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Agroclimatic Suitability for The Banana Crop in The States Piauí and Paraíba, Brazil

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ABSTRACT

For any agricultural area, it is very important to know its potential in order to grow certain vegetal. Because of that, the definition of the agro-climatic suitability of this area is crucial. The objective of the presente work is to perform the climatic suitability for banana crop in the states of Piauí and Paraíba, located in Brazil. Rainfall and temperature series for the period 1962 to 2019, acquired from the Instituto Nacional de Meteorologia (INMET, 2020) were used. The methodologies were used to perform the computation of the climatological water balance, elaborated in electronic spreadsheets counting the soil water, in which the pluviometry conceives the gain and loss of moisture, estimating the water surplus and water deficiency. Based on the referenced methodology, the soil water storage capacity of 100 mm was estimated and performed the computation of potential evapotranspiration. The regions of Piauí state were classified as unsuitable for banana production, as there is a high water deficit and lack of water for supplementation by irrigation. In spite of it was found that the agroclimatic conditions of the state of Paraíba were classified as restricted to banana cultivation, due to the occurrence of severe water deficit, there is in some regions adequate subsidy for the planning and implementation of the banana crop by farmers in this state.

INTRODUCTION

Climatic suitability is defined as the risk of each area for a given agricultural crop through maps, considering the hydroclimatic requirements of each species of agricultural interest, containing information on agroclimatic risk, suitability and indication of the planting and/or harvesting time. Since man does not control meteorological events, zoning should be the first information to be considered in the agricultural project (SENTELHAS et al., 2009).

Local and/or regional climate knowledge and the frequency of its extreme climate events are increasing becoming of interest to society, as their estimates and frequency are of fundamental importance. As evidenced in several studies, where planning is used to land occupation, several areas of knowledge such as construction, agriculture and water resources have fundamental importance (ARCHIE et al., 2018; MASON et al., 2018; TSAVDAROGLOU et al., 2018).

For agriculture, the study of agrometeorology is necessary because it directly influences the type of crop to be produced in a given region, planting period, use of agrochemicals, soil management, and in all stages of the production process (CARAMORI et al., 2008). Furthermore, the study of agrometeorology makes it possible to reduce the impacts of weather variations and minimize the risks to the that agriculture production (BERLATO et al., 2003; CARAMORI et al., 2008). Works that identify and predict periods of drought, intense rain, windstorms and frosts contribute to promoting agricultural planning and crop manipulation, aiming at a better way to extract the maximum potential of crops and obtain good results (PATHMESWARAN et al., 2018; KARIMI et al., 2018; WIRÉHN, 2018; AGOVINO et al., 2019).

Agricultural planning concerns the actions and practices to be established before the implementation of the crop and in its production cycle. Therefore, planning is basically based on information about the climate/zoning and its interannual variability, in the place of interest, thus establishing a better planting and harvesting period, and on the handling of the crop, avoiding use the resource unnecessary in the production and conducting to the rational use of natural resources (SALLUSTIO et al., 2018).

Information on the characteristics of soils and climates will help in the choice of cultivars and decision-making, in the search for higher incomes and lower losses. Among the agrometeorological information used in agricultural projects, agroclimatic zoning is the best known. Studies that identify the climate risk for agriculture are essential, where extreme heat, drought, excess rain and windstorms can cause great damage to the phenological development of crops (MARTINS et al., 2017; TREFALT et al., 2018).

Fruit growing is an activity that can contribute to the national and state socioeconomic growth thanks to its capacity to generate income and employment at different scales, from the small producer to agribusiness (DE CAMPOS et al., 2015). In addition, fruit growing contributes to the increase of maximum biodiversity than in the soybean-corn-wheat succession (CAMBUI et al., 2017; OLIVEIRA et al., 2018; AGOVINO et al., 2019).

In banana crop, an inadequate irrigation management can harm the growth of plants, reducing productivity. Under severe water deficit, the banana leaf rosette compresses, making it difficult or even preventing the release of the inflorescence. Consequently, the bunch may not have commercial value (MOREIRA, 1997).

In order to have performance of its morphology and the hydration of its tissues, the banana has a high water consumption. The highest productions are associated with a precipitation of 1900 mm, well distributed throughout the year (ALVES, 1997). In a large part of the regions, where the banana is cultivated, rainfall is insufficient to meet water needs, making supplementary irrigation essential, as occurs in the semi-arid Northeast region of Brazil.

To plants, usually, the water requirements are closely related to evaporative rates, as the crop depends essentially on microclimatic conditions, such as: precipitation, wind intensity, temperature, relative humidity, and solar radiation. Considering the characteristics of the plant, they are: cultivar, vegetative stage, leaf area index, extension and depth of the roots and metabolic activity of the plant, without minimizing the amount of water in the soil (FERREIRA, 1988).

