuations have direct consequences on agricultural production in Brazil and especially for the State of Piauí, whose economy is based on this sector. Temperature varies over time and across regions. The temperature distribution on the globe is influenced by several factors such as the distance between water bodies, the radiation incident on the site, the relief, prevailing winds, and ocean currents.

Climatic factors are atmospheric quantities capable of being measured and altered by climatic elements. They are responsible for setting the weather and climate of a location or region. They are radiation, temperature, and soil, relative humidity, wind intensity and direction, precipitation, cloudiness, among others. These elements influence both plant metabolic processes and the most diverse activities in the field (MONTEIRO, 2009) such as soil preparation, sowing, fertilization, irrigation, spraying, harvesting, among others (PEREIRA et al., 2002).

Information on the climatic characteristics of a given region is essential for sustainable agricultural production, helping to prevent adverse atmospheric phenomena or enhancing agricultural production (FOLHES et al., 2006). These subsidies can help to choose species that are more adapted to the region, as well as being a decisive factor in the development of pathogens.

Information on the characteristics and peculiarities of climate and soil help in choosing the crop and in decision-making, in the search for higher yields and lower losses. Among the agrometeorological information used in agricultural planning, agroclimatic zoning is the best known. Studies that identify the climate risk for agriculture are essential, since frost, extreme heat, drought, excessive rain, windstorm and hail events can cause great damage to the phenological development of several crops (MEZHER et al., 2012; RICCE et al., 2014; MORAIS et al., 2015; MARTINS et al., 2017).

The temperature influences the decision on adaptable locations and with characteristics for developments, plants, animals, agribusiness, agriculture, and agribusiness. For plant species, information about temperature performance is essential, as their metabolism is dependent on their fluctuations. In agricultural activities, the temperature can be decisive for the choice of the type of culture to be adopted, for the propagation of viruses and fungi, and their growth and development (DUARTE, 2011). The daily temperature range can negatively affect crops, as they are determining factors for growth and development rates (SEGOVIA et al., 1997), in-plant productivity, as extreme values during the reproductive phase can cause grain sterility (BURIOL et al., 2000; KUINCHTNER et al., 2007; HOCH et al., 2008; KUINCHTNER et al., 2007). Portela et al. (2008) mention that there must be good water availability in the soil and the maximum air temperature values must not exceed 33°C.

Medeiros et al. (2012) studied the daily fluctuations of air temperature for the areas of Parnaíba, Picos, and Gilbués, located in Piauí state, Brazil, with different methodologies, and concluded that the methods can be applied in the evaluations of the referred temperatures. According to the authors, in 2018, thermal fluctuations are one of the physiographic variants that best explain the monthly and annual temperature variation in the state of Pernambuco, Brazil.

Cavalcanti et al. (2017) revealed that these temperature increases have resulted in extreme events and changes in rainfall patterns, with greater occurrence of droughts and floods. This sequence of natural ecosystem imbalance can originate the phenomenon of desertification from the impoverishment and degradation of land in arid, semi-arid, and sub-humid zones (MMA, 2010; ALMEIDA et al., 2014).

Medeiros (2018) showed that the variability of the thermal amplitude for Recife, Pernambuco state, Brazil, increased fluctuations in the thermal amplitude and have been due to the lack of city planning, afforestation, and the high incidence of fires and deforestation.

Moreno et al. (2016) stated that the spatial and temporal variability of long series of meteorological elements contributes as recommendations for suitable locations for the sowing and planting system of cultivars, indicating their respective periods and possible climatic discontinuities.

The climate variability can be observed the longer the data period, as it is the result of the dynamic characteristics of atmospheric circulation and is closely linked to the concept of recurrence intervals. Therefore, if the zonal characteristics account for the broad features of the climate rhythm, atmospheric circulation in close interaction with the geographic aspects of a given area is responsible for climate variability (TAVARES, 2014).

Holanda et al. (2016) carried out the monitoring of insolation as being a relevant activity for agriculture, energy, and heat source, analyzed its average buoyancy of insolation in the municipal area of Caruaru, Pernambuco state, Brazil. They showed that the lack of more in-depth and specific studies for the Brazilian semiarid region, including a methodological one, has to carry out a balance of radiation and energy, with approaches to influencing biomes.

Medeiros et al. (2018) showed that places in the State of Piauí, Brazil, which is located close to the Equator, receive a high incidence of sunlight directly on the surface. They also stated that low cloud cover, thermal oscillation, the occurrence of fires, and burning may have conditioned the values of the incidence of insolation in the regions of Piauí during July to October. These variabilities are associated with the thermodynamic conditions of the South Atlantic Subtropical Anticyclone, which, by inhibiting the formation of clouds, favors an increase in the short wave radiative flux and an increase in the flux of the radiation balance. This fact can potentialize appearing diseases to the population through the warming of the Atmospheric Boundary Layer because imply in a pre-disposition of this area the proliferation of vectors.

The objective of the present work is to analyze the annual thermal oscillations of the maximum, average, and minimum temperatures for the city of Lagoa Seca, Paraíba state, Brazil, between 1981-2019.

MATERIALS AND METHODS

The municipality of Lagoa Seca is located in the Microregion with the same name and in the Mesoregion Agreste Paraibano, Brazil. With a territorial area of 109 km², is limited by the municipalities of Campina Grande, Massaranduba, Matinhas, São Sebastião de Lagoa de Roça, Montadas, and Puxinanã. The municipal center is located at Latitude 07º 10' 15'' south; Longitude 35º 51' 13'' west of Greenwich, and at 634 meters of altitude. (Figure 1).

Figure 1 - Location of Lagoa Seca municipality, Paraíba state, Brazil.

Source: Medeiros (2021).

The southern part of the municipality is located in the hydrographic basin of the Paraíba River, in the Lower Paraíba region, with its main watercourse being the Marinho stream. The northern and eastern parts are located in the Mamanguape river basin, whose main watercourse is the river itself. All watercourses have an intermittent flow regime and the drainage pattern is of the dendritic type.

According to Köppen (1928) and Köppen et al. (1931), the climate is of the "As" type, classified as hot and humid Tropical rainy. Studies such as the one by Alvares et al. (2014) corroborate the type of climate for the studied area. According to the classification of Thornthwaite (1948) and Thornthwaite et al. (1955), Lagoa Seca has a dry subhumid, mega thermal (C1ADa') climate, with little or no excess water and evapotranspiration (ETP) with 29.66% of the annual potential evapotranspiration concentrated in the warmest quarter of the year.

In Lagoa Seca, the rains start around the second half of March, increasing in volume in the first days of April and lasting until August, with the rainy quarter being between May and July. The factors causing rainfall in the municipality are aspects such as the following: formation of instability lines on the coast and transported inland by northeast trade winds; development of convective clusters, from heat stored on the surface and transferred to the atmosphere; orography; contributions from the formation of cyclonic vórtices; and having as the main system the positioning of the Intertropical Convergence Zone (ITCZ). Usually, the rains have moderate intensity, of regular weather and around eight to ten hours of daily discontinuous rain, followed by irregularity due to the failures of the active meteorological systems. The occurrence of dry spells (occurrences of several consecutive days without rain during the rainy season) in the rainy four-month period (April to July) is possible and varies from year to year. Its magnitude varies depending on the season and meteorological factors. Occurrences with periods of summers greater than 17 days per month have been registered in the time interval that occurred within the four months (Medeiros, 2016).

