IJSRM
INTERNATIONAL JOURNAL OF SCIENCE AND RESEARCH METHODOLOGY
An Official Publication of Human Journals

Human Journals
Review Article
July 2021 Vol.:19, Issue:1

Water Balance for The Pole of The Local Productive Arrangement of Agreste Pernambuco – Brazil

IJSRM
INTERNATIONAL JOURNAL OF SCIENCE AND RESEARCH METHODOLOGY
An Official Publication of Human Journals

Romildo Morant de Holanda[1], Raimundo Mainar de Medeiros*[1], Manoel Viera de França[1], Wagner Rodolfo de Araújo[2], Luciano Marcelo Fallé Saboya[3], Fernando Cartaxo Rolim Neto[1]

1 Universidade Federal Rural de Pernambuco, Brasil

2 Universidade Estácio de Sá, Brasil

3 Universidade Federal de Campina Grande, Brasil

Submitted: 23 June 2021
Accepted: 29 June 2021
Published: 30 July 2021

HUMAN JOURNALS

www.ijsrm.humanjournals.com

Keywords: Semiarid; Water Scarcity; Jeans Laundries

ABSTRACT

Water scarcity in Agreste de Pernambuco, aligned with the misuse of natural resources, is enhanced by the number of jeans laundries in the territory of the Local Productive Arrangement since the textile processing industry's production process has water as its main input. The objective of this research was to perform the calculation of the water balance for the pole of the Local Productive Arrangement of Agreste Pernambuco - Brazil, aiming at the water surplus in the contribution of the transport and dilution of the textile sludge to the water flow of the Ipojuca River. The Pernambuco Water and Climate Agency in the state of Pernambuco provided the rain data. The average temperature data were estimated through the software, Estima_T, since the Local Productive Arrangement pole does not have equipment for such measurement. The rainfall and thermal data comprise the 1962-2016 series. The municipalities of the APL presented water deficiencies between eight and ten months of the year, as evidenced in this water balance, thus demonstrating the need for planning the dilution of the textile sludge. The trend of increasing temperatures and evaporative indices may cause extreme events of short-term and high-intensity precipitation, increasing water surpluses and causing flooding or flooding and reducing the volume of textile sludge from the respective jeans factories.

INTRODUCTION:

Water is an abundant renewable natural resource that occupies about 70% of the planet's surface, but its availability for human consumption is very low, as only 2.5% of the volume is freshwater, with 97.5% of saltwater (FAO, 2007).

França et al., (2019) performed the analysis of the climatological water balance used by the methodology of (Thornthwaite 1948; Thornthwaite *et al*., 1955) between 2000-2016 and its comparison with 2016 in order to investigate water deficit and water storage in the municipality of Serra Talhada – PE. Meteorological data show that sudden changes have occurred and that the inhabitants will have to change their tactics in the future in relation to planting, water storage and survival conditions. Future studies should be taken into account to better understand how transient atmospheric systems and local effects will affect rainfall variability, evapotranspiratimon and evaporation. According to the authors, an increasing trend in temperature and evaporative indices may cause extreme events of precipitation in a short period of time and with high magnitude.

Medeiros et al., (2020) performed the calculation of the water balance, aiming to verify the oscillations of the climatic elements, determining and making available the contributions for elaborations of rural, urban and agricultural planning. The HB comes from detailed knowledge of the climatic elements of the studied period, generating extraordinary information for governmental decision makers and for the creators of livestock, agricultural, agribusiness projects, for horticultural producers aiming at a sustainable development of production in the studied area.

The Agreste region of Pernambuco is located in a semiarid area that suffers from lack of water, due to low rainfall and high evapotranspiration (Silva *et al*., 2012). Water scarcity in the region, in line with the misuse of natural resources, is enhanced by the number of laundries in the Local Productive Arrangement (APL) territory and by the lack of manufacturing infrastructure in the units, since most laundries are located in cities in residential neighborhoods, in residential buildings with little or no adaptation (Lorena *et al*., 2018; Pernambuco, 2015).

Most rivers in the semiarid region are intermittent due to climatic characteristics, with irregular rainfall, concentrated in a few months of the year and high evapotranspiration. These characteristics cause a high variability in the volume of the reservoirs, thus causing, in periods of drought, a reduction in the water quality of the reservoirs as the nutrients are concentrated with the loss of water volume through evaporation (Tucci, 2008; Marengo, 2014; Medeiros, 2016).

Jean laundries are among the industrial activities of environmental priority, due to their high polluting potential and chemical complexity of the generated effluents, since the production process of the textile processing industry has water as its main input (Alkaya *et al*., 2014).

Viana *et al.* (2018), when calculating the water footprint in Caruaru of some laundries, found the consumption of 17 to 60 liters of water for processing per piece, corroborating the result of 37.5 liters per piece found and referred to by the author himself. Water management is an important factor in the city of Caruaru, it goes through long periods of drought, which leads to a reduction in the water level in the city's reservoirs. Jerônimo (2016) comments that the amount of water for washing jeans depends on the technology used by the industry. In addition to using a large amount of water in its processing process, using 70 and 150 liters of water to process 1 kg of dry fabric, which are discarded at the end of the process with chemical loads (Allègre, *et al*., 2006).

In this way, water planning becomes the basis for dimensioning the management of water resources, and the Climatological Water Balance (CHB) can be used as a tool for understanding the water availability of a territory (Carvalho *et al*., 2011).

For Lira (2006) the clusters of textile industries in the Agreste region of Pernambuco emerged as a work alternative for the population, due to the need for alternatives to the precarious conditions for agriculture.

The water deficit is the main responsible for the reduction and losses in the production of crops in the rainfed regime in the northeastern semiarid region. In this regard, research aimed at evaluating the time of occurrence of water deficit, such as its proportion and its influence on plant productivity, are of paramount importance (Carvalho *et a*l., 2011). This article presents similarities with the study in discussions.

