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Comparisons of sequential water balances between 1920-2018 in the municipality of Serra Talhada and São Bento do Una – Pe, Brazil

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Abstract

A sequential water balance was performed using the Thorn Thwaite and Mather method in order to verify the contribution of water storage and damming in the municipality of São Bento do Una in relation to the water crisis. The monthly average climatological precipitation data were grouped into 95 years, characterizing a period of climatological normal, where the software was used in electronic spreadsheets to extract the values of the monthly, annual averages of precipitation for the period from 1920 to 2018. Were estimated by the multiple regression line methods applied to the T-estima software, taking into account the geographic coordinates. Climatic impacts have caused changes in the region's water balance in the last decade. Environmental degradation, the local effect of human action, has by itself accelerated the process of modifying the regional climate, thus directly affecting the conditions of the rainfall regime and the availability of water in the soil. It is extremely necessary to use rainwater harvesting and other storage sources for human, animal and plant survival, thus contributing to the agricultural and poultry sector in the region. Climatic impacts may cause changes in the region's water balance, as heavy and short-lived rains are expected, leading to a drop in poultry and agricultural production.

Keywords: Rain and Thermal Fluctuations; Water Deficiency and Surplus; Extreme Events; Contributing to the agricultural

1. Introduction

The water balance (BH) represents the rate of change in the amount of water over a defined portion of soil over a given period of time, indicating the water retention competence per period as a function of some parameters, such as the type of soil, temperature, monthly rainfall. For balance purposes, it is necessary to define magnitudes as positive and negative, respectively, the volume of water that enters and leaves the soil.

The balance of water deficit or increase can reduce production and/or product quality, while excess irrigation, in addition to water and energy losses, can contribute to the leaching of nutrients and agrochemicals to the lower layers of the soil or even reaching the water table. In arid and semi-arid regions, inadequate use of irrigation can also lead to soil salinization. On the other hand, through proper planning and management, we can determine the amount of water in a crop, which implies studies of soil surveys, climate and cultural factors.

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Water planning is the basis for scaling any form of integrated management of water resources, thus, BH allows for the knowledge of soil water needs over time. The BH as a management unit allows classifying the climate of a region, carrying out agroclimatic and environmental zoning, the time of water need in the soil, in addition to favoring the integrated management of water resources [24].

A study by [37] in the city of Picuí, Paraiba, indicates that rainfall levels will not be sufficient for various types of crops, which makes rainfed cultivation unfeasible if the pessimistic scenarios are confirmed. The author also warns that in the face of a pessimistic scenario, the condition of rainwater storage for human and animal consumption will suffer significant impacts, making it necessary, therefore, to plan for coexistence with the drought through the construction of cisterns and other similar ones, which allow water storage and minimization of the impacts of lack of rain.

[37] evaluated the daily temperature in the municipalities of Parnaiba, Picos and Gilbués in the State of Piauí with different methodologies, and concluded that the methods measured in relation to the normal standard had a performance classified as "Very Good and Great", with a confidence index ranging between 0.83 to 0.98, and that said methods can be applied in the evaluations of said air temperatures. According to the author in (2018), thermal fluctuations are one of the physiographic variants that best explain the monthly and annual temperature variation in the state of Piauí.

[6] used past scenarios of spatial and temporal variability of climate indices, from normal climatological and serial annual data for a period of fifty years and with twenty rainfall stations in the state of Paraíba. The methodology of [58] and [18] was used and the conceptual application of spectral methods was used as subsidy, with the subsequent application of wavelet analysis to serial climatic indices. The UNEP aridity index proved to be less judicious for climatic classifications than in the use of the Thornthwaite indices, showing less aridity conditions. By the ondolet methodology, the interdenominal variability.

[33] calculated the monthly BH for Matinhas (PB), targeting projects for citriculture. The BH resulted in eight months (August to March) of accumulated water deficit of 354.5 mm, with water surplus occurring in June and July, evapatranspired 32% of registered rainfall, annual evaporation was 906.7 mm.

[14] analyzed the water balance using the method of [58;59] between the period 2000-2016 and its comparison with the year 2016 in order to verify the water deficit and the influence of water storage in the soil in the municipality of Serra Talhada - Pernambuco. The meteorological elements show that sudden changes have taken place and that the inhabitants will have to change their tactics in the future in relation to plantations, water storage and survival conditions. Future studies should be considered to better visualize how transient systems and local effects affect rainfall variability, evapotranspiration and evaporation. Tendency to increase in temperature and in evaporative indices may cause extreme precipitation events in a short period of time and of high intensity.

According to [37] the BH technique provides the balance of water available in the soil for the plant, that is, it accounts for the input (precipitation and/or irrigation) and output (potential evapotranspiration), considering a certain water storage capacity by the soil.

Water scarcity is the main problem facing humanity in this century. The sustainable use of water cannot be a priority only for the agricultural sector and regions that experience water scarcity, but must be a priority for all socioeconomic sectors and regions, in accordance with [46].

According to [5] climatic factors are the main causes of fluctuations in crop grain yield and flexibilities in agriculture, as temperature, humidity and precipitation cannot be controlled or modified by humans on a large scale.

Precipitation happens to be the only source of water supply. Therefore, when running off the surface, the water is dammed up in small weirs and used for supply and irrigation. A small portion of rainwater is captured and stored in cisterns for drinking purposes. Precipitation is extremely variable both in magnitude and in spatio-temporal distribution for any region and, in particular, in Northeast Brazil (NEB) according to the authors [1; 2].

Water is essential for the development of crops, its lack or excess can influence the agricultural production of a particular location or region. According to [37] the water balance technique provides the balance of water available in the soil for the plant, that is, it accounts for the input (precipitation and/or irrigation) and output (evapotranspiration), considering a certain water storage capacity by the soil.

In-depth verification of the behavior of the most used interpolators in precipitation mapping needs to be well conducted, as the works developed do not demonstrate the best or most suitable method of spatial interpolation, according to the authors [32; 60].

The prominence of the annual water balance (BH) estimate is based on the importance that water has for its storage and impoundment, human, plant and animal survival, the development of grains, agriculture, livestock, citrus, fruit, poultry, fruit and vegetables, irrigation, reductions in energy and water consumption in addition to water and laser pumping time reduction.

[6] Reported that crop evapotranspiration is a key variable in the planning and execution of irrigation management. [35; 7] studying the municipality of Campina Grande - PB, observed that Potential Evapotranspiration has an annual rate of 1.076,8 mm, with variations from 105.4 mm in December to 71.3 mm in August. Many different methods of estimating potential evaporation from one or more variables have been developed according to local climatic conditions and availability of adequate data [52; 53; 61 and 62].

In view of the above, the objective is to estimate the computation of the sequential water balance (BHs) by the method of [58;59] for the municipality of São Bento do Una in order to verify the contribution of storage, damming, in relation to the water crisis, in addition to generating and providing subsidies for planning and agricultural projects in the area under study.

2. Material and methods

São Bento do Una is located in the Agreste mesoregion and in the Ipojuca Valley Microregion of the State of Pernambuco with geographic coordinates of 08°31'22" south latitude and 36°06'40" west longitude and altitude of 614 meters. The municipality of Serra Talhada is located in the territory of Pajeú in the Sertão mesoregion of the state of Pernambuco with the geographic coordinates of latitude 07º59' South and longitude 38º17' West and an altitude of 429 m. (Figure 1).

Source: Medeiros (2022)

Figure 1 Location of the municipalities of São Bento do Una and Serra Talhada in the state of Pernambuco

According to the climate classification of [21; 22], São Bento do Una and Serra Talhada have an “As” climate (Rainy Tropical, with dry summer). This classification is in agreement with the authors [40; 3]..

The factors that cause rainfall in the municipality are the contribution of the Intertropical Convergence Zone (CZIT), formation of high-level cyclonic vortices (ASVC), contribution of the northeast trade winds in the transport of steam and moisture which condense and form clouds causing rains. From moderate to strong, formations of instability lines, orography and their local and regional contributions in accordance with [33].

The average monthly precipitation data of the municipalities in the studies were characterized as a period of climatological normal, where the software was used in electronic spreadsheets to extract the values of the monthly, annual averages of precipitation from the period from 1920 to 2018. Data were provided by the Pernambuco State Water and Climate Agency [4] and by the Northeast Development Superintendence [54; 23].

Average air temperature values for the municipality of São Bento do Una were used and estimated by the software Estima_T [10; 11]), since the aforementioned municipality does not have the equipment to carry out such an observation. Estima_T is a software for estimating air temperatures in the NEB Region. The coefficients of the quadratic function were determined for the monthly average temperatures as a function of the local coordinates: longitude, latitude and altitude according to the authors [11] given by:

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

Where: C0, C1,...., C9 are the constants; λ, λ2, λ Ø, λ h longitude; Ø, Ø2, λ Ø latitude; h, h2, λ h, Ø h height.