The maximum, mean and minimum temperature data were estimated by the Estima_T software for the period 1981-2019 (CAVALCANTI et al., 2006; CAVALCANTI et al., 1994) since that municipality does not have the equipment to carry out such observation. Estima_T is software for estimating temperatures in the Northeast Region of Brazil (NEB). The coefficients of the quadratic function were determined for monthly average temperatures as a function of local coordinates latitude, longitude, and altitude (CAVALCANTI et al., 2006), given by:

$$T = C0 + C1\lambda + C2Ø + C3h + C4\lambda 2 + C5Ø2 + C6h2 + C7\lambda Ø + C8\lambda h + C9Øh \qquad (1)$$

Where: C0, C1 ..., C9 are the constants; λ, λ2, λ Ø, λ h are longitudes; Ø, Ø2, λ Ø are latitudes; h, h2, λ h; Ø h are altitudes.

The worked data used here in this work has 38 years of continuous observations. According to the World Meteorological Organization - (WMO, 2019) the climate of a given area or region is characterized by a minimum period of 30 years, with continuous observations, as the longer the data period. These present historical series used here in this work are long enough to be classified in terms of climate variability and are evenly distributed across the studied municipality.

The data were prepared in electronic spreadsheets by Microsoft Office Excel 2016, generating graphs and tables, performing analyzes for the maximum, average, and minimum temperatures, and trend occurrences, using the aforementioned parameters.

The coefficient of variation (Cv) is a measure of dispersion and expresses the standard deviation as a percentage of the mean, according to the Equation 2.

$$Cv = \frac{s}{\bar{x}}.100(\%) \qquad (2)$$

Where: Cv = Coefficient of variation; S = Standard Deviation; X = simple arithmetic mean

Another element considered in the study was the asymmetric coefficient (Cas), whose parameter quantifies the standard deviation of a given distribution with a symmetrical distribution, while the resulting sign ± provides the type of asymmetry of the distribution, expressed by the Equation 3.

$$Cas = \frac{1}{n}\sum[(x_i + \bar{x})/(s)]^3 \quad (3)$$

Where: Cas = Asymmetry Coefficient; Xi = observed value; X = Simple arithmetic mean; S = Standard Deviation

The kurtosis coefficient (Ck) is considered a measure of dispersion, which characterizes the degree of "flattening" of the distribution function curve, and this parameter can be found using the following Equation 4.

$$Ck = \frac{1}{n}\sum[(x_i + \bar{x})/(s)]^4 - 3 \quad (4)$$

Where: Ck = Kurtosis Coefficient; Xi = observed value; X = Simple arithmetic mean; S = Standard Deviation

RESULTS AND DISCUSSIONS

Figure 2 shows the maximum annual temperature fluctuations oscillating between 26.4 ºC (in the years 1984, 1985, 2000, and 2011) and 27.4 ºC (in the years 1986, 1997, 1998, and 2016). The trend line has a positive slope with R^2 of 0.0404.

Also, in figure 2 can be seen that the average annual temperature oscillates between 21.4 ºC (in the years 1984, 1985, 1989, 1990, 1999, 2000, 2008, 2011, and 2018) and 23.5°C (in 2002). The average annual temperature has a trend line with a positive angle and a low R^2 of 0.0189. Its annual fluctuations flowed between 18.3ºC in 1984, 1985, 1989, 1999, and 2001. The minimum annual fluctuation registered in the year 2002 with 19.6ºC. It should be noted that the average fluctuations are on the interventions of the registered maximum and minimum temperature fluctuations.

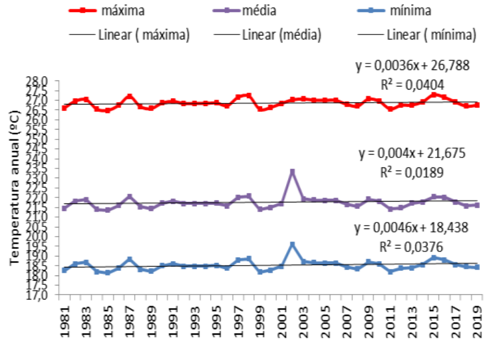

Figure 2 - Variability of maximum, mean, and minimum annual air temperature and their respective trend lines, for the period 1981-2019, in Lagoa Seca municipality, Paraíba state, Brazil.

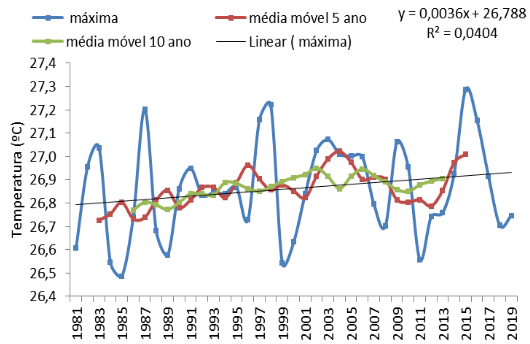

Figure 3 - Fluctuation of the maximum temperature and its moving averages for 5 and 10 years followed by its respective trend line, for the period 1981-2019, in Lagoa Seca municipality, Paraíba state, Brazil.

Source: Medeiros (2021).

Trends of fluctuations in air temperature increase were previously verified in the city of Teresina, Piauí State, Brazil, by some authors (FEITOSA et al., 2011; MEDEIROS, 2014; MEDEIROS, 2017; ALBUQUERQUE et al., 2016), as a result of the growing urbanization and vegetation reduction, which corroborate with the study here in this work.

Among productive activities, horticultural products are the most dependent on climatic fluctuations in such a way that they are responsible for 70% of the final production variability. This dependence is mainly related to the seasonal variation of climatic factors, which determine the seasons of the year and the times when the best conditions and the lowest risks for the development of cultivars occur.

Figure 4 shows the fluctuations of maximum temperatures and their moving averages for 5 and 10 years, followed by their respective trend line for the period 1981-2019 in Lagoa Seca municipality, Paraíba state, Brazil. The maximum annual temperature fluctuates between 26.5 ºC to 27.3 ºC. The low points occurred in the years 1985, 1999, and 2011. The maximum points were recorded in the years 1987, 1998, and 2015. The 10-year moving average has a better representation when compared to the 5-year one. The minimum peaks registered in 1989 and between 2009 and 2012 are highlighted. The maximum peaks occurred between 1994 and 1998 to 2004. The maximum temperature trend has a positive angular coefficient and R^2 of low representativity.

