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Variability of temperature, rainfall and reference evaporation of catolé do Rocha-PB municipality, semi-arid region of Brazil

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Géssica Martins de Figueredo[1]
https://orcid.org/0000-0002-1647-9947
Universidade Estadual da Paraíba, Brasil
E-mail: gessicamf2508@gmail.com

Caio da Silva Sousa[2]
https://orcid.org/0000-0003-1608-618X
http://lattes.cnpq.br/7062083562541883
Universidade Estadual da Paraíba, Brasil
E-mail: caiosilvafla16@gmail.com

Evandro Franklin de Mesquita[3]
https://orcid.org/0000-0001-5722-2235
http://lattes.cnpq.br/3678539134744796
Universidade Estadual da Paraíba, Brasil
E-mail: elmesquita4@pq.cnpq.br

Francisco de Oliveira Mesquita[4]
https://orcid.org/0000-0002-8580-079X
http://lattes.cnpq.br/2630263044186621
Universidade Estadual da Paraíba, Brasil
E-mail: mesquitaagro@yahoo.com.br

José Paulo Costa Diniz[5]
https://orcid.org/0000-0002-9247-8970
http://lattes.cnpq.br/3441055539954519
Universidade Estadual da Paraíba, Brasil
E-mail: josepaulo.rc06@gmail.com

José Félix de Brito Neto[6]
https://orcid.org/0000-0002-1547-5557
http://lattes.cnpq.br/2914252834567589
Universidade Estadual da Paraíba, Brasil
E-mail: netobritoagro@gmail.com

Alberto Soares de Melo[7]
https://orcid.org/0000-0002-4586-5388
http://lattes.cnpq.br/3736022078444776
Universidade Estadual da Paraíba
E-mail: alberto.melo@servidor.uepb.edu.br

Josinaldo Lopes Araújo Rocha[8]
https://orcid.org/0000-0003-4669-6114
http://lattes.cnpq.br/8792518421189353
Universidade Federal de Campina Grande Paraíba
E-mail: jhosinal_araujo@yahoo.com.br

[1] Licenciada em Ciências Agrárias
[2] Possui graduação em Licenciatura plena em Ciências Agrárias (2019) e Bacharelado em Agronomia (2022) pelo Centro de Ciências Humanas e Agrárias da Universidade Estadual da Paraíba (UEPB). Especialização (2022) pelo Programa de Pós-Graduação em Sistemas Produtivos Sustentáveis para o Semiárido, Universidade Estadual da Paraíba (Campus IV/DAE). Mestrando no Programa de Pós-Graduação em Horticultura Tropical pela Universidade Federal de Campina Grande (UFCG).
[3] Possui graduação em agronomia (1998), mestrado em Gestão do Solo e da Água (2005), ambos, pela Universidade Federal da Paraíba e doutorado em Engenharia Agronômica, área de concentração: irrigação e Drenagem pela Universidade Federal de Campina Grande (2010).
[4] Doutorado em Manejo de Solo e Água, área de concentração Fertilidade do Solo.
[5] Graduado em Licenciatura plena em Ciências Agrárias (2019) e Bacharelado em Agronomia (2022) pelo Centro de Ciências Humanas e Agrárias da Universidade Estadual da Paraíba (UEPB).
[6] Engenheiro agrônomo, mestre em Manejo de Solo e Água, Doutor Agronomia
[7] Possui graduação em Agronomia pela Universidade Federal de Viçosa - UFV (1994), mestrado em Ciências Agrárias pela Universidade Federal da Bahia (1999) e doutorado em Recursos Naturais pela UFCG (2007). Pós-doutorado Sênior na área de Engenharia Agrícola pela UFC (2021-2022).
[8] Engenheiro Florestal, mestre em Ciência do Solo, Doutor em Ciência do Solo, área de concentração Fertilidade do Solo e Nutrição de Plantas

