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Banana growing and its climate suitability in the municipality of Recife-Pe, Brazil

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Abstract

The banana tree is a plant characteristic of the tropical region, demanding in temperatures and rainfall with good regional distribution, due to its low cost and high nutritional value, it is an integral part of the diet of populations. The objective is to analyze the climatic oscillations, from the calculation of the water balance and its climatic classification, according to the methods of Thorn Thwaite and Köppen, for the city of Recife, verifying the occurrence of the aptitude of the banana cultivar. The average rainfall and temperature data were acquired from the National Institute of Meteorology, for the period between 1962 and 2016. Banana plantations are moderate because they have a water deficit of 287.4 mm. The evaporative power registered in the municipal area is high, but the demand for irrigation complements the scarcity of water to cultivate it. The local altitude is in the range of planting of the cultivar as well as the variability of the relative humidity of the air. Wind is one of the limiting factors for commercial exploitation of banana cultivation, if the cultivars are tall and planted in sandy soils.

Keywords: Available water in the soil; Irrigation; Climatic elements; Variability Climatic

1. Introduction

The banana tree is a typically tropical plant, demanding at high temperatures and with regular or well-distributed rainfall. The optimal temperature for the development of banana plants ranges from 28 °C, temperature variations between 15.0 °C and 35.0 °C are the extreme limits for the exploitation of the culture. The banana (Musa sapientum) is a tropical fruit equally explored worldwide. Due to its low cost and high nutritional value, it is an integral part of the diet of low-income populations. Brazil is among the largest banana producers in the world, occupying the third position, with an approximate production of 6.3 million tons year-1, in 2004, occupying an area of 508 thousand hectares [6]. It is worth mentioning that this fruit is cultivated in all Brazilian states. Temperature and precipitation impose limits on the banana crop, according to the statement by [4]. Inadequate irrigation management harms the growth and development of plants, reducing their productivity. Under severe water deficit, the banana leaf rosette is compressed, making it difficult and/or preventing the release of the inflorescence and the bunch may not have commercial value as stated by [17].

To define the suitability of a region for banana cultivation, the project designer must be aware of the climatological characteristics and their seasonal variations, since the banana tree does not tolerate waterlogging, strong winds and

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average air temperatures below 15 ºC according to with [22] Due to its morphology and the hydration of its tissues, the banana tree has a high consumption of water. The largest productions are linked to an annual rainfall of 1,900 mm, with good distribution throughout the year, according to [1]. In most regions where bananas are cultivated, rainfall is insufficient to meet water needs, making it necessary to use supplementary irrigation.

Of the various irrigated tropical fruit trees, the banana plant is very sensitive to water stress, it also has a high leaf area index, which results in high transpiration; the root system is very superficial, which is why the banana is a species that presents a considerable physiological response to the scarcity of water from which they demand water throughout the year because it is a perennial crop with constant production according to the [22].

The authors [20] showed that the crops exploited in a given region depend on the regularity and amount of rainfall. The spatial and temporal variability of rainfall in arid and semi-arid regions are limiting factors for rainfed cultivation, a survival technique performed by small family farmers in the semi-arid region of northeastern Brazil [2a].

In your studies [8] shows that the variability of meteorological elements for banana cultivation in the state of Piauí. They concluded that the wind may be one of the limiting factors for the commercial exploitation of banana cultivation, if the cultivars are tall and planted in sandy soils. The fluctuations in altitude change the duration of the banana cycle, showing that there is an increase of 30 to 45 days in the production cycle of this crop for every 100 m increase in altitude.

Potential 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 in a vegetated community. It means the maximum demand for water by the crop and becomes the reference for maximum replacement of water for the crop, whether through irrigation and/or rainfall according to [4].

[16], studying the municipality of Campina Grande - PB, observed that the ETP recorded an annual rate of 1.076,8 mm, with variations from 105.4 mm in December to 71.3 mm in August.

Several components are important in irrigation management, including reference evapotranspiration, which is one of the main components of the water balance, being very useful in climatology, either in climate classifications or for the quantification of regional water availability, as well as in the management of water in irrigation systems [22].Evapotranspiration is, therefore, important for the design of systems and irrigation water management, which requires the adoption of studies, evaluations and adjustments for its correct use[21; 4].