Water deficiencies in the studied municipalities are related to low rainfall in the Agreste region of Pernambuco. After precipitation, it is the largest component of the hydrological balance and fundamental for the assessment of water resources and sustainable water management policies (Gharbia *et al*., 2018).

The aim was to calculate the water balance for the Local Productive Arrangement of Agreste Pernambuco – Brazil, aiming at the water surplus in the contribution of the transport and dilution of the textile sludge to the water flow of the Ipojuca River.

MATERIAL AND METHODS:

The study area comprises 9 municipalities in the APL according to the classification of Sebrae (2013). (Figure 1).

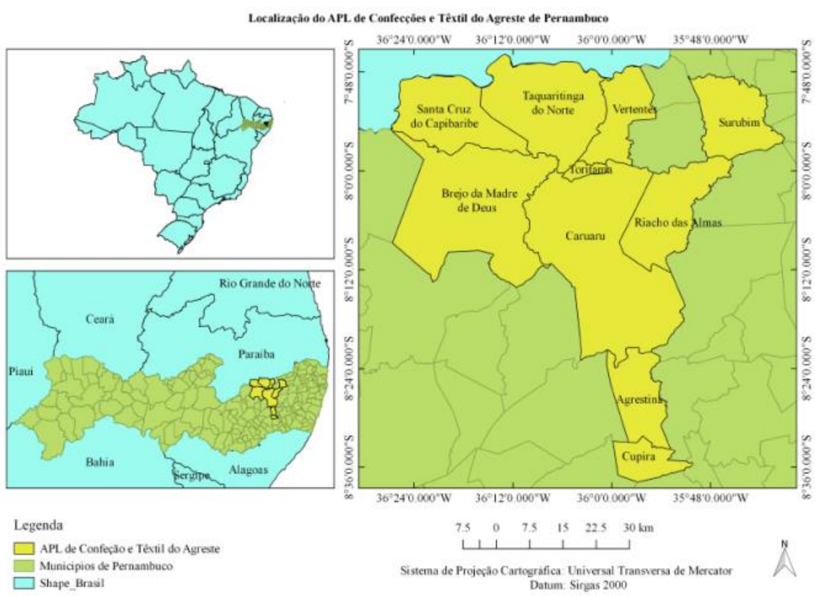

Figure No. 1. Location of the municipalities that are part of the Local Productive Arrangement of Clothing and Textile Arrangement of the Agreste of Pernambuco.

Source: Lorena, (2020).

On Table 1 have the location of municipalities, geographic coordinates (latitude and longitude (º ‘)), altitude and climate classification by the Koppen method.

Table No. 1. Location of municipalities, geographic coordinates (latitude and longitude (º ‘)), altitude and climate classification by the Koppen method.

Municipalities	Latitude (º ‘)	Longitude (º ‘)	Altitude (metros)	Study period	Köppen classification
Agrestina	08 45	35 95	458	1962-2016	As
Brejo de Madre Deus	08 14	36 36	556	1962-2016	BSh
Caruaru	08 17	35 58	537,2	1962-2016	BSh
Riacho das Almas	08 13	35 85	443	1962-2016	AS
Santa Cruz Capibaribe	07 33	36 33	511	1962-2016	BSh
Surubim	07 58	37 53	367	1962-2016	AS
Taquaritingá do Norte	09 05	36 26	528	1962-2016	BSh
Toritama	07 80	37 28	384	1962-2016	BSh
Vertentes	07 65	35 31	176	1962-2016	As

Source: Medeiros, (2020).

According to the climate classification of (Köppen 1928; Köppen *et al*., 1931) the municipalities that are part of the Local Productive Arrangement of Clothing and Textile Arrangement of the Agreste of Pernambuco have the climate “As” and “BSh”, such classifications are in accordance with the authors' studies (Medeiros et al., 2018); and (Alvares et al., (2014).

The rainy season starts in February with pre-season rains (rainfalls that occur before the rainy season) and ends at the end of August and may last until the first half of September. The rainy quarter focuses on the months of May, June and July and its dry months occur between October, November and December. The factors causing rainfall in the municipality are the contribution of the Intertropical Convergence Zone, formation of high-level cyclonic vortices, contribution of northeast trade winds in the transport of steam and moisture, which condense and form clouds causing moderate to heavy rains, formations instability lines, orography and their local and regional contributions (Medeiros, 2016).

The data used in this study were the monthly averages of air temperature (°C) from 1962 to 2016, according to (Cavalcanti et al. 1994; Cavalcanti et al. 2006; Silva et al. 2006), for each of the regions, the coefficients of the quadratic function were determined for the average, maximum and minimum monthly temperatures as a function of local coordinates: longitude, latitude and altitude.

The result of the Water Balance (WB) was obtained through the climatological temperature and average precipitation of the municipal areas. A field capacity of 100 mm was used. The methodology used was that proposed by (Thornthwaite 1948; Thornthwaite et al., 1955).

The monthly average rainfall data in studies were characterized as a period of climatological normality, where the software in electronic spreadsheets was used to extract the values of monthly and annual average rainfall for the period from 1962 to 2016. The Executive Water and Climate Agency of the State of Paraiba (APAC, 2017) provided said data.

The Thornthwaite et al. method was used to calculate the climatological water balance (WCB) on a monthly scalefor the area studied, that is, the BHC, elaborated from the climatological normals of temperature and mean precipitation. This technique is used to work with global water balance data from a climatological point of view. By accounting for the natural supply of water to the soil, through rainfall (P), and atmospheric demand, through potential evapotranspiration (ETP), considering a maximum possible level of storage (CAD). The BHS provides an estimate of actual evapotranspiration (ETR), water deficit (DEF), water surplus (EXC) and effective soil water storage (ARM), which can be elaborated from the daily to monthly scale (Camargo, 1971). The calculation of the BHC was computed using an electronic spreadsheet prepared by Medeiros (2016).