The annual average temperature fluctuations ranged from 21.3 ºC in 1985 to 22.1 ºC in 1999 (Figure 4). The highest recorded average temperature of 23.4 ºC in 2002 stands out. The highest average temperature peaks were in the years 1987, 1998, and 2016. The 5-year and 10-year trend lines have significance, except for the period of years between 1998 to 2007 and 2010 to 2015, which are different from the trend characteristics of previous years. With a positive angular coefficient and low $R^{2,}$ nothing can be said about its future trends (Figure 4).

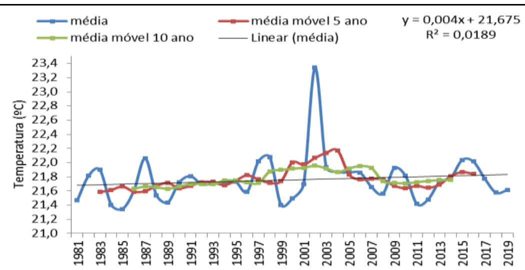

Figure 4 - Average temperature fluctuation and its moving averages for 5 and 10 years, and its respective trend line, for the period 1981-2019, in Lagoa Seca municipality, Paraíba state, Brazil.

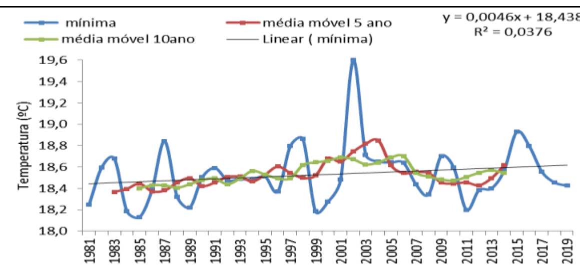

Figure 5 - Minimum temperature fluctuation and its moving averages for 5 and 10 years, and its respective trend line, for the period 1981-2019, in Lagoa Seca municipality, Paraíba state, Brazil.

Source: Medeiros (2021).

Studies such as that of some authors (Medeiros, 2017; Medeiros, 2016; IPCC, 2014; Rossato, 2011; Horokoshi et al., 2007; Marengo et al., 2008; and Nobre et al., 2005) demonstrated coherence of systematic warming in the studied area.

Figure 5 shows the fluctuations in the minimum temperature and its moving averages for 5 and 10 years, followed by its respective trend line, with a positive angular coefficient and low R^2. The fluctuation of the minimum temperature ranges from 18.1 ºC in 1985 to 19.9 ºC in 2016. In 2002 the highest minimum temperature of 19.6 ºC was registered. The highest peaks of minimum temperature occurred in the years 1987, 1998, and 2016, and the smallest peaks of minimum were in 1985, 1999, and 2011.

The most significant straight line for the next ones with minimum temperatures equal to or lower is represented for the 10-year moving averages, except for the period of years between 1998 to 2006 and 2009 to 2012.

The study by Marengo et al. (2008), which analyzed trends in maximum and minimum temperatures in the south of northeastern Brazil, during the period 1960-2002, pointed out coherences for systematic warming of the studied area.

Figure 6 shows the maximum, average, and minimum temperature fluctuations and their trend lines for the period 1981-2019 in Lagoa Seca municipality, in the summer season. For both temperatures, a trend line with a positive slope and R^2 with low levels of significance can be observed.

The maximum temperatures in the summer season ranged between 28.3ºC in 1984, 1985, and 1989 and 29.4 ºC in 1982, 1998, and 2016, with an average of 28.3 ºC. In 38 years with observations, minimum peaks were registered in 1984, 1985, 1989, 2000, 2001, and 2009 with 28.3 ºC and 24.8 ºC respectively. The maximum temperature peaks were registered in 1999 with 29.6 ºC and 2017 with 29.7 ºC. The maximum temperature of the minimum flowed between 19.0 ºC in the years 1984 and 1985, 1989 to 20.2ºC in the years 1998 and 2016. The extreme temperatures in the summer season have the same behavior. The same was recorded for the average maximum temperature (Figure 6).

Trend analysis of maximum and minimum temperatures for the southern region of Brazil during the years 1960-2002 recorded a systematic thermal increase in this region (MARENGO et al., 2008). The authors detected trends positive annual and seasonal of the elements in their study, contradicting the results presented in this study where the maximum temperature has been going through reductions and the minimum temperature through increases.

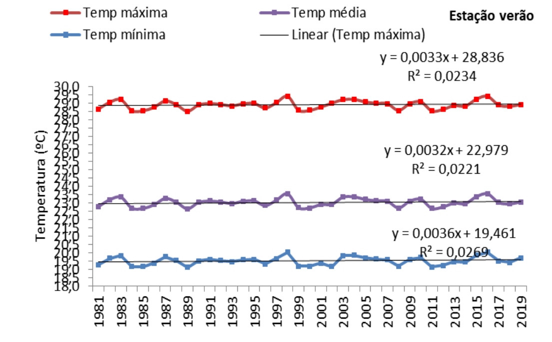

Figure 6 - Maximum, mean and minimum temperature oscillations and their trend lines, for the period 1981-2019, in the summer season, in Lagoa Seca municipality, Paraíba state, Brazil.

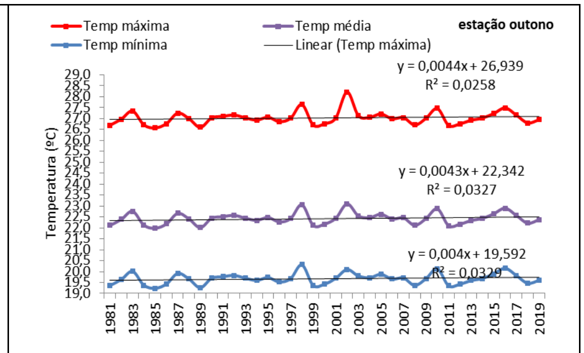

Figure 7 - Maximum, mean and minimum temperature oscillations and their trend lines, for the period 1981-2019, in the autumn season, in Lagoa Seca municipality, Paraíba state, Brazil.

Source: Medeiros (2021).

Figure 7 shows the oscillations of maximum, average, and minimum temperatures and their trend lines for the period 1981-2019 in Lagoa Seca municipality, in the autumn season. This season has an average of 27.0 ºC; a standard deviation of 0.30 ºC; a coefficient of variance of 0.012; and the maximum and minimum absolute values recorded with 28.2 ºC in 2002 and 26.6 ºC in 1985. The highest maximum peaks occurred in 1998 and 2002. The thermal minimum peaks were verified in 1985 and 1989. The maximum temperature of the autumn season has a trend line with a positive slope and low R^2.

The average temperature fluctuations in the autumn season are 22.4 °C; the standard deviation of 0.26 ºC, variance coefficient of 0.01 ºC the maximum absolute value occurred in 1998 and 2002 with 23.1 ºC and the minimum absolute value of 22 ºC in 1985 and 1989. The average temperature autumn has a trend line with a positive slope and low R^2. The minimum average temperature peaks were registered in 1995 and 1989 with 21.9 ºC and the maximum peaks in 1998 and 2002 with 23.4 ºC.