França et al. (2018) determined the climatic variability, using the computation of the water balance and applied the climatic classification, according to the methods of Thornthwaite and Köppen, for Caruaru municipality, Pernambuco state, Brazil, verifying the occurrence of the suitability of the banana cultivar.

França et al. (2020) analyzed the agroclimatic potential for the mango cultivar, aiming to provide information to small farmers and family subsistence agriculture for the implantation of mango trees in the municipal area of Recife city, Pernambuco state, Brazil. The authors concluded that the cultivation was conditioned to isolated planting in small places such as: backyards, small farms, city squares, car lane division beds, parks and streets.

Medeiros et al. (2016) carried out the study of suitabilities and agroclimatic zoning for forage cactus cultivar and the productive potential of cashew cultivation based on climate indicators established with the requirements of cultivars. In Recife and its surroundings, the physiological activities of forage cactus are quite restricted due to inadequate conditions of availability of temperature and moisture content, being within the restricted range or unsuitable for crop growth. The classification technique and climatic suitabilities using the water deficit numbers for Recife does not provide high reliability subsidies for the classification and suitability of cashew.

Some authors (MEDEIROS et al., 2015; MEDEIROS et al., 2013) characterized the climatic variability and its zoning for 11 cultivars indicating the acceptable cultivation suitabilities for the city of Barbalha, Ceará state, Brazil. The region is fully suitable for the cultivation of pineapple, herbaceous cotton, beans, castor beans, cassava and sisal. The cashew, corn and sorghum cultivars had moderate suitability, while only the sugarcane cultivation was restricted due to the region presenting an accentuated water deficit.

França et al. (2018) studied the meteorological elements, climatic factors, climatological water balance developed by Thornthwaite and Mather (1953), climatic classification by the methods of Thornthwaite (1948), Köppen (1928), and Köppen et al. (1931) for the state of Piauí, Brazil, followed by its classification for banana cultivation. The authors concluded that the wind can be one of the limiting factors for the commercial exploitation of banana farming, if the cultivars are tall and planted in sandy soils. In places with high insolation, the period for the bunch to reach the cutoff point varies between 80 and 90 days. Under little insolation, this cut-off period varies between 85 and 112 days after its emission. The banana tree, which must be cultivated in places ranging from 0 to 1,000 meters, demonstrates altimetry within the citations of several authors.

The objective of this work is to carry out the agroclimatic suitability for the banana species in the states of Piauí and Paraíba, Brazil, through agroclimatic suitabilities, being possible to verify if banana crop is viable.

MATERIALS AND METHODS

Rainfall and temperature series for the period 1962 to 2019, acquired from the Instituto Nacional de Meteorologia (INMET, 2020) were used. Rainfall distributions are recorded irregular and with variation throughout the years. Data were evaluated for consistency, homogenization and filling of gaps and organized in electronic spreadsheets. Data acquisitions were from INMET stations for the studied areas.

The methodologies of Thornthwaite (1948) and Thornthwaite et al. (1955) were used to perform the computation of the Climatological Water Balance (CWB). This computation was elaborated in electronic spreadsheets carried out by Medeiros (2016) that counts the soil water, in which the pluviometry conceives the gain and loss of moisture, estimating the Water Surplus (EXC) and Water Deficiency (DEF).

Based on the referenced methodology, the soil Water Storage Capacity (WSC) of 100 mm was estimated. The computation of potential evapotranspiration (ETP) was performed by the methodology of Thornthwaite (1948), through the Equation 2.

$$ETp = Fc \cdot 16 \cdot \left(10\frac{T}{I}\right)^{a} \qquad 2$$

Where

ETP - Annual potential evapotranspiration (mm year^{-1});

Fc - correction factor;

T – Monthly temperature;

I - Heat index, appropriate to the sum of the twelve monthly indexes;

a - cubic function of the annual heat index given by the equation.

a = 6,75*10-7*I3-7,71*10-5*I2+0,01791*I+0,492.

Table 1 shows the correction factors applied to the methodology of Thornthwaite (1948) as a function of the months of the year.

Table 1 - Correction factor according to the methodology of Thornthwaite (1948) in performance of months of the year.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1,80	0,97	1,05	0,99	1,01	0,96	1,00	1,01	1,00	1,06	1,05	1,10

The methodology of Thornthwaite (1948), was adapted for regional cultivars for the applicability of agricultural zoning.

$$I_h = 100(EXC/ETP)$$

$$I_a = 100(DEF/ETP)$$

$$I_u = I_h - 0,6 \cdot I_a$$

Where:

Ih - water index (%);

Ia - aridity index (%);

Iu - moisture content (%);

EXC – water surplus (mm $year^{-1}$);

DEF - water deficit (mm $year^{-1}$); and

ETP - potential evapotranspiration (mm $year^{-1}$).