RESULTS AND DISCUSSIONS:

Over the years, textile activities have become an alternative for the local economy of the Agreste, with the advance of the appearance of jeans laundries in a way that was not thought about the need for water, thus the proper planning of economic activities linked to the needs of water consumption can reduce impacts on the environment and provide well-being for the population. The results and discussions of the water balance are represented in tables and graphic which allow visualizing the variations of the main monthly Agrometeorological data over the years.

With regard to the relationship between potential evapotranspiration and actual evapotranspiration, it is possible to highlight the importance of crop aspects, where they become essential in the water conditions that occur in the soil, as both excess and water deficit can interfere with activities metabolic effects of cultures. The information on the variables that make up the BH favor agricultural planning and production control practices, providing information that enables producers to identify climatic conditions, being an essential tool for the success of agriculture, as a consequence, it allows the decision to choose or not by irrigation systems to supply the water deficit in the soil (Santos et al., 2010).

It should be noted that the annual values of the elements that make up the BHC were inserted in all the exhibited and analyzed graphs for a better visualization and understanding.

Table 2 shows the result of the BHC in the municipality of Agrestina – PE by the method of (Thornthwaite 1948; Thornthwaite et al., 1955) for the period 1962-2016. T = mean air temperature (°C); P = mean precipitation (mm); ETP = potential evapotranspiration (mm); ETR = actual evapotranspiration; DEF = Water deficit (mm) and EXC = Water surplus (mm). With an average annual temperature of 23.2ºC, its monthly fluctuations range from 20.9ºC in July to 24.9ºC in January. The average annual precipitation is 797.9 mm and its monthly fluctuations occur between 15.0 mm in October and 130.1 mm in July. With 1163.5 mm of annual evapotranspiration and its monthly fluctuations ranging from 71.7 mm in June to 119.7 mm in December, evapotranspiration was 45.8% above the rainfall. The annual evaporation recorded was 766.7 mm, ranging from 37.3 mm in January to 100.4 mm in April, evaporating 3.91% above the rainfall. The annual deficiency of 396.9 mm and its monthly fluctuations ranged from 0.2 mm in August to 89.8 mm in December, there was no water deficit between April and July. The water surplus was 31.2 mm in the month of July. Such oscillations are consistent with the results found by Matos et al. (2020) for the municipality of Barbalha – CE.

Table No. 2. Climatological Water Balance of the city of Agrestina – PE by the method of Thornthwaite et al., (1955); T = mean air temperature (°C); P = mean precipitation (mm); ETP=potential evapotranspiration (mm); ETR= actual evapotranspiration; DEF = Water deficit (mm) and EXC = Water surplus (mm).

Months	T (ºC)	P (mm)	ETP (mm)	ETR (mm)	DEF (mm)	EXC (mm)
January	24,9	35,1	119,1	37,3	81,8	0,0
February	24,8	47,6	108,9	48,4	60,5	0,0
March	24,6	91,2	116,3	91,4	24,8	0,0
April	23,8	113,0	100,4	100,4	0,0	0,0
May	22,7	103,2	89,8	89,8	0,0	0,0
June	21,5	117,8	73,3	73,3	0,0	0,0
July	20,9	130,1	70,0	70,0	0,0	31,2
August	21,0	65,3	71,7	71,5	0,2	0,0
September	22,3	40,6	83,4	73,2	10,1	0,0
October	23,5	15,0	101,9	50,5	51,5	0,0
November	24,2	15,4	109,1	31,0	78,1	0,0
December	24,6	23,7	119,7	29,9	89,8	0,0
Annual	23,2	797,9	1163,5	766,7	396,9	31,2

Source: Medeiros, (2020).

Figure 2 shows the graph of the climatological water balance of the municipality of Agrestina – PE for the period 1962-2016. Water surpluses were recorded in July, soil water replacement between April and July, soil water withdrawal between August and December and water deficit predominated between September and March. Therefore, the CAD of 100 mm was not necessary to obtain a rainy period between normal.

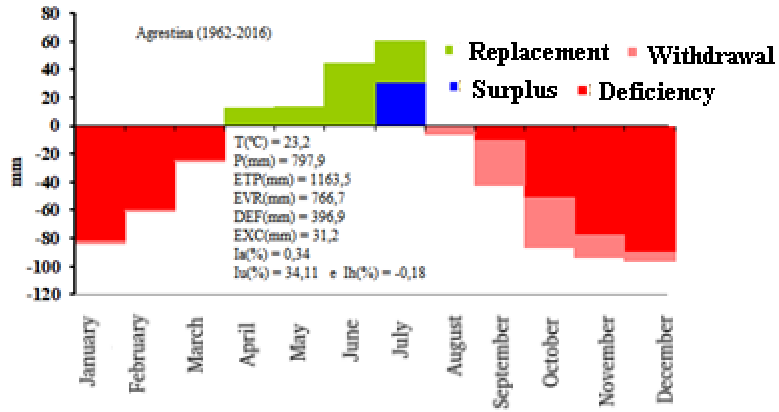

Figure No. 2 Shows the graph of the climatological water balance of the municipality of Agrestina – PE for the period 1962-2016.

Source: Medeiros, (2020).

Table 3 shows the result of the climatological water balance for the municipality of Brejo de Madre de Deus – PE. The average temperature was 22.8ºC ranging from 20.5ºC to 24.4ºC, with an average rainfall of 530.8 mm flowing with 5.5 mm in November to 105.3 in April. Annual evapotranspiration ranged from 1116.6 mm to 67.6 mm in July to 114.6 mm in December. Evapotranspiration was 53.1% above the rainfall rate. The recorded evaporation was 530.9 mm and its monthly fluctuations ranged from 5.9 mm in November to 102.7 mm in March. The rainfall index was equal to the evaporated rate. Recorded disability between the months of May to March, the month of April there was no disability. Water surpluses were not accounted for in the municipality of Brejo de Madre de Deus – PE. The 100 mm CAD was not needed to maintain soil moisture and textile sludge dilution.