To determine the water needs of the plant, it is based on the study of ETP, as they fundamentally depend on microclimatic conditions, such as precipitation, wind speed, temperature and relative humidity, solar radiation; the characteristics of the plants, among them, cultivar, vegetative stage, leaf area index, extension and depth of the roots and the metabolic activity of the plant and the available water in the soil [7].

[12] State that the use of water balance for a region is of paramount importance, as it considers soil characteristics such as physical texture, effective depth of the root system of plants and the movement of water in the soil throughout the year. Therefore, the Thornthwaite climate classification method is widely used, which is based on data from the climatological normals of temperature, precipitation and potential evapotranspiration, which is more efficient to detect small climatic spatial variations when compared to the Köppen classification in accordance with [5].

The objective is to analyze the climatic oscillations, from the calculation of the water balance and its climatic classification, according to the methods of Thornthwaite and Köppen, for the city of Recife, verifying the occurrence of the aptitude of the banana cultivar.

2. Material and methods

Recife is among the three largest urban agglomerations in the Northeast. It occupies a central position, with a distance of around 800 km from the other metropolises, Salvador and Fortaleza, disputing with them the strategic space of influence in the Region. With a territorial area of 330 km2, it is limited to the north by the cities of Olinda and Paulista, to the south by the municipality of Jaboatão dos Guararapes, to the west by São Lourenço da Mata and Camaragibe, to the east by the Atlantic Ocean. According to data from the 2010 census, the city of Recife has a population of over two million inhabitants [9]. Located at latitude 08º01'S; longitude 34º51'W, with an average altitude in relation to sea level of 72m (Figure 1).

Source: Adapted by Kozmhinsky (2017).

Figure 1 Location of the city of Recife

According to the climate classification of [11] the city of Recife is classified with the type of climate "Am" – monsoon climate, complying with the studies by [14]. The atmospheric systems that contribute to the precipitation of the Metropolitan Region of Recife are the Frontal Systems, the Eastern Wave Disturbances and the Sea and Land Breezes. The eastern waves that are common in autumn/winter, aided by the southeast trade winds. The Waves hit the eastern coast of the Northeast, causing heavy rains. The Intertropical Convergence Zone (CZIT) is one of the main rain-causing systems, a disturbance associated with the expansion towards the southern hemisphere of the thermal equator (zone of ascension of the trade winds by thermal convection). The CZIT reaches Recife, mainly in autumn, and causes rains with thunderstorms and changes in the direction of the winds from SE to NE, or even calms. The formations of the High Level Cyclone Vortex (VCAS) systems, from February to April, with their edges over the NEB, especially above the state of Pernambuco, increase cloud cover and cause moderate to heavy rainfall in short period of time, causing damage to communities such as flooding, floods, floods and the socioeconomic sector [15;15].

The method of [23] was used, which requires information on precipitation and average temperature to calculate the water balance for the study area. The average rainfall and temperature data were acquired from the National Institute of Meteorology [10], the data period comprises the series from 1962 to 2016.

The monthly average climatological data were applied to electronic spreadsheets, to obtain the values of monthly and annual averages of air temperature and precipitation, essential for the calculation of the water balance by the method of [23] The prominence of the water balance estimate for the municipality of Recife is based on the importance that water has for its performance of soil water storage, human survival, irrigation, agriculture and laser.

In the calculations of the climatological water balance (BHC) the CAD value representative of the soils found in the study region was used - CAD = 100 mm for soil with high storage capacity, such as the alluvial soils of the municipality. Based on the BHC, the methodologies of [23; 15] were applied for climate classification according to predetermined CAD values.

Most of the banana root system is concentrated in the first 40 cm of soil depth. The practice of subsoiling should be carried out whenever the banana tree is cultivated for the first time and on the occasion of the reform for a new planting. The banana tree requires well-aerated and drained soils, being of great need for soils that are prone to waterlogging and/or waterlogging.