For the municipality of Serra Talhada, the compensated air temperature data were acquired from the database of the National Institute of Meteorology of the conventional station operating in the municipality of Serra Talhada.

The method of [58; 59] was used to calculate the sequential water balance on a monthly scale for the areas of the municipalities of São Bento do Una and Serra Talhada, that is, the sequential water balance, elaborated from of the climatological normals of temperature and average precipitation. This technique is the most used to work with global water balance data from a climatological point of view. 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 BH 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 [8].

In the calculations to obtain the BHS, the CAD value representative of the soils found in the study region was used - CAD = 100 mm for a soil with high storage capacity, such as alluvial soils in the municipalities. The calculations of the sequential water balances (BHs) were performed using an electronic spreadsheet prepared by [47; 40].

3. Results and discussion

The rainfall fluctuations in the municipality of São Bento do Una can be seen in Table 1, which provides subsidies for the delimitation of the basic statistical parameters. The rainy season starts in February and lasts until July with an average of 74.6 mm. The dry period corresponds to the months of August to January with an average rainfall of 26.3 mm. The rainy quarter focuses on the months of March, April and May with an average rainfall of 85.4 mm and the dry months are September, October and November with an average rainfall of 20.2 mm. The average annual rainfall of 605.4 mm. The maximum absolute rainfall recorded was 1079.9 mm in the year 1966, its maximum absolute fluctuations ranged from 105.7 mm in the month of August of the year 1922 to 332.5 mm in the month of April of the year 1985. The fluctuations Absolute minimum rainfall ranged from 0.1 mm in the year 1949 to 9.4 mm in the month of July 1930. The absolute minimum annual rainfall was 227.8 mm in the year 2012. The median variability ranges from 0.0 mm in the months of November and December of the year 1970 to 104.3 mm in the month of March of the year 1979, with a total year of 486.6 mm in the aforementioned year [40]. The absolute maximum and minimum values have the possibility of return between six to eighteen months. Similar studies were developed by [31; 26] and corroborate the results presented.

Galvani (2011) in his studies on the standard deviation showed that it is extraordinary to have information on the “degree of dispersion of the values in relation to the mean value”. The coefficient of variance that is used to make comparisons in relative terms and expresses “the variability of each data set normalized in relation to the mean, in percentage.”

The rainfall variability of the municipality of Serra Talhada are visible in Table 2 which provided subsidies for the delimitation of the basic statistical parameters. The rainy season in the municipality of Serra Talhada begins in December with pre-season rains (rain that precedes the rainy season) and ends at the end of May, with an average of 86.1 mm. The dry period comprises the months from June to November with an average rainfall of 16.5 mm. The rainy quarter focuses on the months of February, March and April with an average rainfall of 119.2 mm, the dry quarter corresponds to the months of August, September and October with an average rainfall of 8.6 mm. The average annual rainfall of 633.8 mm. In accordance with the authors [6; 18], the Coefficient of Variation (Coef. Var.) Is continuously higher than 25% in dry regions, exceeding by up to 40% along the desert areas, thus showing the climatic and ecological fragility of the studied area. The Coefficient of Variance. It ranged from 2.33 in August to 0.65 in March with 0.38 annually. The annual rainfall is 633.8 mm and its buoyancy ranges from 5.2 mm in September to 144.5 mm in March. Between December and May, rainfall accounts for 78.7% of the annual rainfall and in the months of June to November, annual rainfall contributes 16% of its annual value. The annual median is equal to the rainfall rates, its monthly fluctuations fluctuate between 8.1 mm in October, and 165.5 mm in February, the median valuesare not more likely to occur than the average [1]. Standard deviations range from 12.1 mm in September to 94.2 mm in March with an annual value of 241.3 mm. The annual absolute minimum rainfall was 110.9 mm in the year 1958. The fluctuations in the absolute maximum rainfall values flow from 100.4 mm in September to 491.9 mm in the month of February, with a maximum value of 1645.1 mm in the year 1985. These fluctuations are available in Table 2.

Table 1 Statistical parameters of rainfall (mm) between the years 1920-2018 in the municipality of São Bento do Una - PE

Parameters/ months	Mean	Median	Standard deviations	Coefficient of variance	Absolute maximum rainfall	Absolute minimum rainfall
January	39.8	63.1	41.5	1.0	217.2	0.0
February	53.6	13.8	49.2	0.9	233.7	0.5
March	91.0	104.3	70.4	0.8	305.9	0.1
April	84.2	62.7	61.9	0.7	332.5	4.6
May	81.0	49.3	51.3	0.6	263.6	0.8
June	73.7	47.9	47.5	0.6	292.8	4.0
July	64.0	97.6	36.9	0.6	189.8	9.4
August	32.9	23.4	21.1	0.6	105.7	2.4
September	20.0	6.1	18.5	0.9	112.6	0.0
October	19.2	18.4	27.0	1.4	150.3	0.0
November	21.4	0.0	36.2	1.7	287.5	0.0
December	24.6	0.0	35.8	1.5	259.2	0.0
Annual	605.4	486.6	190.8	0.3	1079.9	227.8

Source: Medeiros (2022).

Table 2 Statistical parameters of rainfall (mm) between the years 1920-2018 in the municipality of Serra Talhada – PE

Parameters/ months	Mean	Median	Standard deviations	Coefficient of variance	Absolute maximum rainfall	Absolute minimum rainfall
January	78.7	72.6	78.0	1.0	452.5	0.0
February	106.3	165.5	78.2	0.7	491.9	0.0
March	144.5	83.0	94.2	0.7	434.0	0.0
April	106.8	96.0	76.8	0.7	368.6	0.0
May	48.4	77.5	46.7	1.0	223.3	0.0
June	26.9	18.0	28.5	1.1	141.6	0.0
July	16.9	27.8	19.3	1.1	84.2	0.0
August	7.9	42.8	18.3	2.3	112.1	0.0
September	5.2	8.1	12.1	2.3	100.4	0.0
October	12.6	42.5	22.7	1.8	123.4	0.0
November	29.4	0.0	40.8	1.4	165.7	0.0
December	50.1	0.0	51.9	1.0	246.9	0.0
Annual	633.8	633.8	241.3	0.4	1645.1	110.9

Source: Medeiros (2022).

The World Meteorological Organization suggests that in comparative studies of climate, the average series should be used for periods with more than 30 years of observations, for that the data need to have consistency and homogeneity in their comparison between their values analyzed.

[56] Showed that information on the climatic elements of a given region is essential so that strategies can be developed aiming at correct guidelines on natural resources, seeking to find sustainable expansion and applying new viable and safe agricultural techniques for local biomes.

Table 3 shows the statistical parameters of the average air temperature (°C) between the years 1920-2018 in the municipality of São Bento do Una - PE. The annual average temperature is 22 °C and its monthly oscillations fluctuate between 19.5 °C in the month of July to 23.5 °C in the months of December and January. Between 19.7 °C and 24.3 °C in the month of December. The standard deviation flow between 0.3°C to 0.4°C with an annual rate of 0.3°C. The variance coefficients fluctuate between 0.012 °C in the month of April to 0.016 °C in the month of December with an annual coefficient of 0.012 °C.

Table 3 Statistical parameters of the average air temperature (°C) between the years 1920-2018 in the municipality of São Bento do Una – PE

Parameters/ months	Mean	Median	Standard deviation	Coefficient of Variance	Absolute maximum temperature	Absolute minimum temperature
January	23.5	23.7	0.4	0.015	24.6	22.7
February	23.4	23.6	0.3	0.014	24.5	22.8
March	23.2	23.3	0.3	0.013	24.2	22.7
April	22.8	23.0	0.3	0.012	23.6	22.3
May	21.6	21.9	0.3	0.013	22.4	21.0
June	20.4	20.7	0.3	0.014	21.0	19.8
July	19.5	19.7	0.3	0.014	20.1	18.9
August	19.7	19.9	0.3	0.014	20.4	19.2
September	20.8	21.1	0.3	0.014	21.6	20.2
October	22.3	22.8	0.3	0.014	23.2	21.6
November	23.2	23.8	0.4	0.015	24.2	22.4
December	23.5	24.3	0.4	0.016	24.6	22.6
Annual	22.0	22.3	0.3	0.012	22.6	21.4

Source: Medeiros (2022).

