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Climate Approach for the Banana Cultivation in Caruaru-Pe, Brazil

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ABSTRACT

The banana tree is a typical tropical plant, demanding high temperatures, well-distributed precipitation, and availability of soil moisture. The banana (*Musa sapientum*) is one of the most explored tropical fruit in the world. Improper irrigation management can damage plant growth and its development reducing productivity. Study the variability of the climatic elements, based on the calculation of water balance developed by Thornthwaite and Mather (1948, 1955) and the climatic classification, according to the methods of Thornthwaite and Köppen, for the municipality of Caruaru, verifying the occurrence of the aptitude of the banana for the studied area. The air temperature data (maximum, minimum, average, and amplitude), relative humidity, intensity, and predominant wind direction, evaporation, and evapotranspiration, total sunshine, cloud cover, and precipitation were obtained from the agrometeorological study and the calculation of the water balance by Thorntwaite and Mather (1948, 1955) was developed by Medeiros (2016) corresponding to the years of 1962-2019. Banana planting becomes restricted because it presents a 556.5 mm water deficit whose value is close to the annual precipitation and evaporation (573.8 mm) levels. Another factor that aggravates banana cultivation in the area is the high evaporative power that is registered in the municipal area, besides the lack of water for irrigation supplementation.

1. INTRODUCTION

The banana tree is a typical tropical plant, demanding high temperatures, WELL-DISTRIBUTED precipitation, and availability of soil moisture. The optimum temperature for the development of banana trees is around 28 °C, while temperatures of 15 °C and 35 °C are the extreme limits for the exploitation of the crop. Thus, if a region presents temperature values within these limits and adequate supply of water and nutrients, it is possible to grow banana in this area.

The banana (*Musa sapientum*) is one of the most explored tropical fruit in the world. Due to its relatively low cost and high nutritional value, it is an integral part of the diet, especially of the low-income population. Brazil is among the largest banana producers in the world, occupying the third position, with an approximate production of 6.3 million tons per year-1, in 2002, occupying an area of 508 thousand hectares (FAO, 2006).

In banana cultivation, inadequate irrigation management can damage plant growth and its development, reducing productivity. Under severe water deficiency, the leaf rosette of the banana tree is compressed, making it difficult or even preventing the inflorescence. Consequently, the banana bunch may not present commercial value according to Moreira (1997).

Due to its morphology and the hydration of its tissues, the banana tree presents a high consumption of water. The largest productions are associated with total annual precipitation of 1,900 mm, well distributed over the year reported by Alves (1997). In most regions where banana is cultivated, rainfall is insufficient to meet water needs, making it necessary to use supplementary irrigation, as it occurs in the northeastern semi-arid region.

To determine the water needs of the plant, it is necessary for the study of evapotranspiration (ETP), since they depend fundamentally on the microclimatic conditions, such as precipitation, wind speed, temperature, and relative humidity of the air and solar radiation. Concerning the plant characteristics, among them are, crop growth, vegetative stage, leaf area index, root extension and depth metabolic activity of the plant, and also of the available water in the soil according to Ferreira (1988).

From the several irrigated tropical fruit trees, the banana plant is very sensitive to water stress, it also has a high index of leaf area, which results in high transpiration. The root

system is very superficial, which is why banana is a species that presents a considerable physiological response to water scarcity as reported by Vosselen et al. (2005). Moreover, they demand water throughout the year because it is a perennial crop with constant production.

Matos et al. (2014) stated that the use of water balance for a region is of great importance since it considers the soil characteristics such as physical texture, the effective depth of the root system, and the movement of water in the soil all year around. In order to do so, the Thornthwaite method of climatic classification is widely used, which is based on data from climatic normals of temperature, precipitation, and potential evapotranspiration (ETp), which is more efficient to detect small spatial climatic variations when compared to Köppen classification according to With Cunha and Martins (2009).

According to Silva et al. (2011), the success of crops harvested in a given region depends on the regularity and quantity of precipitation. The spatial and temporal variability of rainfall in the 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, according to Alves (2013).

To define the region's ability to grow bananas, the producers must be aware of the climatic characteristics and their seasonal variations, since the banana tree does not tolerate waterlogging, strong winds, and average air temperatures below 15ºC according to Ventura and Gomes (2005).

