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CLIMATE VARIABILITIES IN THE MUNICIPALITY OF CAMALAU - PARAIBA, BRAZIL

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ABSTRACT

The objective is to study the climatic variability of the elements, maximum temperature, minimum temperature, average temperature, thermal amplitude, relative humidity, wind intensity, evapotranspiration, evaporation as well as to evaluate the estimate of the climatological water balance for the municipality of Camalaú, Paraíba. Monthly and annual precipitation data, referring to the 52-year period of observed data (1962-2014), from which graphs of annual variations, monthly and seasonal averages of precipitation were obtained to satisfactorily represent the region's rainfall regime. Maximum, average, minimum temperature and thermal amplitude were estimated by the "Estima_T" software, as well as relative air humidity, wind intensity, evapotranspiration and evaporation. The fluctuations of the minimum air temperature resulted from the synoptic systems acting in the rainy season and the dry season, as well as from the impacts on the environment when in the fluctuations, they may be related to the factors that cause inter-regional pluviometric indices. The variability of relative humidity is linked to cloud cover and thermal fluctuations in the study area.

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INTRODUCTION

Araújo *et al*. (2020) aimed to characterize the differences existing in the climate of Bom Jesus do Piauí regarding climate oscillations, in extreme temperatures, average and thermal amplitude for 1990-2018 and compared with the historical average of 1960-2018. They verified that the average oscillations of the minimum temperatures tend to increase and the maximum temperatures tend to remain unchanged. In this way, the average temperature and the thermal amplitudes tend to remain at elevations. Altitude and latitude have inversely proportional analogies, while longitude has a proportional relationship with temperature. Of the temperatures studied, the minimum temperature stands out as the one with the greatest increase and the greatest spatial consistency. Medeiros *et al*. (2020) analyzed the average thermal variability and its spatio-temporal behavior for the Pernambuco forest area and found that the thermal series showed decreasing trends and a seasonal component with a periodicity of 0.7 to 1.4 months. The authors obtained a good fit for the models of the series of the moving averages for 5 and 10 years with expected values within the confidence interval, a satisfactory result, considering the uncertainties of the standard error and the climate that can change the expected results. In agriculture, the risks of greater tensions are presented with increases in evapotranspiration and evaporation and the recurrence of irrigated water use is not ruled out. Medeiros *et al*, (2018) carried out the analysis of the spatio-temporal variability of the average temperature in the State of Pernambuco distributed by homogeneous regions. They showed that the results of thermal fluctuations are related to elevation and latitude, being one of the physiographic variables that best explain the monthly and annual temperature variation in the study area. The fluctuations in the average temperature result from the synoptic systems active during the rainy season and the dry season, as well as from the impacts on the environment. Temperature reductions occurred in accordance with the displacement of the rainy season and the actions and/or contributions of regional and local effects. Matos *et al*. (2015) used monthly extreme temperature data for Barbalha – Ceará and demonstrated that elevation, latitude, are the physiographic variables that best explain annual temperature variation and mean temperature variability resulting from synoptic systems active during the rainy season, or dry, as well as impacts on the environment. Medeiros *et al*. (2020) analyzed the variability of average air temperatures and their space-time behavior for the Mata Pernambucana area composed of 44 municipalities in the period 1950-2017. They found that the time series showed decreasing trends and a seasonal component with a periodicity of 0.7 to 1.4 months. The authors obtained a good fit for the models of the series of the moving averages for 5 and 10 years, with expected values within the confidence interval, a satisfactory result, considering the uncertainties of the standard error and the climate that can change the expected results. In the agricultural part, the risks of greater tensions are presented with the increase of evapotranspiration and evaporation, the recurrence of water use for irrigation is not discarded. Altitude and latitude are physiographic variables that best explain the variation in mean air temperature in the studied area. Melo *et al*. (2015) showed that temperature is one of the most important meteorological elements and in much of the national territory the scarcity of meteorological data is one of the factors that most limit the realization of sufficiently detailed studies on climate types. The increase in temperature and humidity may be related to a higher incidence of vectors for the propagation of viruses and microorganisms that cause diseases such as meningitis, dengue and pneumonia (SOUSA *et al*., 2007).