Table No. 3. Climatological Water Balance of the municipality of Brejo de Madre de Deus – PE by the method of Thornthwaite & Mather (1955); T = mean air temperature (°C); P = mean precipitation (mm); ETP=potential evapotranspiration (mm); ETR= actual evapotranspiration; DEF = Water deficit (mm) and EXC = Water surplus (mm).

Months	T (°C)	P (mm)	ETP (mm)	ETR (mm)	DEF (mm)	EXC (mm)
January	24,4	31,4	113,8	31,5	82,4	0,0
February	24,2	55,2	103,1	55,2	47,9	0,0
March	24,0	102,7	110,2	102,7	7,5	0,0
April	23,2	105,3	95,3	95,3	0,0	0,0
May	22,2	63,5	85,9	65,5	20,4	0,0
June	21,0	55,0	70,4	56,1	14,3	0,0
July	20,5	56,8	67,6	57,5	10,2	0,0
August	20,6	19,8	69,8	22,2	47,6	0,0
September	22,0	11,4	81,6	13,2	68,3	0,0
October	23,2	6,0	98,9	7,1	91,8	0,0
November	23,8	5,5	105,4	5,9	99,5	0,0
December	24,2	18,6	114,6	18,7	95,8	0,0
Annual	22,8	530,9	1116,6	530,9	585,6	0,0

Source: Medeiros, (2020).

Figures 2 show the graph of the climatological water balance of the municipality of Brejo de Madre Deus – PE, with a predominance of water deficit between the months of May and March and water replacement in the month of April. The removal of water took place between the months of May and December. No excess water was recorded during the study period. The atmospheric systems causing rainfall incidence were blocked and did not activate the meso and micro scale systems.

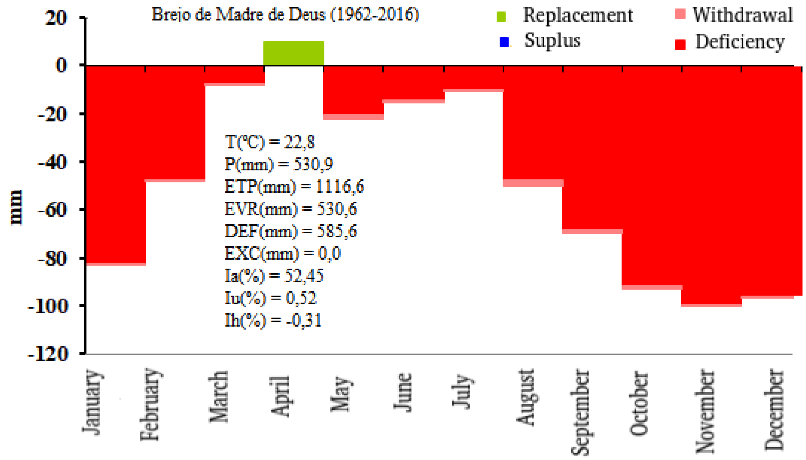

Figure No. 3: Shows the graph of the climatological water balance of the municipality of Brejo de Madre Deus – PE for the period 1962-2016.

Source: Medeiros, (2020).

Table 4 shows the result of the climatological water balance for the municipality of Caruaru – PE by the method of Thornthwaite 1948; Thornthwaite et al., 1955). Caruaru records an average temperature of 22.9ºC and its monthly thermal fluctuations range from 20.6 in July to 24.7ºC in November. The average annual precipitation recorded was 573.8 mm and its fluctuations ranged from 8.9 mm in October to 92.0 mm in June. With annual ETP of 1130.3 mm ranging from 68.3 (July) to 115.6 mm in November. The registered annual EVR was equal to the pluvial index. Deficiency and excess water were 556.5 mm and 0.0 mm, respectively. It emphasizes that the period studied was classified as very dry, since the 100 mm CAD was not necessary and sufficient for soil supply, nor for the dilution and transport of the textile sludge.

Table No. 4: Climatological Water Balance of the municipality of Caruaru – PE by the method of Thornthwaite & Mather (1955); T = mean air temperature (°C); P = mean precipitation (mm); ETP=potential evapotranspiration (mm); ETR= actual evapotranspiration; DEF = Water deficit (mm) and EXC = Water surplus (mm).

Months	T (°C)	P (mm)	ETP (mm)	ETR (mm)	DEF (mm)	EXC (mm)
January	23,9	33,5	107,2	33,8	73,3	0,0
February	24,1	47,5	101,4	47,6	53,7	0,0
March	24,1	63,7	110,6	63,8	46,8	0,0
April	23,6	73,4	99,1	73,5	25,6	0,0
May	22,7	80,1	90,4	80,1	10,3	0,0
June	21,6	92,0	75,4	75,4	0,0	0,0
July	20,6	80,5	68,3	68,3	0,0	0,0
August	20,9	42,3	71,8	49,6	22,1	0,0
September	21,7	23,7	78,3	32,7	45,6	0,0
October	23,1	8,9	97,8	16,2	81,6	0,0
November	24,7	12,4	115,6	15,7	100,0	0,0
December	24,2	15,9	114,4	17,0	97,4	0,0
Annual	22,9	573,8	1130,3	573,8	556,5	0,0

Source: Medeiros, (2020).

Figure 4 shows the result of the BHC for the municipality of Caruaru – PE, where water shortages were recorded between the months of August and May, and removal of water from the ground between the months of September and November. No record of excess water, replacement of water in the soil between the months of June and July. The municipality was classified as dry since the CAD of 100 mm was not enough to dilute the textile sludge and drag it into the rivers. The study by Medeiros (2018) corroborates the results and discussions presented in this study.