This paper aims to study the variability of the climatic elements, based on the calculation of the water balance developed by Thornthwaite and Mather (1948, 1955) and the climatic classification method according to Thornthwaite and Köppen for the municipality of Caruaru, verifying the occurrence of aptitude of the banana growth for the studied area.

2. MATERIAL AND METHODS

The city of Caruaru is located in the Agrestemesoregion and the Ipojuca Valley Microregion in the State of Pernambuco, being limited to the north with Toritama, Vertentes, Frei Miguel and Taquatinga do Norte, to the south with Altinho and Argentina, to the east with Calves and Riacho das Almas, and to the west with Brejo da Madre de Deus and São Caitano. The city's area occupies 928.1 km^2 and represents 0.94% of the State of Pernambuco, with 16.6

km² being in the urban perimeter and the remaining 903.9 km² forming the rural area. The city's headquarters has an altitude of 554 meters and geographic coordinates of 08 ° 17'S latitude and 35 ° 58'W of longitude, with an average altitude of 545 meters, distant 140.7 km from the capital, Recife. Figure 1 shows the location of the municipality of Caruaru.

Figure No. 1: Location of the municipality of Caruaru - PE. Source: adapted by the author

The city of Caruaru is inserted in the geoenvironmental unit of the Borborema Plateau, formed by massive and high hills, with altitude varying between 650 and 1.000 meters. It occupies an arch area that stretches from the south of Alagoas to Rio Grande do Norte. The relief is generally active with deep and dissected narrow valleys. About the fertility of the soils, it is quite varied with a certain predominance from average to high. The municipality is cut by perennial rivers, but of small flow and the groundwater, the potential is low.

The vegetation is formed by subsurface and deciduous forests, typical of wilderness areas. It has the "caatinga" as dominant vegetation of the municipality, with its typical trees, such as: "Juazeiro, baraúna, mulungú, algaroba and imburana", bushes of the type "velameiro, quinceiro and nettle, bromeliaceas of the type caroá, macambira and gravatá and the cactáceas of the type Xique-Xique, Mandacarú, Crown-of-Friar, and Candlestick". It also has humid and arboreal vegetation (tropical forest) to the south because it borders Pernambuco's marsh region at the southern end of the municipality.

Caruaru's climate according to the Köppen-Geiger classification is semi-arid (BSh), with hot and dry summers and mild and rainy winters. The rainy season begins in February with pre-season rains (rainfall occurring before the rainy season) with its end occurring at the end of August and may extend until the first half of September. The rainy trimester focuses on May, June, and July and its driest months occur between October and December. The factors that cause rainfall in the municipality are a contribution of the Intertropical Convergence Zone

(ITCZ) and the formation of High- Level Cyclonic Vortices (HLCV) when its center is located in the ocean, which is an influence of the contribution of the northeast trade winds in the transportation of vapor and humidity to which they condense and form clouds, the formations of the instabilities lines, the orography and their local contributions according to Medeiros (2016).

Due to its location in the lands of Borborema, the soil has smooth, wavy to undulating surfaces. The Planosols are moderately deep, strongly drained, acid to moderately acidic and medium natural fertility, and the Podzols, which are deep of clayey texture and natural fertility medium to high. In the elevations occur Litolics, which are shallow soils of clayey texture and average natural fertility. In the valleys of rivers and streams, planosols occur which are moderately deep, imperfectly drained, medium/clayey texture, moderately acidic, high natural fertility, and salt problems. There are also rock outcrops.

It was used the method of Thornthwaite and Mather (1948, 1955), which demands information of precipitation and average temperature for the calculation of the water balance for the municipality of Caruaru.

The average precipitation and temperature data were obtained from the Northeast development oversight database (SUDENE, 1990) and the Pernambuco State Agency for Water and Climate (APAC, 2019) for the period from 1913 to 2019.

The monthly average climatological data was applied to electronic spreadsheets to obtain monthly and annual averages of air temperature and precipitation, essential for calculating the water balance using the method of Thornthwaite and Mather (1948, 1955). The prominence of the estimation of the water balance for the municipality of Caruaru is based on the importance that water has for its performance of soil water storage, human survival, irrigation, agriculture, and leisure.