The banana crop has temperature ranges that contribute to its development as described below:

- Average annual temperature (Ta) = 15°C indicates the lower limit of the temperature range suitable for banana production. Below this limit, the crop suffers from thermal deficiency, which causes a drop in production, making the area restricted or unsuitable for commercial cultivation.
- Average annual temperature (Ta) between 15°C and 35°C indicates the thermal range favorable to the banana crop.
- Average annual temperature (Ta) greater than 35°C indicates the upper limit of the thermal range favorable to the banana crop.

Air temperature data (maximum, minimum, average and range); relative humidity; intensity and predominant wind direction; evaporation and evapotranspiration; Total insolation, cloud cover and precipitation were acquired from the agrometeorological study developed by [15] corresponding to the period 1962-2016.

Climatic classification was performed according to the method proposed by Thornthwaite and by Köppen, described in [12] The climatic type of the region by the Thornthwaite method was determined based on the values of the water index (Ih), aridity (Ia), humidity (Iu) and the thermal efficiency (TE), which are a function of the potential evapotranspiration, the deficiency and the water surplus resulting from water accounting calculations. The classification proposed by Köppen takes into account the average data of air temperature and precipitation in the region and associates it with a symbology that represents the types and climatic varieties. According to the Köppen climate classification, Recife has the type of climate Am, this type of climate is in agreement with the studies carried out by [3] and by [13].

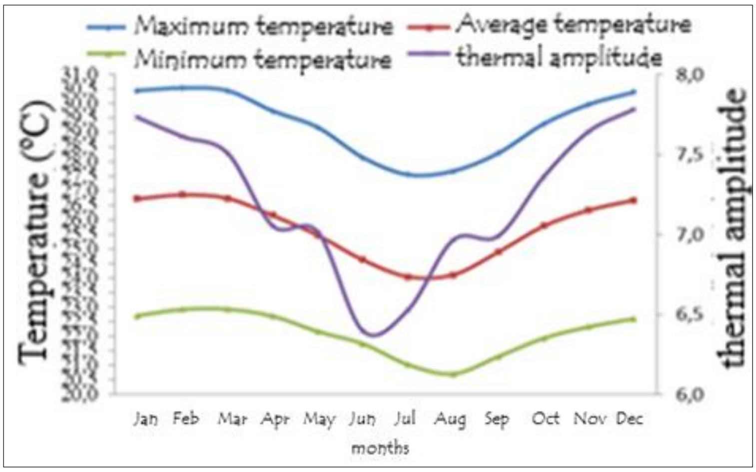
The BH was calculated from the mathematical model proposed by [23] and its program was developed by [15]. The value of available soil water capacity (CAD) of 100 mm was taken; and as a reference value for water deficit (DEF) the value of 100 mm was adopted. Therefore, annual water deficit of DEF = 100 mm, considered the limit, above which the range becomes restricted and unsuitable for banana cultivation.

3. Results and discussion

The variability of the global climate has been causing changes over the years, which leads us to think about human actions, which have been altering the environment and nature, and through new technologies which seek to consent to the pressures of consumption patterns, each increasingly demanding. In Recife, the effects can be observed in the behavior of the climate, more precisely in the oscillation of temperature, relative humidity and precipitation, as they manifest themselves more directly in the daily life of the population.

The analysis of the variability of meteorological elements such as temperatures (maximum, average, minimum and thermal amplitude) of the air; wind; precipitation; relative humidity; evapotranspiration; evaporation and insolation recorded between the years 1962-2016 for the city of Recife as contributions to the study of banana culture and its conditions conducive to cultivation.

The municipality of Recife has an average altitude of 72 meters, considered satisfactory for cultivation. The best altitudes for local planting range from 0 to 1,000 m above sea level, as stated by Alves (1997). The fluctuations in altitude change the duration of the banana cycle, showing that there is an increase of 30 to 45 days in the production cycle of this crop for every 100 m increase in altitude referenced according to [2].



Source: Medeiros (2022).