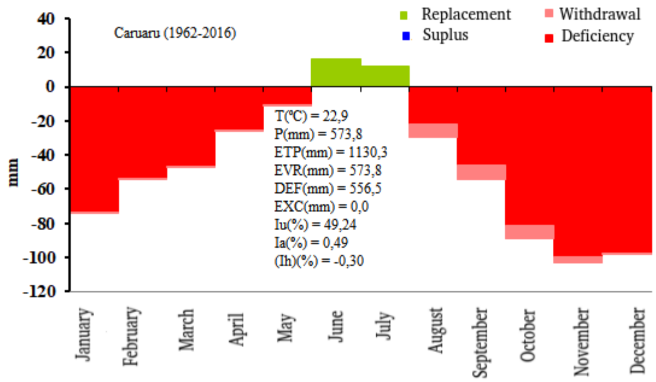

Figure No. 4: shows the graph of the climatological water balance of the municipality of Caruaru – PE for the period 1962-2016.

Source: Medeiros, (2020).

The municipality of Riacho das Almas – PE has an average annual temperature of 23.4°C and its monthly fluctuations range from 21.1°C in July to 25.0°C in January. Annual precipitation of 615.1 mm and its monthly fluctuations ranging from 6.8 mm in November to 102.1 mm in April. Evapotranspired 91.5% above the rainfall index, evaporated equal to the amount of rainfall (615.1 mm). Water deficiencies were recorded between the months of August to March and May, totaling 562.6 mm, no excess water was recorded during the study period. (Table 5).

Table No. 5: Climatological Water Balance of the municipality of Riacho das Almas – PE by the method of Thornthwaite & Mather (1955); T = mean air temperature (°C); P = mean precipitation (mm); ETP = potential evapotranspiration (mm); ETR = actual evapotranspiration; DEF = Water deficit (mm) and EXC = Water surplus (mm).

Months	T (ºC)	P (mm)	ETP (mm)	ETR (mm)	DEF (mm)	EXC (mm)
January	25,0	30,7	120,3	30,9	89,4	0,0
February	24,9	47,6	109,8	47,7	62,1	0,0
March	24,7	92,4	116,9	92,4	24,5	0,0
April	23,9	102,1	101,2	101,2	0,0	0,0
May	22,9	78,2	91,1	78,3	12,8	0,0
June	21,7	82,6	74,6	74,6	0,0	0,0
July	21,1	83,7	71,4	71,4	0,0	0,0
August	21,2	29,6	73,0	37,0	35,9	0,0
September	22,5	25,2	84,5	31,3	53,2	0,0
October	23,7	11,8	103,0	16,3	86,8	0,0
November	24,4	6,8	110,5	8,7	101,8	0,0
December	24,8	24,6	121,3	25,2	96,1	0,0
Annual	23,4	615,1	1177,7	615,1	562,6	0,0

Source: Medeiros, (2020).

Figure 5 shows the graph of the climatological water balance of the municipality of Riacho das Almas – PE where it is observed that there was no water surplus, water deficiencies predominated between the months of August to March and May, the withdrawal of water occurred between the months of August to November and replenishment of water in the soil in the months of April, June and July. CAD was not enough to replenish soil water and cause water surpluses. The municipality was classified as very dry for the study period.

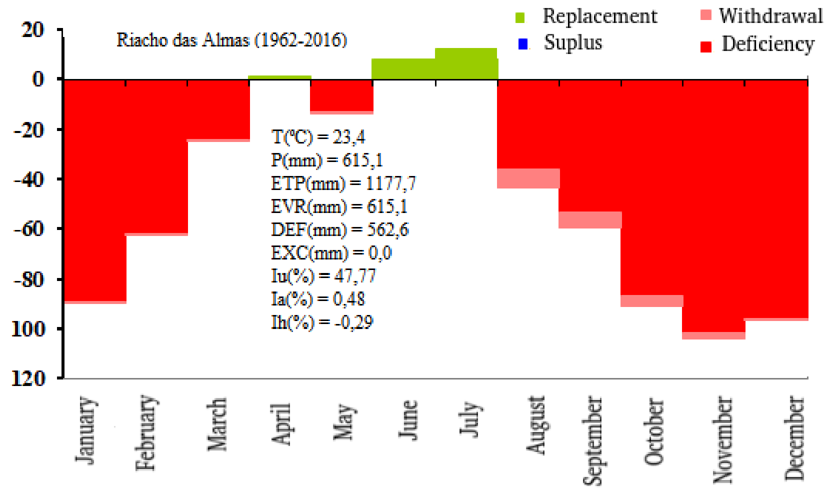

Figure No. 5: Shows the graph of the climatological water balance of the municipality of Riacho das Almas – PE for the period 1962-2016.

Source: Medeiros, (2020).

The climatological water balance of the municipality of Santa Cruz do Capibaribe between the period 1962-2016 showed the following climatic variability: There was no water surplus, annual water deficit was 719.8 mm. Evapotranspired 156.1% above the rainfall index and evaporated equal to the rainfall index (428.2 mm). (Table 6).

Table No. 6: Climatological Water Balance of the municipality of Santa Cruz do Capibaripe – PE by the method of Thornthwaite & Mather (1955); T = mean air temperature (°C); P = mean precipitation (mm); ETP=potential evapotranspiration (mm); ETR= actual evapotranspiration; DEF = Water deficit (mm) and EXC = Water surplus (mm).

Months	T (°C)	P (mm)	ETP (mm)	ETR (mm)	DEF (mm)	EXC (mm)
January	24,7	25,5	116,6	25,5	91,1	0,0
February	24,5	52,0	105,6	52,0	53,7	0,0
March	24,3	96,0	112,6	96,0	16,6	0,0
April	23,5	96,2	97,8	96,2	1,6	0,0
May	22,6	43,5	88,4	43,5	44,9	0,0
June	21,4	43,7	72,8	43,7	29,2	0,0
July	20,9	36,0	70,1	36,0	34,0	0,0
August	21,0	12,5	72,3	12,5	59,7	0,0
September	22,3	6,1	84,0	6,1	78,0	0,0
October	23,5	2,9	101,7	2,9	98,7	0,0
November	24,2	3,4	108,3	3,4	105,0	0,0
December	24,5	10,4	117,7	10,4	107,4	0,0
Annual	23,1	428,2	1148,0	428,2	719,8	0,0

Source: Medeiros, (2020).