In the calculations of the climatological water balance (CWB), the representative values of AWC (available water capacity) for the soils found in the studied region were AWC = 100 mm and it was used for soil with high storage capacity, such as alluvial soils of the municipality. Based on the CWB, the methodologies of Tornthwaite (1948) and Thornthwaite and Mather (1955) were applied for the climatic classification according to the pre-determined AWC values.

Most of the banana root systems were concentrated in the first 40 cm of soil depth. The practice of subsoiling should be carried out whenever the banana is first cultivated and when the old planting is reforested. The banana requires well-aerated soils, so drainage is required for soils that are prone to flooding or drenching.

Banana culture has temperature ranges that contribute to its development as described below:

a) Average annual temperature (Ta) = 15 °C indicates the lower limit of the thermal range suitable for banana production. Below this limit, the culture suffers thermal deficiency which causes a decrease in production making the restricted area unfit for commercial culture.

b) Mean annual temperature (Ta) between 15 °C and 35 °C indicates the favorable thermal range for banana cultivation.

c) Annual average temperature (Ta) higher than 35 °C indicates the upper limit of the favorable thermal range of the banana.

The air temperature data (maximum, minimum, mean, and amplitude), relative humidity, intensity, and predominant wind direction, evaporation, and evapotranspiration, total sunshine, cloud cover, and precipitation were acquired from the agrometeorological study developed by Medeiros (2016) corresponding to the years of 1962-2016.

The climatic classification was carried out according to the method proposed by Thornthwaite and Köppen, described in Vianello and Alves (1991). The climatic type of the region by the Thornthwaite method was determined based on the values of the water index (Ih), dryness (Ia), humidity (Iu), and thermal efficiency (TE), which are due to potential evapotranspiration and water surplus resulting from water accounting calculations. The classification proposed by Köppen takes into account the average air temperature and precipitation data of the region and associates it with a symbology representing climatic types and varieties.

The BH was calculated from the mathematical model proposed by Thornthwaite and Mather (1955) and a program developed by Medeiros (2016). The value of available water capacity in the soil (AWC) of 100 mm was taken and the reference value for water deficit (WD) was 100 mm. Therefore, the annual water deficiency of WD = 100 mm, considered the limit above which the range becomes restricted to inapt for the banana crop.

3. RESULTS AND DISCUSSION

Global climate has undergone modifications over the years, which leads to thinking about the actions of mankind when it changes the environment, and through new technologies seeks to meet the pressures of consumption patterns which are increasingly demanding. In Caruaru, the results can be observed in the behavior of climate, more precisely in the temperature, relative humidity, and precipitation because they manifest more directly in the daily life of the population.

The variability of the global climate has brought about changes over the years, which leads to thinking about the anthropic actions, which have been changing the environment and nature, and through new technologies that seek to consume the pressures of consumption patterns, each more demanding. In Recife, the effects can be observed in the behavior of the climate, more precisely in the temperature oscillation, the relative humidity of the air and precipitation, because they manifest themselves more directly in the day to day of the population.

The analysis of the variability of the meteorological elements as temperatures (maximum, average, minimum, and thermal amplitude) of the air; wind; precipitation; relative humidity; evapotranspiration; evaporation, and sunshine recorded between the years 1962-2019 for the municipality of Caruaru as contributions to the study of banana culture and its conditions conducive to cultivation.

The municipality of Caruaru has an average altitude of 545 meters, considered satisfactory for the crop. The best altitudes for local planting range from 0 to 1,000 m above sea level as stated by Alves (1997). According to the author, the oscillations at altitude alter the duration of the banana cycle, evidencing that there is an increase of 30 to 45 days in the production cycle of this crop for every 100 m of increase in the altitude referenced.

The wind is another important climatic element, being able to cause, from small damages, until the destruction of the bananas. Wind velocity less than 8.3 ms-1 generally does not harm the plant, ie it is not limiting for banana cultivation.

It is observed that some isolated areas that have an aptitude but are restricted to the crop, due to lack of water for irrigation in the months of major water deficiencies.