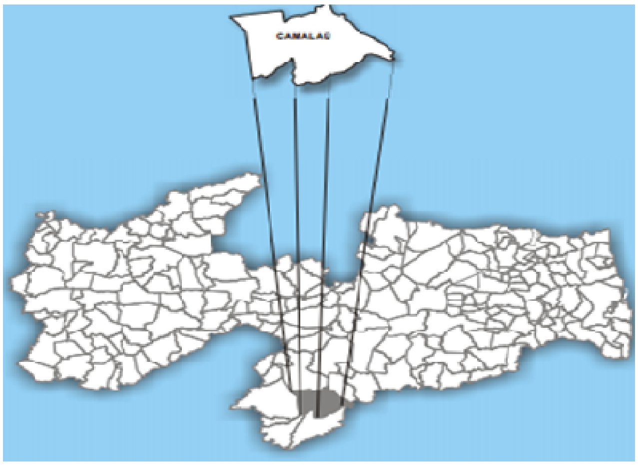
Melo *et al*. (2015) delimited the variability of relative air humidity (RH) for 11 municipalities in the state of Pernambuco in the period 1961-1990. With the development and urban expansion, large areas are being deforested, not taking into account the contribution of meteorological elements among them, especially the RH that can minimize the occurrence of damages from anomalous effects that may happen. Observed data of relative air humidity were used, such as monthly, annual, maximum and minimum values. Observing the variability of the relative humidity of the air for the area under study throughout the year, it was possible to delimit the wettest quarter and its monthly and annual values, as well as the observed absolute maximum and minimum values. Such delimitations of the wetter quarters and the information of the times of lower relative humidity of the air, served as an alert to the federal, state and municipal authorities, in addition to the decision makers for a better planning.
Relative humidity is important in agriculture, hydrology and in the various engineering fields, its monitoring also becomes fundamental for public health management. A very low or very high value of air humidity may be related to health problems, according to Sousa *et al*. (2007). Barcellos (2009) stated that climatic characteristics such as temperature, humidity and precipitation, associated with the physical and chemical characteristics of pollutants present in the atmosphere, can potentiate the effects caused by climate change. High temperatures and low air humidity favor the transport of pollutants that, associated with climatic conditions, affect the health of the population, even far from sources that generate pollution. This can increase the effects of respiratory illnesses and other complications associated with low humidity such as allergies, nosebleeds, dry skin and eye irritation.

Costa *et al*. (2015) evaluated the variation of evaporation in the class "A" tank in the municipality of Teresina - Piauí in three and a half decades and made a comparison with the changes in urbanization that occurred in that period, finding changes in the evaporative indices in the face of the occupation of Man and their respective modifications in space, for the decades 1976-1985 and 1986-1995 that presented the smallest variations. The decade of 2006-2011 in the month of October presented the biggest fluctuation of the studied periods. Annual fluctuations ranged from 1.852.7 to 2,409.4 mm. The evaporative indices had greater significance from the 1996s onwards due to urban verticalization, alteration of the vegetation area, soil compaction with paving, backfilling of ponds and eutrophication of water bodies. Evapotranspiration (ETP) is the phenomenon associated with the simultaneous loss of water from the soil through evaporation and from the plant through transpiration. The ETP estimate shows the maximum possible water loss to occur on a vegetated surface. It means the maximum water demand by the crop and becomes the reference for maximum water replacement for the crop, either through irrigation or precipitation (BARROS *et al*., 2012). Medeiros *et al*, (2020a) carried out the BHS, with the purpose of verifying climatic fluctuations, determining and making available the contributions for the elaboration of agricultural plans. The BHS provides detailed information on climate variables, promoting subsidies to government powers and project developers for the sustainable development of production in the studied area, Medeiros *et al*, (2020a). The monthly evapotranspiration values are connected with geographic coordinates and orography. Medeiros (2020b) carried out the BHS for the municipality of São Bento do Una, PE - Brazil in order to determine the contribution of water storage and impoundment, in relation to the water crisis, generating and providing subsidies for planning and designing. Climatic impacts have been causing changes in the regional water balance for the last decade. Environmental degradation, the local effect of human action, has been anticipating the process of regional climate change, directly affecting the conditions of the rainfall regime and the availability of water in the soil Medeiros (2020b). The need to capture rainwater and other storage sources helps human, animal and plant survival and contributes to the agricultural sector and in particular the poultry sector in the region. França *et al*. (2020b) evaluated the water conditions through the climatic panorama of field capacity variability in order to detect soil erosive fluctuations in the municipality of Amparo de São Francisco - Sergipe, by calculating the water balance. The methodology applied to compute the water balance was Thornthwaite. Field capacities of 25 mm; 50 mm and 75 mm recorded high erosive rates.