Figure 2 Average annual variation of maximum, average, minimum temperature and thermal amplitude in the city of Recife, in the period 1962 - 2016

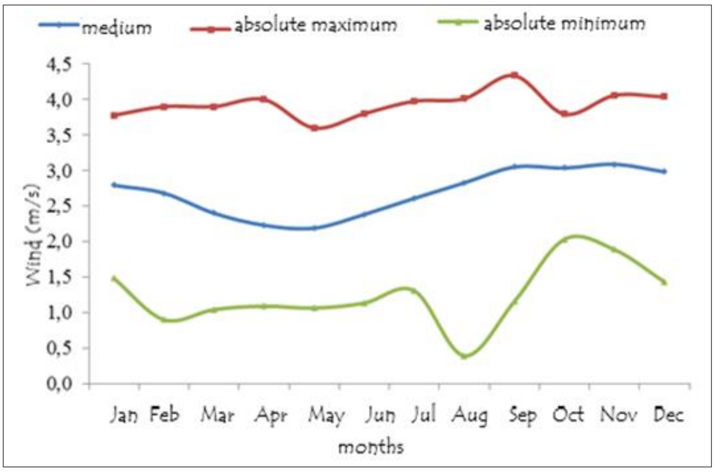
The maximum annual temperature is 29.3 °C, with monthly oscillations between 27.6 °C in the month of July and 30.5 °C in the months of January and February. With an average annual temperature of 25.7 °C, and its monthly fluctuations ranging from 24.1 °C in July and August to 26.9 °C in February. With monthly oscillations flowing between 20.7 °C in the month of August to 22.9 °C in the months of February and March and with 22.1 °C are the minimum temperature variability. The annual temperature range is 7.2 °C and its monthly oscillations flow from 6.4 °C in June to 7.8 °C in December.

The wind is another important climatic element, which can cause, from small damages, to the destruction of the banana plantation. Wind speed below 8.3 ms^{-1} generally does not harm the plant, that is, it is not limiting for banana cultivation.

Figure 3 shows the average variability, maximum and minimum monthly wind intensity. With regard to wind speed, more important than the daily or monthly average is its instantaneous value (gust) throughout the day, as a gust of wind or a gale that occurs in a few minutes is capable of causing total destruction, or partial of the banana plantation. It should be noted that these values do not include the gusts of wind that occur in this area.

The average annual intensity is 2.7 ms^{-1}, the monthly oscillation fluctuates between 2.2 ms^{-1} in the months of April and May to 3 ms^{-1} in the months of September, October and December. The absolute maximum wind intensity variability ranges from 4.3 ms^{-1} in the month of September to 3.6 ms^{-1} in May, with an absolute maximum recorded of 3.6 ms^{-1}. The annual absolute minimum intensity was 1.5 ms^{-1} and monthly oscillations occur between 0.4 ms^{-1} in August and 2 ms^{-1} in October.

The predominant direction of the average wind is from the Southeast (SE) in the months from January to October and December the same direction occurs in the annual value, in the month of November there is a predominant direction of East (E).



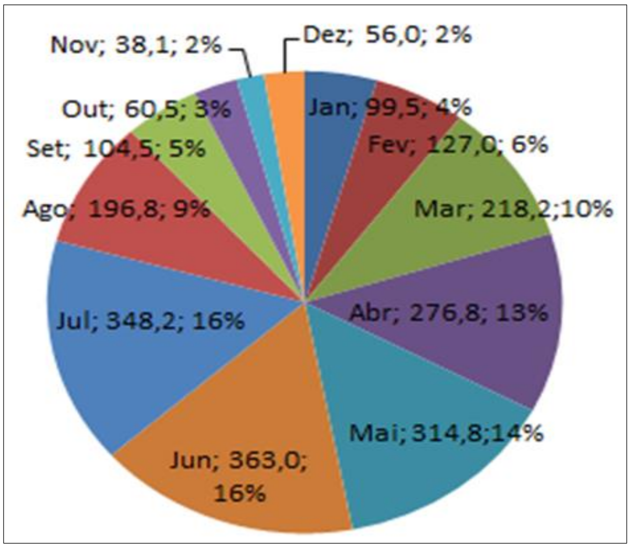
Source: Medeiros (2022)

Figure 3 Average, maximum and absolute minimum wind in the city of Recife, in the period 1962 – 2016

Figure 4 shows the fluctuations in precipitation for the period 1962 - 2016 for the city of Recife. The monthly irregularity in rainfall is due to the meteorological factors that inhibit and/or activate rain-provoking systems in the area under study, aided by local and regional contributions. The studied municipality has a rainfall of 2.188,7 mm $year^{-1}$.