Abstract
The state of Paraíba, specifically in the alto sertão of Paraíba, is characterized by the spatial and temporal variability of rainfall, of temperature and evapotranspiration, coming from the semi-arid climate that is inserted in the region, and yet, the performance of different meteorological systems. The objective was to quantify the rainfall, temperature and reference evaporation (mm/ month and mm/year) comprised in the experimental period between 2016 to 2020, in the municipality of Catolé do Rocha-PB, in order to determine the history of the rainy and dry season, and thus, minimize agricultural production losses due to environmental factors. The daily rainfall, temperature and reference evaporation data were obtained by means of a rain gauge and the indirect method of the class A tank, respectively. The rainfall (mm year^{-1}) was analyzed by the nonparametric Friedman test, the Conover test and reference evaporation (mm year^{-1}) applied the parametric test of the ANAVA and the test of Tukey HSD. Both parametric and non-parametric tests were analyzed by Real Statistics. Temperature data was compiled from the website (www.inmet.gov.br) in order to control, statically collecting and decision-making in the process of building scientific knowledge regarding meteorological data (climate - Temperature). Were also analyzed pearson's correlation matrices and elementary principal components analysis for the rainfall variables, Eto and Temperature in the studied experimental period. Were also studied the principal component analysis between the years 2016 to 2020 and its significance by the t test. The average reference evaporation between 2016 and 2020 was 2.1 times greater than rainfall. Mean rainfall and reference evaporation in Catolé do Rocha-PB between 2016 and 2020 were 827 mm ano^{-1} and 1704 mm year^{-1} and are compatible with historical averages of 800 mm year^{-1} and 1700 mm year^{-1}, respectively. Inglesa.

Keywords: *Climate change. evapotranspiration. Semiarid region.*

1. Introduction

Determining the amount of water needed for human consumption and agriculture is one of the main parameters for proper planning, dimensioning and management of any system that uses water, as well as for the assessment of water resources. The quantity and quality of water depends directly on the meteorological factors of a region, among them, rainfall and evapotranspiration. In that regard, arid climate regions and semiarid, where evapotranspiration is greater than rainfall, causing water deficit for agriculture and even for human consumption, fact confirmed by Mesquita et al. (2021) when they affirmed that the dependence seems more serious in the areas of the Alto Sertão of Paraíba, due to the volumetric decrease of water sources, in response to insufficient and irregular distribution of rainfall, compromising growth, development and agricultural productivity.

The semi-arid climate present high temperatures, scarce and poorly distributed rainfall, with long periods of drought. It is the hottest climate in Brazil, dominant in the northeastern hinterland. In Brazil, this climate is present mainly in the Northeast and in a small part of the Southeast, covering 9 states: Bahia, Ceará, Alagoas, Piauí, Paraíba, Pernambuco, Sergipe, Rio Grande do Norte and a portion of the northern region of Minas Gerais. The Brazilian semiarid is a region delimited by the Superintendence of Development of the Northeast, SUDENE, considering dominant climatic conditions of semiaridity, in particular the rainfall (Carvalho, 2020). Therefore, the knowledge of air temperature becomes fundamental in agricultural studies and in analyzes of crop adaptation to semi-arid regions.

In semi-arid and arid regions where water scarcity is a real fact due to climatic conditions, there is concern about the availability of water resources for irrigated and rainfed agriculture in semi-arid lands, in periods of annual aridity, since in these areas the water deficit reduces the availability of water in the soil and, in fact, the agronomic efficiency of water use by plants, with a negative impact on crop growth and yield (Bertino et al., 2015; Barbosa et al., 2016; Lopes et al., 2020).

The Catolé do Rocha micro-region, located in Alto Sertão da Paraíba, presents great diversity in its production systems with environmental feasibility for the development of new agricultural activities. In this context, the historical arithmetic mean between the periods of 2016 to 2020 of rainfall and reference evaporation was 745.3 and 1868 mm year^{-1}, respectively, obtained from the meteorological station of the State University of Paraíba, Campus IV (Mesquita et al., 2021). The reference evaporation (ET0) was 2.5 times greater than rainfall. Thus, the determination of the rainy and dry season becomes essential for the sustainability of the region, being necessary the quantification of rainfall and reference evaporation, among other climatic factors to minimize the effects of inclement weather in a region.

Rainfall and temperature are meteorological variables of major importance to society and directly influence agriculture in a region, fact confirmed by Dallacort et al. (2015), Rainfall is one of the most important and active meteorological components in environmental situations, essentially for agriculture, interfering precisely with the growth of agricultural crops and their final formation. For Dantas (2019), excess or scarcity of rainfall causes socio-economic and environmental damage of great magnitude, being a tool that helps in the prediction of these natural phenomena, and its daily monitoring is extremely important for the agricultural sustainability of a region. Similarly, Silva et al. (2013) state that rainfall and evapotranspiration are essential in the formation of the climate of a stipulated region, basically dealing with the balance of water in the soil, in the temperature and humidity of the air.

Given the above, knowledge about the variability and distribution of rainfall and evapotranspiration in a region are of scientific and sustainable values, especially for dry farming in arid and semi-arid regions. With this, the objective was to quantify the rainfall and reference evaporation (mm/month and mm/year), between 2016 and 2021 in Catolé do Rocha-PB in order to determine the rainy and dry season, and thus, minimize the losses of agricultural production due to environmental factors.