The field capacity of 100 mm; 125 mm and 150 mm recorded moderate erosivity, and weak erosive indices for the 175 mm capacity. The rainfall indices for the field capacities studied should cause more erosive incidences where heavy rains with large magnitudes and in a short time interval are expected. The results obtained indicate critical situations in the soil conditions of the area under study, which could cause major impacts on water resources and on the practice of rainfed crops. Medeiros (2016) prepared the monthly water balance for the city of Matinhas-PB, aiming to plan citrus farming. It resulted for the months from August to March with water deficiency totaling 354.5 mm, registering water surplus between the months of June and July, evapotranspiration 32% above the pluviometric indexes, annual evaporation of 906.7 mm. It is of fundamental interest to discuss alternative and mainly effective plans, with reduced consumption and waste of water in times of scarcity (Augusto *et al*. 2012). Medeiros *et al* (2014) showed that the climatic variations of a region or micro-region are determinant in the choice of agricultural activities developed and the type of management to be established. They performed the climate classification from the Climatological Water Balance, for CAD values estimated at 125, 100, 75, 50 and 25 mm. The water storage capacity in the soil did not interfere in the Climate Classification of the municipality, however, soils with different CAD, did not cause increases in the potential Evapotranspiration rates, as well as did not change the values of Water Deficiencies and Surpluses. The objective is to study the climatic variability of the elements maximum temperature, minimum temperature, average temperature, thermal amplitude, relative humidity, wind intensity, evapotranspiration, evaporation and to evaluate the estimate of the climatological water balance for the municipality of Camalaú, Paraíba.

MATERIALS AND METHODS

Camalaú is located in the Borborema Mesoregion and in the Western Cariri Microregion. It is limited to the state of Pernambuco and the municipalities of São João do Tigre, São Sebastião do Umbuzeiro, Monteiro, Sumé and Congo. The seat of the municipality has the geographical coordinates in Latitude: 07º10'15'' south and Longitude: 35º51'13'' west of Greenwich with an altitude of 634 meters (Figure 1). Monthly and annual rainfall data for the 52-year period of observed data (1962-2018) were obtained from graphical data of annual variations, monthly and seasonal averages of rainfall. In order to satisfactorily represent the region's rainfall regime, such as maximum, average and minimum temperature, thermal amplitude, they were estimated by the "Estima_T" software, according to (Cavalcanti *et al*, 1994; Cavalcanti *et al*, 2006), relative humidity, wind intensity, evapotranspiration, evaporation; data provided by the



Source: Medeiros (2022).

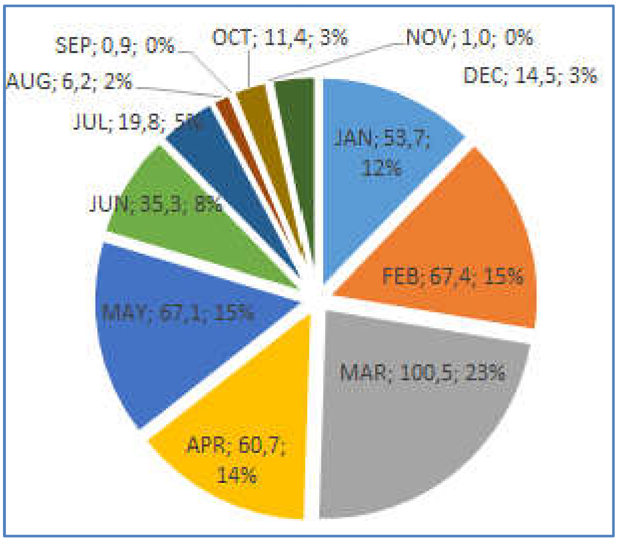
Figure 1. Location of the municipality of Camalaú

Executive Agency for Water Management of the State of Paraíba (AESA, 2022). The factors that cause rainfall for the study area are: Intertropical Convergence Zone (ITCZ) and the contributions of High Level Cyclonic Vortex systems (HCVs) when in activity on the NEB, in addition to the effects resulting from the northeast trade winds aided by the formation of the South Atlantic Cyclonic Vortexes (VCAS) and the convective clusters strengthened by the Dipole Pattern in the Tropical Atlantic Ocean and the undulating disturbances in the field of the trade winds, providing events of droughts, floods, floods, flooding, overflowing rivers, streams , ponds, dams, dams, ponds, lakes and wells. Four types of climate classifications were used; method (Thorntwaite 1948; Thorntwaite *et al*, 1955) for the periods: Normal; Rainy; Regular and Dry. In the Normal period, the classification was of the type C_1A'S2a'; in the rainy season there is a classification of type C_2D'a'; for the period of regular rain the classification was of the type $C_2B'_2$a' and in the dry period it was classified with C_2E'Ra'. According to the classification of (Köppen 1928; Köppen *et al*, 1931) it has a climate of type BSh. The classification is in accordance with the study by Alvares *et al.* (2014).

