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AGRICULTURAL SUITABILITY OF THE SOUTHWEST REGION OF THE STATE OF PIAUÍ, BRAZIL, THROUGH THE CLIMATOLOGICAL WATER BALANCE

APTIDÃO AGROPECUÁRIA DA REGIÃO SUDOESTE DO ESTADO DO PIAUÍ, BRASIL, POR MEIO DO BALANÇO HÍDRICO CLIMATOLÓGICO

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ABSTRACT: The objective of this research was to verify the agricultural aptitude from the climatological water balance for the Southwest region of the State of Piauí, Brazil, which covers the municipalities of Bom Jesus, Caracol, Cristino Castro, and Floriano (cities with more than 40 years of historical data collected using conventional meteorological stations) and Alvorada, São Raimundo Nonato, and Uruçuí (cities with more than 10 years of historical data collected using automatic stations). The water balance was determined using historical monthly rainfall and air temperature data. The results verified that the cities of Bom Jesus, Floriano, and São Raimundo Nonato had soil water deficits in all months of the year, reaching 1146, 1205, and 1445 mm year-1, respectively. Caracol, Cristino Castro, and Alvorada had water deficiencies in all but one month of the year, reaching 641, 1114, and 1271 mm year-1, respectively. The deficiency occurred in ten months (1025 mm year-1) in Uruçuí. Planting planning is necessary so that the phases of maximum water demand of crops do not coincide with the months of maximum water deficiency in the soil to guarantee high yield and quality in agricultural production.

Keywords: crop planning, grain production, climatological zoning, cerrado, irrigation, INMET.

RESUMO: O objetivo desta pesquisa foi verificar a aptidão agropecuária a partir do balanço hídrico climatológico para a região Sudoeste do Estado do Piauí, Brasil, que abrange os municípios de Bom Jesus, Caracol, Cristino Castro, Floriano (cidades com estação meteorológica convencional com série histórica de 40 anos de dados), Alvorada, São Raimundo Nonato e Uruçuí (cidades com série histórica de dados superior a 10 anos, sendo oriundos de estação automática). O balanço hídrico foi conduzido utilizando dados de séries históricas mensais de precipitação pluviométrica e temperatura do ar. Os resultados permitiram verificar que os municípios de Bom Jesus, Floriano e São Raimundo Nonato apresentam deficiência hídrica no solo em todos os meses do ano, chegando a 1146, 1205 e 1445 mm ano-1, respectivamente. Em Caracol, Cristino Castro e Alvorada, onze dos doze meses do ano tiveram deficiência hídrica, e 641, 1114 e 1271 mm ano-1 (respectivamente). Em Uruçuí a deficiência deu-se em dez meses (1025 mm ano-1). Para garantir altas produtividades e qualidade na produção agropecuária, é necessário um planejamento do plantio, de modo que as fases de máxima exigência hídrica das culturas não coincida com os meses de máxima deficiência de água no solo.

Palavras-chave: *planejamento de safra, produção de grãos, zoneamento climatológico, cerrado, irrigação, INMET.*

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INTRODUCTION

Water resources in the most varied regions suffer from disturbances, and climate change is expected to lead to water stress and uncertainty (WANG et al., 2016). Climate change has caused a reduction in rainfall in the Northeast of Brazil, generating more intense drought periods (ARTAXO, 2014). Lacerda et al. (2016) identified trends toward a decrease in annual rainfall, showing an increase in the amount of rainfall in a large part of the Brazilian Northeast, which has a natural characteristic of high potential for water evaporation due to the high availability of solar energy and high temperatures.

Water planning is considered the starting point for the integrated management of water resources, and determining the climatological water balance (CWB) provides knowledge of the need for and availability of water in the soil over time (SANTOS et al., 2010). This approach can mitigate the effects of poor distribution of water caused by irregular rainfall, enhancing agricultural profitability, especially in crops, and reducing losses in regions with agricultural suitability where rainfed grain cultivation is predominant, such as, cities in the Southwest of Piauí.

These municipalities are important in the scenario as they are part MATOPIBA, a region in in Piauí encompassingwhich 33 municipalities and nearly 74 million hectares, with 91% of the area falling within the Cerrado biome (IBGE, 2010).

Passos et al. (2017) conducted a CWB for the municipality of Balsas, Maranhão. Souza et al. (2013) calculated the CWB for 12 municipalities in Mato Grosso, Brazil. Medeiros et al. (2013) studied the CWB to identify the suitability of the Barbalha region, Ceará, for banana cultivation. Oliveira & Oliveira (2018) calculated the CWB for the municipality of Arinos, Minas Gerais, and Fernandes et al. (2020) from the city of Bom Jesus, Piauí.

The objective of this research was to conduct the CWB in the municipalities of Bom Jesus, Caracol, Cristino Castro, and Floriano (cities with more than 40 years of historical data collected using conventional meteorological stations) and Alvorada, São Raimundo Nonato, and Uruçuí (cities with more than 10 years of historical data collected using automatic stations) from the Southwest region of Piauí, using the method of Thornthwaite and Mather (1955).

MATERIAL AND METHODS

The study was conducted using monthly historical data on rainfall and air temperature for cities in the Southwest region of the State of Piauí, which included Bom Jesus, Caracol, Cristino Castro, and Floriano. These municipalities have conventional meteorological stations (EMCs), with 40 years of historical data.

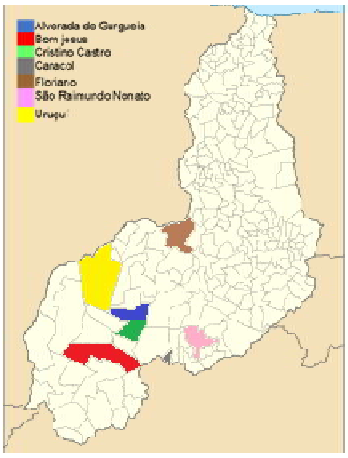
For the cities of Alvorada do Gurguéia, São Raimundo Nonato and Uruçuí (data collected for 10 years), data were collected using automatic meteorological stations (EMA) (Table 1).