The variability of the maximum absolute temperature ranged from 20.1 °C in July to 24.6 °C, recording 22.6 °C in the annual value. The maximum temperature of the absolute maximum recorded was 32.4 °C in the year 1997 and the maximum minimum temperature was 24.8 °C in the year 1956. The annual minimum temperature was recorded in the year 1960 with 21.4 °C. The minimum maximum temperature was 20.5 °C in the year 1998, which occurred in the months of January and February. [30; 31; 39] corroborates the results of this study.

[46; 44] showed that fluctuations in the indices of maximum and minimum air temperatures remain integrated with the amount of solar energy received, cloud cover, relative humidity of air and soil, wind and the parameters orography, altitude and local latitude.

Table 4 shows the variability of the statistical parameters of the average air temperature (°C) between the years 1920-2018 in the municipality of Serra Talhada - PE. The average temperature ranges from 23.3 °C in July to 26.8 °C in December, with an annual average temperature of 25.3 °C. The annual median is 25.5 °C and its fluctuations occur between 23.6 °C in July and 26.7 in December. The most likely values to occur in the future are the median values as they are normally symmetrical. Studies such as those of the authors [26; 30; 31; 40] corroborate the results of this study.

In Serra Talhada, the annual standard deviation is 0.46 mm and its monthly oscillations fluctuate between 0.40 in July and 0.59 in December. Coef. Var ranges from 0.017% in July to 0.022 in December with its annual value of 0.018%.

Table 4 Statistical parameters of the average air temperature (°C) between the years 1920-2018 in the municipality of Serra Talhada - PE

Parameters/ months	Mean	Median	Standard deviation	Coefficient of Variance	Absolute maximum temperature	Absolute minimum temperature
January	26.5	27.2	0.51	0.019	27.7	25.6
February	25.8	26.4	0.49	0.019	27	25
March	25.3	25.8	0.5	0.02	26.6	24.7
April	25.1	25.5	0.45	0.018	26.3	24.5
May	24.4	24.8	0.43	0.018	25.5	23.6
June	23.6	24	0.44	0.018	24.7	22.8
July	23.3	23.6	0.4	0.017	24.4	22.6
August	24	24.2	0.47	0.019	25.2	23.3
September	25.3	25.4	0.48	0.019	26.5	24.5
October	26.4	26.2	0.52	0.02	27.7	25.4
November	26.7	26.5	0.57	0.021	28.2	25.8
Decembe	26.8	26.7	0.59	0.022	28.2	25.7
Annual	25.3	25.5	0.46	0.018	26.5	24.5

Source: Medeiros (2022).

The annual absolute maximum temperature is 26.5 °C and its monthly oscillations occur between 24.4 °C in July and 28.2 °C in November and December. The annual absolute minimum temperature is 24.5 °C and its monthly oscillations occur between 22.6 °C in July and 25.7 °C in December.

The Climatological Water Balance was conceived to use climatic data, aiming at the climatic comparison between regions in the USA [58; 59]. However, the Climatological Water Balance and the Sequential Water Balance can be used in agroforestry planning and studies of territorial vocation, such as: identifying sowing dates with lower average occurrence of days with water surplus for crops [25] ; to subsidize the agricultural planning of a region by spatializing water deficiencies according to the CAD [9; 15] feasibility studies of agroforestry enterprises [45]; hydro-agricultural and environmental studies of hydrographic basins [50]; Climate change studies [16; 4]. They can also support the management of agricultural and tourist activities, identifying the most favorable times for activities, Agricultural Zoning of Climate Risk [41].

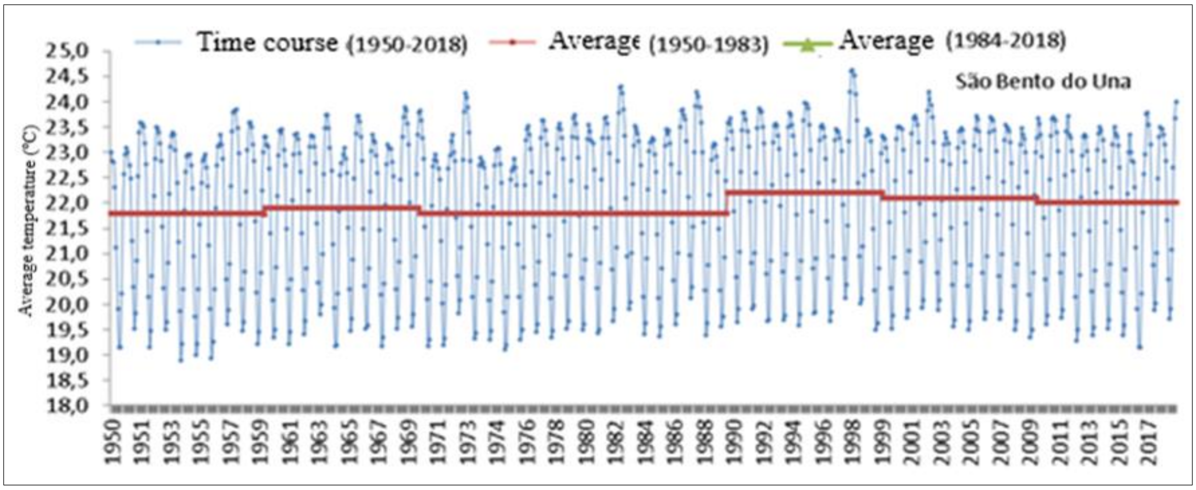
The computations of the sequential water balances correspond to the period from 1950 to 2018 for the municipalities of São Bento do Una and Serra Talhada, where we seek to understand their fluctuations and variability, which are represented in the Figures below.

After performing the computation of the BHS, the elements Average temperature, precipitation, evaporation, evapotranspiration were separated and graphs of water deficiencies and surpluses were prepared to better visualize their fluctuations and understand the decadal oscillations as shown below.

It should be noted that for each decade discussed and presented, the average maximum and minimum thermal values were not detailed year-to-year monthly fluctuations, as the text would be intense and tiring to read. The richness of details can be seen in Figure 2 and 3.

Figure 2 shows the average air temperature fluctuations between the years 1950-2018 and the decadal averages (1950-1959; 1960-1969; 1970-1979; 1980-1989; 1990-1999; 2000-2009; 2010 -2018) in the municipality of São Bento do Una - PE.

In the decade 1950-1959, the average annual temperature recorded was 21.8 °C and the maximum temperature oscillations of 23.9 °C in the year 1958 and the minimum temperature of 19 °C recorded in the years 1955 and 1956. From 1960-1969 there was an increase in the average temperature of 0.1 °C compared to the previous decade. The maximum temperature of the decade 1960-1969 was 23.9 °C recorded in the year 1969 and the minimum temperature occurred in the year 1963 with 19.8 °C. With an average temperature of 21.8 °C and its maximum temperature of 24.2 °C in the year 1972 and minimum temperature of 19.9 °C in the year 1973 were recorded in the decade of 1970-1979. Comparing the climatic decadal increases, an average temperature of 0.1°C in the 60's is recorded in the 50's and 70's. The 80's recorded an average temperature of 21.9°C, with maximum temperature in the years 1982 and 1983 (24.3 °C). The decadal minimum temperature (19.4°C) was recorded in 1981; 1984 and 1988. With an average temperature of 22.2 °C in the 1990s, a maximum temperature of 24.6 °C in the years 1987/1998 and a minimum temperature of 19.5 °C in 1999. The 2000s had a temperature average of 22.1°C and its maximum and minimum temperatures recorded were: 24.2°C in the year 2002 and 19.4°C (2009), respectively. In the 2010s, the maximum and minimum temperatures recorded occurred in the years 2017 (23.8 °C) and 19.2 °C in the year 2016, with a decadal average of 22.0 °C.