2. Material and methods

The study was developed at the Center for Human Sciences, located at the State University of Paraíba (UEPB, Campus IV, Catolé do Rocha-PB, located in the municipality of Catolé do Rocha-PB, PB, in the period between 2016 and 2020. The daily reference evaporation values (ET0) and rainfall were collected from January 1 to December 31, 2016, 2017, 2018, 2019 and 2020 at the Meteorological Station of the Escola Agrotécnica do Cajueiro (latitude 6021’8,055”S, longitude 37043’23,817”w and altitude 237 m).

The climate of the region is of the type BSWh’, i.e, hot and dry steppe type, according to the Koppen classification, characterized by being hot semi-arid, with two distinct seasons, one rainy with irregular precipitation and the other without precipitation. According to Fiplan's classification, the municipality has an average annual temperature of 27º C, average annual evaporation of 1707 mm and the average annual rainfall of 874.4 mm, most of which is concentrated in the February/April quarter, with irregularly distributed rainfall.

The reference evaporation (ET0) was determined daily by the USWB Class A Tank indirect method as seen in Fig. 1A. The average rainfall data obtained in the experimental period were determined by means of a rain gauge, model type Ville De Paris Complete Pluviometer + beaker (Fig. 1B). The evaporimeter installed in the meteorological station of this institution on Campus IV consisted of a circular galvanized steel tank, plate n. 22 and 121 cm de internal diameter and 22.5 cm of deep, installed on a wooden platform 15 cm of height, filled with water up to 5 cm from the top edge. Water level is replenished daily to avoid lower limit 7.5 cm from the upper edge, according to the methodology used by Bernardo et al. (2019), according Figura 1B (ET0) was calculated by the following equation 1.

Fig. 1. Tank class A (A) and rainfall (B) from the meteorological station of the Agrotechnical School of Cajueiro/UEPB/Campus IV.

ETo= Kt*EV, onde:
Kt = tank coefficient, which was 0.75, according to meteorologicals data, second Doorenbos and Pruitt (1977).
EV= Tank evaporation, in mm/day.

The rainfall data comprised in the period from 2016 to 2020 were subjected to the analysis of descriptive statistics of position and dispersion, in order to obtain better scientific results more improved. The mean, the median, the standard deviation and the coefficient of variation were the tools used in order to verify the measures of position and dispersion, whose details can be found in Ferreira (2018).

The rainfall data between 2016 and 2020 were subjected to error normality (normal distribution), homogeneity of variance through the tests Shapiro Wilk and Leven's, respectively, and the presence of outliers through Box Plot. Data did not show normal distribution and/or error normality ($P < 0.05$), except the year of 2020 ($P = 0.056$). There is also no homogeneity of variance with value p igual 0.003. Finally, the data did not show outliers. Thus, the median is the most appropriate measure of dispersion to analyze the data. For this, Friedman's nonparametric test and the CONOVER because they are more appropriate for analyzing the data.