Table 1. Conventional and automatic meteorological stations in the Southwest of the State of Piauí, Brazil, evaluated in the study.

Station	Location	Latitude	Longitude	Altitude (m)
	Bom Jesus	-9.10	-44.11	296.00
Conventional	Caracol	-9.28	43.33	522.77
	Cristino Castro	-8.41	-43.71	265.00
	Floriano	-6.76	-43.01	123.27
	Alvorada	-8.44	-43.86	261.00
Automatic	São Raimundo Nonato	-9.03	-42.70	383.00
	Uruçuí	-7.44	-44.34	399.00

Source: INMET (2018).

The spatial distribution of EMC's and EMA's was implemented considering the conventional and automatic stations existing in the Southwest region of the State of Piauí and thus contributing to its Socioeconomic and Ecological Zoning (Figure 1A). The area is characterized by differentiated altimetric variations, such as the high plateaus of the South-Southwest with altitudes around 600 meters. These decrease toward the north, reaching the lowest point along the coast of the State of Piauí (Figure 1B).



A

B

Figure 1: Spatial distribution of conventional and automatic meteorological stations in the INMET network, Southwest region of the State of Piauí (A). The State of Piauí is highlighted (B). Source. Wikipedia (2020).

The State of Piauí is situated in the Northeast region of Brazil (NEB), positioned between the humid Middle North and the semi-arid Northeast. This gives rise to unique geoenvironmental conditions.

Data were obtained from the National Institute of Meteorology (INMET), based on a historical series from the Meteorological Database for Teaching and Research (BDMEP). Monthly data on average air temperature and rainfall were collected. Next, the data were tabulated using Microsoft Excel, and the averages of all months of the period were calculated. Subsequently, information from the scenarios was used to determine and calculate the elements that comprise the water balance. The data on potential evapotranspiration, water surplus, and water deficit were then grouped into a spreadsheet for later preparation of the figures.

The available soil water capacity (SWC) was 100 mm (the readily available water capacity for plants). Cardoso et al. (2003) conducted a simulation of an agroclimatic water balance for a period of 20 years based on the average values of precipitation and evapotranspiration, and verified that the probability of occurrence of water deficits is very low for SWC conditions of 75 and 100 mm, the probability of no water deficit was greater than 50% for most ten-day periods of the year for SWC values of 50 mm, and the probability of the occurrence of water deficits was significantly high for SWC values of 25 mm, presenting significant magnitudes, especially in summer. This would justify the need to use irrigation in these situations.

Potential evapotranspiration (PET) was estimated using the method described by Thornthwaite and Mather (1955), following the considerations made by Pereira et al. (1997):

when: $0 < Tn < 26.5$ °C
$$PET = 16\ (10\ Tn/I)\ \hat{}a \quad (1)$$

when: $Tn \geq 26.0$ °C
$$PET = -415.85 + 32.24\ Tn - 0.43\ Tn2 \quad (2)$$

where Tn is the average temperature of month n (°C), and I is an index that expresses the heat level of the region.

The subscript n represents the month; for example, n = 1 is January, and n = 2 is February.

The value of I depends on the annual temperature rhythm, integrates the thermal effect of each month, and is calculated using the following equation:

$$I = 12\ (0.2\ Ta)1.514 \quad (3)$$

where Ta denotes the average annual temperature.

The exponent “a,” being a function of I, is also a regional thermal index, and is calculated by the expression:

$$a = 6.75\ 10\text{-}7\ I3 - 7.71\ 10\text{-}5\ I\ 2 + 1.7912\ 10\text{-}2\ I + 0.49239 \quad (4)$$

The PET value represents the total monthly evapotranspiration that would occur under the thermal conditions of a standard month of 30 days and each day with a 12-hour photoperiod (N). Therefore, PET must be corrected according to N and the number of days in the period (NDP).

$$Color = (ND/30)\ (N/12) \quad (5)$$

The following formula was used for the surplus: EXC = (P- PET)-ALT. where P is precipitation, PET is potential evapotranspiration, and ALT is the change in soil moisture. In relation to the water deficit, the following equation was used: DEF = PET – ETR.

where PET is the potential evapotranspiration, and ETR is the actual evapotranspiration, determined by the formula ETR = P – ALT.

RESULTS AND DISCUSSION

Table 2 presents the CWB results for the municipality of Bom Jesus. The highest average monthly temperatures were observed in September, (30.9 °C) and October (30.3 °C), with the lowest monthly thermal average in January (26.5 °C). The average annual temperature was 28.2 °C, showing little variability.

Table 2. Climatological water balance of the municipality of Bom Jesus, State of Piauí.

Month	T	PET	P	P- PET	NEG.AC	ARM	ALT	ETR	DEF	EXC
	-°C-	----------mm----------				------------------mm------------------				
JAN	26.5	185	166	-20	-20	82	82	83	102	0
FEV	27.0	172	164	-8	-27	76	-6	170	2	0
MAR	27.2	185	166	-18	-46	63	-13	179	6	0
ABR	27.6	170	108	-61	-107	34	-29	137	32	0
MAI	28.0	162	30	-132	-239	9	-25	55	107	0
JUN	27.7	145	5	-139	-378	2	-7	12	133	0
JUL	27.6	152	5	-147	-526	1	-2	6	146	0
AGO	29.3	180	7	-174	-699	0	0	7	173	0
SET	30.9	204	17	-188	-887	0	0	17	188	0
OUT	30.3	218	75	-144	-1031	0	0	75	143	0
NOV	28.6	200	122	-78	-1109	0	0	122	78	0
DEZ	27.2	191	154	-37	-1146	0	0	154	37	0
ANO		2164	1018	-1146			0	1018	1146	0

T: air temperature; P: precipitation; PET: potential evapotranspiration; P- PET: amount of water remaining in the soil; NEG.AC: accumulated negative; ARM: soil water storage; ALT: current ARM-previous ARM; ETR: actual evapotranspiration; DEF: water deficiency and EXC: water surplus.