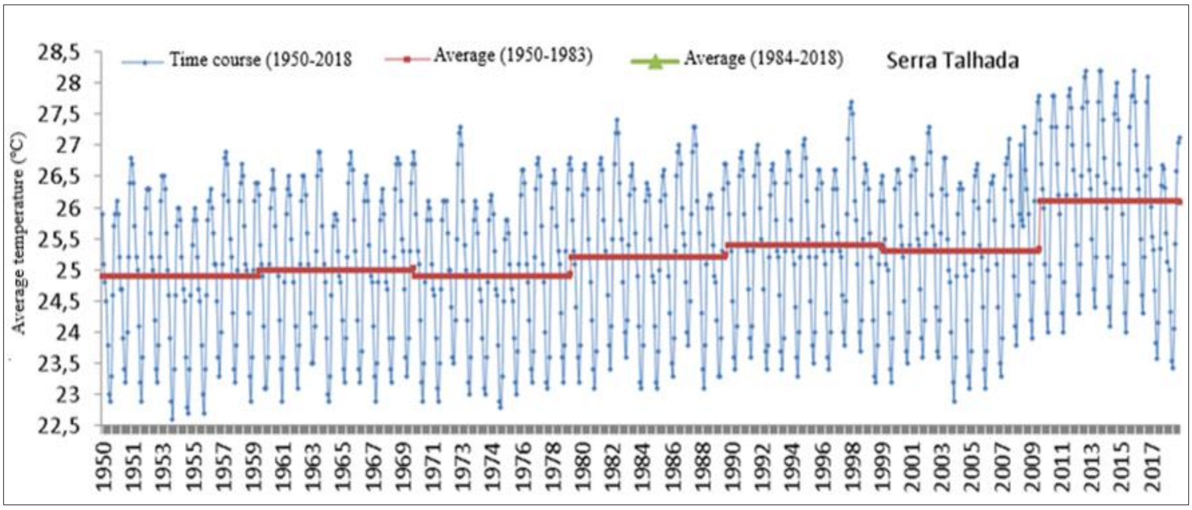
Source: Medeiros (2022)

Figure 2 Variability of the average air temperature between the years 1950-2018 and the decadal averages (1950-1959; 1960-1969; 1970-1979; 1980-1989; 1990-1999; 2000-2009; 2010-2018) in municipality of São Bento do Una - PE

Such oscillations have been reported in studies by [26; 29; 31 and 39].

Figure 3 highlights the variability of the average air temperature between the years 1950-2018 and the decadal averages (1950-1959; 1960-1969; 1970-1979; 1980-1989; 1990-1999; 2000-2009; 2010 -2018) in the municipality of Serra Talhada - PE.

The air temperature has spatial variation in areas resulting from several factors, among which the use and occupation of the soil, vegetation and orography stand out. In the 1950s, an average decadal temperature of 24.9 °C was recorded, with maximum and minimum oscillations occurring between 26.9 °C (1957) and 22.6 °C (1954). In the 60's the thermal oscillations fluctuated between 22.9 °C in the years 1961; 1964 and 1967 at 26.9°C in the years 1963; 1965 and 1969 with an average decadal temperature of 25.0 °C. With an average decadal temperature of 24.9 °C and its maximum and minimum oscillations flowed between 27.3 °C (1972) and 22.8 °C (1975). The maximum temperature recorded in 1982 was 27.4 °C in 1981; 1984; 1985 and 1988 recorded a minimum temperature of 23.1 °C in the 1980s. In the 90s with extreme temperatures (maximum and minimum) ranging from 27.7 °C (1997) to 23.2 °C (1999) and with an average temperature of 25.4 °C. In 2009, a maximum temperature of 27.8 °C was recorded and its minimum temperature was recorded in 2004 with 22.9 °C and an average decadal temperature of 25.3 °C. In the 2010s, the average temperature was 26.1 °C with its maximum and minimum oscillations flowing between 28.2 °C in the years (2012; 2013 and 2016) to 23.4 °C in the year 2018.



Source: Medeiros (2022)

Figure 3 Mean air temperature variability between the years 1950-2018 and decadal averages (1950-1959; 1960-1969; 1970-1979; 1980-1989; 1990-1999; 2000-2009; 2010-2018) in municipality of Serra Talhada - PE

In the 1950s and 1970s, the average temperature recorded was 24.9 °C, comparing these two decades with the others studied, an increase of 0.1 °C in the 60s stands out; 0.3°C at 80; 0.5°C at 90; 0.4 °C in 2000 and 1.2 °C in the last decade in the municipality of Serra Talhada - PE,

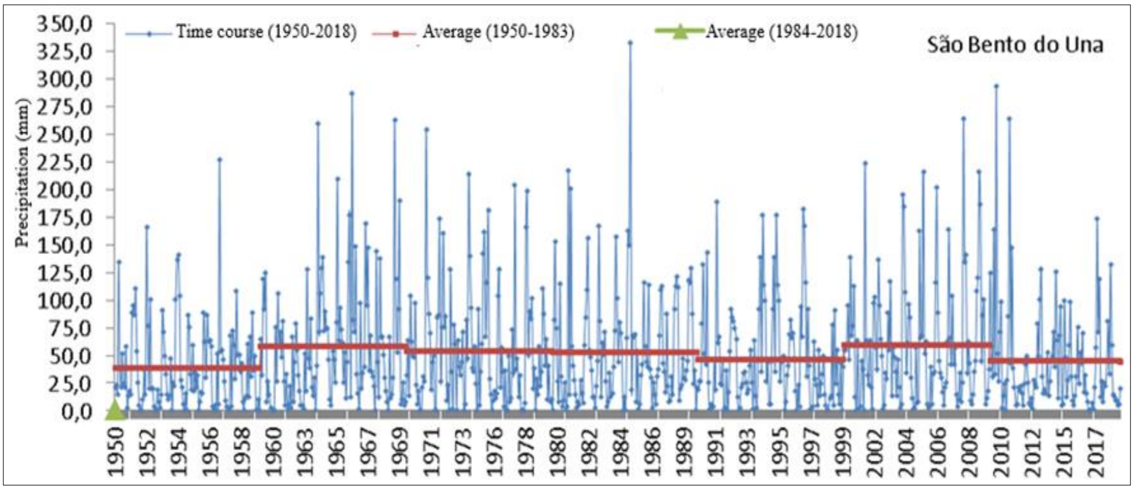
The thermal variability for the municipality of Serra Talhada is of greater intensities than those verified in São Bento do Una.

[5; 48] stated that in the past four decades, experts understood that the finitude of natural resources associated with the fragility of ecosystems on planet Earth would not support the pace of economic growth imposed by humanity. [28] explains that the increase in temperature influences the loss of soil moisture, as a consequence of the increase in evapotranspiration. These studies corroborate the results of the research in discussions.

The BHS provides detailed information on the thermal variability of the period studied, generating important information for governmental decision makers and for the developers of livestock, agricultural, agribusiness projects and for a sustainable development of poultry production in São bento Una.

Figure 4 shows the variability of rainfall between the years 1950-2018 and the decadal averages (1950-1959; 1960-1969; 1970-1979; 1980-1989; 1990-1999; 2000-2009; 2010-2018) in the municipality of São Bento do Una - PE. With an average decadal rainfall (1950-1959) of 38.6 mm and it's maximum and minimum variability from 226.7 mm (1957) to 0.0 mm in all years of the decade. In the 60s, a decadal average of 58.1 mm was recorded and the maximum precipitation occurred in 1966 with 286.2 mm and the minimum precipitation between the years of 1960; 1967; 1968 and 1969 without occurrences of rainfall. The minimum rainfall was only recorded in 1979, the maximum rainfall occurred was 254.3 mm in 1971 with an average of 54 mm for the 70's. The 80's recorded an average rainfall of 53.2 mm and the maximum values of precipitation occurred in the year of 1985 with 332,5 mm and the minimum values (0,0 mm) in the years of 1980; 1984; 1985; 1989. In the 1990s, the historical average rainfall was 46.1 mm, its maximum rainfall occurred in 1991 with 188.2 mm, the 1990s; 1993 and 1994 registered minimum rainfall of 1.6 mm; 2.0 and 2.6 mm respectively. The 2000s recorded maximum rainfall in 2008 with 264.1 mm and minimum rainfall in the demi years, except for the year 2000 when its value was 0.0 mm, that is, without occurrence rains. In the 2010s, the average precipitation was 44.6 mm, minimum rain of 0.4 mm in 2016 and in the other years without occurrence of record the maximum precipitation was 292.8 mm in the year 2010.

