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Hydric balance and climatic classification of the city of Porto Nacional, state of Tocantins, inserted in the Legal Amazon, Brazil

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***Abstract*—** *The objective of this study was to carry out the Climatological Water Balance in conjunction with the climatic characterization, using precipitation and air temperature data in the municipality of Porto Nacional, belonging to the Legal Amazon, Tocantins state, by Thornthwaite and Mather (1955) for 20 years, from 1997 to 2016. From the results of potential evapotranspiration, real evapotranspiration, water surplus and water deficit, the water, aridity and humidity indices were established based on the number of continuous data from the conventional meteorological station , of WMO Code 83064, of the National Institute of Meteorology, located in the district Setor Aeroporto, municipality of Porto Nacional. The climatic formula obtained for the municipality of Porto Nacional was C2wA'a ', which characterized the climate in wet subhumid, with two well defined seasons, rainy and dry, being the dry season in the winter season where it presents moderate water deficiency and megatérmico, with values high annual evapotranspiration potential, with 28.29% of this evapotranspiration concentrated in the summer season.*
Keywords*— *Climate classification, Hydric Balance, Thermal Index.

I. INTRODUCTION

Water availability depends on the water capture capacity of a watershed and one of the most effective methods to estimate and determine the hydrological behavior, recharge capacity and water flow is the climatological water balance. Water balance is an accounting system for monitoring soil water and results from the application of the principle of mass conservation for water in the volume of vegetable soil, being the variation of storage in a given time interval, which represents inputs and outputs of water from the volume control.

The climatic characterization of a municipality is fundamental to understanding the living conditions of any region, allowing a reliable evaluation of its aspects, which makes it relevant for areas with a high population density. Knowledge of the climatic conditions of a region is necessary to establish strategies with a more appropriate management of natural resources, aiming the pursuit of sustainable development and the implementation of viable and safe farming practices for the various biomes of the region (Sousa et al, 2010.)

With the reduction of water precipitation in the rainy months in the cities of the state of Tocantins, it is noticeable that the recharge of water to the reservoirs of sanitation companies are increasingly low and over the years we have identified the necessity of a climatic characterization for proper decision making in the operation of water supply reservoirs, since the population suffers greatly from the quantity and quality of water during periods of drought in some cities of the State of Tocantins, where it can lead to negative socio-environmental and economic impacts, such as: reduction of industrialized products, removal of solids deposited in domestic reservoirs (Water Box), clogging of domestic networks, pathologies in the structures of sanitation networks and hydraulic and sanitary installations such as

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liquid hammering and cavitation caused by the absence or water reduction.

For (Mota et al, 2013), the search for strategies to assess adverse atmospheric phenomena and the interaction of bioclimatology with biodiversity (Fauna and Flora) depends heavily on the effects of weather and climate. According to (CUPOLILLO et al. 2013) the results of a hydric balance can be used for economic and ecological zoning involving the agro climatic functions of the region, potential water demand from irrigated crops in order to plan the priorities to preserve the region's water bodies.

The hydric balance has the characteristics of identifying and quantifying the variation of water storage in the soil, whether precipitation or infiltration, atmospheric demand and availability of water capacity. It will present estimates of actual evapotranspiration, water surplus and deficit and water storage in the soil. The model proposed in this work was that of Thornthwaite (1948), modified by Mather (1955), which became known as the Hydric Balance of Thornthwaite and Mather (1955), having as main function the climatic classification.

In this context the main purpose of this work was to perform the Hydric climatological Report together with the climatic characterization, using precipitation and air temperature data from the city of Porto Nacional, state of Tocantins, Brazil.

II. MATERIAL AND METHODS

The study was developed taking as basis the daily meteorological data from the conventional station 83064-Porto Nacional, which is part of the INMET stations network, in the period of January 1997 to December 2016, located in the city of Porto Nacional in 10°71’ S e 48°41’ W, with an altitude of 239,2 meters at sea level, according to figure (1).