The annual precipitation reached an average value of 1018 mm, with a period of greater precipitation from January to April and October to December, with over 90% of the annual rainfall recorded in these months.

The annual potential evapotranspiration was 2164 mm, representing a monthly average of 180 mm, with the months with the highest and lowest PET values were October and June (218 and 145 mm, respectively).

Actual evapotranspiration was 1018 mm, with a monthly average of 85 mm (Table 2 and Figure 2).

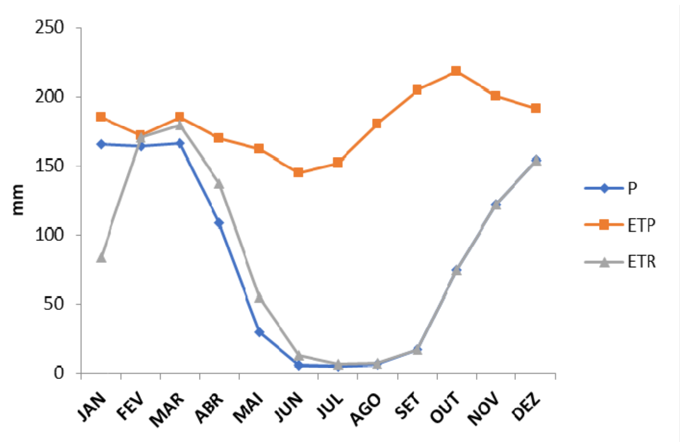


Figure 2: Average monthly data on precipitation (P), potential evapotranspiration (PET) and actual evapotranspiration (ETR), city of Bom Jesus, State of Piauí.

The annual water deficit was 1146 mm (Table 2 and Figure 3). The municipality has a water deficiency for all months of the year. Although there was a high concentration of precipitation in the first and last quarters of the year, high temperatures caused an increase in evapotranspiration rates, causing water consumption by plants to be greater than that available in the soil (Figure 3).

Figure 4 shows the water storage in the soil in relation to the available water capacity in the municipality of Bom Jesus.

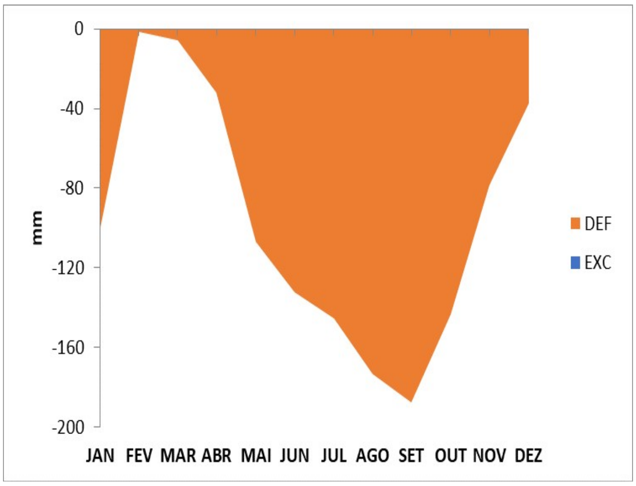


Figure 3: Extract of the climatological water balance of the municipality of Bom Jesus, State of Piauí.

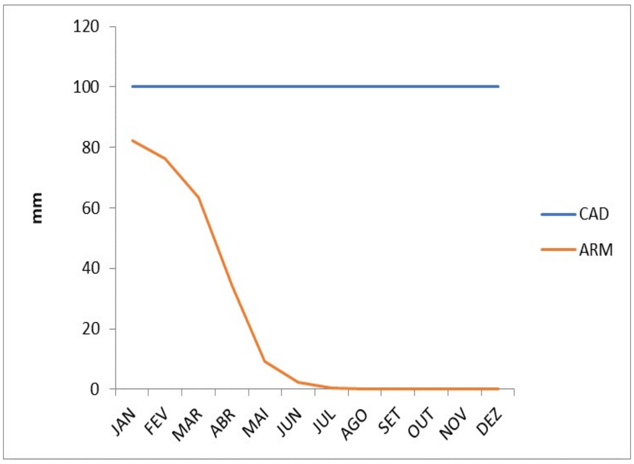


Figure 4: Available water capacity (AWC) and soil water storage (SWS), city of Bom Jesus, State of Piauí

In the municipality of Floriano, an average annual temperature of 27.7 °C was observed, with a minimum monthly temperature of 26.2 °C in February and a maximum of 30.1 °C in September. Rainfall reached 915 mm, with the highest value recorded in January (Table 3). The annual potential evapotranspiration was 2119 mm, with a monthly average of 177 mm. The highest and lowest values were recorded in October and June (214 and 148 mm, respectively).

There was a water deficit of 1205 mm throughout the year.

Table 3. Climatological water balance of the municipality of Floriano, State of Piauí.

Month	T	PET	P	P- PET	NEG.AC	ARM	ALT	ETR	DEF	EXC
	-°C-	---------mm---------				------------------mm------------------				
JAN	26.5	180	163	-17	-17	84	84	79	101	0
FEV	26.2	160	140	-20	-38	69	-16	155	5	0
MAR	26.4	176	156	-20	-58	56	-13	169	8	0
ABR	26.6	162	112	-50	-107	34	-22	134	28	0
MAI	26.9	157	47	-110	-217	11	-23	70	87	0
JUN	27.0	148	8	-140	-357	3	-9	17	131	0
JUL	27.4	156	4	-151	-508	1	-2	6	149	0
AGO	28.8	181	1	-181	-689	0	-1	1	180	0
SET	30.1	201	8	-193	-882	0	0	8	193	0
OUT	30.0	214	56	-158	-1040	0	0	56	158	0
NOV	28.7	197	89	-107	-1147	0	0	89	107	0
DEZ	27.4	188	131	-57	-1205	0	0	131	57	0
ANO		2119	915	-1205		258	0	915	1205	0

T: air temperature; P: precipitation; PET: potential evapotranspiration; P- PET: amount of water remaining in the soil; NEG.AC: accumulated negative; ARM: soil water storage; ALT: current ARM-previous ARM; ETR: actual evapotranspiration; DEF: water deficiency and EXC: water surplus.