The positive slope and low R^2 were recorded for minimum temperature in the autumn season. The smallest and largest peaks of minimum temperature were registered in 1985 and 1989 with 19.2ºC and in 1998 with 20.6ºC. The autumn season registered an average minimum temperature of 19.7

ºC; the standard deviation of 0.25 °C; coefficient of variance of 0.01 °C; the maximum absolute values occurred in 1998 with 20.3ºC and the absolute minimum in 1985 with 19.2ºC.

Figure 8 shows the oscillations of maximum, average, and minimum temperatures and their trend lines for the period 1981-2019 in Lagoa Seca municipality, in the winter season. With a trend line of positive angular coefficients and low R^2 for the three temperatures in studies. The maximum temperature flows between 23.5 °C in the years 1984, 1985, 1988, and 1999 and 24.7ºC in the year 2002. The minimum-maximum temperature peaks correspond to the years 1984, 1985, 1988, and 1999, and the maximum peaks of the maximum for the years 2002 and 2016.

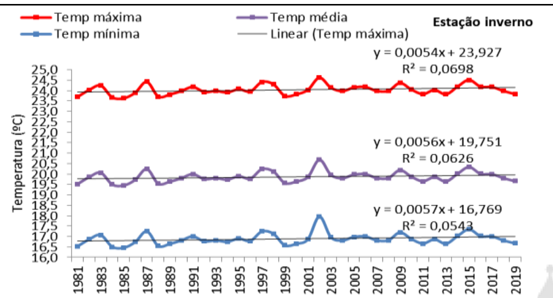

Figure 8 - Maximum, mean and minimum temperature fluctuations and their trend lines, for the period 1981 2019, in the winter season, in Lagoa Seca municipality, Paraíba state, Brazil.

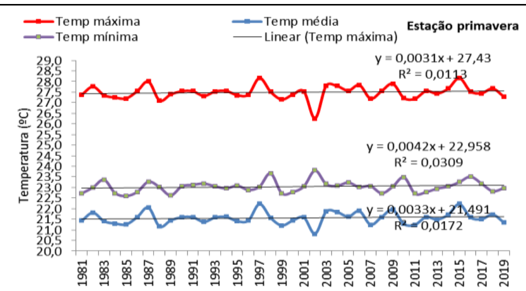

Figure 9 - Maximum, mean and minimum temperature oscillations and their trend lines, for the period 1981-2019, in the spring season, in Lagoa Seca the municipality, Paraíba state, Brazil.

Source: Medeiros (2021).

The average temperature of the maximum and the minimum of the maximum in the winter season has the same temperature variability as the maximum temperature of the maximum, that is, it has the same maximum and minimum variations only with representative values of each element understudy, for the referred years. Similar values were found by Medeiros & Cavalcanti (2020).

In the spring season (Figure 9) it was verified the maximum, average, and minimum temperature fluctuations and their trend lines for the period 1981-2019 in Lagoa Seca municipality. The trend lines of the maximum, an average of the maximum, and the minimum of the maximum temperatures have positive slopes and R^2 of low significance. The maximum temperature oscillations of the maximum fluctuate between 26.4 ºC in the year 1997 and 2016 to 26.4 ºC in the year 1997. The same fluctuations are registered for the average and minimum temperature of the maximum.

Costa et al. (2016) affirm that the results showed that elevation and latitude are the physiographic variables that best explain the monthly and annual air temperature variation in the study area, and that temperature variations result from synoptic systems active in the rainy season and the dry season. In addition, large-scale systems also had a high degree of contribution in the temperature variation in years in which they acted intensely.

Studies such as those from some authors (Medeiros, 2017; Medeiros, 2016; IPCC, 2014; Rossato, 2011; Horokoshi et al., 2007; Marengo et al., 2008; and Nobre et al., 2005) showed that the thermal indices have similarities with those described in this article.

Figure 10 shows the maximum, average, and minimum temperature anomalies for the period 1981-2019 in Lagoa Seca municipality, in the seasons of the year. The oscillations of the maximum, average, and minimum temperature anomalies have their fluctuations of -0.5 ºC (average); -0.4 ºC (maximum), and 0.35 ºC (minimum) in 1985, followed by 1989, 1999, and 2011 with practically the same negative anomaly values. Positive anomalies flowed from 0.0 ºC (mean); 0.1 ºC (maximum and minimum) to 1.5 ºC (average); 1.1 °C (minimum) and 0.1 °C (maximum). In 2012, the highest average and minimum temperature peaks were registered. Studies such as that of Medeiros (2017), IPCC (2014), Rossato (2011), and Horokoshi et al. (2007) show similarities with the results discussed here.

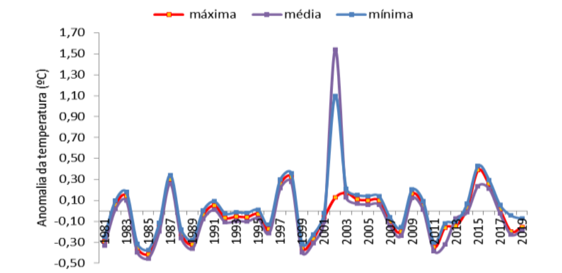

Figure 10 - Maximum, mean and minimum temperature anomalies for the period 1981-2019, during the seasons, in Lagoa Seca municipality, Paraíba state, Brazil.

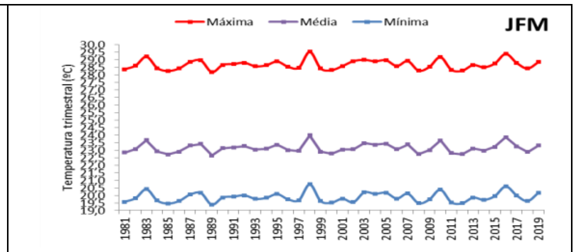

Figure 11 - Quarterly variation of the months January, February, and March (JFM), of the maximum, average and minimum temperatures, for the period 1981-2019, in Lagoa Seca municipality,

Paraíba state, Brazil.

Source: Medeiros (2021).

These fluctuations in recent years are due to local and regional factors such as disproportionate deforestation, fires, and soil without vegetation cover, followed by anthropogenic activities where man does not protect the soil, forests, and water bodies. The years 1989, 1999, 2000, and 2012 are highlighted when the atmospheric systems acted and caused a reduction in the levels and/or levels of temperature (Medeiros et al., 2020).

Figure11 shows the oscillations of the quarter January, February March (JFM) of the maximum, average, and minimum temperature for the period 1981-2019 in Lagoa Seca municipality. Analyzing the quarterly curve of the maximum temperature, it has an average of 28.7 ºC; mean of 28.4 ºC; the standard deviation of 0.31 ºC; coefficient of variance of 0.01 and the maximum and minimum absolute values of 29.5 °C and 28.2 °C, respectively. The variability of the quarterly mean temperature registered an average of 23.1ºC; median 22.9 °C; the standard deviation of 0.3 °C; coefficient of variance 0.01; and the maximum and minimum absolute values of 22.9 °C and 22.6 °C, respectively. The quarterly fluctuations of the minimum temperature registered a minimum average of 19.9 ºC; median of 19.6 °C; the standard deviation of 0.3 °C; coefficient of variance 0.01; and the maximum and minimum absolute values of 20.7 °C and 19.4 °C, respectively. This variability is by the study by Marengo (2008), IPCC (2007), and IPCC (2014).