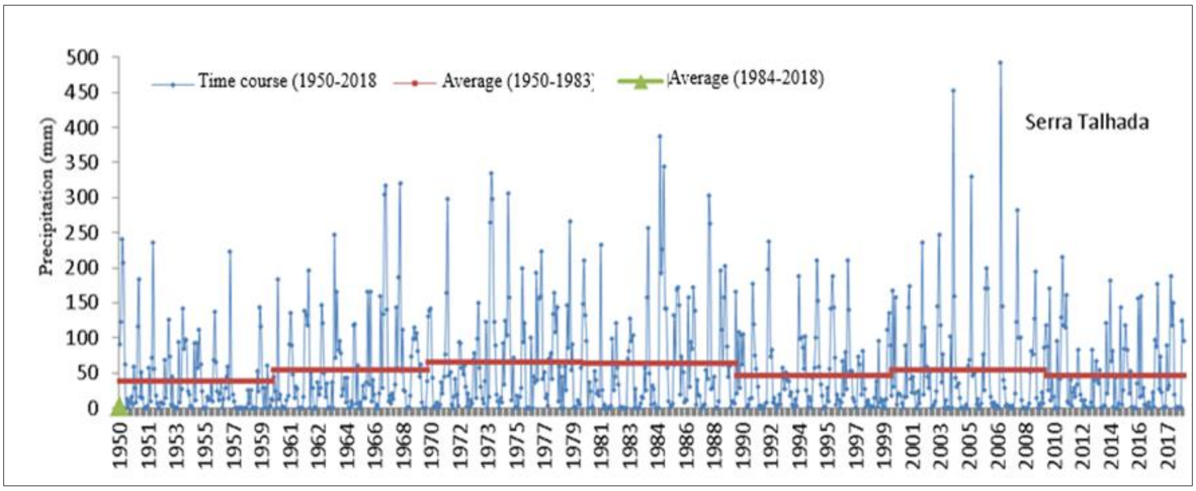
A summary of the mean values of rainfall by decade was: 50 with 38.6 mm; 60 with 58.1 mm; 70 with 54.0 mm; 80 with 53.2 mm; 90 with 46.1 mm; 2000 with 59.1mm and 2010 with 44.6mm. Study such as the [19; 18; 17 and 29 contribute to the results of the values found in this study.



Source: Medeiros (2022)

Figure 4 Variability of rainfall between the years 1950-2018 and decadal averages (1950-1959; 1960-1969; 1970-1979; 1980-1989; 1990-1999; 2000-2009; 2010-2018) in the municipality of São Bento do Una – PE

Figure 5 shows the fluctuations in rainfall variability between the years 1950-2018 and decadal averages (1950-1959; 1960-1969; 1970-1979; 1980-1989; 1990-1999; 2000-2009; 2010-2018) in the municipality of Serra Talhada - PE. In the 1950s, the average decadal precipitation was 38.3 mm, maximum precipitation was 240.4 mm in the year 1950, minimum precipitation was not recorded in all years, and that is, it did not rain. Every year, the maximum rainfall was 319.7 mm with an annual average of 54.6 mm. With a maximum rainfall of 334.0 mm in the year 1974 and in the years 1972 and 1997 without occurrence of rain, totaling 64.8 mm of average decadal precipitation (1970). In the 80's, an average rainfall of 63.6 mm was recorded, with maximum precipitation occurring in 1985, totaling 387.5 mm, in 1985 and 1986 there were no minimum rainfall indices. There were no minimum rains, that is, it rains every day. The maximum precipitation in the 90's was 237 mm in the year 1992. The average decadal precipitation is 46.4 mm. In the 2000s, the maximum rainfall was 452.5 mm with an annual decadal average of 55.1 mm. With a historical average rainfall of 46.0 mm and a maximum rainfall of 215.3 mm in 2011, these were the fluctuations of the 20.



Source: Medeiros (2022)

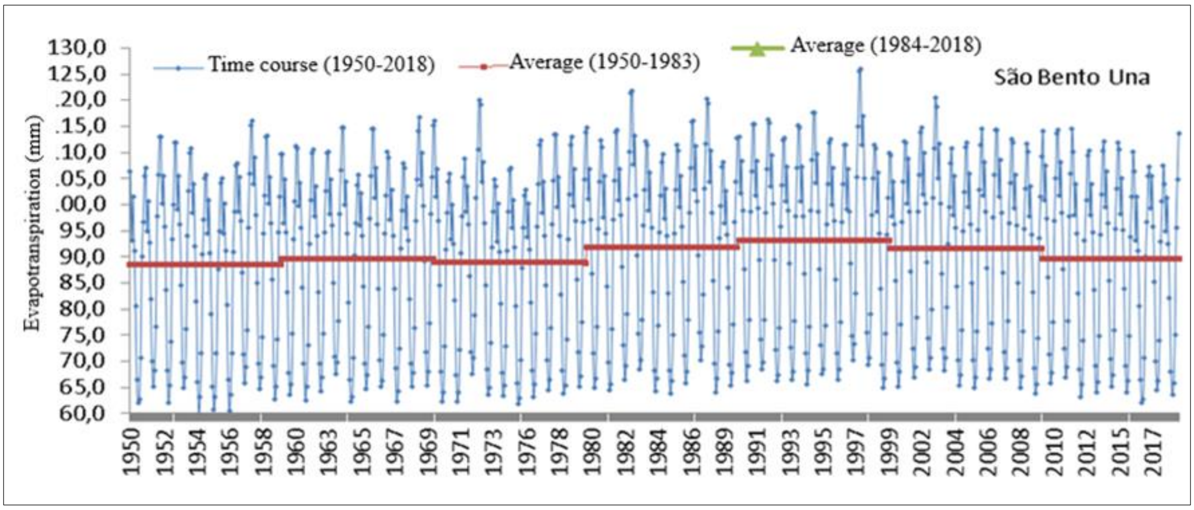
Figure 5 Variability of rainfall between the years 1950-2018 and decadal averages (1950-1959; 1960-1969; 1970-1979; 1980-1989; 1990-1999; 2000-2009; 2010-2018) in the municipality of Serra Carved – PE

The fluctuations or rainfall intensities for São Bento do Una are more irregular and of short time intervals than those recorded in Serra Talhada.

The oscillations of decadal rainfall rates flowed as follows in the decades studied for the municipality of Serra Talhada: 50 with 38.3 mm; 60 with 54.6 mm; 70 with 64.8 mm; 80 with 63.6 mm; 90 with 46.4 mm; 2000 with 55.1 mm and 2010 with 46.0 mm.

The consumption of how much is actually being evapotranspiration is expressed by the potential evapotranspiration (ETP), which behaves similar to the rainfall distribution. These fluctuations occur due to oscillations between the dry and rainy periods, it is also recalled that the movements of the factors that provoke and/or inhibit rain depend exclusively on large, meso and large-scale elements, as well as the contributions of local effects, for, for example, the positioning of the Intertropical Convergence Zone; the performance of High Level Cyclonic Vortices, the dipole, the intensities of the trade winds, among other elements [39].

The evapotranspiration oscillations of São Bento do Una can be seen in Figure 6, the evapotranspiration rates between the years 1950-2018, range from 60 mm to 125 mm, in the decadal averages they register irregularities as can be seen in the red line (decadal averages). In the 50's; 70 and 2010 their averages were reduced between 0.5 mm and in the 60s; 80 and 90, there was an increase in the evapotranpirative indexes. These fluctuations were due to the meso and large scale phenomena that sometimes acted or not with more regularity, the wind and temperature elements were the ones that most contributed to these oscillations of increase and reduction in the indices as stated by [42].



Source: Medeiros (2022)

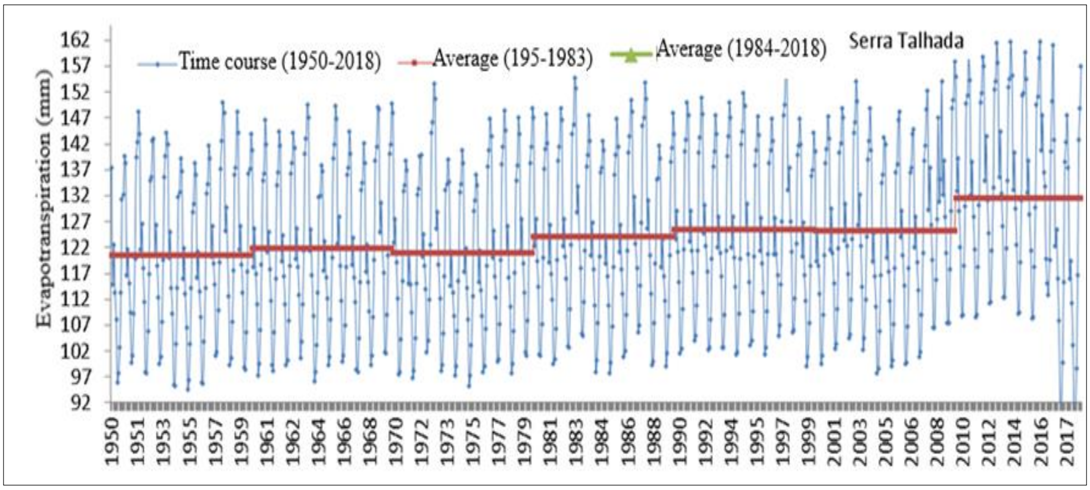
Figure 6 Variability of evapotranspiration between the years 1950-2018 and decadal averages (1950-1959; 1960-1969; 1970-1979; 1980-1989; 1990-1999; 2000-2009; 2010-2018) in the municipality of São Bento do Una – PE.