Actual evapotranspiration presented an annual total of 915 mm, with a monthly average of 76 mm (Table 3 and Figure 5). The municipality presented a water deficiency across the 12 months of the year, with an accumulated total of 1205 mm (Table 3 and Figure 6). Figure 7 shows the available water capacity and water storage in the soil in the municipality of Floriano.

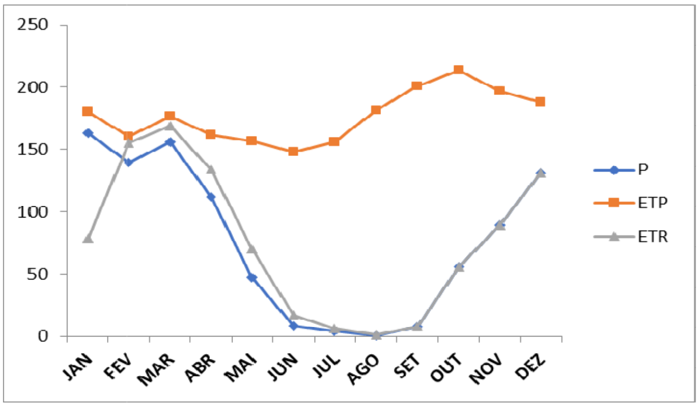


Figure 5: Monthly data on precipitation (P), potential evapotranspiration (PET) and actual evapotranspiration (ETR), municipality of Floriano, State of Piauí.

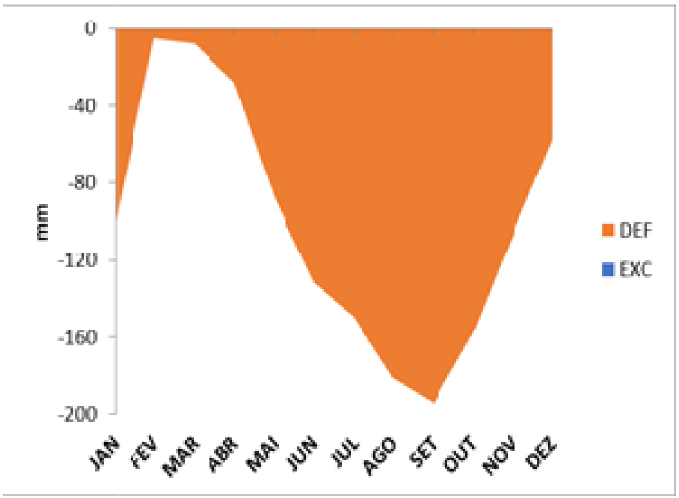


Figure 6: Extract of the climatological water balance of the municipality of Floriano, Piauí.

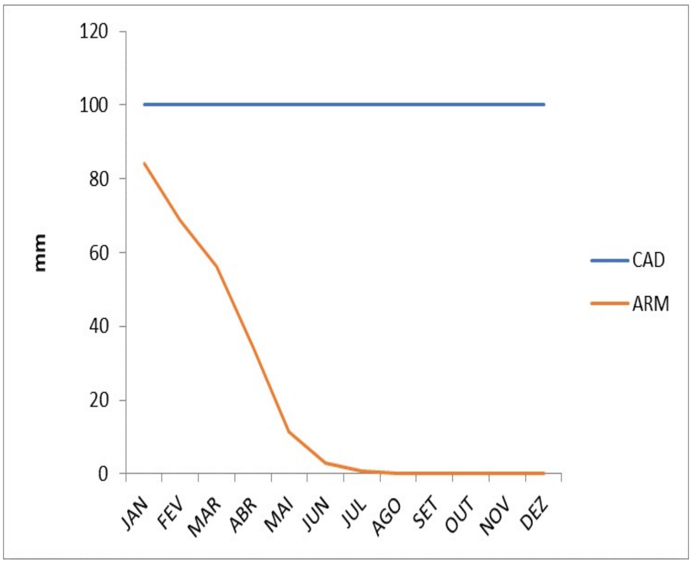


Figure 7: Available water capacity (AWC) and soil water storage (SWS) of the municipality of Floriano, Piauí.

In the municipality of Caracol, the average annual precipitation reached 751 mm, with the period of greatest precipitation between January and April and November and December, with more than 90% of the precipitation (Table 4).

Table 4. Climatological water balance of the municipality of Caracol, State of Piauí.

Month	T	PET	P	P- PET	NEG.AC	ARM	ALT	ETR	DEF	EXC
	-°C-	----------mm----------				------------------mm------------------				
JAN	24.5	143	120	-23	-848	0	0	120	23	
FEV	24.3	125	134	8	-246	9	8	125	0	0
MAR	24.6	138	125	-13	-13	88	79	204	66	0
ABR	24.4	121	86	-35	-48	62	-26	112	9	0
MAI	24.2	110	30	-80	-128	28	-34	64	46	0
JUN	23.4	90	3	-87	-215	12	-16	19	71	0
JUL	23.3	93	2	-92	-306	5	-7	9	85	0
AGO	24.3	116	2	-114	-420	1	-3	5	111	0
SET	26.1	160	5	-155	-575	0	-1	6	154	0
OUT	26.9	184	33	-151	-727	0	0	33	151	0
NOV	25.7	159	91	-68	-795	0	0	91	68	0
DEZ	25.0	151	122	-29	-824	0	0	122	29	0
ANO		1590	751	-839		204	0	909	681	0

T: air temperature; P: precipitation; PET: potential evapotranspiration; P- PET: amount of water remaining in the soil; NEG.AC: accumulated negative; ARM: soil water storage; ALT: current ARM-previous ARM; ETR: actual evapotranspiration; DEF: water deficiency and EXC: water surplus.

The annual potential evapotranspiration was 1590 mm, with a monthly average of 132 mm. The highest and lowest values were recorded in October and June (184 and 90 mm, respectively). The actual evapotranspiration reached an annual total of 909 mm, with a monthly average of 76 mm. The annual water deficit was 681 mm (Table 4, Figures 8 and 9).