Wollmann et al. (2013) report that local climatic and climatic conditions are taken into account in agroclimatic zoning, aiming at the exploitation of economically profitable crops. These are the agroclimatic characteristics of this locality that determine suitability to the development of the cultures, which corroborates with the study in development. A study with França et al. (2018) corroborates with similar results.

The following analysis of the variability of the meteorological elements shows fluctuations between the years of 1913 to 2019 for rainfall in the municipality of Caruaru as a contribution of the study of the banana culture and its favorable conditions for cultivation.

As previously mentioned, the municipality of Caruaru presents an average altitude of 545 meters, considered satisfactory for the cultivation of which should be cultivated in places that vary from 0 to 1,000 m above sea level as stated by Alves (1997). The changes in altitude alter the duration of the banana cycle, evidencing that there is an increase of 30 to 45 days in the production cycle of this crop for each 100 m increase in altitude Alves (1997).

Table No.1: presents the climatological average values of the meteorological elements studied for the city of Caruaru, from 1962 to 2019.

Maters/Months	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	annual
Maximum temperature	29,7	30,0	29,3	28,4	27,1	25,4	24,4	25,4	26,8	29,1	30,1	30,4	28,0
Minimum temperature	19,7	19,8	20,1	20,0	19,3	18,4	17,3	17,4	17,9	18,6	19,3	19,6	19,0
Average temperature	23,9	24,1	24,1	23,6	22,7	21,6	20,6	20,9	21,7	23,1	24,7	24,2	22,9
Thermal amplitude	10,0	10,2	9,2	8,4	7,8	7,0	7,1	8,0	8,9	10,5	10,8	10,8	9,1
Insolation	222,9	199,9	198,0	175,1	166,4	140,3	141,5	180,7	185,1	247,0	253,2	248,4	2358,5
Cloud cover	0,6	0,6	0,7	0,7	0,8	0,8	0,8	0,7	0,7	0,6	0,6	0,6	0,7
Evapotranpiration	107,2	101,4	110,6	99,1	90,4	75,4	68,3	71,8	78,3	97,8	115,6	114,4	1130,3
Evaporation	33,8	47,6	63,8	73,5	80,1	75,4	68,3	49,6	32,7	16,2	15,7	17,0	573,8
Air relativa humidity	75,1	75,2	78,6	81,3	83,1	85,7	85,8	83,8	79,9	74,9	50,0	72,4	77,2
Precipitation	33,5	47,5	63,7	73,4	80,1	92,0	80,5	42,3	23,7	8,9	12,4	15,9	573,8
Wind intensity	1,9	1,8	1,8	1,8	1,9	1,8	2,1	2,1	2,1	2,1	2,3	2,1	2,0
Predominant direction	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE
Photoperiod	12:47	12:35	12:17	12:23	12:11	11:56	12:04	12:24	12:07	12:30	12:35	12:44	12:19
Water Deficiency	73,3	53,7	46,8	25,6	10,3	0,0	0,0	22,1	45,6	81,6	100,0	97,4	556,5
Water surplus	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

Average municipal temperatures range from 20.6 °C in July to 24.7 °C in November, with an average annual value of 22.9 °C. The oscillation of the minimum monthly temperature fluctuates from 17.3 ºC in July to 20.1 ºC in the month of March, its annual temperature is 19 ºC, (Figure 2). It has an annual thermal amplitude of 9.1 ºC and its monthly variation oscillates between 7.8 ºC in May to 10.8 ºC in the months of November and December. The

maximum temperature ranges from 24.4 °C in July to 30.4 °C in December, with a maximum annual temperature of 28°C.

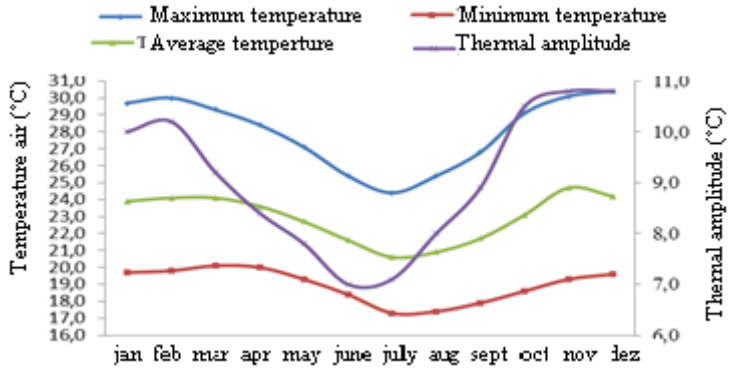

Figure No. 2: Average annual variation of maximum, mean, minimum, and thermal amplitude for the city of Caruaru, Source: Medeiros (2019).