In Figure 6, there is the BHC graph for the municipality of Santa Cruz do Capibaribe between the periods 1962-2016, it is observed that the predominance of water deficiencies was total. Such variability is in accordance with the studies by Marengo et al. (2004; 2007; 2008 and 2011).

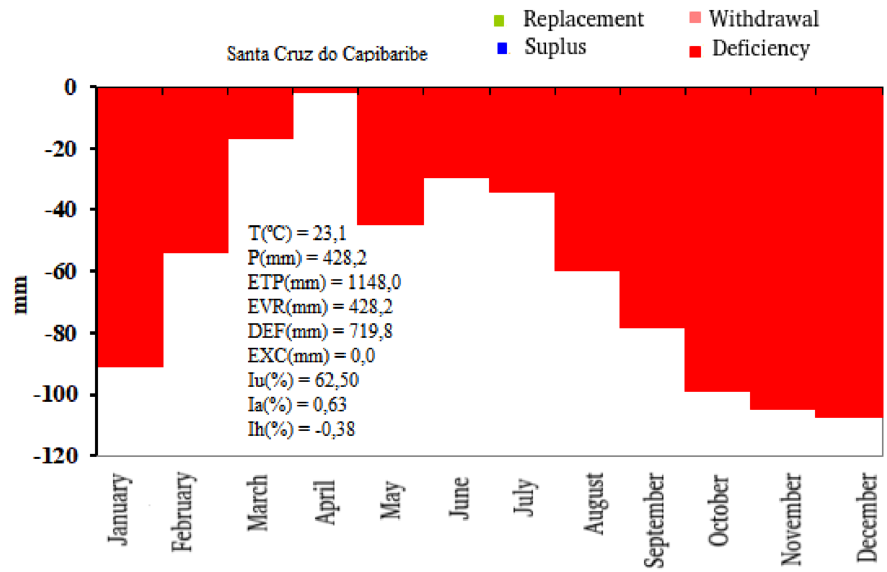

Figure No. 6: Shows the graph of the climatological water balance of the municipality of Santa Cruz do Cabipabire – PE for the period 1962-2016.

Source: Medeiros, (2020).

Table 7. Climatological Water Balance of the municipality of Surubim – PE has an average annual temperature of 23.9°C, annual precipitation equal to the evaporative index totaling 767.9 mm, evapotranspiration 60% above the precipitated value, water deficiencies were 463, 2 mm without overshoot.

Table No. 7: Climatological Water Balance of the municipality of Surubim – PE by the method of Thornthwaite & Mather (1955); T = mean air temperature (°C); P = mean precipitation (mm); ETP=potential evapotranspiration (mm); ETR= actual evapotranspiration; DEF = Water deficit (mm) and EXC = Water surplus (mm).

Months	T (°C)	P (mm)	ETP (mm)	ETR (mm)	DEF (mm)	EXC (mm)
January	25,4	34,8	125,3	36,0	89,3	0,0
February	25,3	50,8	114,7	51,2	63,5	0,0
March	25,1	96,4	121,8	96,5	25,2	0,0
April	24,3	112,7	105,9	105,9	0,0	0,0
May	23,4	104,6	95,6	95,6	0,0	0,0
June	22,2	120,0	78,8	78,8	0,0	0,0
July	21,7	112,7	75,4	75,4	0,0	0,0
August	21,7	47,8	76,6	71,5	5,1	0,0
September	22,9	34,5	87,9	63,9	24,0	0,0
October	24,1	16,1	107,2	41,0	66,2	0,0
November	24,8	13,8	115,1	24,4	90,7	0,0
December	25,3	23,7	126,8	27,6	99,2	0,0
Annual	23,9	767,9	1231,0	767,9	463,2	0,0

Source: Medeiros, (2020).

The municipality of Surubim recorded the following variability, a predominance of water deficiencies between the months of August and March. Water withdrawal between the months of August to January, without excess water and water replacement recorded between the months of April to July. (Figure 7).

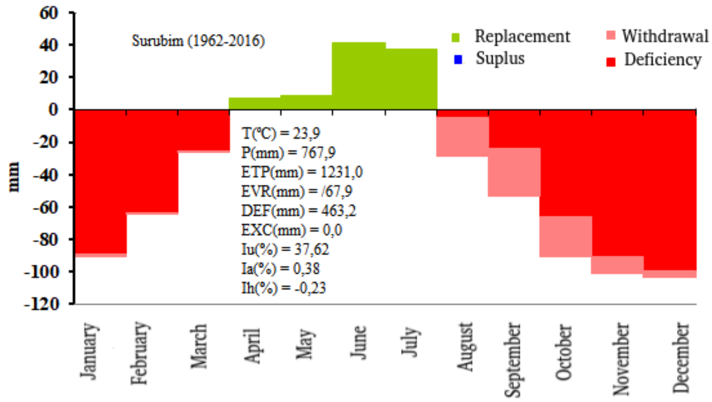

Figure No. 7: Shows the graph of the climatological water balance of the municipality of Surubim – PE for the period 1962-2016.

Source: Medeiros, (2020).

In Table 8 of the Climatological Water Balance of the municipality of Taquaritinga do Norte, the following variability was registered: Annual temperature of 22.9ºC; precipitation equal to evaporative indices 579 mm; evapotranspiration was 113.3 mm above the rainfall index, the water deficit was 553.7 mm without the occurrence of excess water during the period studied.

Table No. 8: Climatological Water Balance of the city of Taquaritinga do Norte – PE by the method of Thornthwaite & Mather (1955); T = mean air temperature (°C); P = mean precipitation (mm); ETP=potential evapotranspiration (mm); ETR= actual evapotranspiration; DEF = Water deficit (mm) and EXC = Water surplus (mm).