[27] showed that in the NEB region it is naturally distinguished by the high evaporative water potential in performance of the wide availability of solar energy and high temperature fluctuations. Temperature increases associated with climate change resulting from global warming, regardless of what may happen with the rains, would already be enough to cause greater evaporation from lakes, dams and reservoirs and greater evaporative demand from plants. That is, unless there is an increase in rainfall, water will become a scarcer commodity, with serious consequences for the sustainability of regional development.

Figure 7 shows the fluctuations in evapotranspiration between the years 1950-2018 and the decadal averages (1950-1959; 1960-1969; 1970-1979; 1980-1989; 1990-1999; 2000-2009; 2010-2018) in the municipality of Serra Talhada - PE.

For the 1950s; 1970 reduced evapotranspiration in its climatology. In the 1960s; 1980; nineteen ninety; 2000 and 2010 there was an increase in the evapotranspired power, these increases are related to increases in thermal indices and winds in the region (31; 19].

The evapotranspiration variability between the municipalities of São Bento de Una and Serra Talhada can be seen its fluctuations in the representative figures.



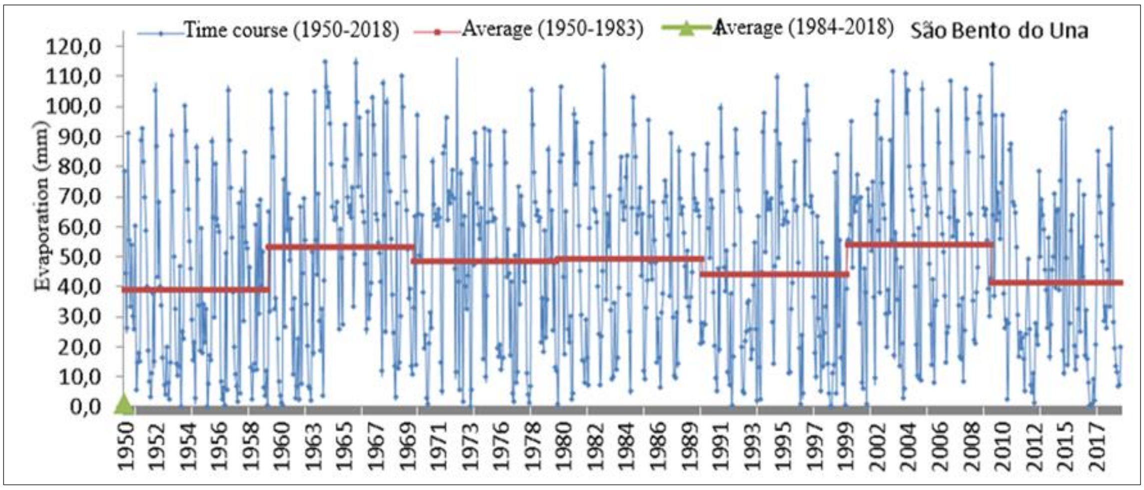
Source: Medeiros (2022)

Figure 7 Variability of evapotranspiration between the years 1950-2018 and decadal averages (1950-1959; 1960-1969; 1970-1979; 1980-1989; 1990-1999; 2000-2009; 2010-2018) in the municipality of Serra Carved – PE

[57] ensured that ETR, unlike ETP, satisfies a total availability of water, simulating the volume that is removed from the system by evapotranspiration and that is used in primary production by plants. Considering that the EVR is the one that occurs in the real conditions to which the plant is subjected, with no satisfactory water availability and uniform vegetation on the surface, a direct relationship between the rainfall indices and the EVR is verified, with the lowest EVR indices being relate to low rainfall and higher EVR rates to high rainfall. This statement by Sales reaffirms the oscillation values found in this article.

[42] stated that an increase in air temperature increases evaporation and evapotranspiration rates, causing water deficit and changes in the hydrological cycle. This result demonstrated by the authors corroborates the study under development.

In Figure 8. Variability of evaporation between the years 1950-2018 and decadal averages (1950-1959; 1960-1969; 1970-1979; 1980-1989; 1990-1999; 2000-2009; 2010-2018) in the municipality of São Bento do Una – PE. The 1950s; 1970; 1980; 1990 and 2010 recorded reductions of up to 20 mm in their evaporated indices, these reductions were caused by rainfall reduction or by regional rainfall irregularities that did not reach their normal standard caused by the blocking systems.

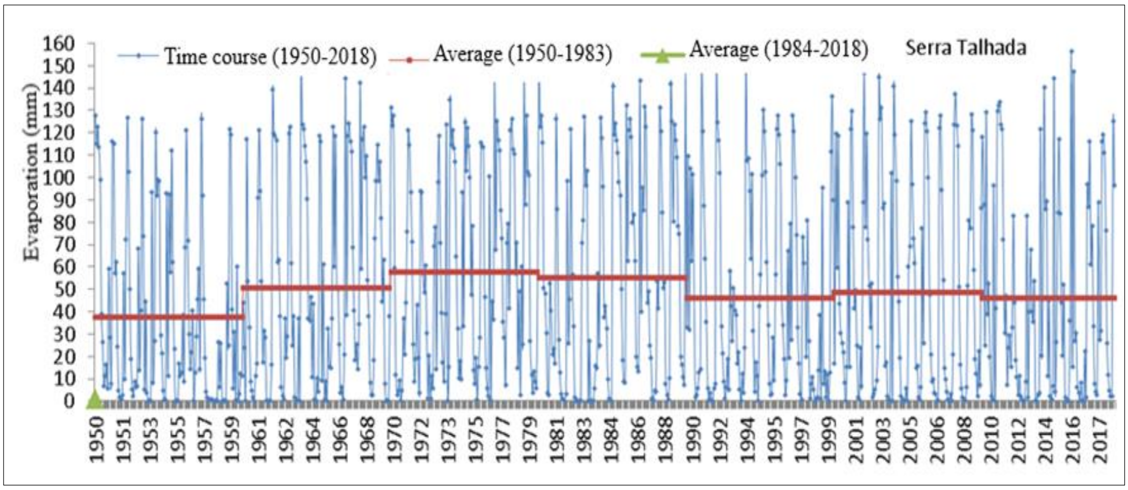


Source: Medeiros (2022)

Figure 8 Variability of evaporation between the years 1950-2018 and decadal averages (1950-1959; 1960-1969; 1970-1979; 1980-1989; 1990-1999; 2000-2009; 2010-2018) in the municipality of São Bento do Una – PE

The evaporative indices of Serra Talhada (Figure 9) show average reductions for the 1950s, 1990s and 2010s, these reductions were caused by atmospheric blockages in the rain-causing systems.

Between the 1950s and 1960s, there were 10 mm reductions in its climatology; increase of 7.5 mm between the 1960s and 1970s; reduction of 0.5 mm between the 1970s-1980s and in the 1980s-1990s a reduction of 10 mm, a small evaporative increase in the 2000s and a reduction in the 2010s. These oscillations corroborate the studies by [26; 19].

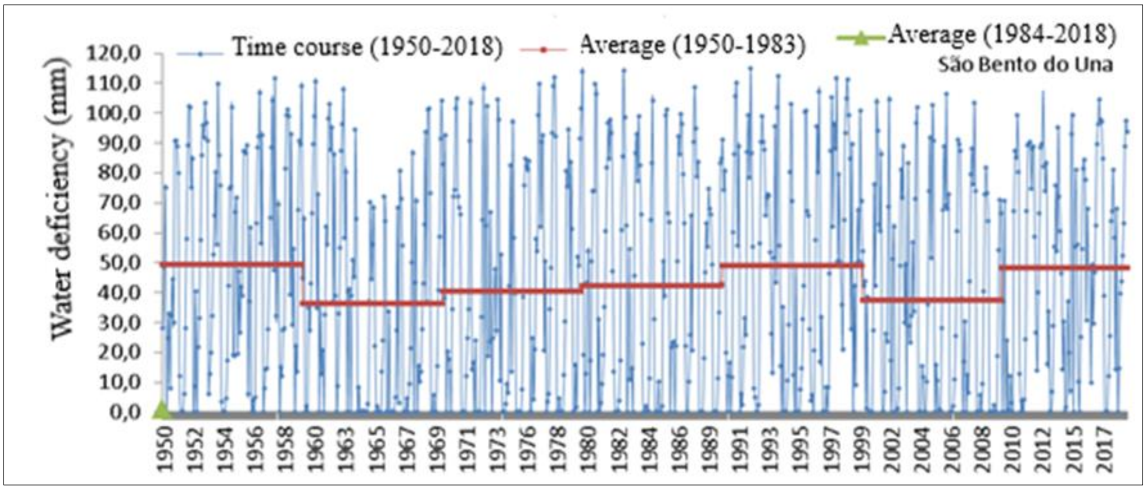


Source: Medeiros (2022)

Figure 9 Variability of evaporation between the years 1950-2018 and decadal averages (1950-1959; 1960-1969; 1970-1979; 1980-1989; 1990-1999; 2000-2009; 2010-2018) in the municipality of Serra Carved – PE

[57] explains that the availability of water in the soil is influenced by thermal fluctuations and the spatiotemporal distribution of rainfall.