The wind is another important climatic element, being able to cause small damages to even the destruction of the whole banana plantation. Wind velocity less than 8.33 ms-1, generally does not harm the plant, that is, it is not limiting the cultivation of the banana.

Figure 3 shows the average monthly and annual variability of wind intensity. In the months of January and May, the average intensity is 1.9 ms-1. In the months of June to October, the recorded intensity is 2.1 ms-1, in the months of February, March, April, and June it is 1.8 ms-1, in the month of November 2.3 ms-1. The average annual intensity is 2 ms-1. With regard to wind speed, more important than the daily or monthly average, is its instantaneous value throughout the day, because a gust of wind or a gale that occurs in a few minutes is capable of destroying the banana plantation. It should be noted that these values do not account for wind gusts occurring in this area.

The predominant direction of the average wind in the Southeast (SE) during all months and the same direction occurs in annual value.

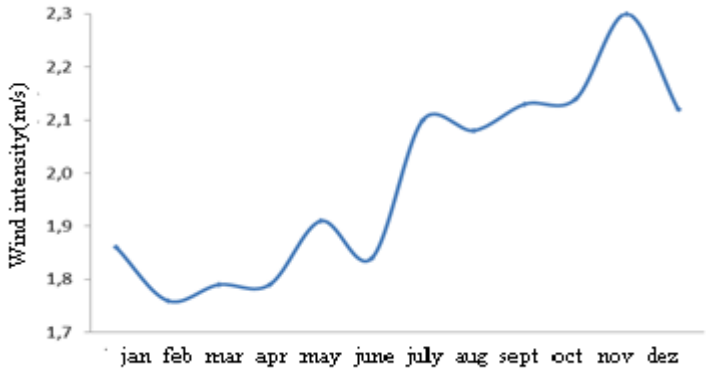

Figure No. 3: Mean annual variation of wind intensity in the municipality of Caruaru, from. Source: Medeiros (2019).

The monthly irregularity in the rainfall indexes is due to the meteorological factors that inhibit and/or activate rainfall systems in the area under study with local and regional contributions. Figure 4 shows the fluctuations of climatological precipitation and relative humidity of the period from 1962 to 2019 for the city of Caruaru. The monthly irregularity in the rainfall indexes is due to the meteorological factors that inhibit and / or activate rainfall systems in the area under study with local and regional contributions.

The municipality of Caruaru climatologically records a rainfall index of 573.4 mm year-1. The months from March to July, where the highest incidence of rainfall occurred, contributed 68% of the annual index. Between August and February, the months where rainfall rates are low, it contributed to 32% of the annual value (figure 4).

Relative humidity ranges from 50% in November to 85.8% in July, with 77.2% annual humidity. The quarter of low humidity of the air comprises the months of October to December with oscillations between 50 to 74.5%. The months of June to August comprise the high humidity quarter and its fluctuations occur between 83.8 to 85.8%. The month of low humidity is November (50% of high humidity is the month of July 85.8%).

The average relative humidity of the studied area is inferior to the adequate annual and monthly averages for the banana tree, which presents better development in places with annual averages of relative air humidity, higher than 80%. This limit is due to the origin of the specie (banana tree) of humid tropical regions.

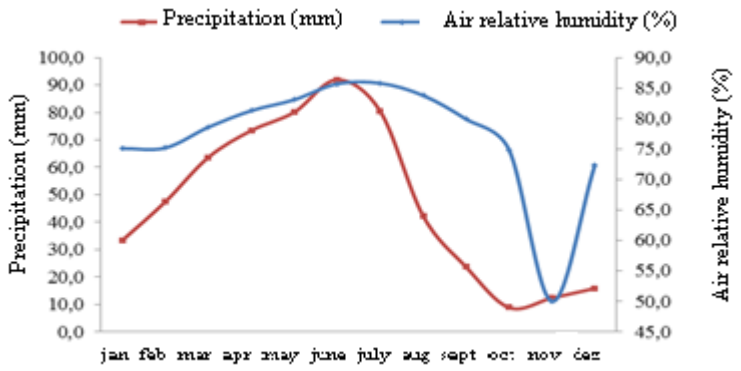

Figure No. 4: Fluctuations in climatological precipitation and relative humidity for the municipality of Caruaru. Source: Medeiros (2019).