Figure 10 shows SWC and soil water storage (SWS) in the municipality of Caracol, PI.

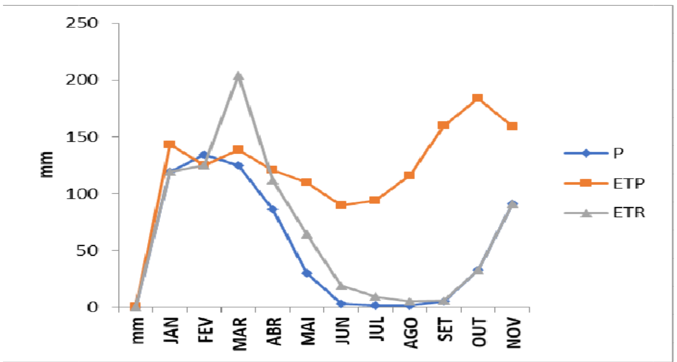


Figure 8: Monthly data on precipitation (P), potential evapotranspiration (PET) and actual evapotranspiration (ETR) in Caracol, State of Piauí.

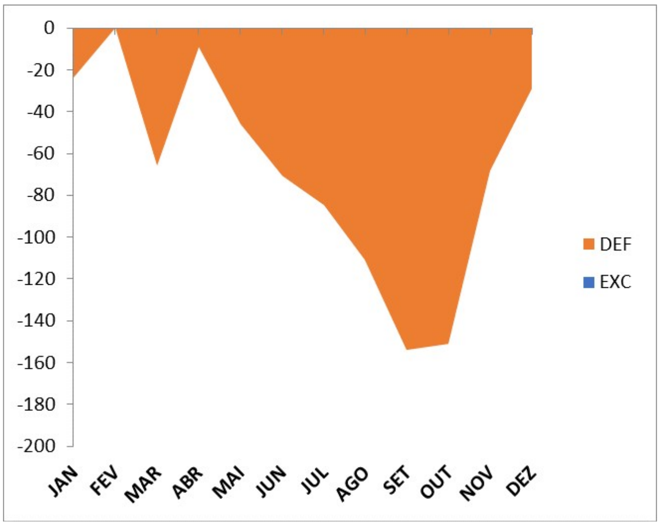


Figure 9: Extract of the climatological water balance of the municipality of Caracol, Piauí.

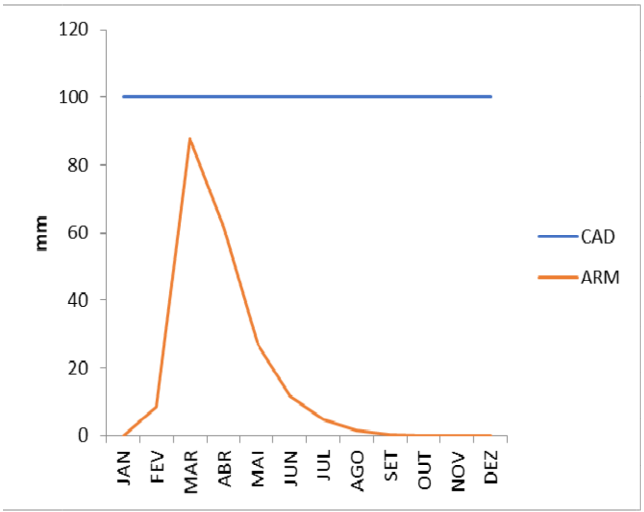


Figure 10: Available water capacity (AWC) and soil water storage (SWS) of the municipality of Caracol, state of Piauí.

The municipality of Cristino Castro presented an average annual rainfall of 849 mm (Table 5). The annual potential evapotranspiration was 1963 mm, with a monthly average of 164 mm. The highest and lowest values were recorded in October and June (209 and 130 mm, respectively).

Table 5. Climatological water balance in Cristino Castro, Piauí.

Month	T	PET	P	P- PET	NEG.AC	SWS	ALT	ETR	DEF	EXC
	-°C-	----------mm----------				-----------------mm-----------------				
JAN	25.8	162	146	-15	-1117	0	0	146	15	0
FEV	25.5	139	142	3	-359	3	3	139	0	0
MAR	25.8	154	134	-20	-20	82	79	55	99	0
ABR	26.1	154	98	-56	-76	47	-35	133	21	0
MAI	26.4	147	38	-108	-184	16	-31	69	77	0
JUN	26.1	130	3	-128	-312	4	-11	14	116	0
JUL	26.4	141	0	-141	-452	1	-3	3	137	0
AGO	27.9	168	1	-167	-619	0	-1	2	166	0
SET	29.5	194	9	-185	-804	0	0	9	185	0
OUT	29.2	209	56	-153	-957	0	0	56	153	0
NOV	27.6	190	93	-96	-1054	0	0	93	96	0
DEZ	26.0	176	128	-48	-1102	0	0	128	48	0
ANO		1963	849	-1114			0	849	1114	0

T: air temperature; P: precipitation; PET: potential evapotranspiration; P- PET: amount of water remaining in the soil; NEG.AC: accumulated negative; SWS: soil water storage; ALT: current SWS-previous SWS; ETR: actual evapotranspiration; DEF: water deficiency and EXC: water surplus.

The annual actual evapotranspiration was 849 mm, with a monthly average of 71 mm. There was an annual water deficit of 1114 mm (Table 5 and Figures 11 and 12). The water balance did not exhibit a water surplus (Table 5 and Figure 12). Figure 13 shows the available water capacity and water storage in the soil of the municipality of Cristino Castro.