Months	T (°C)	P (mm)	ETP (mm)	ETR (mm)	DEF (mm)	EXC (mm)
January	24,6	28,8	116,1	29,0	87,0	0,0
February	24,4	50,9	105,0	51,0	54,0	0,0
March	24,2	90,7	111,8	90,7	21,0	0,0
April	23,4	97,0	96,6	96,6	0,0	0,0
May	22,4	65,7	86,9	65,8	21,1	0,0
June	21,2	84,2	71,3	71,3	0,0	0,0
July	20,7	80,0	68,5	68,5	0,0	0,0
August	20,8	38,3	70,4	45,2	25,2	0,0
September	22,1	13,5	82,2	22,5	59,7	0,0
October	23,3	6,3	99,9	11,9	88,1	0,0
November	24,0	5,3	107,1	7,6	99,5	0,0
December	24,4	18,1	116,9	18,9	98,0	0,0
Annual	22,9	579,0	1132,7	579,0	553,7	0,0

Source: Medeiros, (2020).

Figure 8 shows the variability of the climatological water balance chart for the municipality of Taquaritinga do Norte – PE for the period 1962-2016. There was no record of excess water, replacement of water in the months of June and July, withdrawal of water between the months of August to November and water deficit in the months of August to March and May.

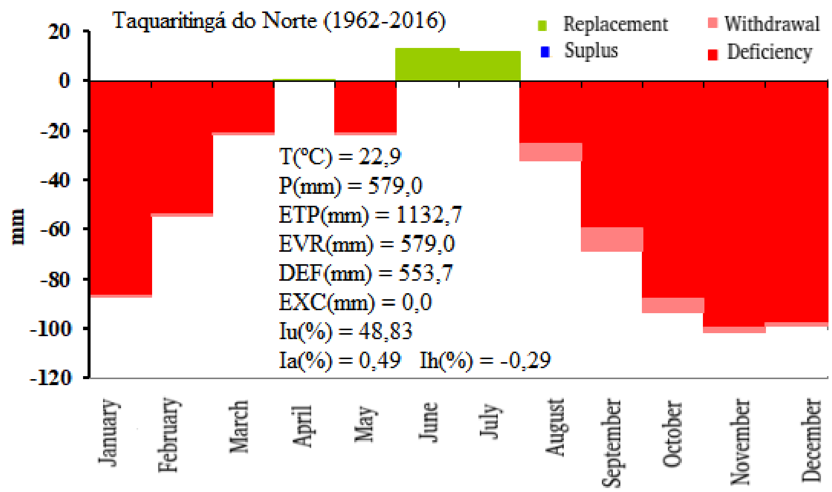

Figure No. 8: Shows the graph of the climatological water balance of the municipality of Taquaritinga do Norte – PE for the period 1962-2016.

Source: Medeiros, (2020).

In the municipality of Toritama - PE, the BHC calculation registered the following values for its elements: Annual temperature of 23.8ºC, Precipitation and evaporation totaled 583.7 mm, evapotranspiration 93% above the pluvial value, water deficit was 642.9 mm and there was no water surplus. A study such as the one by Matos et al. (2020) corroborates the results discussed. (Table 9).

Table No. 9: Climatological Water Balance of the municipality of Toritama – PE by the method of Thornthwaite & Mather (1955); T = mean air temperature (°C); P = mean precipitation (mm); ETP=potential evapotranspiration (mm); ETR= actual evapotranspiration; DEF = Water deficit (mm) and EXC = Water surplus (mm).

Months	T (°C)	P (mm)	ETP (mm)	ETR (mm)	DEF (mm)	EXC (mm)
January	25,4	29,6	124,5	29,7	94,8	0,0
February	25,2	50,0	113,7	50,0	63,7	0,0
March	25,0	93,3	120,8	93,3	27,5	0,0
April	24,3	97,4	105,2	97,4	7,8	0,0
May	23,3	71,4	95,0	71,4	23,6	0,0
June	22,2	78,8	78,3	78,3	0,0	0,0
July	21,7	80,0	75,1	75,1	0,0	0,0
August	21,8	26,6	76,9	28,7	48,2	0,0
September	23,0	17,3	88,5	19,0	69,5	0,0
October	24,1	9,0	107,6	10,0	97,7	0,0
November	24,8	4,2	115,0	4,6	110,4	0,0
December	25,2	26,1	126,0	26,3	99,8	0,0
Annual	23,8	583,7	1226,6	583,7	642,9	0,0

Source: Medeiros, (2020).

The municipality of Toritama presented, as a graphic result of the BHC, a predominance of water deficit between the months of August and May, water replacement in the months of June and July and there was no water surplus, the withdrawals of water occurred between the months of August and November. (Figure 10).

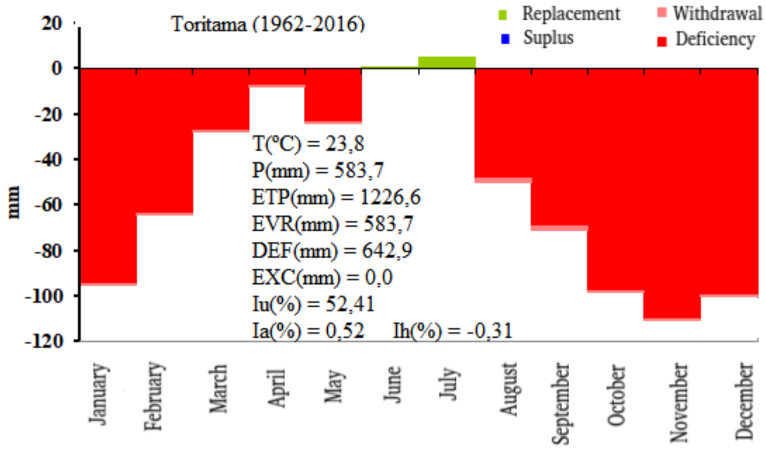

Figure No. 9: Shows the graph of the climatological water balance of the municipality of Toritama – PE for the period 1962-2016.