The meteorological information used; maximum temperature, minimum temperature and average temperature, thermal amplitude were estimated by the software "Estima_T", according to (Cavalcanti *et al*, 1994; Cavalcanti *et al*, 2006), relative humidity, wind intensity, predominant wind direction, evapotranspiration, evaporation, were estimated by multiple linear regressions and simplified interpolations were performed, using monthly and annual data for the period from 1962 to 2018. The climatological water balance was used on the monthly scale for an average year, that is, the cyclic water balance, elaborated from the climatological normals of average temperature and precipitation. The most used technique to work with global water balance data from a climatological point of view is the water balance of (Thornthwaite 1948; Thornthwaite *et al*, 1955) where the program developed by Medeiros (2014) was used. By accounting for the natural supply of water to the soil, through rainfall (P), and atmospheric demand, through potential evapotranspiration (ETP), considering a maximum possible level of storage (CAD). The water balance provides estimates of real evapotranspiration (ETR), water deficit (DEF), water surplus (EXC) and effective soil water storage (ARM), and can be prepared from daily to monthly scales according to Camargo (1971). The field capacity (CAD) used was for a 100 mm blade.

RESULTS AND DISCUSSION

Figure 2 shows the monthly distribution of precipitation and its percentage in relation to the annual value for the municipality of Camalaú - Paraíba between 1962-2018. In the months of July to December the rains represent 13% of the annual value, highlighting the months of September and November that do not register rains. Between January and June it rains 87% of the annual rate, with emphasis on the month of March when it rains 23% of the annual value. These oscillations corroborate the studies by Marengo *et al*, (2007), Nobrega *et al*, (2014) and Medeiros *et al*, (2021).



Source: Medeiros (2022).

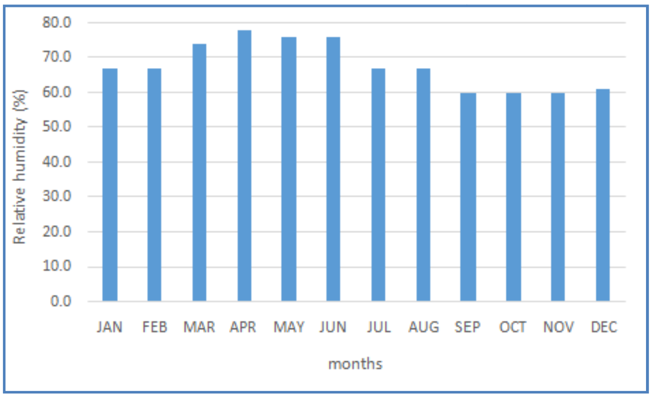
Figure 2. Monthly distribution of rainfall and its percentage in relation to the annual value for the municipality of Camalaú - Paraíba between 1962-2018

The evaporative and evapotranspiration fluctuations are represented in figure 3 for the municipality of Camalaú – Paraíba in the period 1962-2018. From October to January, the highest evaporative rates are registered and from June to September, the lowest evapotranspiration rates. Its monthly oscillations flow from 78 mm (July) to 120 mm (December). Evaporation ranges from 100 mm (March) to 8.4 mm and 9.8 mm (September and November) respectively. From May to September, there was a gradual reduction in evaporation. Similar variabilities were detected by Camargo (1971) and Costa *et al* (2015).

Source: Medeiros (2022).