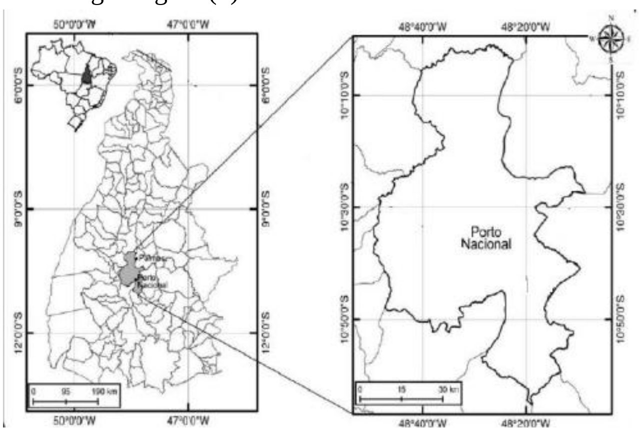

Fig. 1: Municipality of Porto Nacional – Tocantins

Belonging to the Legal Amazon in the state of Tocantins, the city of Porto Nacional has a total distance of 64 km to the state capital, the city of Palmas, possessing a territorial area of 4.449.917 km² and a total population of 52.510 people (IBGE, 2017). The weather is typically tropical, with an annual average temperature of 26,1°C and an annual pluviometry average of 1,667,9 mm, referring to the period between 1961-1990 (AGRICULTURE AND AGRARIAN REFORM MINISTERY, 1992).

The climatic characterization of the municipality under study was obtained by the Thornthwaite (1948) methodology, which considers the water, aridity and humidity indices, together with potential evapotranspiration, based on monthly and annual values of temperature and precipitation, according to “equations 1, 2 and 3”.

$$I_H = 100 \cdot \frac{(100 \cdot EXC - 60 \cdot DEF)}{ETP} \qquad \textit{Equation 1}$$

In which:

I_H=water level

EXC = water surplus

DEF = water deficit

ETP = potential evapotranspiration

In the second step was determined the dryness index given by:

$$I_A = 100 \cdot \frac{DEF}{ETP} \qquad \textit{Equation 2}$$

in which:

I_A= dryness index

DEF = water deficit

ETP = potential evapotranspiration

The humidity index was calculated by using the values of the previous indexes, given by:

$$I_M = 100 \cdot \frac{EXC}{ETP} \qquad \textit{Equation 3}$$

In which:

I_M= humidity index

EXC = water surplus

ETP = potential evapotranspiration

After calculating the humidity, water and dryness indexes, it was used the table of the water balance extract to characterize the climate of Porto Nacional according to the purposed methodology, in which the water index, being the first classification symbol, was used to identify the climatic type, according to table (1).

Table. 1: First symbol of climatic classification according to Thornthwaite and Mather (1955)

Symbol	Climate Type	I_H
A	Very humid	More than 100
B_4	Humid	80 to 99,9
B_3	Humid	60 to 79,9
B_2	Humid	40 to 59,9
B_1	Humid	20 to 39,9
C_2	Humid subhumid	0 to 19,9
C_1	Dry subhumid	-19,9 to 0
D	Semiarid	-39,9 to -20

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E	Arid	-60 to -40

With the dryness and/or humidity indices, according to the classification symbol, it was identified the climatic types indicative of the seasonal regime of humidity, according to table (2).

Table. 2: Second symbol of climatic classification according to Thornthwaite and Mather (1955)

Symbol	Period of the year with water deficit or excess	I_A e I_M
	Humid Climates: A, B, C_2	**Dryness Index**
R	Deficit non-existent or very slight	0 to 16,7
S	Moderate summer deficit	16,7 to 33,3
W	Moderate winter deficit	16,7 to 33,3
s_2	Sharp summer deficit	Greater than 33,3
W	Deficit accentuated in winter	Greater than 33,3
	Dry Weather: C1, D, E	**Moisture Index**
D	Excess nonexistent or very slight	0 to 10
S	Excess moderate in summer	10 to 20
W	Excess moderate in winter	10 to 20
s_2	Excessive accentuated in summer.	Greater than 20
w_2	Excessive accentuated in winter	Greater than 20

With the information of potential evapotranspiration, we found the third symbol, defining the climatic type indicative of thermal efficiency, according to table (3).