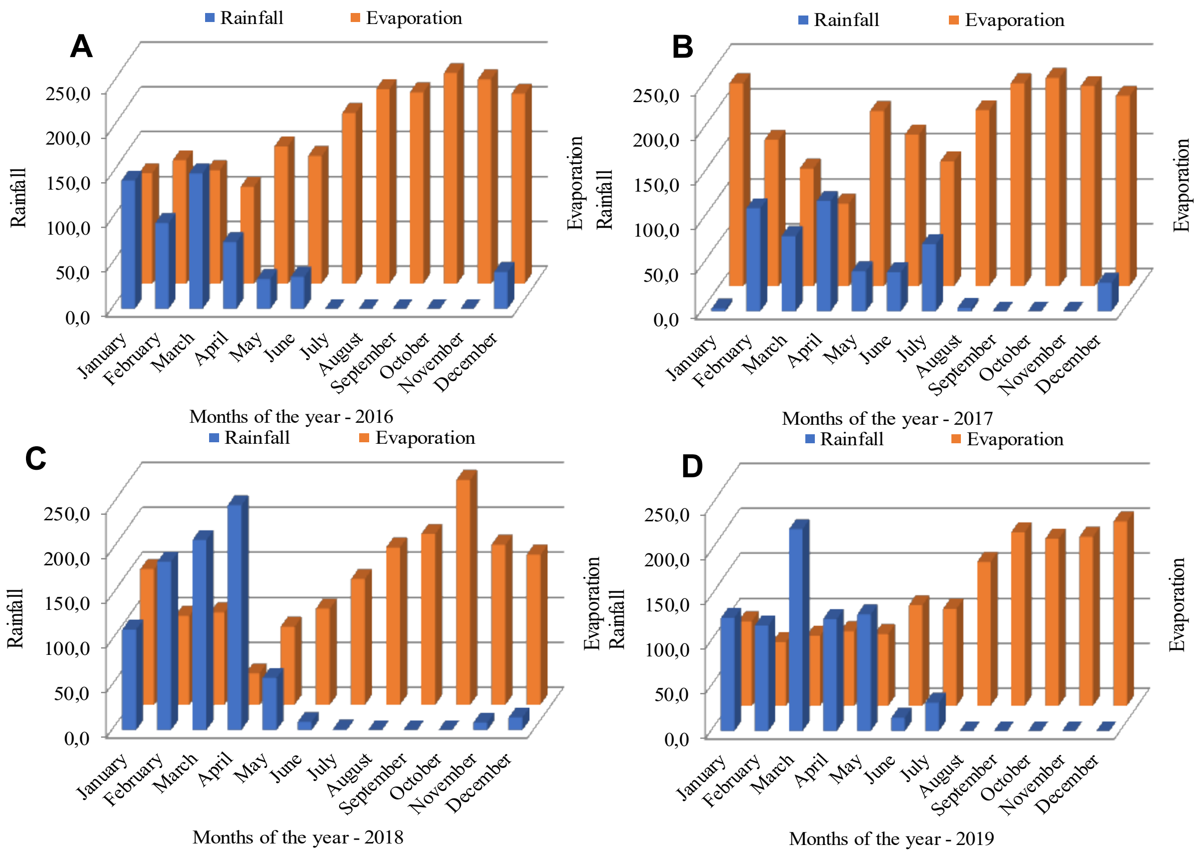
The reference evaporation data from 2016 to 2020 were subjected to error normality (normal distribution), homogeneity of variance through the Shapiro Wilk and Leven's tests, respectively, and the presence of outliers through Box Plot. The data has a normal distribution and/or error normality (P > 0.05) and homogeneity of variance with p value equal to 0.83. Finally, the data did not show outliers. With this, the assumptions were met, the mean is the most appropriate measure of dispersion to analyze the data, for this, the parametric test of ANAVA of repeated measures and the test of Tukey HSD.

Temperature data was compiled from the website (www.inmet.gov.br) in order to control, collect and statically make decisions in the process of building scientific knowledge regarding meteorological data (climate - Temperature). These data have the main objective to study and understand the different correlation matrices and analysis of elementary principal components of the data presented in this work as rainfall and ET_o.

Temperature data was compiled from the website (www.inmet.gov.br) in order to control, collect and statically make decisions in the process of building scientific knowledge regarding meteorological data (climate - Temperature). These data have the main objective to study and understand the different correlation matrices and analysis of elementary principal components of the data presented in this work as rainfall and ET_o.

3. Results

Regarding the monthly rainfall (mm/month) between the years 2016 to 2021, it appears that there is a concentration of rainfall (Figure 2A, B, C, D, E and F) between january to june, regardless of the year, with values of 534.87; 488.79; 885.44; 769.40 and 1279.90 mm, referring to the years 2016, 2017, 218, 2019 and 2020, representing 92.82; 93.14; 97.43, 100 e 94.35% of annual rainfall, whose annual values were 576.23; 524.79; 908.21; 769.40 and 1356,50 mm year^{-1}, respectively.



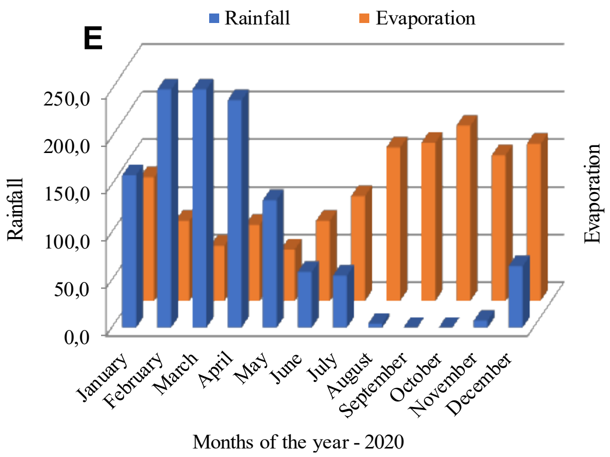


Fig. 2. Absolute frequency of rainfall (mm/month) and reference evaporation (mm/month) in the corresponding years 2016 (A), 2017 (B), 2018 (C), 2019 (D) and 2020 (E) from the municipality of Catolé do Rocha-PB, Brazil.