The centralization of ETP in the warm season, obtained by the following Equation, represents the annual ETP% that occurs in months j, k, l, in the hottest quarter of the year.

$$Cv = 100 \cdot (ETP_j + ETP_k + ETP_l) / ETP$$

On what:

Cv – centralization of evapotranspiration;

ETPj; ETPk; ETPl – potential evapotranspiration in month j; month k; month l, respectively

ETP – annual potential evapotranspiration.

Based on the annual humidity index (Iu) ranges of Thornthwaite and Mather (1955), the criterion used in the division of thermal zones was based on the normal average temperatures of the warmest month for the states of Piauí and Paraíba, Brazil, where the agroclimatic potential for the crop was determined (Table 2).

Table 2. Summary of climatic suitability of banana

CROP	SUITABILITY	CLIMATE INDEX	DEFICIENCY/EXCESS
	Full	Def < 200mm	Good water conditions for the development of the crop.
Moderate		→ 200mm < Def < 350mm	Seasonal water insufficiency, extending the crop cycle.
Banana restricted		→ 350mm < Def < 700mm	Marked water deficit, being possible the cultivation only in floodplains and wetter places.
Disability		→ Def > 700mm	Very severe water deficit. Cultivation is only possible through irrigation.

RESULTS AND DISCUSSIONS

Figure 1 is a map of climatic suitability for bananas for the state of Piauí, Brazil, where two classes of well-defined suitabilities are established: restricted and unsuitable. In restricted suitability, planting can be carried out with soil treatment and water supply through irrigation. Moderate and full suitabilities do not stand out on the map.

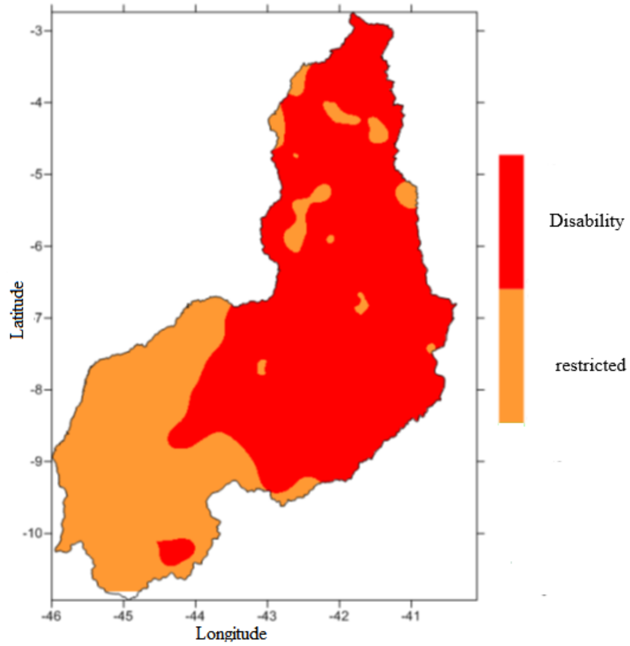

Figure 1. Climate suitability for the banana crop in the state of Piauí, Brazil.

Source: Medeiros (2021).

The elements of the CWB computation flowing from 30 to 100 years in the state of Piauí, Brazil, are available in Table 3 and Figure 1, considering the Water Storage Capacity (WSC) of 100 mm. The consumption of how much water is actually being evapotranspiration is expressed by the actual evapotranspiration (ETR), which behaved similarly to the rainfall distribution. The indices of aridity (Ia), humidity (Iu), water (Ih) and CV (centralization of evapotranspiration) were determined by the hottest quarter of the year.

Table 3 represents the average CWB in the state of Piauí, Brazil, and it can be seen that the average temperature ranges from 25.3 °C in February to 28.3 °C in October, with an annual temperature of 26.5 °C. The annual precipitation of the 221 municipalities of Piauí is 943.7 mm. The rainy quarter is represented by the months of January, February and March with fluctuation between 166.4 mm month^{-1} to 210.5 mm month^{-1}. The dry quarters occur in the July, August and September and flow between 2 mm month^{-1} to 5.6 mm month^{-1}.

The annual ETP is 1, 630.1 mm and the quarter with the highest evaporative values occurs in the months of August, September and October. Its monthly oscillation flows between 142.2 mm to 178.5 mm. In the months of February, March and April occur the lowest evaporative indices flowing from 106.6 mm to 124.1 mm. The annual real evaporation (EVR) is 2, 319.5 mm. The months with the highest evaporation occur between September, October and November, ranging from 234.4 mm to 253.7 mm. The months of February, March and April register the lowest evaporatives rates with fluctuations between 151.7 mm to 176.4 mm.

Table 3 - Climatological Water Balance of the state of Piauí, Brazil.