The variability of precipitation and its percentages are represented in figure 4, where the months from March to August are highlighted, which rains 78% of the annual value, and in the months from September to February, 22% of the annual rainfall occurs. The months of June and July represent 16% of the annual value and the months of November to December with 2% of the annual value. In the months from October to December, irrigation should be used to complement the needs of the plants.

To meet the water needs of the banana tree, which needs 1200 mm per year or, on average, 100 mm per month. In the city of Recife, it is necessary to use irrigation during the months of October, November, December, January and February, since in these months there is a water deficit. And the rainfall recorded does not cover such demand, it is also noted that the subsoil water has potential for the use of irrigation.

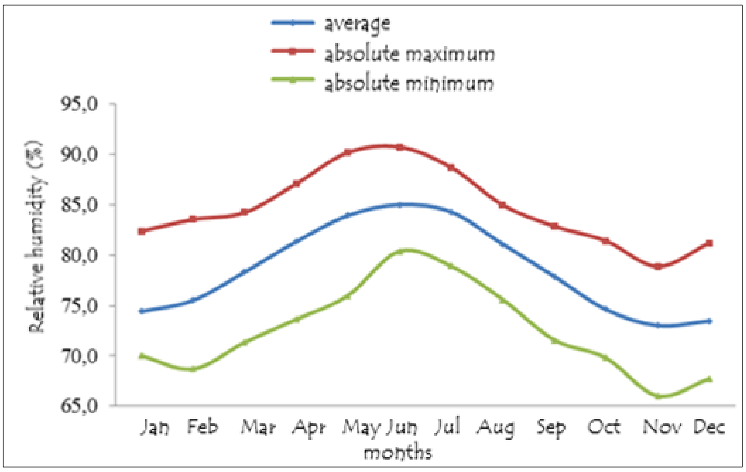


Source: Medeiros (2022)

Figure 4 Monthly distribution of rainfall and its percentages in the municipality of Greater Recife - PE, from 1962 to 2016

The relative humidity of the air flows between 73% in the month of October to 85% in the month of May, with 78.6% of annual humidity. The low air humidity quarter comprises the months of September to November. The months of May to July comprise the quarter of high humidity. The months of maximum absolute humidity are May and June and the months of absolute minimum relative humidity are the months of October to December and February. (Figure 5).

The average relative humidity of the studied area is between the average annual and monthly ranges suitable for planting bananas, which presents better development in places with annual averages of relative humidity above 80%. This limit is due to the origin of the species, from humid tropical regions.

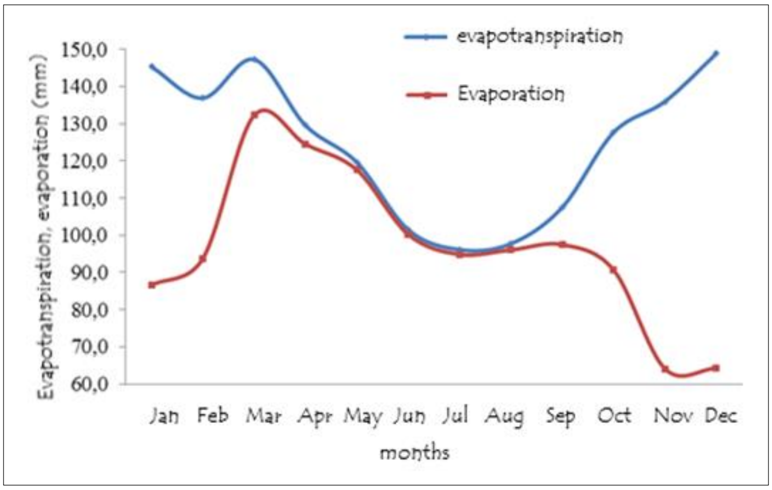


Source: Medeiros (2022)

Figure 5 Fluctuations in relative humidity for the period 1962 - 2016 for the city of Recife

Figure 6 shows the fluctuations in evapotranspiration and evaporation from 1962 to 2016 for the city of Recife. The evapotranspiration rates are higher than the evaporation between the months of January and May and between the months of September and December and in the months of June, July and August these values are equal.