Source: Medeiros, (2020).

Table 10 shows the result of the BHC in the municipality of Vertente – PE with an average annual temperature of 23.4ºC, rainfall equal to the evaporative index, which is 707.4 mm, evapotranspiration 66.54% above the rainfall index. There were no water surpluses and water deficits totaled 470.7 mm.

Table No. 10: Climatological Water Balance of the municipality of Vertente – PE by the method of Thornthwaite & Mather (1955); T = mean air temperature (°C); P = mean precipitation (mm); ETP=potential evapotranspiration (mm); ETR= actual evapotranspiration; DEF = Water deficit (mm) and EXC = Water surplus (mm).

Months	T (°C)	P (mm)	ETP (mm)	ETR (mm)	DEF (mm)	EXC (mm)
January	25,0	31,1	119,9	32,2	87,8	0,0
February	24,8	50,1	109,2	50,5	58,7	0,0
March	24,6	92,1	116,2	92,2	24,1	0,0
April	23,9	102,8	100,9	100,9	0,0	0,0
May	22,9	86,6	91,1	86,7	4,4	0,0
June	21,7	111,8	75,0	75,0	0,0	0,0
July	21,2	111,0	71,9	71,9	0,0	0,0
August	21,3	53,8	73,6	67,8	5,8	0,0
September	22,5	22,2	85,1	52,1	33,0	0,0
October	23,7	11,2	103,4	31,7	71,6	0,0
November	24,4	11,4	110,7	20,0	90,7	0,0
December	24,8	23,3	121,1	26,4	94,7	0,0
Annual	23,4	707,4	1178,1	707,4	470,7	0,0

Source: Medeiros, (2020).

The municipality of Vertente between the periods 1962-2016 presented the following conditions: Replenishment of water in the soil between the months of April, June and July, water deficiencies predominated between the months of August to March and May. The removal of water from the soil was registered between the months of August and January. The 100 mm CAD was not needed to supply the soil and carry out water drainage. The municipality was classified as very dry for the period under study. (Figure 11).

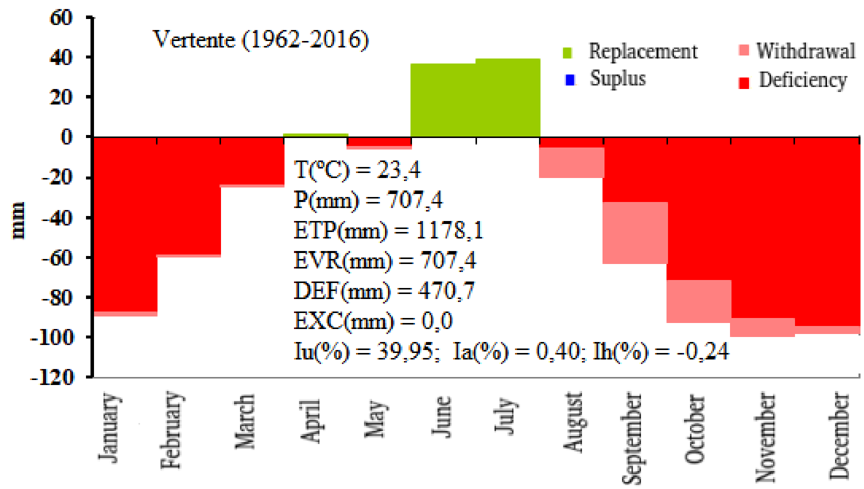

Figure No. 10: Shows the graph of the climatological water balance of the municipality of Vertente – PE for the period 1962-2016.

Source: Medeiros, (2020).

Horikoshi et al. (2007) comment that if a certain region has a deficiency or excess of water during the year, it is essential to compare two opposite elements of the water balance: precipitation, which increases soil moisture, and evapotranspiration, which reduces soil moisture. This statement corroborates the study in progress.

The pluvial indices in the region of the municipalities of the APL have irregular spatial and temporal distributions and their fluctuations ranged from 428.2 mm in the municipality of Santa Cruz de Capibaribe to 797.9 mm in the municipality of Agrestina. The water surpluses registered were in the order of large rainfall. When no surplus is detected, this means that the precipitation is equal to or close to the real annual evaporation (França *et al.*, 2018).

CONSIDERATIONS FINAIS:

The municipalities in the APL had water deficiencies between eight to ten months of the year, verified in this water balance, thus demonstrating the need for planning the dilution of textile sludge.

A tendency to increase temperature and evaporative indexes may cause extreme events of precipitation in a short period of time and of high intensity, increase water surpluses and cause flooding or flooding, and reduce the volume of textile sludge in the respective jeans factories.

Projects must be elaborated using the daily pluvial indices aiming at the dilution of the textile sludge and its dragging to the rivers.

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Image *Author -1*	***Author Name – Corresponding Author*** – Romildo Morant de Holanda *Author Affiliation* – Universidade Federal Rural de Pernambuco, Brazil
Image *Author -2*	***Author Name*** – Raimundo Mainar de Medeiros *Author Affiliation* – Universidade Federal Rural de Pernambuco
Image *Author -3*	***Author Name*** – Manoel Vieira de França *Author Affiliation* - Universidade Federal Rural de Pernambuco
Image *Author -4*	***Author Name*** Wagner Rodolfo de Araújo *Author Affiliation* Universidade Estácio de Sá
Image *Author -5*	***Author Name*** Luciano Marcelo Fallé Saboya *Author Affiliation* Universidade Federal de Campina Grande - UFCG
Image *Author -6*	***Author Name*** Fernando Cartaxo Rolim Neto *Author Affiliation* Universidade Federal Rural de Pernambuco - UFRPE