Medeiros *et al.* (2005) showed that air temperature is the climatic factor that exerts the most direct and significant influence on the physiological processes of living beings. Capuchinho et al. (2019), showed that this climatic factor is also responsible for influencing various economic activities developed by society, in its multiple aspects. Climate variability must be considered in several sectors, such as economy, livestock, engineering, and energy production (Medeiros et al., 2019).

Figure 12 shows the quarterly fluctuations of April, May, and June (AMJ) of the maximum, average, and minimum temperature for the period 1981-2019 in Lagoa Seca municipality. The maximum temperature fluctuations for the AMJ quarter flowed with an average of 25.6 ºC; median 25.3 °C; the standard deviation of 0.3 °C; coefficient of variance 0.0 °C; The maximum and minimum absolute values were 27.2 ºC and 25.2 ºC, respectively.

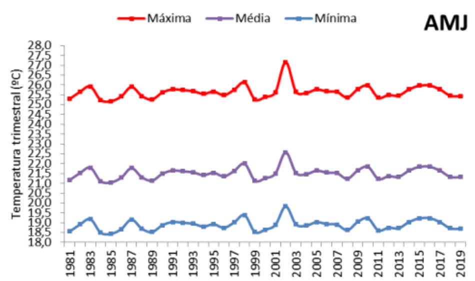

Figure 12 - Quarterly variation of the months April, May, and June (AMJ) of the maximum, average and minimum temperatures, for the period 1981-2019, in Lagoa Seca the municipality, Paraíba state, Brazil.

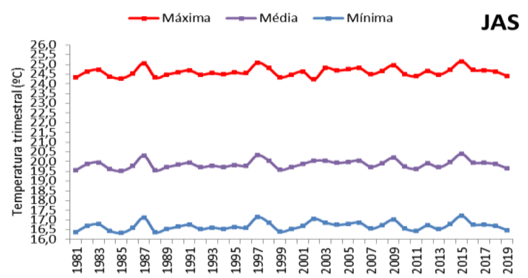

Figure 13 - Quarterly variation of July, August and September (JAS), of the maximum, average, and minimum temperatures, for the period 1981-2019, in Lagoa Seca municipality, Paraíba state, Brazil.

Source: Medeiros (2021).

Figure 13 shows the quarterly fluctuations of July, August, and September (JAS) of the maximum, average, and minimum temperature for the period 1981-2019 in Lagoa Seca, municipality. The average maximum annual temperature was 24.6 °C and its oscillations flowed between 24.2 °C and 24.3 °C, with a standard deviation of 0.21 °C, a coefficient of variance of 0.009 °C, and a median of 24.3 °C. The highest maximum temperature was registered in 1987, 1997, and 2015. The lowest thermal indices were in 1985 and 2002, with an average temperature of 19.9 °C and its maximum and minimum annual oscillations flowing between 20,4 °C and 19.6 °C. The Standard deviation was 0.21 °C, coefficient of variance of 0.011 °C, and median of 19.6 °C. The minimum temperature has an average of 16.7 °C, standard deviation of 0.22 °C, coefficient of variance of 0.013, the minimum-maximum temperature of 17.2 °C and minimum temperature of 16.3 °C, with a median of 16.4 °C. These temperature fluctuations can cause damage to horticultural crops, especially at dawn, when there is the lowest temperature and dew deposited on the foliage of vegetables that will cause burning.

Figure 14 shows the quarterly fluctuations of the months October, November, and December (OND) of the maximum, average, and minimum temperature for the period 1981-2019, in Lagoa Seca municipality. The average temperature was 28.5 °C, standard deviation 0.34 °C, coefficient of variance 0.012 °C, the maximum and minimum recorded in the maximum temperature were 29.2 °C and 28.1 °C, respectively, and the median registered 28.1 °C. The mean temperature has a standard deviation of 0.319 °C, a coefficient of variance of 0.0111, an average of 22.3 °C and its maximum and minimum oscillations from 21.6 °C to 21.9 °C and a mediadian of 21.9 °C. At minimum temperature, the mean was 18.4 °C, the standard deviation of 0.303, coefficient of variance of 0.016 °C, the maximum and minimum oscillations flowed between 19.1°C and 17.9 °C with a median of 18.0 °C.

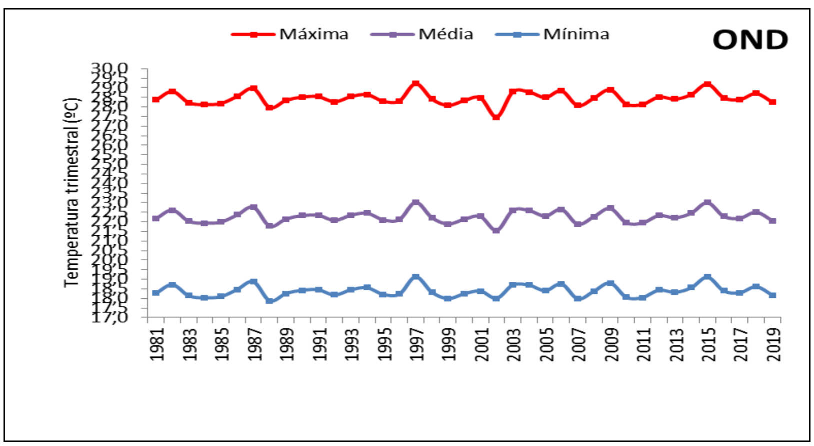

Figure 14 - Quarterly oscillations of the months October, November, and December (OND) of the maximum, average, and minimum temperatures, for the period 1981-2019, in Lagoa Seca municipality, Paraíba state, Brazil.

Source: Medeiros (2021).

Table 1 shows the maximum temperature return time ranging from 1.4 years in 2002, to 1.6 years in 2008, and for most years the return time is 1.5 years. The return time oscillations for the average temperature ranged between 1.7 years and 1.9 years, with a return time of 1.8 years predominating. Return times to minimum temperature ranged from 2.0 years to 2.2 years.

The deficiency observed in point estimates, in the present case of the maximum and minimum temperature, is the fact that they do not express the confidence that one might have about the greater or lesser difference between the estimate of the maximum and minimum temperature and its real value. The inference can be supplemented whenever possible, with assumptions about the probabilities of this parameter being close or not to its point estimates. This can be done by constructing confidence intervals with a known probability that the parametric value is contained there. The oscillations of the average temperature return time are interlinked with the oscillations of the maximum and minimum temperature.