Months	T (°C)	P (mm)	ETP(mm)	EVR(mm)	DEF (mm)	EXC (mm)	%P/ETP	%P/EVR
Jan	25,9	166,4	126,3	126,3	0,0	0,0	31,7	31,7
Feb	25,3	171,3	108,3	108,3	0,0	3,1	58,2	58,2
Mar	25,7	210,5	124,9	124,9	0,0	85,6	68,5	68,5
Apr	25,6	150,7	117,8	117,8	0,0	32,9	27,9	27,9
May	25,7	54,7	120,7	103,0	17,7	0,0	-54,7	-46,9
Jun	27,2	12,0	143,4	49,8	93,6	0,0	-91,6	-75,9
Jul	25,7	5,3	119,9	14,7	105,1	0,0	-95,6	-63,9
Aug	26,7	2,0	139,1	5,3	133,8	0,0	-98,6	-62,3
Sep	28,0	5,6	162,4	6,4	156,0	0,0	-96,6	-12,5
Oct	28,3	21,6	177,1	21,8	155,3	0,0	-87,8	-0,9
Nov	27,7	55,0	160,3	55,0	105,3	0,0	-65,7	0,0
Dec	26,7	88,6	145,9	88,6	57,3	0,0	-39,3	0,0

Source: Medeiros (2021).

The pluvial values surpassed the evapotranspiration and evaporative indexes from January to April. From May to December the evapotranspiration power was superior to the pluvial ones. Between November and December, evaporative indices were equal to rainfall.

Figure 2 shows the graphical representation of the CWB in the state of Piauí. There were no water surpluses and water shortages would occur between May and December. Replenishment of water in the soil takes place between April and the removal of water from the soil from May to August. Its annual variabilities are shown in the aforementioned chart. It should be noted that, taking into account the climatic rainfall for the entire state of Piauí, its averages are camouflaged caused by the semi-arid area of Piauí, where its rainfall levels are extremely irregular.

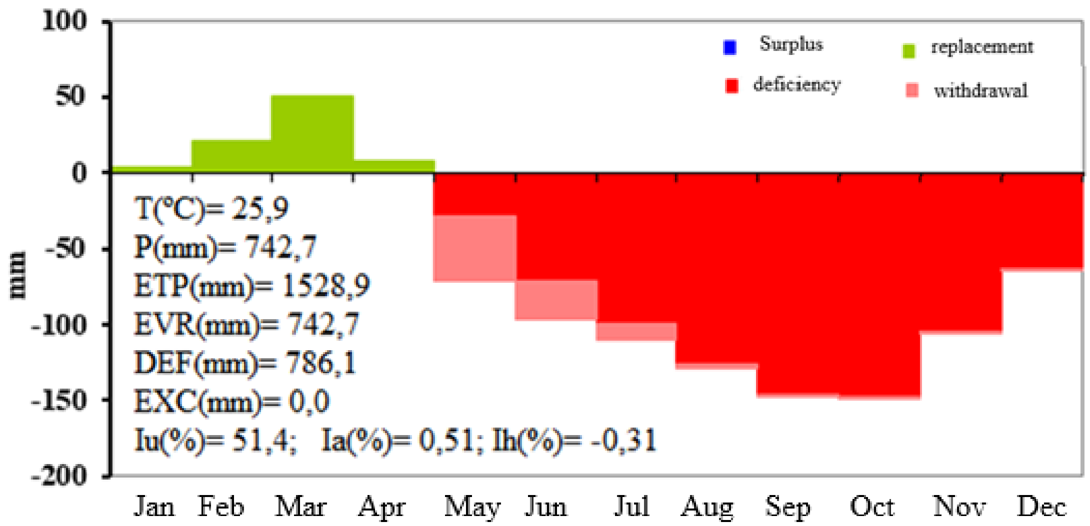

Figure 2. Graphic representation of the climatological water balance of the state of Piauí, Brazil.

Source: Medeiros (2021).

In the phases of calculations, evapopluviogram and application in tables, the results of climate indices are shown in Table 4. These indices are in accordance with several studies carried out for the Brazilian semi-arid region (MEDEIROS et al., 2013; MATOS et al., 2014; RICCE et al., 2014).

Using the points of the evapopluviogram, were determined the indices of vegetation (Iv), dry rest (Irs), cold rest (Irf) and water (Ih). Finally, the values of the climatic indexes were applied in Table 2 to determine the climatic suitability of the region, classifying the crops in full suitability, moderate suitability, restricted suitability and disability (unsuitability).

The climatic indexes (Table 4) indicate the conditions for the cultivation in a sustainable way, aiming at planning to obtain an economic return. Based on the climate and soil of the region, it is possible to obtain greater profitability in agricultural crops (MEDEIROS, 2011).

Table 4 - Climatic indexes and parameters for the state of Piauí, Brazil.