To meet water needs, especially banana, which needs at least 1200 mm per year or, on average, 100 mm per month. In the municipality of Caruaru, it is necessary to use irrigations during the months of August to May, since in these months water deficit occurs. And the recorded rainfall does not cover such demand, it is also noted that underground water does not guarantee the use of irrigation.

Figure 5 shows the evapotranspiration fluctuations and evapotranspiration for the period from 1962 to 2016 for the municipality of Caruaru. It should be noted that evapotranspiration is greater than evaporation between January, February, March, April, May, August, September, October, November, and December, and in June and July, these values are the same.

The evapotranspiration oscillates between 68.3 mm in July to 115.6 mm in November. The annual evapotranspiration is 1,130.3 mm almost one and a half times the amount of annual precipitation. The four-month period of greatest evaporative power is from November to February and the four months of the lowest evapotranspiration power occurs from June to September. The evaporation flows between 15.7 mm in November to 80.1 mm in May with an annual rate in the order of 573.8 mm, it precipitates 5 mm more than the annual value of the evaporation.

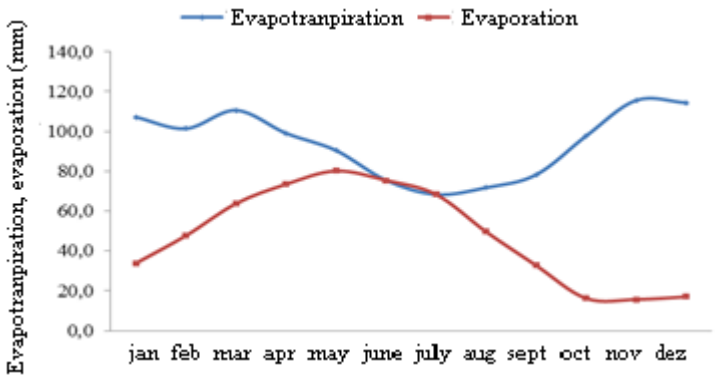

Figure No. 5: Average evaporation variation, evapotranspiration for the city of Caruaru. Source: Medeiros (2019).

The variability of total sunshine and cloud coverage is shown in figure no. 6. It is highlighted the increase in cloud coverage between March to September and reductions between October to February. The months of May, June, and July have coverage of 0.8 tenths and the months of October to January the cloud coverage is 0.6 tenths. The annual cloud coverage is 0.7 tenths.

In the total insolation curve, the inverse of the cloud cover occurs. The annual insolation is of 2.358,5 hours, the month of greater insolation is November and the lowest in June. The fourth quarter with the highest solar incidence corresponds to October to January, and the months of April to June show the lowest incidence of insolation.

The effect of lightness on the vegetative cycle of the banana tree is evidenced in some publications with denser planting, for example. In places with high insolation, the period for which the banana bunch reaches the cut point oscillates between 80 and 90 days. After its emission, under low insolation, the period for the banana bunch to reach the commercial cutting point can vary between 85 and 112 days. On the other hand, there is an increase in photosynthetic activity when in the light band between 2000 and 10,000 lux, being slower in the range of 10,000 to 30,000 lux. Values less than 1,000 lux are insufficient for plant development, and high values can lead to the burning of the leaves, especially when they are in the cartridge phase.

When no surplus is detected, this means that the precipitation is equal to or approximate to the actual annual evaporation. In the municipal area, no surpluses were detected. In contrast to the moderate water excesses of the rainy season, the dry period, in addition to being

relatively long, usually has large water deficits, extending from August to May, except for June and July, which presents zero. The annual deficiency is 556.5 mm.