The evapotranspiration fluctuates between 96.1 mm in the month of July to 148.9 mm in December, The annual evapotranspiration is 1,494 mm almost once the annual precipitation value is reduced, the quarter with the highest evaporative power is in November, December and January and the quarter with the lowest evapotranspiration power occurs in the months of June, July and August. Evaporation flows from 64.1 mm in November to 132.3 mm in March with an annual evaporative rate of 1.162,2 mm. It evaporates 46.9% of the annual precipitation value.



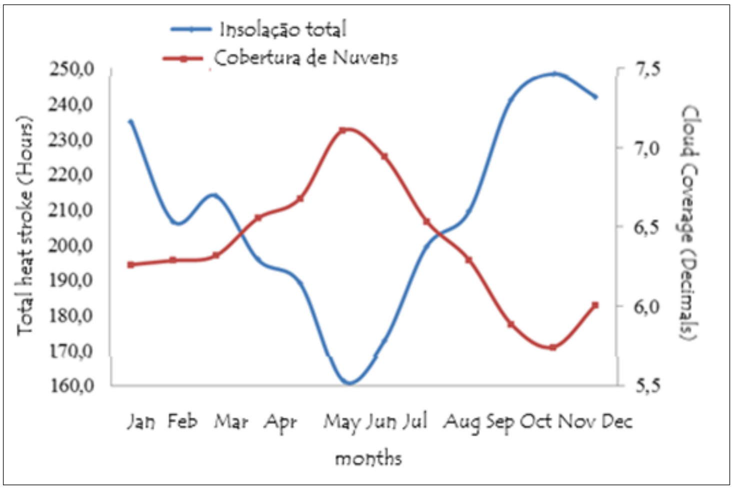
Source: Medeiros (2022)

Figure 6 Average variation of evaporation, evapotranspiration in the city of Recife, in the period 1962 – 2016

The oscillations of total isolation and cloud coverage are shown in figure 7. An increase in cloud coverage between the months of April and August and reductions between September and March are highlighted. The months of low cloud coverage are centered between October and December. The months from May to July are the months with the greatest cloud coverage. Annual cloud coverage is 6.4 tenths.

In the curve of the total insolation it occurs in the inverse of the cloud cover. The annual insolation is 2,516 hours. The quarter with the highest solar incidence corresponds to the months from October to December, and the month from May to July has the lowest incidences of insolation.

The effect of luminosity on the vegetative cycle of the banana tree is evidenced in some publications with dense planting, for example. In places with high insolation, the period for the bunch to reach the cut-off point is between 80 and 90 days. After its issuance, under low insolation, the period for the bunch to reach the commercial cut-off point can vary between 85 and 112 days. On the other hand, there is an increase in photosynthetic activity when in the light range between 2.000 and 10.000 luxes, being slower in the range of 10.000 to 30.000 luxes. Values lower than 1,000 lux are insufficient for plant development, and high values can cause leaf burn, especially when they are in the cartridge phase.



Source: Medeiros (2022).

Figure 7 Average annual variation of sunshine and cloud cover in the city of Recife, in the period 1962 – 2016

If there is no water surplus, the precipitation is equal or close to the real annual evaporation. Table 2 presents a summary set of the climatic suitability of the banana crop for the full, moderate, restricted and unsuitable capabilities.

Table 2 Presents a summary of the climatic suitability of the banana crop

Culture	Fitness	Climate Index	Deficiency / Excess
	full	Def<200mm	Good water conditions for the culture development.
	moderate	200<Def<350mm	Seasonal water shortage, prolonging the crop cycle
BANANA	restricted	350<Def<700mm	Marked water deficiency, bein Cultivation possible only in floodplains and more humid places.
	Disability	Def>700mm	Cultivation is only possible through irrigation.