Figure 3. Monthly distributions of evaporation and evapotranspiration for the municipality of Camalaú - Paraíba between 1962-2018

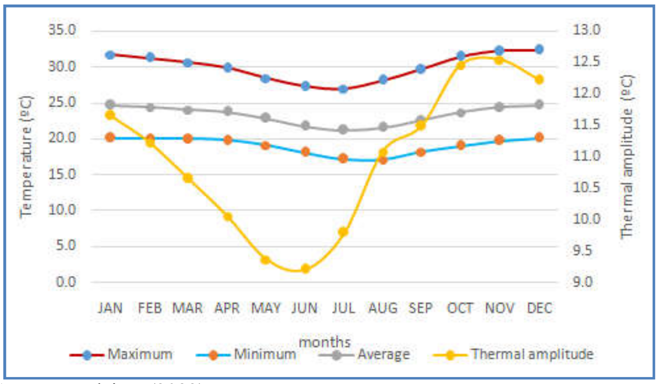
Figure 4 shows the fluctuations in the monthly distributions of relative air humidity for the municipality of Camalaú - Paraíba between 1962-2018. In the months from March to June, the greatest fluctuations in humidity are recorded, ranging from 73% to 78.8%. The months of September to November the relative humidity oscillates close to 60%. These fluctuations are intertwined with cloud cover and thermal variability in the study area. More details on fluctuations in relative humidity for the state of Paraíba can be seen in the study by Medeiros (2016). The thermal amplitude is characterized by the difference between the maximum temperature minus the minimum.



Source: Medeiros (2022).

Figure 4. Monthly distributions of relative air humidity for the municipality of Camalaú - Paraíba between 1962-2018

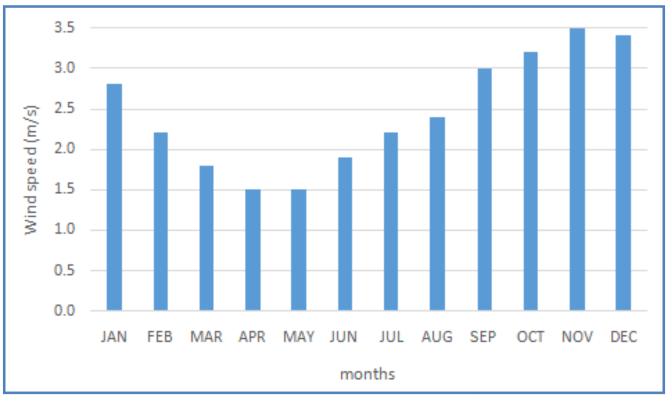
Its oscillations occur between 9.2 ºC (June) and 12.7 ºC (November), its minimum peaks occur between June and July and the maximum peak in the months of October and November. The minimum temperature ranges from 24.9 ºC (December/January) to 18.3 ºC (July/August), between April and August there is a reduction in the minimum temperature and a gradual increase from September to February (Figure 5). The maximum temperature registers a gradual reduction between February to June and an increase increase from July to January, its maximum maximum peak occurs in July and its maximum maximum temperature peak in January.



Source: Medeiros (2022).

Figure 5. Monthly distributions of maximum, average and minimum temperatures and thermal amplitude for the municipality of Camalaú - Paraíba between 1962-2018

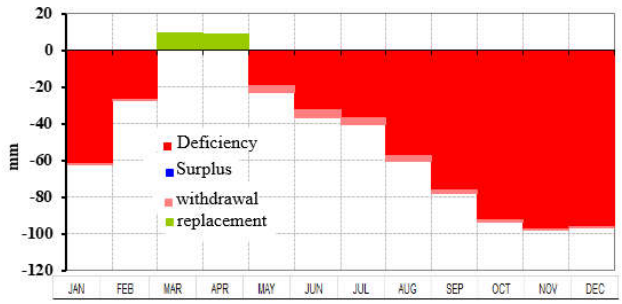
Figure 6 shows the monthly distributions of wind speed for the municipality of Camalaú - Paraíba between 1962-2018. The low intensities of the winds were registered in the months of April and May with 1.5 m/s.



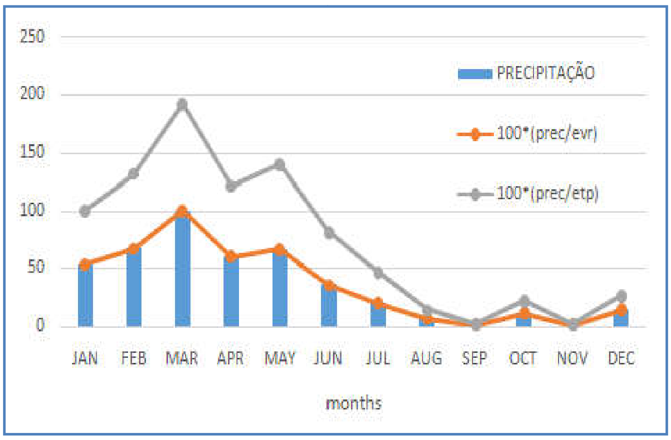
Source: Medeiros (2022).