The results in Table 2, shows that there is no occurrence of water surplus between the months of the year. Water deficiencies occur between August and May, with October, November, December, and January being those with high deficiency rates, it is recommended to supplement the water in the soil through the use of irrigation, especially in the months listed, where the loss of soil water occurs. Water replenishment occurs in the soil in June and July and soil withdrawal occurs between August and December, water deficiencies predominate between September and May. Water surpluses do not occur for 100 mm AWC (Figure no. 6). The indexes of humidity, aridity, and water are 49.24%, 0.49%, and -0.30% respectively.

Table No. 2: Climatological Water Balance of the Municipality of Caruaru, according to Thornthwaite and Mather (1955) (AWC = 100 mm).

Parameter/months	Precipitation (mm)	Evapotranpiration (mm)	Evaporation (mm)	Water Deficiency (mm)	Water surplus (mm)
Jan	33,5	107,2	33,8	73,3	0,0
Feb	47,5	101,4	47,6	53,7	0,0
Mar	63,7	110,6	63,8	46,8	0,0
Apr	73,4	99,1	73,5	25,6	0,0
May	80,1	90,4	80,1	10,3	0,0
June	92,0	75,4	75,4	0,0	0,0
July	80,5	68,8	68,3	0,0	0,0
Aug	42,8	71,8	49,3	22,1	0,0
Sept	23,7	78,3	32,7	45,6	0,0
Oct	8,9	97,8	16,2	81,6	0,0
Nov	12,4	115,6	15,7	100,0	0,0
Dez	15,9	114,4	17,0	97,4	0,0

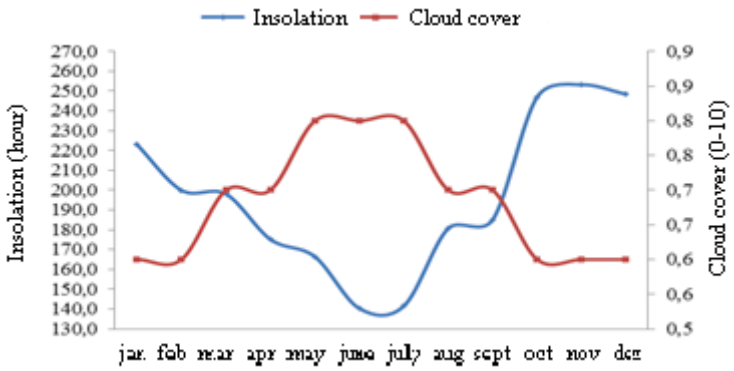

Figure No. 6: Annual average variation of sunshine and cloud cover for the city of Caruaru. Source: Medeiros, (2019).

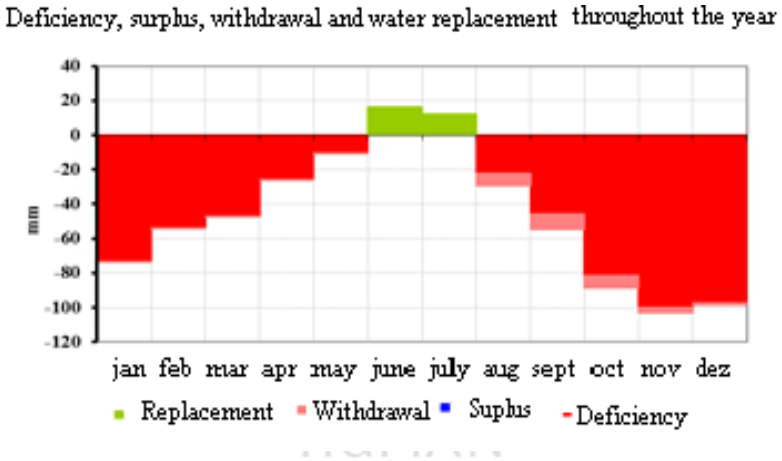

Figure No. 7: Climatological Water Balance of the Municipality of Caruaru according to Thornthwaite and Mather (1955). Source: Medeiros (2019).

4. CONCLUSION

Banana planting is restricted because it presents a water deficit of 556.5 mm, the value is close to annual precipitation and evaporation (573.8 mm); Another factor that aggravates banana cultivation in the studied area is the high evaporative power that is registered for the city of Caruaru-PE, besides the lack of water for irrigation supplementation.

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