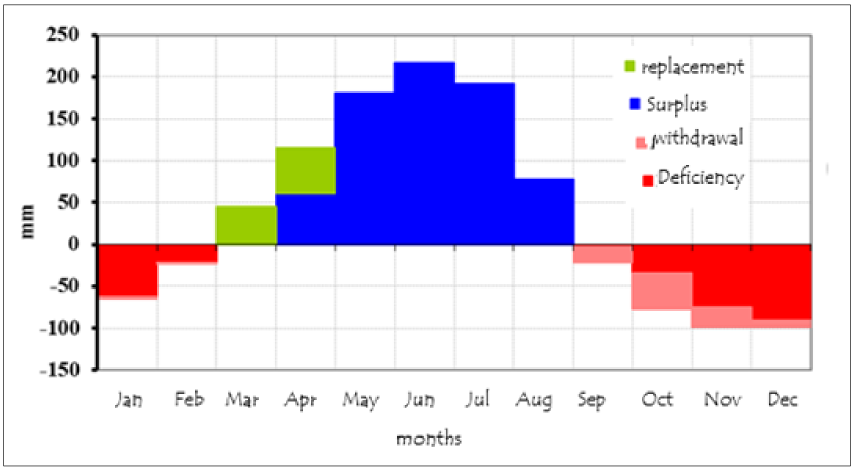
Table 3 shows the result of the water balance for the municipality of Recife - PE, for the period 1962-2016, showing the variability of evapotranspiration, evaporation, deficiency and water surplus.

Table 3 Climatological Water Balance of the Municipality of Recife, according to Thornthwaite and Mather (1955) (CAD = 100 mm)

Parameters/months	Precipitation (mm)	evapotranspiration (mm)	Evaporation (mm)	Deficiency hydro (mm)	deficiency hydro (mm)
January	79.9	144.9	82.3	62.5	0.0
February	113.7	136.4	114.2	22.2	0.0
March	191.1	146.6	146.6	0.0	0.0
April	243.6	129.0	129.0	0.0	61.2
May	300.1	119.4	119.4	0.0	180.7
June	318.1	101.3	101.3	0.0	216.7
July	287.9	96.0	96.0	0.0	191.9
August	174.8	97.6	97.6	0.0	77.2
September	85.2	107.3	105.1	2.3	0.0
October	49.7	127.5	93.0	34.4	0.0
November	37.1	135.7	60.2	75.5	0.0
December	49.4	148.5	58.0	90.5	0.0

Source: Medeiros (2022).

The results shown in Table 3 record the occurrence of water surplus between the months of April and August with an annual total of 727.6 mm. Water deficiencies occur between the months of September and February, it is recommended to supplement the water depth in the soil through the use of irrigation. Replacement of water in the soil occurs in the months of March and April, the withdrawal of water in the soil occurs between the months of September and December, water deficiencies predominate between the months of September and February. Water surpluses occur from April to August for the use of 100 mm CAD (Figure 7). The indices of humidity, aridity and water are: 19.28%; 0.19% and 0.37% respectively.



Source: Medeiros (2022).

Figure 8 Graph of the Climatological Water Balance of the Municipality of Recife according to Thornthwaite and Mather (1955). Period: 1962 - 2016

Water is essential for the expansion of culture, its lack and/or excess can influence the agricultural production of a given location or region. According to [17] 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 (potential evapotranspiration), considering a certain water storage capacity by the soil.

4. Conclusion

The banana plantation becomes moderate due to the water deficit of 287.4 mm. The evaporative power registered in the municipal area is high, but the demand for irrigation complements the scarcity of water to cultivate it.

The local altitude is in the range of planting of the cultivar as well as the variability of the relative humidity of the air.

Wind is one of the limiting factors for commercial exploitation of banana cultivation, if the cultivars are tall and planted in sandy soils.

Compliance with ethical standards

Disclosure of conflict of interest

All authors contributed to the development of the article.

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