Table 1 - Years, maximum, average, and minimum annual temperature and their respective return times, in the period 1981-2019, for the municipality of Lagoa Seca, Paraíba state, Brazil.

Years	T_x Annual	Return Time Tx Annual	T_M Annual	Return Time Tn Annual	T_n Annual	Return Time Tn Annual	Years	T_x Annual	Return Time Tx Annual	T_M Annual	Return Time Tn Annual	T_n Annual	Return Time Tn Annual
1981	26,6	1,5	21,5	1,9	18,2	2,2	2001	26,8	1,5	21,7	1,8	18,5	2,2
1982	27,0	1,5	21,8	1,8	18,6	2,2	2002	29,4	1,4	23,3	1,7	19,6	2,0
1983	27,0	1,5	21,9	1,8	18,7	2,1	2003	27,1	1,5	21,9	1,8	18,7	2,1
1984	26,5	1,5	21,4	1,9	18,2	2,2	2004	27,0	1,5	21,9	1,8	18,7	2,1
1985	26,5	1,5	21,3	1,9	18,1	2,2	2005	27,0	1,5	21,9	1,8	18,6	2,1
1986	26,7	1,5	21,6	1,9	18,4	2,2	2006	27,0	1,5	21,9	1,8	18,6	2,1
1987	27,2	1,5	22,1	1,8	18,8	2,1	2007	26,8	1,5	21,7	1,8	18,4	2,2
1988	26,7	1,5	21,5	1,9	18,3	2,2	2008	26,7	1,5	21,6	1,9	18,3	2,2
1989	26,6	1,5	21,4	1,9	18,2	2,2	2009	27,1	1,5	21,9	1,8	18,7	2,1
1990	26,9	1,5	21,7	1,8	18,5	2,2	2010	27,0	1,5	21,8	1,8	18,6	2,2

1991	27,0	1,5	21,8	1,8	18,6	2,2	2011	26,6	1,5	21,4	1,9	18,2	2,2
1992	26,8	1,5	21,7	1,8	18,5	2,2	2012	26,7	1,5	21,5	1,9	18,4	2,2
1993	26,8	1,5	21,7	1,8	18,5	2,2	2013	26,8	1,5	21,7	1,8	18,4	2,2
1994	26,8	1,5	21,7	1,8	18,5	2,2	2014	26,9	1,5	21,8	1,8	18,6	2,2
1995	26,9	1,5	21,7	1,8	18,5	2,2	2015	27,3	1,5	22,0	1,8	18,9	2,1
1996	26,7	1,5	21,6	1,9	18,4	2,2	2016	27,2	1,5	22,0	1,8	18,8	2,1
1997	27,2	1,5	22,0	1,8	18,8	2,1	2017	26,9	1,5	21,8	1,8	18,6	2,2
1998	27,2	1,5	22,1	1,8	18,9	2,1	2018	24,5	1,6	21,6	1,9	18,5	2,2
1999	26,5	1,5	21,4	1,9	18,2	2,2	2019	26,7	1,5	21,6	1,9	18,4	2,2
2000	26,6	1,5	21,5	1,9	18,3	2,2							

Abbreviation meaning:

Source: Medeiros (2021).

Figure 15 shows the variability of maximum, average and minimum temperature probability for Lagoa Seca municipality. The information on the probability of temperature occurrence in a given time is of essential importance for several agricultural activities. The average temperature of a given region, by itself, does not seem to be the most adequate climate parameter for efficient agricultural programming, as the probability of repetition is very low (50%), which constitutes a risk for the producer. Hence, to minimize risks in planning rational agriculture, probability percentages below 75% should not be used.

Observing the 2002 and 2018 years in figure 15, it can be seen that in the year 2002 the amplitudes of the temperature probabilities flowed according to their increase or decrease. In the year 2018, the reduction in probabilities was caused by local and regional effects in the records of the maximum temperature, while the minimum and average temperatures maintained an equal segment.

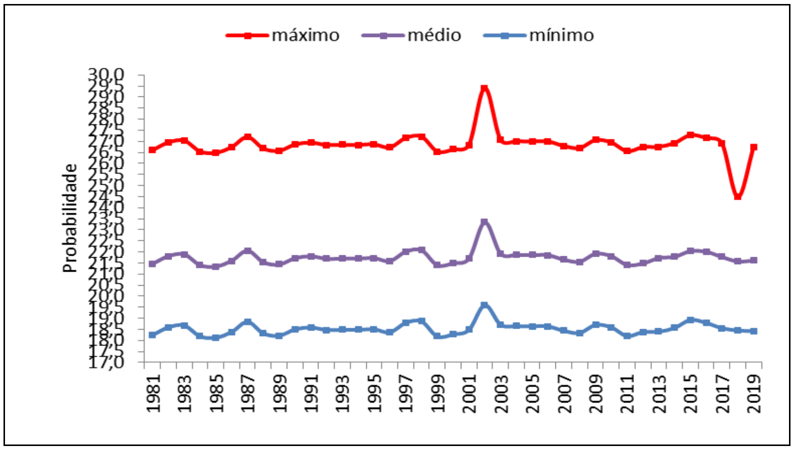

Figure 15 - Probability of maximum, average, and minimum temperature for the period 1981-2019, in Lagoa Seca municipality, Paraíba state, Brazil.

Source: Medeiros (2021).

The regression determination coefficients were not significant for all parameters (Table 2), with the highest R^2 being the maximum temperature of the winter season, with 0.069, and the lowest R^2 the maximum temperature of the spring season with 0.113 of the diversified complex of thermal seasonality in the study area.

Table 2 - Parameters, linear equation, regression determination coefficient (R^2), of the temperatures in Lagoa Seca municipality, Paraíba state, Brazil.

Parameters	Linear Equation	R^2
Maximum temperature	Y = 0,0036X + 26,788	0,0404
Average temperature	Y = 0,0040X + 21,675	0,0189
Minimum temperature	Y = 0,0046X + 18,438	0,0376
Maximum temperature summer season	Y = 0,0033X + 22,979	0,0234
Average temperature summer season	Y = 0,0032X + 22,979	0,0221
Minimum temperature summer season	Y = 0,0036X + 19,461	0,0260
Maximum temperature autumn season	Y = 0,0044X + 26,939	0,0258
Average temperature autumn season	Y = 0,0043X + 22,342	0,0327
Minimum temperature autumn season	Y = 0,0040X + 19,592	0,0329
Maximum temperature winter season	Y = 0,0054X + 23,927	0,0698
Average temperature winter season	Y = 0,0056X + 19,751	0,0626
Minimum temperature winter season	Y = 0,0057X + 16,769	0,0542
Maximum temperature spring season	Y = 0,0031X + 27,430	0,0113
Average temperature spring season	Y = 0,0042X + 22,958	0,0309
Minimum temperature spring season	Y = 0,0033X + 21,491	0,0172

Source: Medeiros (2021).