It is noteworthy, however, that the rainfall model in Catolé do Rocha-PB is characterized by irregularity in both quantity and distribution, even in the rainy season (6 months), may be contributing to the decline of rainfed agriculture in the region due to local producers neglecting and/or not knowing the importance of meteorological data for agricultural sustainability, corroborating with Perez-Marin et al. (2012) when they state that the vulnerability of the semi-arid region of Paraíba is confirmed and that wrong agronomic practices in the caatinga biome, particularly in the desertification centers, have led to exhaustion and soil degradation.

Regarding the rainy season, it is observed that the rain starts in January until July, with this, it is also noted that the months of August to December are the driest months with low rainfall. It is also noted that there is a difference both in the general balance of rainfall, and in the distribution and duration, regardless of the year.

In figure 2A, B, C, D, E and F, Note that the highest reference evaporation mm month^{-1} occurred between the months of July to December, thus characterizing the period of drought or of greater intensity of semi-aridity for the municipality of Catolé do Rocha-PB corresponding to the years 2016 to 2021.

Based on Fig. 2 previously evidenced, we can characterize the period of winter between January and July and of semi-arid or intense drought between August and December, with the month of July being the transition between the winter and the dry period in the city of Catolé do Rocha-PB. Due to the importance of characterizing the winter and drought period, there is a need for more meteorological studies that allow not only to characterize the rainfall regime and reference evaporation ETo, but also the use of innovative techniques or technologies that allow the monitoring or variability of these meteorological data to guarantee the sustainability of society and rural people, mainly.

Note that only between the months 01/2016; 02 and 03/2018; 01 and 03/2019 and 01, 02, 03 and 04/2020, the reference evaporation ET_0 is exceeded by the precipitated volume (Fig. 2), In these months, rainfall volumes were higher than the reference evaporation, according to climatology, on the other side, a ET_0 is high throughout the year, due to persistent high temperatures, a fact confirmed by Mesquita et al. (2021), the average temperature and relative humidity of the day and night air are (34.06 and 24.88 ºC) e and (38 and 63.44%), respectively, in the city of Catolé do Rocha, in the dry period. As a consequence of the high potential evapotranspiration, results in water deficit between 8 and 11 months a year, becoming more worrying, because high temperatures cause an increase in evapotranspiration and a decrease in the water content in the soil.

By Figure 3, it is observed that there are no considered values of outliers, that are outside the lower and upper limits; thus, the values obtained are within the normal range for the caatinga biome. It is also observed that the values for rainfall do not present a normal distribution, except the year 2020. According, the Shapiro Wilk test, whose "p" values were 0.01*, 0.049*, 0.003*,0.002* 0.056ns, referring to 2016, 2017, 2018, 2019 and 2020, respectively, fact proved by the distant values between mean and median, fact proved by Leven's test, whose p values for mean and median were 0.003* and 0.29ns, indicating that the data for rainfall do not have homogeneity of variances (Fig. 3A).