CLIMATE INDEX	I_h	I_v	I_{rs}	I_{rf}	CvT		P	ETP	DEF	EXC
					(%)	ºC	(mm yearly^{-1})			
Value	16,0	32,0	17,0	12,0	30,6	25,9	742,7	1528,9	786,1	0,0

Abbreviation meaning: Ih - water index; IV - vegetative index; Irs - drought rest index; Irf - cold rest index; Cv - concentration of potential evapotranspiration in the warm season; T - average annual temperature, P - pluviometric precipitation; ETp - potential evapotranspiration, DEF - water deficit; and EXC - excess water.

Source: Medeiros (2021).

These oscillations occur due to fluctuations between the municipal dry and rainy seasons. It is also noted that the oscillations of the elements that provoke and/or inhibit the rainfall index depend exclusively on wide, meso and large scale variations, as well as on local effects, such as: orography, positioning of the Intertropical Convergence Zone (ITCZ), the performance of the High Level Cyclonic Vortexes (VCA), South Atlantic Convergence Zone (ZCAS), Cold front penetration when in activity, latent to sensitive heat exchange and vice versa, instability line and its respective local or regional effects.

Wollmann and Galvani (2013) report that local water and climate conditions are taken into account in agroclimatic zoning, with a view to exploiting economically profitable crops. These are the agroclimatic characteristics of a location that determine the suitability for crop development.

Figure 3 shows the distribution of the water sectors and thermal bands of the evapopluviogram for the State of Piauí, Brazil, emphasizing that there are six types of predominant climate in the study area, which are: arid with four months, and has a value of Irs = 12; in the dry climate there are two months with Iv = 4, Ih= 2 and Irs= 4; in the sub-humid type there was one month with Iv=4, Ih=2 and Irs=1; in the type of humid climate, four months were registered with Iv=24, Ih=12 and Irs=0; and in the hyper humid type there was one month with Iv=0. The annual variability is quite irregular and they are interconnected to the period and the factors causing rainfall (MARENGO et al., 2015; MARENGO et al., 2008).

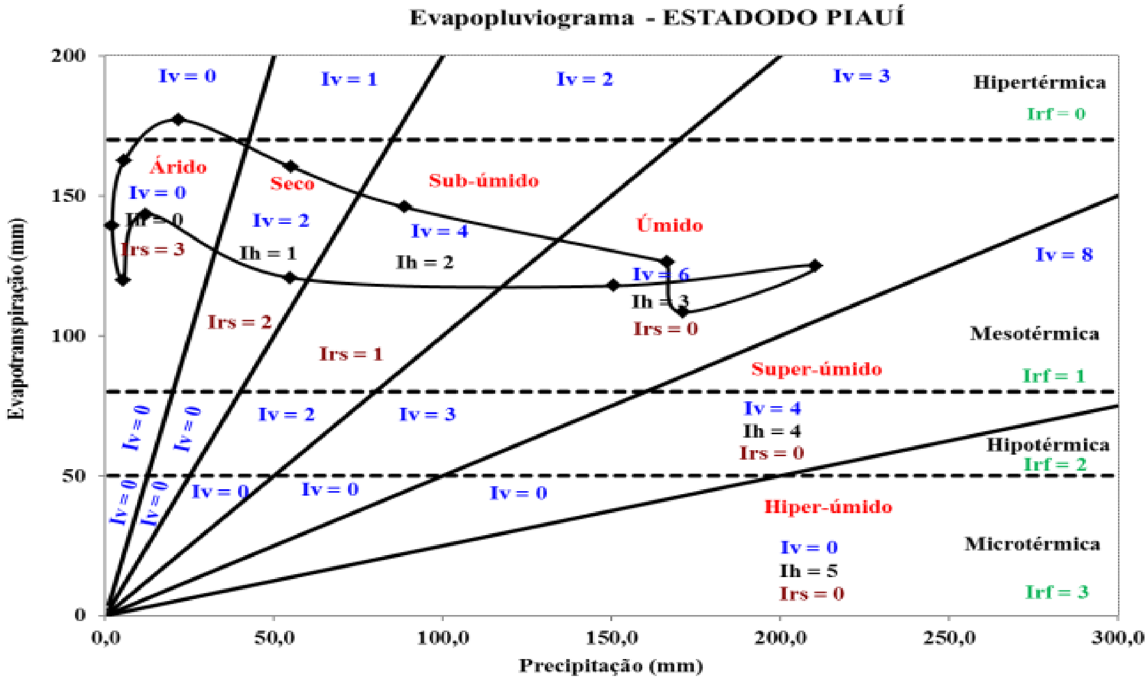

Figure 3. Distribution of water sectors and thermal bands of the evapopluviogram for the State of Piauí, Brazil.

Source: Medeiros (2021).