Table 3 shows the statistical parameters of the maximum monthly air temperature (ºC) for the municipality of Lagoa Seca. The average temperature ranges from 23.6 ºC in July to 29.0 ºC in November with an annual average temperature of 26.9 ºC. The average is 29.7 ºC and its monthly fluctuations range from 23.8 ºC in June to 28.7 ºC in December. The standard deviation ranges from 0.233 in August to 0.391 in October with an annual average of 0.207. The highest absolute maximum values occurred from November to March, flowing above 29 °C between April and October. The lowest absolute maximum values recorded, ranged from 28.5 °C to 24.3 °C, with an annual maximum value of 27.3 °C. In the absolute minimum values during November to March, fluctuations of 27.8 ºC to 28.4 ºC were registered. Between April and October, the oscillations occurred between 23.3 ºC and 26.8 ºC. The coefficients of variance remained within a representative range of occurrences of thermal buoyancy, providing a variation of the data to the mean. Standard errors are within the expected or recommended limits by OMM. In the classification of kurtosis, it is possible to verify that there was no basic curve month that presented a standard flattening degree equivalent to that of the normal curve. The degree of asymmetry of the monthly frequency distributions presented showed that in the month doses, the thermal behavior of the region is asymmetric and shifted to the left.

Table 3 - Statistical parameters of monthly maximum air temperature (ºC) for the municipality of Lagoa Seca, Paraíba state, Brazil.

Months	Average	Median	Stan. Dev.	Abso. Max. Value	Abso. Min. Value	Coef. of Vari.	Kurtosis	Asymmetry	Standard error
Jan	28,9	28,5	0,357	29,8	28,4	0,012	-0,065	-20,949	0,057
Feb	28,8	28,5	0,314	29,7	28,4	0,011	-0,017	-71,422	0,050
Mar	28,3	27,9	0,302	29,0	27,8	0,011	-0,065	-21,539	0,048
Apr	27,2	27,0	0,315	28,4	26,8	0,012	-0,020	-69,162	0,050
May	25,6	25,3	0,383	27,4	25,1	0,015	-0,058	-30,745	0,061
Jun	24,1	23,8	0,353	25,7	23,6	0,015	-0,061	-26,344	0,056
Jul	23,6	23,4	0,239	24,3	23,3	0,010	-0,004	-83,362	0,038
Aug	24,3	24,2	0,233	24,9	23,8	0,010	0,112	-170,048	0,037
Sep	25,9	25,8	0,312	26,5	24,5	0,012	-0,075	-6,446	0,050
Oct	27,8	27,8	0,391	28,5	26,1	0,014	-0,079	-0,049	0,063
Nov	28,8	28,6	0,332	29,6	28,2	0,012	-0,077	-1,481	0,053
Dec	29,0	28,7	0,362	29,8	28,3	0,013	-0,077	-0,216	0,058
Annual	26,9	29,7	0,207	27,3	26,6	0,008	45,212	-70,079	0,033

Abbreviation meaning: Stan. Dev. – Standard Deviation; Abso. Max. – Absolute Maximum; Abso. Min. – Absolute Minimum; Coef. Vari = Coefficient of variance.

Source: Medeiros (2021).

The standard error mean has the advantage of quick understanding and the disadvantage of accentuating the discrepancy when the observed values are very small (Camelo et al., 2016). In this case (Table 2), the standard error is within the acceptable range of values according to OMM.

Katz (1991) stated that changing the regime of a given variable that has an asymmetric distribution will result in a transformation in the form of such a graphical representation. This means that, for example, an asymmetric behavior being shifted to the left will have a clear trend towards negative anomalies. Thus, a study capable of profiling the occurrence of high temperatures in the region can be important for the temporal characterization of maximum temperatures, aiming to accurately determine the production risks associated with certain periods of thermal extremes throughout the year and/or time.

Table 4 shows the statistical parameters of the monthly average air temperature (°C) for the municipality of Lagoa Seca. The average temperature ranged from 19.6 °C in July and August to 23.3°C in February. The average annual temperature is 21.8°C. The median fluctuates between 19.3°C to 22.9°C, with an average annual average of 21.5°C, and its monthly fluctuations ranging from 19.3°C to 22.9°C. The median is the measure more likely to happen than the average temperature. Annual standard deviations of 0.329ºC and its monthly fluctuations ranged from 0.219 in August to 0.366 in January. The absolute maximum temperatures ranged from 20.2ºC August to 24.2 ºC, with an annual value of 23.3ºC. The absolute minimums flowed between 19.2 ºC in July/August to 22.8ºC in February, with an annual value of 21.3ºC. The annual standard error of 0.053 ºC and its monthly fluctuations ranged from 0.035 in August to 0.059 in January. The coefficients of variances are all of low significance. The skewness coefficient shows that the distribution is skewed to the left, as the values are negative, indicating that this side is larger. It should also be noted that the asymmetry coefficient is the distance from the mean and median values, corroborating with studies by Hundecha, Pahlow, and Schumann (2009).

Table – 4 Statistical parameters of average monthly air temperature (ºC) for the municipality of Lagoa Seca, Paraíba state, Brazil.

Months	Average	Median	Stan. Dev.	Abso. Max. Value	Abso. Min. Value	Coef. of Vari.	Kurtosis	Asymmetry	Standard error
Jan	23,0	22,6	0,366	23,9	22,5	0,016	-0,066	-20,040	0,059
Feb	23,3	22,9	0,315	24,2	22,8	0,014	-0,018	-71,209	0,050
Mar	23,1	22,8	0,286	23,9	22,7	0,012	-0,065	-21,821	0,046
Apr	22,6	22,4	0,275	23,3	22,1	0,012	0,011	-95,950	0,044
May	21,6	21,4	0,310	22,7	21,1	0,014	-0,037	-52,642	0,050
Jun	20,4	20,1	0,325	21,7	19,9	0,016	-0,057	-31,529	0,052
Jul	19,6	19,3	0,270	20,6	19,2	0,014	-0,026	-63,136	0,043
Aug	19,6	19,5	0,219	20,2	19,2	0,011	0,218	-236,914	0,035
Sep	20,4	20,3	0,242	21,0	19,8	0,012	1,063	-19,239	0,039
Oct	21,7	21,6	0,317	22,4	20,6	0,015	-0,077	-0,333	0,051
Nov	22,5	22,4	0,306	23,3	22,0	0,014	-0,077	-1,101	0,049
Dec	22,9	22,7	0,360	23,8	22,3	0,016	-0,077	-0,184	0,058
Annual	21,8	21,5	0,329	23,3	21,3	0,015	-0,062	-25,492	0,053

Abbreviation meaning: Stan. Dev. – Standard Deviation; Abso. Max. – Absolute Maximum; Abso. Min. – Absolute Minimum; Coef. Vari = Coefficient of variance.

Source: Medeiros (2021).

Blain et al. (2007) showed that in the characterization of the thermal temporal distribution, there is inconsistency in the use of the arithmetic mean, for the climatic characterization of the studied region, because there was a reasonable distance between the mean and median values.