The distribution of water deficit can be seen in Figure 10. Water deficiencies range from 0 mm to 108.6 mm, with emphasis on the first two decades and between the years 1980-2000, which recorded the greatest variability of water deficits. These variabilities were caused by the low rainfall and its irregularities in some years for the rainy season.



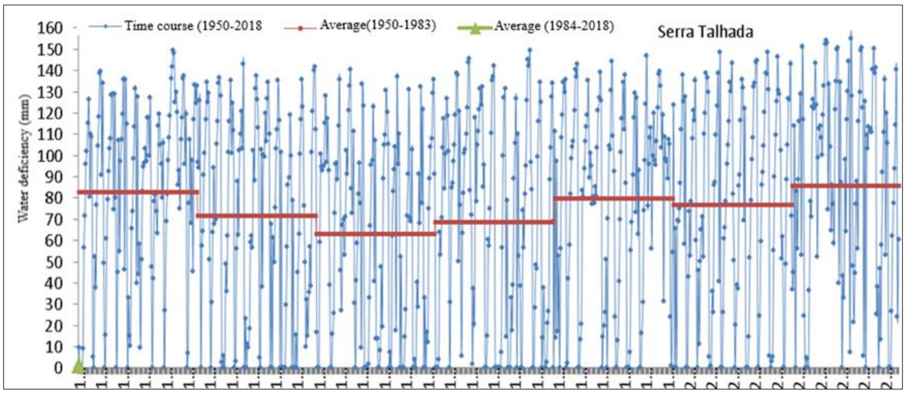
Source: Medeiros (2022)

Figure 10 Variability of water deficit between the years 1950-2018 and decadal averages (1950-1959; 1960-1969; 1970-1979; 1980-1989; 1990-1999; 2000-2009; 2010-2018) in the municipality of São Bento do Una – PE

[8] showed that to assess whether a region has a deficiency or excess of water during the year, two elements should be considered: precipitation, responsible for increasing soil moisture, and evapotranspiration, responsible for removing moisture from the soil.

The years that showed deficiencies are: 1953; 1955; 1973; 1993 and 2012 these deficiencies are related to atmospheric fluctuations causing or inhibiting rain in the region. It should also be noted that the rainfall that occurred were not enough to restore the field capacity (100 mm).

In general, both for São Bento do Una and for Serra Talhada, the deficiencies as a whole were practically the same in their sizing, that is, the decadal oscillations have the same formats for both areas studied.

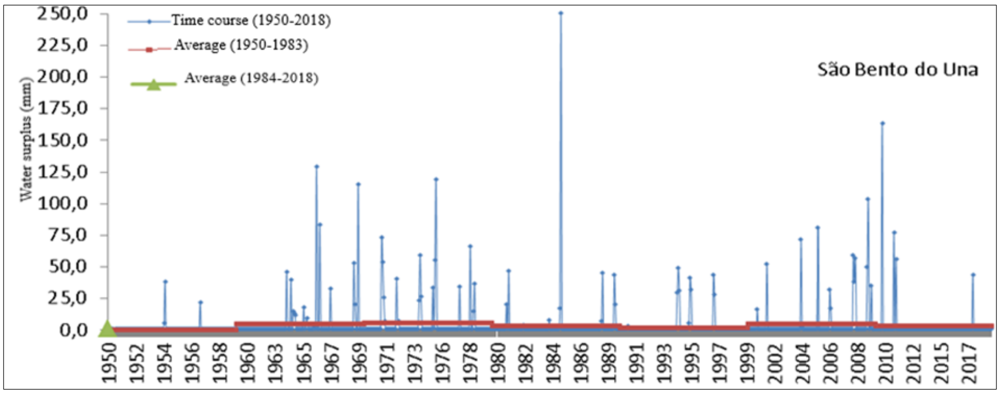


Source: Medeiros (2022)

Figure 11 Water deficit variability between the years 1950-2018 and decadal averages (1950-1959; 1960-1969; 1970-1979; 1980-1989; 1990-1999; 2000-2009; 2010-2018) in the municipality of Serra Talhada - PE

[45] stated that fluctuations in water shortages, integrated with periods of prolonged drought during the rainy season, are one of the causes of grain harvest reductions in Brazil and for there to be a reduction in their losses for farmers, it has become it is essential to shape, quantify and map the most suitable areas for planting rainfed crops, taking into account climatic conditions and rainfall distribution.

Figure 12 shows the variability of water surplus between the years 1950-2018 and the decadal averages (1950-1959; 1960-1969; 1970-1979; 1980-1989; 1990-1999; 2000-2009; 2010-2018) in the municipality of São Bento do Una – PE. The annual totals from 1950 to 1959 flowed from 409.3 mm in the year 1954 to 708.7 mm in the year 1953, with a decadal average of 0.5 mm. 118.9 mm in 1964 and its maximum surplus was recorded in 1962 with 728.6 mm. With the maximum water surplus in 1977 with 611.8 mm and its minimum of 331.1 in 1975 and with a decadal average of 5.6 mm for the 70's. The 80's recorded an average of 3.8 mm 3 its extremem oscillations were 591.4 mm in 1983 and 320.4 mm in 1985. In the 90's the water surplus ranged from 330.7 mm in 1995 to 858.6 mm in 1998 with an average of 2.2 mm. With an average of 5.1 mm and its minimum and maximum fluctuations flowed at 341.2 mm, in 2002 a 594.5 mm in 2003 were the behavior of water surpluses in the 2000s. The decade 2010 recorded a maximum water surplus of 815.6 mm in 2012 and 281.1 mm in 2010 with an average of 3.1 mm.



Source: Medeiros (2022)

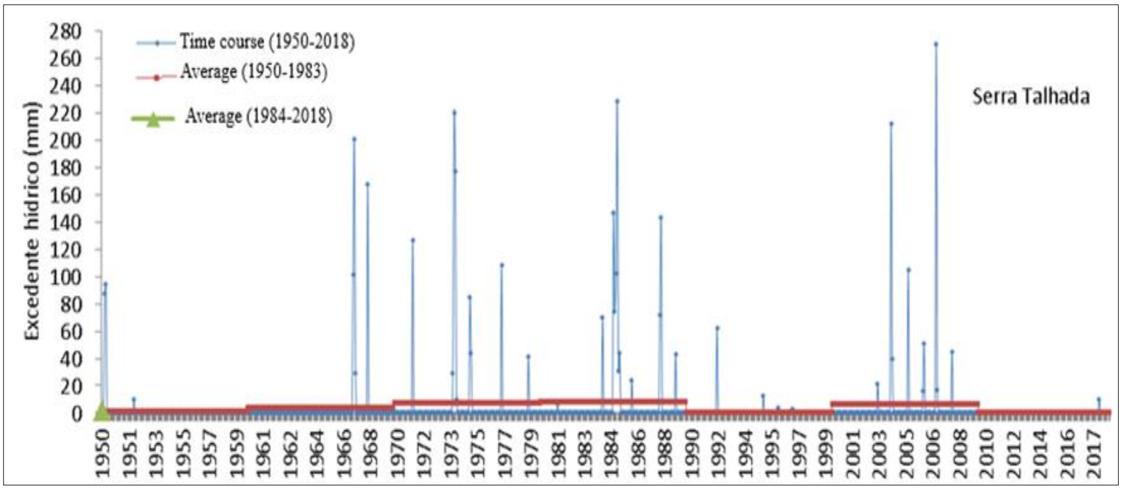
Figure 12 Variability of the water surplus between the years 1950-2018 and the decadal averages (1950-1959; 1960-1969; 1970-1979; 1980-1989; 1990-1999; 2000-2009; 2010-2018) in the municipality of São Bento do Una – PE

The monthly and irregular variability (Figure 12) that was registered in the water surpluses can be verified in the years of: 1954; 1957; 1963; 1964; 1965; 1966; 1967; 1969; 1971; 1972; 1974; 1975; 1977; 1978; 1981; 1985; 1988 1989; 1994; 1995; 1997; 2000; 2001; 2002; 2004; 2005; 2006; 2008; 2009; 2010 and 2011.

Due to the interannual rainfall irregularities recorded in the study area, the oscillations of water surpluses, which in some years did not reach field capacity, and their contributions to the storage and damming of water, stand out.