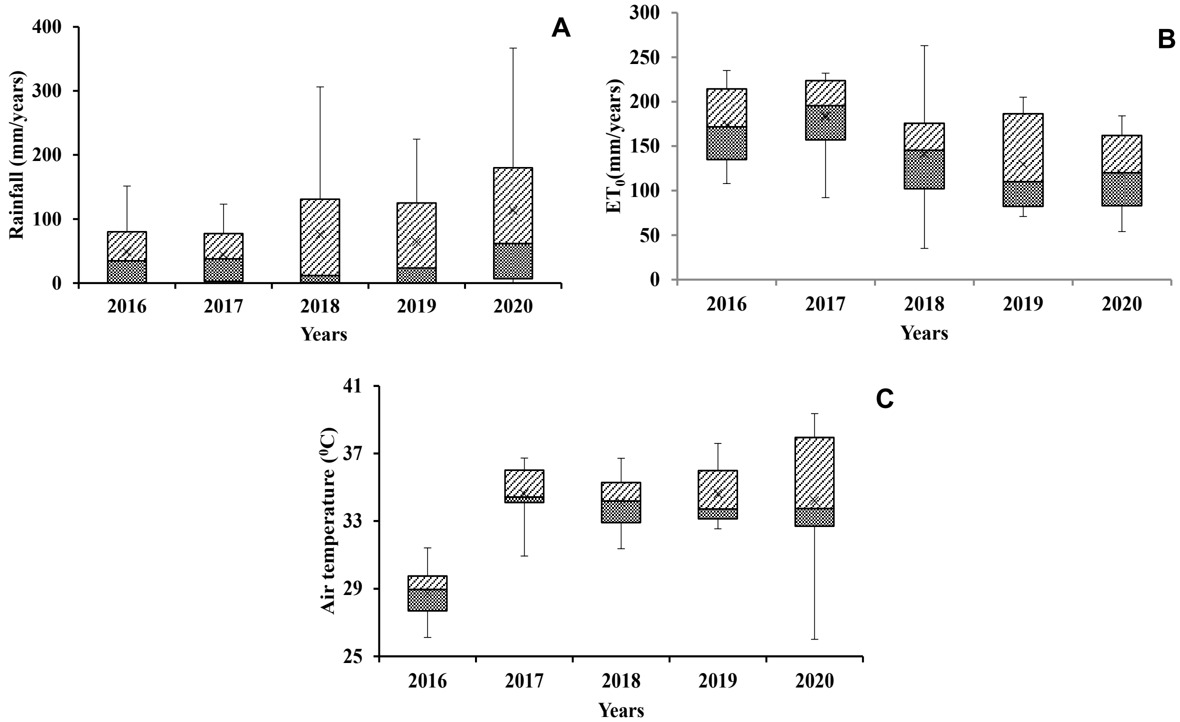


Fig. 3. Box plot of rainfall (A), of reference evaporation (B) and the temperature (C), between 2016 and 2020 in the municipality of Catolé do Rocha-PB.

For reference evaporation (ET_0) (Fig. 3 A) and the air temperature (Fig. 3C), whose p-values (> 0.05), indicating that the data have a normal distribution, by the Shapiro Wilk test. When the variance homogeneity was analyzed by Leven's tests, the values of p-value were 0.89ns and 0.03*, respectively, indicating that the variance can be considered homoscedasticity for the reference evaporation; on the other hand, the variance cannot be considered homoscedasticity for the air temperature.

Em síntese, in summary, for rainfall and air temperature, the median is the most suitable position measure to represent the data. However, for reference evaporation, the mean is measured from the best position to analyze the data. The behavior of rainfall forecasts (Fig. 4A) and reference evaporation (Fig. 4B) are consistent with the occurrence of the analyzed climatic phenomena, considering their transition periods, simultaneous occurrence and data distribution are similar between actual and predicted values. To justify this behavior, the predicted values are within the 95% confidence interval. This result is extremely important for farmers to program their crops, reducing the risk of losses from environmental factors, as they will have the values predicted in subsequent years.

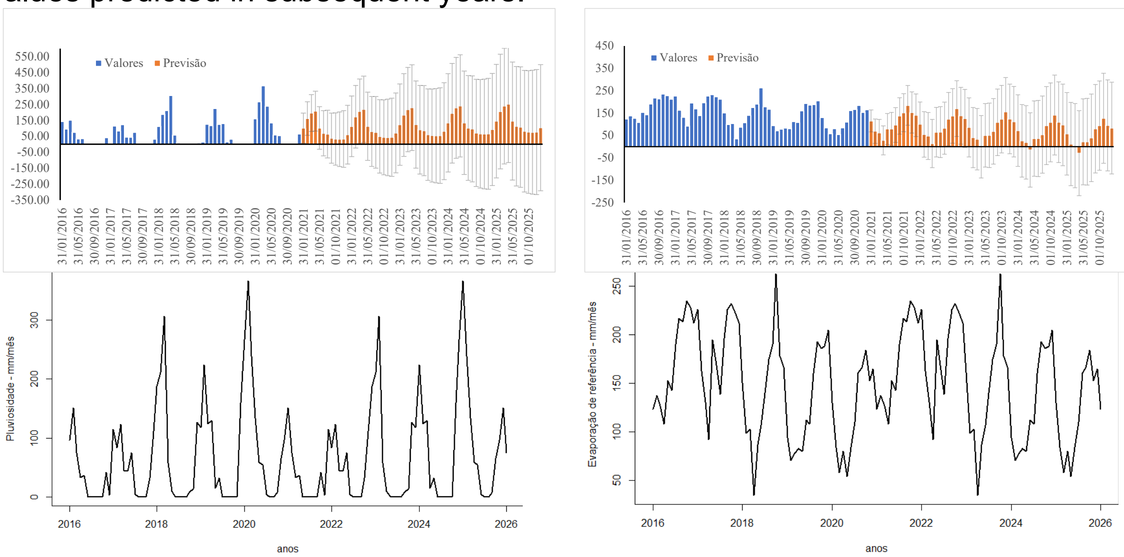


Fig. 4. Reals values referring to the historical period of 2016 to 2020 and forecasts between 2021 and 2025 for rainfall (mm/month) and reference evaporation (mm/month), in Catolé do Rocha-PB.