The distribution of climatic suitability for banana cultivation in the state of Paraíba, Brazil, shows the variability between evapotranspiration and precipitation in this region. It is observed that the most favorable areas for banana cultivation are the coastal, marsh, Agreste and isolated areas on the border with the state of Pernambuco state. The Cariri/Curimataú region and the border with Rio Grande do Norte state stand out as an area not conducive to banana planting. In the Sertão and Altos Sertões regions there are some isolated areas with suitability, but they are restricted to cultivation due to lack of water for crop irrigation in the months when the greatest water deficit occurs (Figure 4).

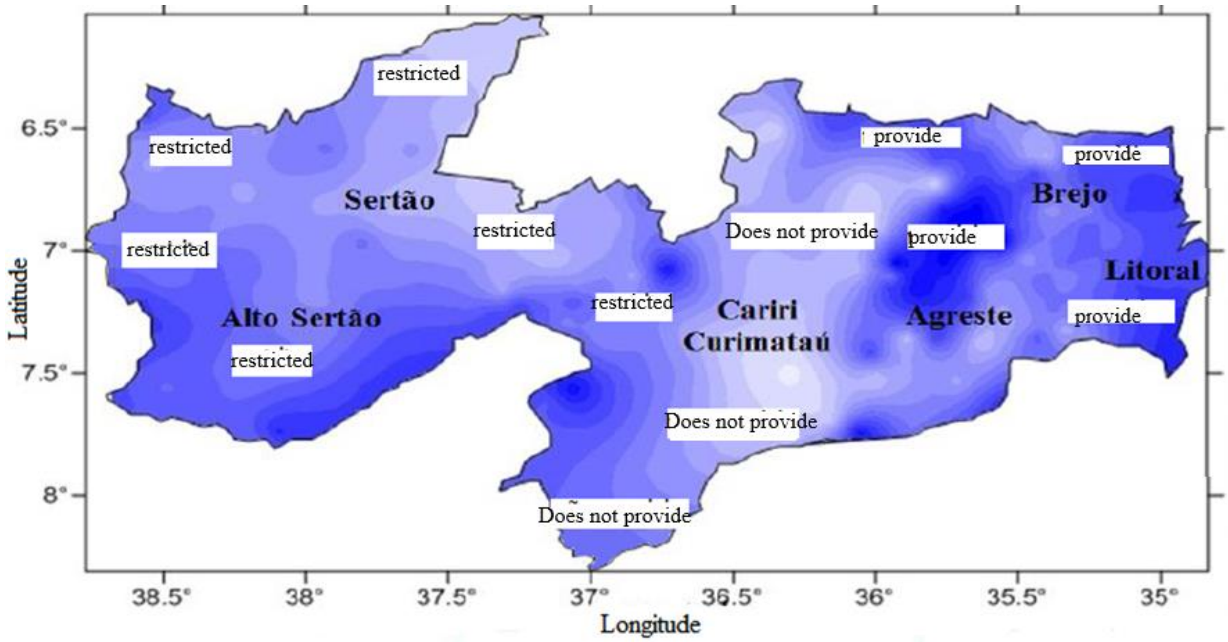

Figure 4. Spatial distribution of climatic suitability for banana cultivation in the state of Paraíba, Brazil.

Source: Medeiros (2021).

In Table 5 there is the representation of the average climatological water balance of the state of Paraíba. The temperature ranges from 22.3 ºC (July) to 25.6 ºC in December and January, with an annual temperature of 24.2 ºC. Annual precipitation of 846.5 mm and its monthly fluctuations range from 11.3 mm (October) to 148.2 mm (April). Monthly ETP flows from 80.2 mm (July) to 130.4 mm (December) with an annual total of 1272.0 mm. With annual EVR equal to the rainfall index (846.5 mm), its monthly fluctuations range from 19.6 mm (November) to 121.1 mm (March). Water deficiencies (DEF) were registered between the months of July and February, flowing between 1.7 mm and 100.5 mm. There was no DEF between March and June. Water surpluses were not registered in any month. (Table 5). The evapotranspirative power surpassed the pluvial indices in the months of January, February and between the months of July to December. In the months of May to June the pluvial indices were higher than the evapotranspirational indices. Evaporation exceeded rainfall rates between January and March and between July and December. Similar results were detected by Medeiros et al. (2016).

The balance of the CWB for the state of Paraíba can help agricultural producers in planning agricultural activities, aiming to minimize losses and increase production. These results are in agreement with several studies carried out for the Brazilian semiarid region (MATOS et al., 2014; MEDEIROS et al., 2018).

Table 5. The average climatological water balance of the State of Paraíba, Brazil.