Figure 6. Monthly wind speed distributions for the municipality of Camalaú - Paraíba between 1962-2018

The high wind speed occurs in the month of November with 3.5 m/s, in the other months the oscillations flow from 1.8 m/s to 3.4 m/s. It should be noted that the high thermal intensity and wind speed may be influencing the variability of evaporative and evapotranspirational power. With an average annual temperature of 23 ºC and its monthly fluctuations ranging from 24.5 ºC (January) to 20.7 ºC (July). Precipitation ranges from 6.4 mm (September) to 119.8 mm (March) and its annual total is 538.3 mm. Photoperiod or duration of solar brightness from sunrise to sunset and 144 hours per year and its monthly variations range from 11.5 hours and tenths of an hour in July to 12.4 hours and tenths of an hour (December/January). Evapotranspired one and a half times more than the rainfall values. The evaporative indices were equal to the rainfall value. With a water deficit of 595.9 mm recorded from May to February, no water surplus was detected (Table 1). The variabilities of the water balance elements discussed corroborate the studies by França *et al* (2020) and Medeiros (2020). Water deficiencies predominated with moderate to strong intensity in the months of May to February, there were no water surpluses, the withdrawal of water from the soil occurred from May to January and the replacement of water in the soil with small capacity occurred between the months of March and April in accordance with figure 7 of the water balance graph for the municipality of Camalaú - Paraíba between 1962-2018. Similar results were observed in studies by Camargo (1971) and by Costa *et al*, (2015).



The monthly distributions of wind speed for the municipality of Camalaú - Paraíba between 1962-2018 may be contributing to the greater evaporative and evapotranspiration fluctuations as seen in figure 8; it is also known that rainfall irregularities and extreme events that cause high magnitude rainfall in a short time interval, have their contributions to evapotranspiration variability. It is noted that the evaporative indices flowed close to or equal to the rainfall rates and in the evapotranspiration the opposite of the rainfall indices occurred, they were much lower than the evapotranspiration (Figure 8).



Source: Medeiros (2022).

Figure 8. Figure 6. Monthly wind speed distributions for the municipality of Camalaú - araíba between 1962-2018

Table 1. Climatological water balance for the municipality of Camalaú in the period 1962-2018

Meses	T	P	N	ETP	ETR	DEF	EXC
	(°C)	(mm)	(Hour)	(mm)	(mm)	(mm)	(mm)
January	24.5	52.5	12.4	114.4	52.5	61.9	0.0
February	24.3	76.5	12.3	103.3	76.6	26.7	0.0
March	24.1	119.8	12.2	110.2	110.2	0.0	0.0
April	23.3	104.8	11.9	96.0	96.0	0.0	0.0
May	22.4	63.9	11.7	87.0	67.7	19.3	0.0
June	21.2	35.3	11.6	72.0	39.8	32.2	0.0
July	20.7	29.1	11.5	69.5	32.5	37.0	0.0
August	21.0	12.2	11.7	72.5	15.2	57.2	0.0
September	22.3	6.4	11.8	84.6	8.4	76.1	0.0
October	23.4	8.3	12.1	101.6	9.4	92.3	0.0
November	24.1	9.7	12.3	107.4	10.1	97.3	0.0
December	24.3	19.8	12.4	115.7	19.9	95.8	0.0
Annual	23.0	538.3	144.0	1134.2	538.3	595.9	0.0

Legend: Average temperature (T), Precipitation (P), Photoperiod (N), Evapotranspiration (ETP), Actual Evaporation (ETR), Water Deficiency (DEF) and Excess Water (EXC). Source: Medeiros (2022).

CONCLUSION

The fluctuations in the minimum air temperature result from the synoptic systems active during the rainy season and the dry season, as well as from the impacts on the environment and these fluctuations may be related to the factors that cause the inter-regional pluviometric indices. The variability of relative humidity is linked to cloud cover and thermal fluctuations in the study area. There were no water surpluses for the studied period, which was caused by poor rainfall distributions and the non-contributions of the microscale synoptic effects and their regional and local aids. The evapotranspiration in the study period exceeded the rainfall rates, such overruns may have been caused by the increase in wind speed, thermal indices and contributions of low cloud cover.

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