In both observed and predicted data, the wettest quarter and the lowest evapotranspiration are formed by the months of february, march and april, which presented the best rainfall volumes and lowest reference evaporation values, understood between 2016 and 2025, and the months of August, September, October, November and December obtained the lowest rainfall and highest reference evaporation values for the same period, a similar fact was obtained by.

In the correspondence analysis of rainfall over the years 2016, 2017, 2018, 2019 and 2020 associated with their respective twelve (12) months (Fig. 5), the proximity of the numbered points shows the correlation between them.

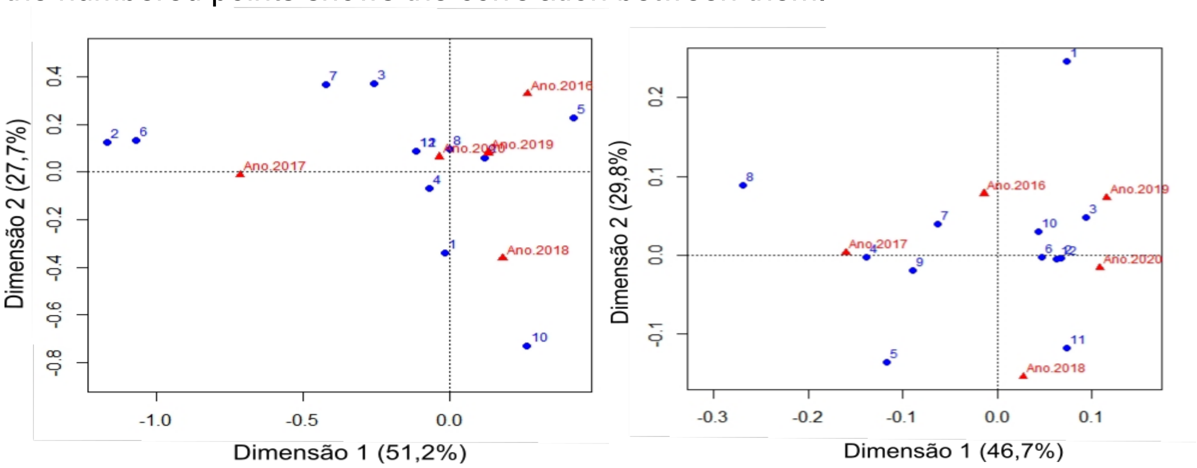


Fig. 5. Rainfall correspondence analysis and reference evapotranspiration evaluating statistically factor Years x Months.

All points are well distributed across the two-dimensional plane, but a certain proximity of the years 2019 and 2020 can be observed with the months 4, 8, 9, 11 and 12, as well as the year 2018 is surrounded by 1 and 10. Therefore, in recent years (2019, 2020), houve relação de maior pluviosidade, em conjunto com os meses iniciais (1, 2, 3, 4, 5 e 6) and minors in the final months (7, 8, 9, 10, 11, 12). Such results provide a wealth of details regarding the behavior of rainfall variability, in the municipality of Catolé do Rocha-PB, allowing the farmer to know the forecast values in subsequent years and to plan with their respective crops.

In the correspondence analysis of the reference evaporation values (ET_0) during the years 2016, 2017, 2018, 2019 and 2020 associated with their respective months (Fig. 6), exhibits a similar behavior with rainfall, proximity of the numbered points (months) of the years of 2016, 2017, 2019 and 2020 with the months 2, 3, 4, 6, 7, 9, 10 and 12, as well as the year 2018 presented the highest evaporation values in the month of 11. By correspondence analysis (Fig. 6), it is observed that rainfall rates are irregular between the years 2016 to 2020, as well as reference evaporation behaves erratically, demonstrating that the Catolé do Rocha-PB microregion is located in the semiarid region. There is a joint behavior from December to March, this occurs in periods that coincide with the summer, even though winter has begun, because it is related to the expansion of the continental equatorial mass, and with the advance of the intertropical convergence (ARAÚJO, 2011), thus increasing the air temperature, reflecting in greater evapotranspiration.

By Figure 6, the study represented by the main component analysis explained 51.60% of the data variability in relation to the rainfall factor, temperature and ETo, being that 34.90% were attributed to PCA referring to the positive quadrant, respectively (Fig. 6A). Por outro lado, On the other side, the positive dimension of PCA is constituted by the climatological variables Temperature, Year and ETo, while the negative dimension is composed solely and exclusively of rainfall.