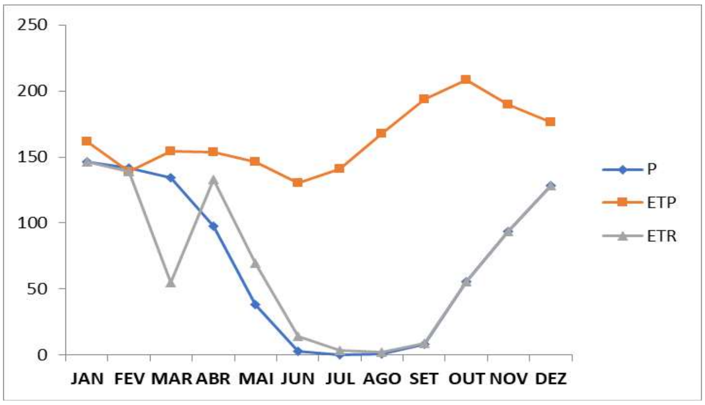


Figure 11: Average monthly data on precipitation (P), potential evapotranspiration (PET) and actual evapotranspiration (ETR) for the municipality of Cristino Castro, State of Piauí.

Figure 12: Extract of the climatological water balance of the municipality of Cristino Castro, Piauí

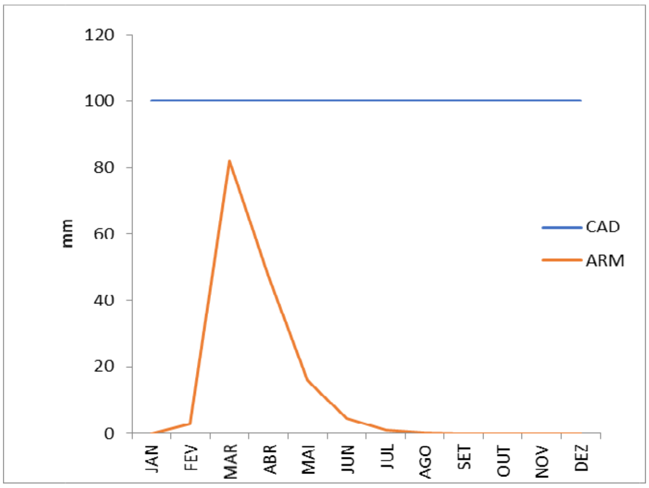


Figure 13: Available water capacity (AWC) and soil water storage (SWS) of the municipality of Cristino Castro, Piauí.

The municipality of Alvorada do Gurgueia (with an automatic station) was characterized by an average monthly rainfall of 62 mm month^{-1}, totaling 737 mm year^{-1}, concentrated in January, February, March, April, and December, accounting for 75% of the total precipitation (598 mm) (Table 6).

Table 6. Climatological water balance of the municipality of Alvorada do Gurgueia, Piauí.

Month	T	PET	P	P- PET	NEG.AC	SWS	ALT	ETR	DEF	EXC
	-°C-	----------mm----------				-------------------mm-------------------				
JAN	26.1	178	134	-45	-1279	0	0	134	45	0
FEV	25.3	138	146	8	-258	8	8	138	0	0
MAR	25.5	151	134	-17	-17	84	77	58	94	0
ABR	25.8	142	96	-47	-64	53	-31	127	15	0
MAI	26.7	151	39	-112	-176	17	-36	74	77	0
JUN	26.7	138	3	-136	-312	4	-13	15	123	0
JUL	26.9	147	0	-147	-459	1	-3	4	143	0
AGO	28.1	171	1	-170	-629	0	-1	2	169	0
SET	29.6	195	4	-192	-821	0	0	4	191	0
OUT	29.8	214	34	-180	-1000	0	0	34	180	0
NOV	28.3	195	59	-136	-1137	0	0	59	136	0
DEZ	26.9	186	89	-97	-1234	0	0	89	97	0
ANO		2008	737	-1271			0	737	1271	0

T: air temperature; P: precipitation; PET: potential evapotranspiration; P- PET: amount of water remaining in the soil; NEG.AC: accumulated negative; SWS: soil water storage; ALT: current SWS - previous SWS; ETR: actual evapotranspiration; DEF: water deficiency and EXC: water surplus.

Annual potential evapotranspiration was 2008 mm, representing a monthly average of 140 mm, with the highest and lowest values recorded in October (214 mm) and February (138 mm). Actual evapotranspiration was 737 mm, with a monthly average of 61 mm (Table 6 and Figure 14).

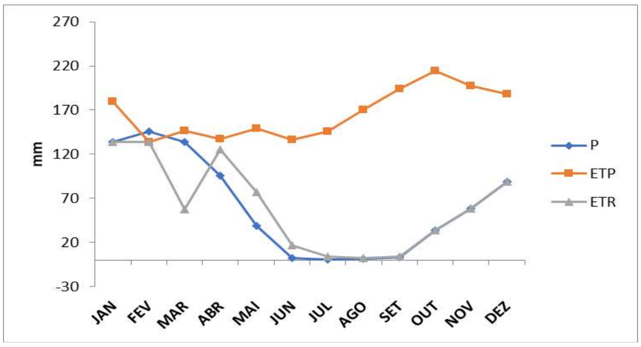


Figure 14: Average monthly data on precipitation (P), potential evapotranspiration (PET) and actual evapotranspiration (ETR). Alvorada do Gurgueia, State of Piauí.

The municipality presented water deficiency in 11 of the 12 months of the year, with a total accumulated of 1271 mm year-1, causing the forces of water retention in the soil to increase, reducing its availability for plants. The water balance presented only one month with water surplus, March, with a total of 44.8 mm (100%). Consequently, the replenishment of water in the soil (ARM) after the dry period also occurred in the month of March, in which precipitation was higher than evapotranspiration (Figure 15).

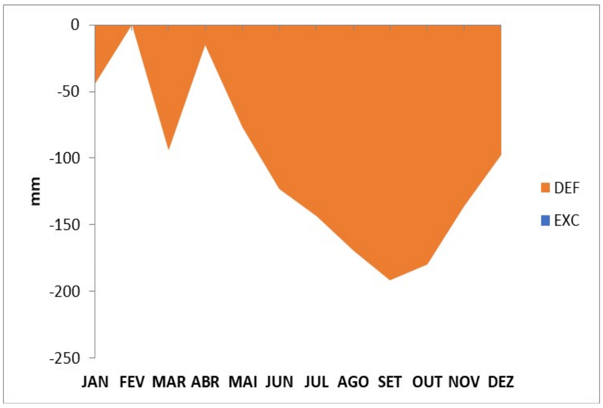


Figure 15: Extract of the water balance of Alvorada do Gurgueia, State of Piauí.