Table. 3: Third symbol of climatic classification according to Thornthwaite and Mather (1955)

Symbol	Climate Type	ETP (mm)
A'	Megathermic	Greater than 1140
B'_4	Mesothermic room	1140 to 998
B'_3	Mesothermic third	997 to 856
B'_2	Second Mesothermic	855 to 713
B'_1	First mesothermic	712 to 571
C'_2	Second microthermic	570 to 428
C'_1	First microthermic	427 to 286
D'	Tundra climate	285 to 143
E'	Cold weather	Less than143

For the fourth and last symbol, the climatic type was obtained through the calculation of the summery concentration of thermal efficiency, according to table (4).

Table. 4: Fourth symbol of climatic classification according to Thornthwaite and Mather (1955)

Symbol	Summer concentration of thermal efficiency
a'	Less than 48
b'_4	48 to 51,9
b'_3	51,9 to 56,3
b'_2	56,3 to 61,6
b'_1	61,6 to 68
c'_2	68 to 76,3
c'_1	76,3 to 88
d'	Greather than 88

The climatological water balance was obtained according to the method of Thornthwaite & Mather (1955), which used the data of normal temperature and precipitation for the period from 1997 to 2016 and from a water storage capacity of 100 mm, with the data being processed in the software developed into Microsoft Excel by Rolim and Sentelhas (1999), in which the values of the variables of potential and actual evapotranspiration, surplus and water deficit were obtained.

III. RESULTS AND DISCUSSION

The result obtained from the climatological water balance is shown in Table 5, through Figure 2, for the series of years from 1997 to 2016 considering the available water capacity (CAD) of 100 mm. For the period under study it was observed that the average annual precipitation was 1563.16 mm with irregular distribution throughout the year, showing two well defined seasons, being the period of drought in the months of May to September, with this period contributing in the study with approximately 6% of the annual rainfall volume and the rainy season between the months of October and April, with this period contributing with approximately 94% of the annual rainfall volume.

Table. 5: Climatological Water Balance from 1997 to 2016 in the city of Porto Nacional

Months	T (°C)	P (mm)	ETP (mm)	ETR (mm)	DEF (mm)	EXC (mm)
January	26,26	251,49	136,65	136,65	0,00	114,84
February	26,34	244,68	136,02	130,20	5,82	108,66
March	26,34	257,735	156,20	155,97	0,23	101,54
April	27,03	156,45	156,77	144,98	11,79	0,00

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May	27,19	48,33	175,22	112,10	63,12	0,00
June	26,90	4,085	145,72	23,29	122,43	0,00
July	26,97	0,085	142,88	3,96	138,92	0,00
August	28,38	3,785	167,46	15,80	151,66	0,00
September	29,58	42,355	176,08	40,79	135,29	0,00
October	28,38	110,85	189,22	77,11	112,11	0,00
November	27,16	189,1	151,97	131,19	20,78	37,13
December	26,78	254,22	140,68	132,36	8,32	113,54
YEAR	27,28	1563,165	1874,87	1104,40	770,47	475,70

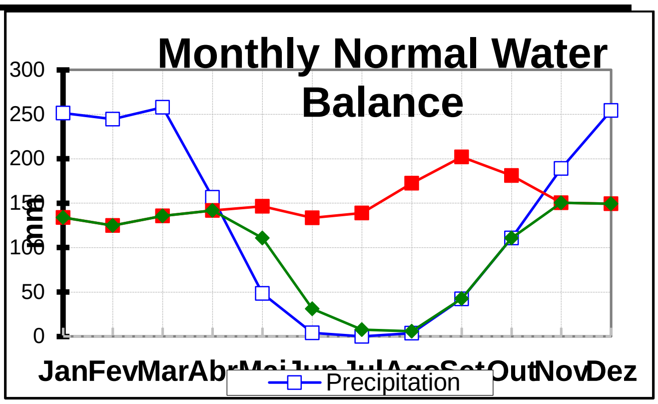

Fig. 2: Climatological Water Balance Chart for the municipality of Porto Nacional from 1997 to 2016.