Table 5 shows the statistical parameters of the monthly minimum air temperature (ºC) for the municipality of Lagoa Seca. The average annual temperature of 18.5 ºC and its monthly fluctuations ranged from 16.4 ºC (August) to 20.1 ºC (March); annual median of 18.3 ºC; and its monthly fluctuations flowed between 16.3 ºC and 19.8 ºC. The annual standard deviation was

0.269 ºC and monthly values ranged from 0.225 ºC to 0.372 ºC. The absolute maximum value ranged between 16.9 °C and 20.9 °C, and the annual average was 19.6 °C. The absolute minimum value ranged from 16.0 °C to 19.7 °C with an average of 18.1 °C. The Coefficient of Variation (CV) provides a variation of the data to the mean, and the value obtained was 2%, being a low value, since the CV is considered low when values obtained are less than or equal to 25%, showing that thermal indices were poorly distributed throughout the year. The Kurtosis and asymmetry coefficients have negative skewed distributions and their values are smaller and distance from the mean and standard deviation.

Table 5 - Statistical parameters of monthly minimum air temperature (ºC) for the municipality of Lagoa Seca, Paraíba state, Brazil.

Months	Average	Median	Stan. Dev.	Abso. Max. Value	Abso. Min. Value	Coef. of Vari.	Kurtosis	Asymmetry	Standard error
Jan	19,5	19,1	0,372	20,4	18,9	0,019	-0,067	-18,607	0,060
Feb	20,0	19,7	0,325	20,9	19,5	0,016	-0,033	-56,997	0,052
Mar	20,1	19,8	0,285	20,9	19,7	0,014	-0,066	-20,215	0,046
Apr	19,8	19,6	0,261	20,4	19,4	0,013	0,023	-105,555	0,042
May	19,1	18,9	0,283	20,0	18,7	0,015	-0,028	-61,466	0,045
Jun	17,8	17,5	0,339	19,3	17,3	0,019	-0,059	-28,825	0,054
Jul	16,5	16,2	0,325	18,0	16,1	0,020	-0,049	-40,811	0,052
Aug	16,4	16,3	0,221	16,9	16,0	0,014	0,211	-232,991	0,035
Sep	17,2	17,1	0,248	17,8	16,6	0,014	-0,068	-17,435	0,040
Oct	18,0	17,9	0,277	18,7	17,4	0,015	-0,077	-0,885	0,044
Nov	18,6	18,4	0,320	19,4	18,0	0,017	-0,076	-2,079	0,051
Dec	19,1	18,9	0,361	20,0	18,5	0,019	-0,077	-0,133	0,058
Annual	18,5	18,3	0,269	19,6	18,1	0,015	-0,046	-43,573	0,043

Abbreviation meaning: Stan. Dev. – Standard Deviation; Abso. Max. – Absolute Maximum; Abso. Min. – Absolute Minimum; Coef. Vari = Coefficient of variance.

Source: Medeiros (2021).

Table 6 shows the fluctuations of quarterly temperatures compared with the quarters of the 1981-2000 and 2001-2019 series and with the historical temperature for the period 1981-2019 for the municipality of Lagoa Seca, Paraíba state, Brazil.

Comparing the studied series with the 1981-2000 and 2001-2019 series, in the JFM and OND quarters, the maximum temperature (Tx) was equal to that of the 2001-2019 series, and in the AMJ and JAS quarters, the Tx was the same for the 1981-2019 series and the 1981-2000 series.

Table 6 - Quarterly temperature fluctuations compared with the quarters of the 1981-2000 and 2001-2019 series and with the historical temperature for the period 1981-2019, for the municipality of Lagoa Seca, Paraíba state, Brazil.

Series/quarters	Maximum temperature				Average temperature				Minimum temperature			
	JFM	AMJ	JAS	OND	JFM	AMJ	JAS	OND	JFM	AMJ	JAS	OND
1981-2019	28,7	25,6	24,6	28,5	23,1	21,5	19,9	22,3	19,9	18,9	16,7	18,4
1981-2000	28,6	25,6	24,6	28,4	23,1	21,4	19,8	22,2	19,8	18,8	16,6	18,4
2001-2019	28,7	25,7	24,7	28,5	23,2	21,6	19,9	22,3	19,9	19,0	16,8	18,4

Abbreviation meaning: JFM = January, February, and March; AMJ =April, May, and June; JAS = July, August, and September; OND = October, November, and December.

Source: Medeiros (2021).

Analyzing the variability of the mean temperature (MT) between the 1981-2019 series and comparing them with the two series 1981-2000 and 2001-2019, it is observed that for the quarter JFM and the quarter AMJ, the MT flowed from -0 0.1 °C to 0.2 °C. In the JAS and OND quarters, the MT was equal to the 2001-2019 series values.

The minimum temperature (Tn) was recorded equally in the 1981-2019 and 2001-2019 series. In the AMJ and JAS quarters of both series, there were fluctuations from 0.1 ºC to 0.2 ºC. In the quarter OND, the Tn fluctuations were 18.4°C.

Studies like the ones by some authors (Medeiros et al., 2020; Marengo et al., 2011; Marengo et al., 2008) corroborate the results discussed in this work. According to the IPCC (1996) and IPCC (2001), there is, on a regional scale, clear evidence of changes in climate variability and extreme weather events due to anthropogenic influences. Therefore, the statistical characterization of time series of climate data must consider the existence of possible changes in the expected regime of the variables understudy in the analysis of the climate of a region (BLAIN et al., 2007).

CONCLUSION

Among the temperatures studied, the minimum temperature is the one that remarkably presents the greatest increase and spatial consistency. The increase in the average temperature is related to the strong tendency to increase the minimum temperature.

The three temperatures show higher values in the most recent period 1980-2009 than in 1950-1979, being more evident for the minimum and average temperatures.

The average thermal fluctuations derive from the synoptic atmospheric systems acting in the rainy and dry season and their impacts on the environment, followed by the transient systems acting at meso and micro-scale aided by local and regional contributions.

It is possible to make a delimitation of the climatic behavior in the studied area, using maximum, average, and minimum temperature data and providing its delimitations of a hot and/or cold period, serving as a warning to authorities and decision-makers, for better agricultural and agribusiness planning.

Interval estimates, provide safer values of probable maximum monthly temperatures and can be used to aid in horticultural planning in the region.

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Image *Author -1*	*Raimundo Mainar de Medeiros* *Universidade Federal Rural de Pernambuco*
Image *Author -2*	*Manoel Vieira de frança* *Universidade Federal Rural de Pernambuco*
Image *Author -3*	*Romildo Morant de holanda* *Universidade Federal Rural de Pernambuco*
Image *Author -4*	*Luciano Marcelo Fallé Saboya* *Universidade Federal de Campina Grande*
Image *Author -5*	*Wagner Rodolfo de Aráujo* *Universidade estacio de Sá*
Image *Author -6*	*Fernando Cartaxo Rolim Neto* *Universidade Federal Rural de Pernambuco*