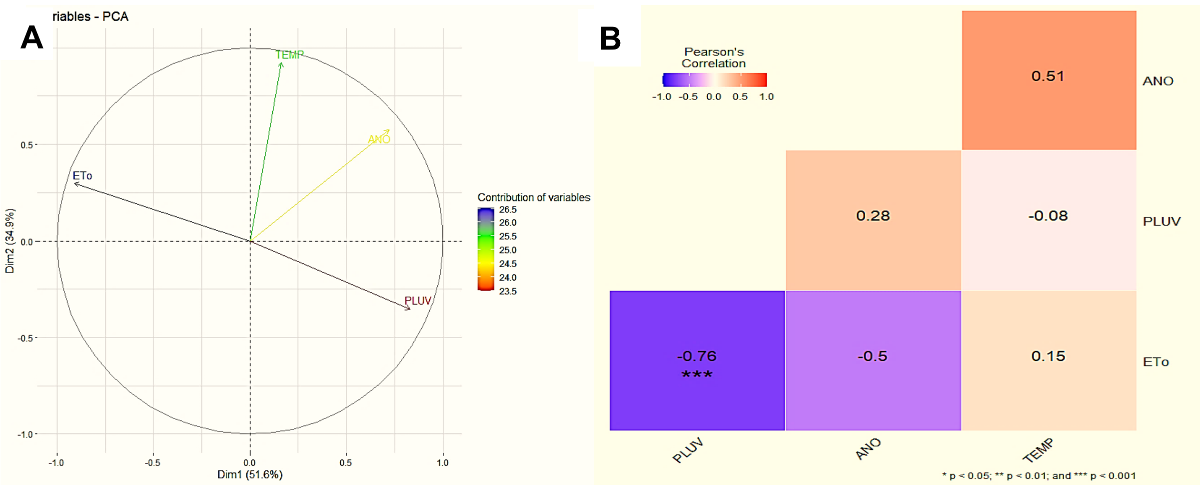


Fig 6. Elementary principal component analysis (A) and Pearson's correlation matrix (B) referring to the historical period from 2016 to 2021 in the city of Catolé do Rocha-PB.

The correlation matrix of climatological variables (temperature, rainfall and ETo) is presented in Fig. 6B. This matrix demonstrates a strong positive correlation for the factor YEAR in order of 51% of probability. Strong negative correlation significant at the level of 1% ($p < 0.01$) occurred for the rainfall factor ($r = -0.76$) and even so, it was not statistically influenced by the correlations of contributions between the variables studied. On the other hand, rainfall and temperature factors did not present significant effects.

4. Discussion

Similar result was obtained by Almeida et al. (2014), what observed a concentration of rain between February and May, in the western Seridó of Paraíba, in compared with the historical average of Catolé do Rocha-PB of 800 mm year^1, the years 2018 and 2020 have higher rainfall, while the years 2016, 2017 and 2019 have lower rainfall.

For Montebeller (2007) states that the rainfall distribution of a region is conditioned by static factors, such as: latitude, longitude, ocean distance and orographic effects, in addition to the dynamic factors such as the movement of air masses that associated with each other, characterize the rainfall indices of a region.

For Moura et al. (2007), the marked interannual variability of rainfall, associated with low total annual rainfall over the Northeast region of Brazil, is one of the main factors for the occurrence of "*drought*" events, characterized by a marked reduction in the total seasonal rainfall during the rainy season.

Corroborating with Schmidt et al. (2018) when stating that the water deficit for a region of predominance of the caatinga biome proved to be quite high throughout the year, without significant water replacement. same reasoning, Silva e Souza (2011) found greater atmospheric demand in the northern Agreste Mesoregion of the state of Pernambuco in the region, corresponding to the months of February to July, the values of ETo were higher than those observed during the period of lower atmospheric demand.

Anjo et al. (2017) observed in a historical series from 1935 to 2016, in the municipality of Serra Grande-PB, the wettest quarter is formed by the months of February, March and April and the months of August and September had the lowest, thus showing that in these months the lowest rainfall was recorded within the 73 years studied.

4. Conclusions

The average of reference evaporation evaluated in the historical period of 2016 to 2020 was of 2.1 times more than the rainfall.

The average rainfall in Catolé do Rocha-PB between 2016 to 2020 was of 827 mm year^{-1} is compatible with the historical average of 800 mm year^{-1}, being inversely proportional to the temperature factor.

The average reference evaporation in Catolé do Rocha-PB between 2016 and 2020 was 1704 mm year^{-1} compatible with historical average of 1700 mm year^{-1}.

5. Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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