The limitation of water resources today is an important condition for socioeconomic development, causing numerous challenges to the planning and management of this resource in accordance with Sousa et al. (2015).

Figure 13 shows the variability of the water surplus between the years 1950-2018 and the decadal averages (1950-1959; 1960-1969; 1970-1979; 1980-1989; 1990-1999; 2000-2009; 2010-2018) in the municipality of Serra Talhada - PE. In the decade 1950-1959, the water surplus registered a total of 181.8 mm with a maximum value in the year 1950 of 94.1 mm, in the year 1952 it totaled 10 mm and its maximum value was 10 mm with a decadal average of 1.6 mm In the 60s its maximum recorded was 200.5 mm totaling 330.8 mm, in 1968 it totaled 167.8 mm and the same value for the maximum EXC. Its decadal mean was 4.2 mm. With an average of 7 mm and recording a monthly total of 435.6 mm in 1974, with a maximum value of 219.3 mm. With an average of 7 mm and its maximum EXC of 219.3 in the year 1974 totaling 435.6 mm were the variabilities of the 70's. The 80's was characterized with an average of 8.2 mm with a total of 626.0 mm in 1985 and with a maximum value of 228.7 mm. The 90's has an average of 0.7 mm and its maximum value and the annual total was 61.9 mm in 1992. In 2007, the water surplus totaled 286.8 mm with a maximum of 269.8 mm and an average of 6.5 mm The 2010s had a surplus and a maximum value of 10.3 with 0.1 mm. It should be noted that more details should be observed in Figure 13.



Source: Medeiros (2022)

Figure 13 Variability of the water surplus between the years 1950-2018 and the decadal averages (1950-1959; 1960-1969; 1970-1979; 1980-1989; 1990-1999; 2000-2009; 2010-2018) in the municipality of Serra Talhada - PE

[39] assured that warming in semi-arid areas could cause high extreme events, such as droughts or floods, which are even more demanded and accentuated, in this way the reports to public managers are aimed at a vision of broad planning and a strengthening of participatory actions that can control, monitor and alert the general population. The authors argue that water governance should be based on principles of shared, decentralized management and broad public participation by users.

Through the computation of the BHS and its analyzes using the decadal periods presented in Table 5 for the municipality of São Bento do Una - PE, its fluctuations in the meteorological elements that make up the BHS are observed. The temperatures recorded were high in the last four decades studied, rainfall levels registered high inter-decadal irregularities, ETP increased in the 80s, 90s, 2000s, while EVR presented the highest evaporative powers in the 60s and 2000s, water shortages were reduced in the 60s and 2000s, the water surpluses followed the rainfall irregularities, highlighting the 70s and 2000s as the largest water surpluses.

Table 6 shows the decadal average variabilities of the parameters studied for the municipality of Serra Talhada. Decadal average temperatures were high in the 2010s, in the other decades there were fluctuations above the historical average.

Rainfall irregularities were recorded in all decades with less variability in the 50's. In the BHS element "ETP" evapotranspiration variability was recorded from 0.3 mm to 6.4 mm. The evaporative fluctuations of greater incidence were recorded in the 60s, 70s and 80s. Water deficiencies and excesses were registered inter-decadal irregularities as shown in Table 6.

Table 5 Decadal averages of the parameters studied for the municipality of São Bento do Una – PE

Parameters/Decades	Average Temperature (ºC)	Rain (mm)	ETP (mm)	EVR (mm)	DEF (mm)	EXC (mm)
1950-1959	21.8	38.6	88.5	38.9	49.5	0.5
1960-1969	21.9	58.1	89.7	53.3	36.5	4.9
1970-1979	21.8	54.0	88.9	48.4	40.5	5.6
1980-1989	22.2	53.2	91.9	49.4	42.5	3.8
1990-1999	22.2	46.1	93.2	44.0	49.2	2.2
2000-2009	22.1	59.1	91.6	54.0	37.6	5.1
2010-2018	22.0	44.6	89.6	41.5	48.1	3.1

LEGEND: ETP=Evapotrnaspiration; EVR=Evaporation; DEF=Water deficiency; EXC=Water surplus; Source: Medeiros (2022).

Table 6 Decadal averages of the parameters studied for the municipality of Serra Talhada

Parameters /Decades	Average Temperature (ºC)	Rain (mm))	ETP (mm)	EVR (mm)	DEF (mm)	EXC (mm)
1950-1959	24.9	38.3	120.4	37.6	82.9	1.6
1960-1969	25.0	54.6	121.9	50.4	71.4	4.2
1970-1979	24.9	64.8	120.9	57.8	63.1	7.0
1980-1989	25.2	63.6	124.1	55.3	68.8	8.2
1990-1999	25.4	46.4	125.5	45.9	79.6	0.7
2000-2009	25.3	55.1	125.2	48.6	76.6	6.5
2010-2018	26.1	46.0	131.6	45.9	85.7	0.1

LEGEND: ETP=Evapotrnaspiration; EVR=Evaporation; DEF=Water deficiency; EXC=Water surplus; Source: Medeiros (2022).

Table 7 Differences or sum between the parameters studied in the municipalities of São Bento do Una/Serra Talhada

Parameters/Decades	Average Temperature (ºC (ºC)	Rain (mm))	ETP (mm)	EVR (mm)	DEF (mm)	EXC (mm)
1950-1959	3.1 **	0.3 **	31.9 **	1.3 *	33.4 **	1.1 **
1960-1969	3.1 **	3.5 *	32.2 **	2.9 *	34.9 **	0.7 *
1970-1979	3.1 **	10.8 **	32.0 **	9.4 **	22.6 **	1.4 **
1980-1989	3.0 **	10.4 **	34.2 **	5.9 **	26.3 **	4.4 **
1990-1999	3.2 **	0.3 **	32.3 **	1.9 **	30.4 **	1.5 *
2000-2009	3.2 **	4.0 *	33.6 **	5.4 *	39.0 **	1.4 **
2010-2018	4.1 **	1.4 **	42.0 **	4.4**	37.6 **	3.0*

LEGEND: ETP=Evapotrnaspiration; EVR=Evaporation; DEF=Water deficiency; EXC=Water surplus; *= Saint Benedict Una; **= Saw Carved; Source: Medeiros (2022).

The fluctuation of water deficit is related to periods of higher and lower air temperatures and rainfall rates. The water loss from the soil is due to the influence of temperature, through the process of evapotranspiration, as well as the reduction of precipitation. [28] explains that the increase in temperature influences the loss of soil moisture, as a consequence of the increase in evapotranspiration.

Table 7 shows the differences or sum of decades between the studied parameters of the BHS in the municipalities of São Bento do Una/Serra Talhada. It should be noted that * the values were higher for the municipality of São Bento do Uma and **the referred values were increased for Serra Talhada.

These fluctuations are due to local and regional effects and the studies by Marengo et al. (2015; 2008 and 2007) and studies by Medeiros et al. (2018 and 2016) have similarities with the values found in both studies.

4. Conclusion

BHS better demonstrates seasonal variations (deficiencies and surpluses), shows more clearly the region's water conditions

The analysis of the sequential water balance showed that for years (2004 and 2010) there is sufficient rainfall to perceive excess water in the rainy season in the region, implying that this method offers greater detail for agricultural planning.

The spatio-temporal variability of precipitation evidenced in the study directly influences the socio-environmental aspects, given the region's incipient technological level and the region's economic and social dependence.

The evaporimetric and evapotranspiration variability did not follow a normal pattern between years, because the influence of synoptic transient atmospheric phenomena acting in each period was detected and proved to be important altering evaporation and evapotranspiration in the study area, and not only that, when it rains, with no adequate surface runoff and at the end of the precipitation the evaporative indices occurred on larger scales due to heat exchange.

The climatic impacts have caused changes in the water balance of the region in the last decade, since the rainfall irregularity has been occurring with strong intensities and for a short period of time, resulting in a drop in poultry, agricultural and livestock production, in water storage.

Environmental degradation, the local effect of human action, has by itself accelerated the process of modifying the regional climate, thus directly affecting the conditions of the rainfall regime and the availability of water in the soil.

It is extremely necessary to use rainwater harvesting and other storage sources for human, animal and plant survival, thus contributing to the agricultural and poultry sector in the region.

The use of rainwater harvesting systems and their application in the poultry industry is an economically viable solution, contributes to the reduction of flooding and allows springs to be used for nobler purposes.

The results presented and discussed can help the decision maker to evaluate, plan, monitor and even create land use scenarios, increasing the possibilities of information that can support public policies, differentiating regions and/or areas and enabling better adequacy. Of these policies to the realities of each locality.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest. All authors had equal participation in the development of the article.

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