Months	T (°C)	P (mm)	ETP (mm)	EVR (mm)	DEF (mm)	EXC (mm)	%(P/ETP)	%(P/EVR)
Jan	25,6	70,9	127,0	71,4	55,7	0,0	-44,2	-0,7
Feb	25,4	99,3	114,9	99,4	15,5	0,0	-13,6	-0,1
Mar	25,1	151,5	121,1	121,1	0,0	0,0	25,1	-87,5
Apr	24,5	148,2	107,0	107,0	0,0	0,0	38,5	38,5
May	23,7	101,7	98,3	98,3	0,0	0,0	3,5	3,5
Jun	22,7	89,7	82,8	82,8	0,0	0,0	8,3	8,3
Jul	22,3	72,0	80,2	78,5	1,7	0,0	-10,2	-8,3
Aug	22,4	38,8	82,8	65,9	17,0	0,0	-53,1	-41,1
Sep	23,6	19,9	94,4	45,6	48,8	0,0	-78,9	-56,4
Oct	24,6	11,3	113,0	26,2	86,8	0,0	-90,0	-56,9
Nov	25,2	14,1	120,1	19,6	100,5	0,0	-88,3	-28,1
Dec	25,6	29,1	130,4	30,9	99,5	0,0	-77,7	-5,8

Abbreviation meaning: Mean air temperature (T), Precipitation (P), Potential Evapotranspiration (ETP), Actual Evaporation (EVR), Water Deficiency (DEF), Water Excess (EXC), percentage of precipitation over potential evapotranspiration (%P/ ETP), percentage of precipitation on evaporation (%P/EVR).

Source: Medeiros (2021).

Water deficiency must be monitored so that it does not interfere with crop development and productivity. Santos et al. (2010) stated that it is essential to use irrigation systems in regions with severe water deficit, especially when this soil water deficit extends almost every month of the year.

There was no water surplus during the study period. This absence of surplus is camouflaged by the average, when are calculated the averages for the Cariri/Curimataú, Sertão and Alto Sertão regions, because in these areas more than 70% of the municipalities are located in the semi-arid region of Paraíba. Water deficiencies prevail between the months of July to February. The removal of water from the soil takes place between the months of July to November. The replacement of water is registered in the months of April to June. (Figure 5).

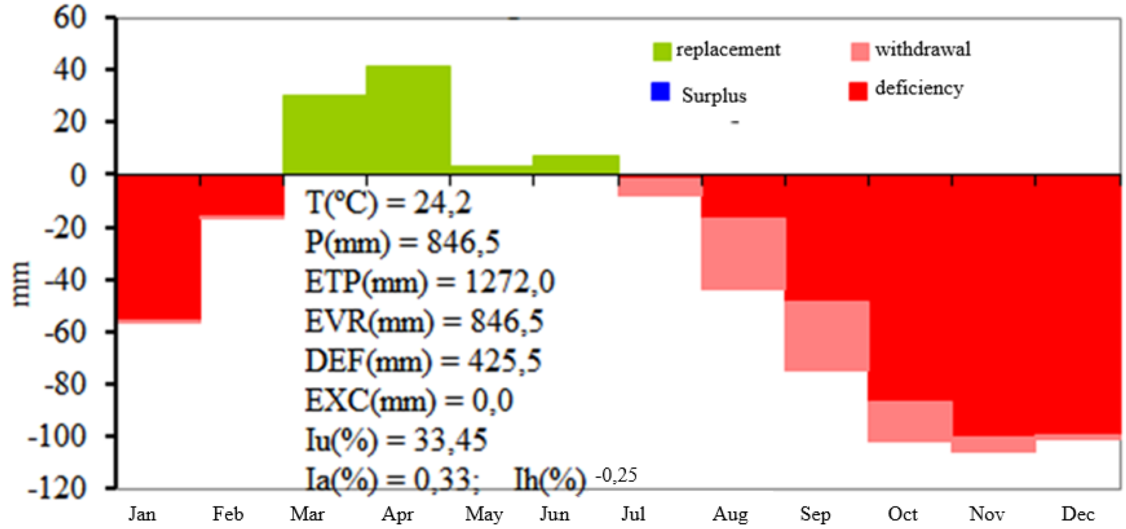

Figure 5. Graphic representation of the climatological water balance of the state of Paraíba, Brazil.

Source: Medeiros (2021).

In the phases of calculations, evapopluviogram and application in tables, the results of climate indices are shown in Table 6. These indices are in accordance with several studies carried out for the Brazilian semi-arid region (MEDEIROS et al., 2013; MATOS et al., 2014; RICCE et al., 2014).

The climatic indexes (Table 6) indicate the conditions for the cultivation in a sustainable way, aiming at planning to obtain an economic return. Based on the climate and soil of the region, it is possible to obtain greater profitability in agricultural crops (MEDEIROS, 2011).

Table 6 - Climatic indexes and parameters for the state of Paraíba, Brazil.

CLIMATE INDEX	I_h	I_v	I_{rs}	I_{rf}	Cv (%)	T ºC	P	ETP	DEF	EXC
							(mm year^{-1})			
Value	-20,1	38,0	17,0	12,0	29,7	24,2	846,5	1272,0	425,5	0,0

Abbreviations meaning: Ih - water index; IV - vegetative index; Irs - drought rest index; Irf - cold rest index; Cv - concentration of potential evapotranspiration in the warm season; T - average annual temperature, P - pluviometric precipitation; ETp - potential evapotranspiration, DEF - water deficit; and EXC - excess water.