The results of the climatic water balance for São Raimundo Nonato, State of Piauí can be seen in Table 7 and Figure 16, where it can be seen that the annual precipitation reaches values of 565 mm, with a period of higher values in the months of January, February, March, April and December, concentrating more than 80% of the annual rainfall in these months. An annual water deficit of 1445 mm is observed.

Table 7. Climatological water balance in São Raimundo Nonato, State of Piauí.

Month	T	PET	P	P- PET	NEG.AC	ARM	ALT	ETR	DEF	EXC
	-°C-	----------mm----------				-------------------mm-------------------				
JAN	26.1	195	93	-101	-101	36	-36	130	65	0
FEV	25.3	171	94	-77	-178	17	19	75	96	0
MAR	25.5	180	99	-81	-259	7	9	90	90	0
ABR	25.8	156	86	-70	-329	4	4	82	74	0
MAI	26.7	144	18	-126	-456	1	3	15	129	0
JUN	26.7	116	8	-109	-564	0	1	7	109	0
JUL	26.9	120	4	-116	-680	0	0	4	115	0
AGO	28.1	152	0	-152	-832	0	0	0	152	0
SET	29.6	179	2	-177	-1010	0	0	2	177	0
OUT	29.8	206	22	-184	-1193	0	0	22	184	0
NOV	28.3	197	54	-144	-1337	0	0	54	144	0
DEZ	26.9	193	84	-109	-1445	0	0	84	109	0
ANO		2010	565	-1445			0	565	1445	0

T: air temperature; P: precipitation; PET: potential evapotranspiration; P- PET: amount of water remaining in the soil; NEG.AC: accumulated negative; ARM: soil water storage; ALT: current ARM-previous ARM; ETR: actual evapotranspiration; DEF: water deficiency and EXC: water surplus.

The annual potential evapotranspiration was 2010 mm, representing a monthly average of 168 mm, with the highest and lowest values recorded in the months of October and June (206 and 116 mm), respectively. The actual evapotranspiration showed an annual total of 565 mm, with a monthly average of 47 mm (Table 7 and Figure 16).

The municipality experienced water deficiency across the 12 months of the year, with an accumulated total of 1445 mm, causing water retention forces in the soil to increase, reducing its availability for plants.

Analyzing the water deficit, October had the highest value (184 mm), and April (74 mm) the smallest. The monthly average was 120 mm (Figure 17).

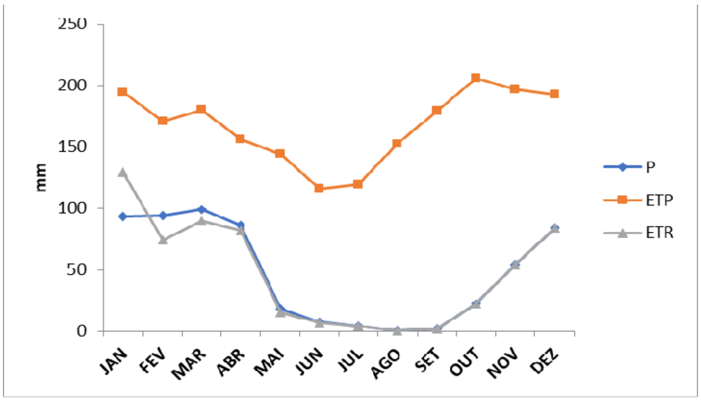


Figure 16: Monthly data on precipitation (P), potential evapotranspiration (PET) and actual evapotranspiration (ETR) in São Raimundo Nonato, State of Piauí.

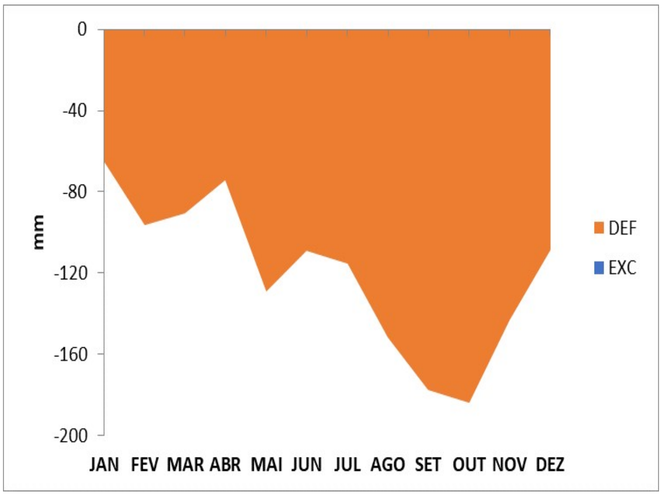


Figure 17: Extract from the Climatological Water Balance of São Raimundo Nonato, Piauí.

SANTOS et al. (2010) stated that it is essential to use irrigation systems in regions with severe water deficiency, especially when this deficit extends to almost every month of the year, to guarantee productivity in terms of the quantity and quality of crops.

The municipality of Uruçuí was characterized by an average rainfall of 62 mm month^{-1}, totaling 742 mm per year, with the rainy months being January, February, March, April, November and December (Table 8).

Table 8. Climatological water balance in Uruçuí, State of Piauí.

Month	T	PET	P	P- PET	NEG.AC	ARM	ALT	ETR	DEF	EXC
	-°C-	----------mm----------				------------------mm------------------				
JAN	25.3	151	94	-57	-1128	0	0	94	57	0
FEV	25.1	131	142	11	11	11	11	131	0	0
MAR	25.1	140	115	-26	-26	77	67	140	0	0
ABR	25.6	137	98	-39	-65	52	-25	123	14	0
MAI	26.0	135	27	-108	-173	18	-34	62	73	0
JUN	26.0	124	8	-116	-289	6	-12	20	104	0
JUL	26.2	140	2	-139	-428	1	-4	6	134	0
AGO	27.2	163	1	-162	-590	0	-1	2	161	0
SET	28.6	187	10	-177	-767	0	0	10	177	0
OUT	28.6	203	51	-152	-919	0	0	51	152	0
NOV	27.0	181	96	-85	-1004	0	0	96	85	0
DEZ	26.1	167	100	-67	-1070	0	0	100	67	0
ANO	-	1859	742	-1117			0	834	1025	0

T: air temperature; P: precipitation; PET: potential evapotranspiration; P- PET: amount of water remaining in the soil; NEG.AC: accumulated negative; ARM: soil water storage; ALT: current ARM-previous ARM; ETR: actual evapotranspiration; DEF: water deficiency and EXC: water surplus.