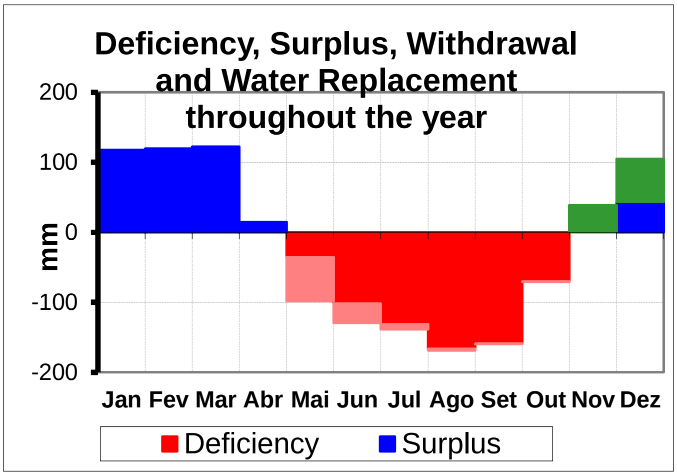

Fig. 3: Monthly Climatological Balance Sheet Extract from 1997 to 2016.

With the two seasons being well defined, the real evapotranspiration (ETR) accompanies the annual rainy season and reached a total of 1104.40 mm. Potential evapotranspiration (ETP) reached an average total of 1874.87 mm and is directly associated with high average monthly temperatures. In Figure 3 we observe that in six months there was an excess of water and in the other six months there was a water deficit, because the potential evapotranspiration is greater than the actual evapotranspiration. In the rainy season, which occurs from October to April, rain replaces the water in the soil, with the reposition occurring specifically in the months of November and December, when the period of water surplus begins, which totaled 475.70 mm. Taking into account the rainier months, January and February, Figure 3 shows that, according to the monthly soil water balance extract, soil saturation reached its maximum, with approximately 120 mm, which is 20% more than the 100 mm of CAD which are taken as the basis.

During the dry season, groundwater withdrawal occurred from May to July, with the beginning of the water deficit taking place from May to October, totaling 770.47 mm, with August and September being the most severe droughts , with the deficit going from 0 to -166.7 mm.

After the calculations of the climatological water balance, the water, dryness and humidity indexes were calculated using the tables in Torres & Machado (2012) by the method of Thornthwaite and Mather (1955), to obtain the climatic classification. The municipality under study obtained, respectively, the following results: IH = 0.72; IA = 41.09; and MI = 25.37.

The climatic classification for the municipality of Porto Nacional, in the state of Tocantins, according to the proposed method is from the "C2" type, with a water index of 0.72, classified as humid sub humid. As for the dryness index, which is a “W” type, the value was 41.09, which represents a moderate water deficiency in winter, with potential evapotranspiration higher than 1140 mm being classified as mega thermal, which is an "A " type, and a value of 1874.87 mm being found in the study period, which represents less than 48% of the total annual evapotranspiration, which is concentrated in the summer.

IV. CONCLUSION

Rainy and dry seasons for the Porto Nacional region are well accentuated by averages and precipitation anomalies in the annual period.

The rainiest months for the region are January, February and March and the least rainy is the month of August. Although the month of December is right in the middle of the months of the rainy season, it is characterized as period of reposition of water in the soil;

The water balance showed that the water reposition happens between the months of November and December, the water surplus occurs from December to April and the water deficit occurring from May to October.

The highest average temperatures contribute significantly for the annual total of the potential evapotranspiration exceeding the annual total of the puvliometric volume;

The climatic type of Porto Nacional is humid Sub humid, with two well defined seasons, rainy and dry, with the drought happening in the winter season in which it presents moderate and mega thermal water deficiency, with high annual values of potential evapotranspiration, with 28, 29% of this evapotranspiration concentrated in the summer season, being able to be defined by the formula as **C2wA'a** '.

With the average temperature of the rainiest month above 26.4 ° C, the annual average precipitation is 1563.165 mm with an annual average temperature is 27.28 ° C. These higher temperatures cause an increase in the consumption of water, both of the animals and of the human being and in the irrigation for the crops, causing a water deficit in the springs and consequently hydraulic problems in the sanitation and sanitary facilities in the municipalities, having as main problem the pressure oscillation, compromising the distribution of water in relation to quantity and quality.

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