Source: Medeiros (2021).

Using the annual water index (Ih) the climate type was defined as Semi-arid (D), through the potential annual evapotranspiration, the thermal classification was obtained as a Megathermal climate (A'), as Ih < 0, generically designated as "dry climates" are framed according to the moisture index (Iu), thus giving rise to the climatic subtype (D) with little or no excess water, and in accordance with the concentration of potential evapotranspiration in the hot season (Cv), defined by the three consecutive months of highest temperature of the year, yet another climate subtype (a') was established indicating the percentage of annual potential evapotranspiration concentrated in the warmest quarter of the year.

In the Figure 6 the arid type sector, occur in four months with Irs= 12; the type of dry climate was registered in just one month with Irs=2, Ih=2, and Iv= 4; the Sub-humid climate type occurred in three months with Irs= 3, Ih=6, and Iv=12; the type of humid climate occur with four months with Irs = 0, Ih=12, and IV = 24.

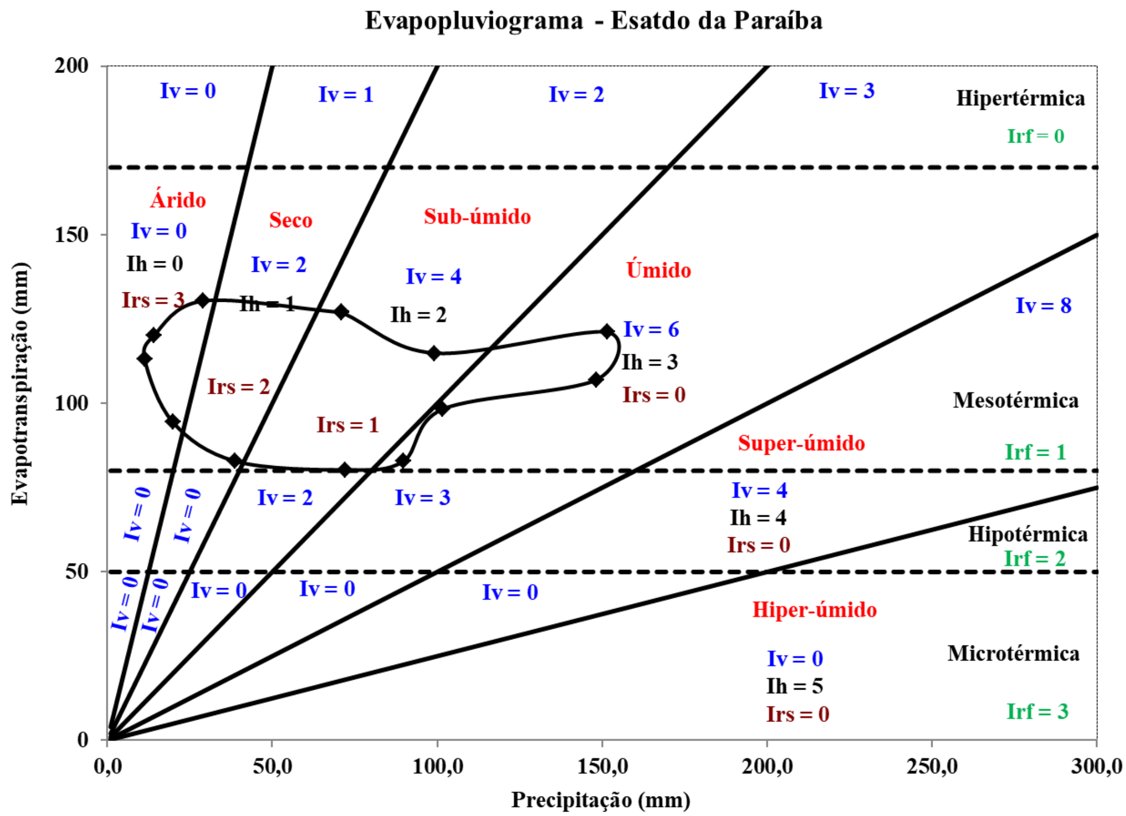

Figure 6. Distribution of water sectors and thermal bands of the evapopluviogram for the State of Paraíba, Brazil.

Source: Medeiros (2021).

CONCLUSIONS

The regions of Piauí state were classified as unsuitable for banana production, as there is a high water deficit and lack of water for supplementation by irrigation.

In spite of it was found that the agroclimatic conditions of the state of Paraíba were classified as restricted to banana cultivation, due to the occurrence of severe water deficit, there is in some regions adequate subsidy for the planning and implementation of the banana crop by farmers in this state.

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