The annual potential evapotranspiration was 1859 mm, representing a monthly average of 155 mm, with the highest and lowest values recorded in October and June (203 and 124 mm, respectively). Actual evapotranspiration presented an annual total of 834 mm (Table 8 and Figure 18).

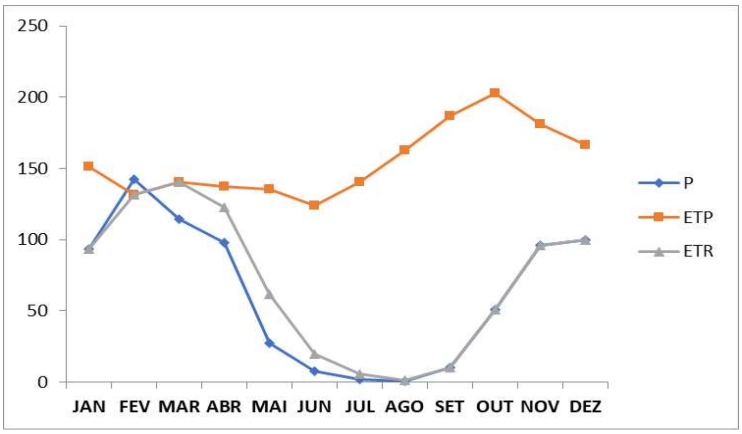


Figure 18: Monthly data on precipitation (P), potential evapotranspiration (PET) and actual evapotranspiration (ETR) in Uruçuí, State of Piauí.

The municipality experienced water deficiency in 10 of the 12 months of the year, with an accumulated total of 1025 mm year-1. The months with the highest deficiency were August and September (161 and 177 mm, respectively). No surplus water was present (Figure 19). This information is important for the planting season, such as pasture formation, the definition of the paddock stocking rate, and agricultural practices, such as fertilization, liming, and activities with agricultural implements.

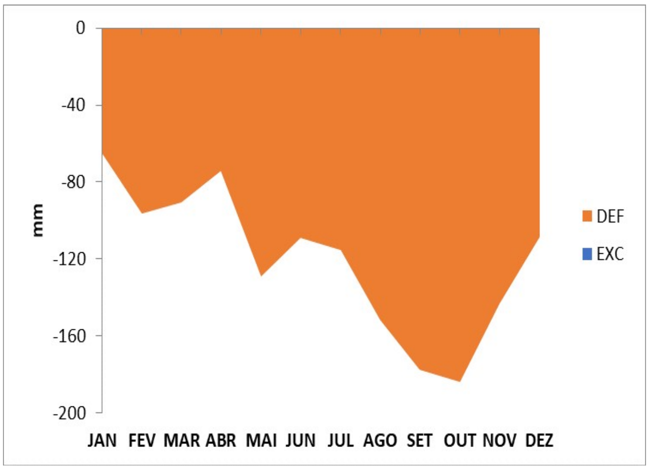


Figure 19: Extract from the Climatological Water Balance of Uruçuí, State of Piauí.

Grain crops that are cultivated under a rainfed regime, mainly in the Cerrados region, such as the cities analyzed here, have rainy months (> 60 mm) mainly from October to March, with average annual precipitation varying from 564 to 1,018 mm, with January to March being the wettest quarter, corresponding to an average of 50.4% of the annual precipitation of the municipalities analyzed, and the driest semester (April to September) with an average value of 11.9%.

An irregular distribution of precipitation was observed by Oliveira & Oliveira (2018), and dry and rainy seasons could be defined based on CWB data from the seven cities in which the meteorological stations in the Southwest of Piauí are located.

When analyzing the CWB in the municipality of São João do Piauí, Piauí, high temperatures caused an increase in evapotranspiration rates, causing plants to consume more water than what was available in the soil, as well as not having any month with a water surplus (Ribeiro et al., 2015).

Water deficiency was observed in 10 or more months of the year in the municipalities analyzed; however, integrated planning of the region's water resources can be determined through the monthly water balance, including the decision to acquire irrigation systems and the sizing of the system's net depth. The irrigator must decide between the greatest need or the greatest deficit considering economic aspects and allow irrigation management (how much and when to irrigate) based on historical evapotranspiration data (SANTOS et al., 2010).

Plants respond to water deficiency in the soil in different ways, including decreased productivity and production, poor distribution and development of the root system, decreased production of leaf area, closure of stomata, reduced flowering and bark oil, and shorter fruit retention times (SANTOS and CARLESSO, 1998).

For the agricultural sector in both municipalities, water balance is essential for establishing strategies that aim to minimize losses and, therefore, increase production. In general, irrigation is used to meet the water needs of crops and agriculture, enabling optimized development (BARRETO et al., 2003).

CONCLUSIONS

The municipalities of Bom Jesus, Floriano, and São Raimundo Nonato, State of Piauí, present soil water deficiency in all months of the year, reaching 1146, 1205, and 1445 mm year-1, respectively, and demonstrated that planting planning so that the phases of maximum water demand from crops do not coincide with these months of maximum water deficiency in the soil, is necessary to guarantee high productivity and quality of agricultural production.

The cities of Alvorada, Caracol, and Cristino Castro, experienced water shortages of 1271, 641, and 1114 mm per year, respectively, across 11 of the 12 months. In Uruçuí the deficiency of 1025 mm occurred across ten months of the year.

No water surplus was recorded at any of the meteorological stations in the cities analyzed.

The CWB highlights the need for irrigation during the months of water deficiency.

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