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CLIMATE CHARACTERIZATION OF SERRA DE MARTINS – RN

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Abstract

The Brazilian Northeast in its largest portionis defined by a Semi-aridclimate. However, when analyzing the regionon a larger cartographic scale, it is possible to reveal are as that escape this context, being characterized as Areas of Exception or wet enclaves. Thus, this research aimedat a climatic characterization of Serra de Martins, in the period from 1973 to 2002, comparing with the municipality of Antonio Martins, located in the Depression Sertaneja. As for the data, rainfall data were made availableby EMPARN andt emperature data were estimate dusing software, following the modelof Cavalcanti and Silva (1994), called *Estima_T*, which provides the averages, maximum and minimum values basedon latitude, longitude and altitude. After data tabulation, theclimatologicalwater balance wasgenerated, according to the model proposed by Thornthwaite and Mather (1955). For Martins, the rain fall average of 1230 mm and 23 ºC wasfound as a termal average. Antonio Martins, meanwhile, foundan average precipitation value of 693 mm and its termal average is 26 ºC. From the data generated in thewater balance, we have the following climaticty pology, B1w2A '(Wet Megatherm with water deficit in winter ands pring) for Martins and C1dA' (Dry Subhumid Megatherm with little or no watersurplus) for Antonio Martins.

Keywords: Climate. Semiarid. Exception Area.

CARACTERIZAÇÃO CLIMÁTICA DA SERRA DE MARTINS – RN

Resumo

A maior parte do Nordeste brasileiro é definido pelo clima semiárido. No entanto, ao analisar a região em escala cartográfica maior, é possível encontrar áreas que fogem a este contexto, caracterizando-se como Áreas de Exceção ou enclaves úmidos. Assim, esta pesquisa objetivou uma caracterização climática da Serra de Martins, no período de 1973 a 2002, comparando com o município de Antonio Martins, situado na Depressão Sertaneja. Os dados pluviométricos foram disponibilizados pela EMPARN e os de temperatura foram estimados em software, seguindo modelo de Cavalcanti e Silva (1994), denominado de *Estima_T* e que disponibiliza as médias, máximas e mínimas com base em dados de latitude, longitude e altitude. Após a tabulação dos dados, o balanço hídrico climatológico foi gerado, conforme modelo proposto por Thornthwaite e Mather (1955). Para Martins encontrou-se a média pluviométrica de 1230 mm e 23 ºC como média térmica. Já Antonio Martins o valor médio de precipitação encontrado foi de 693 mm e sua média térmica é de 26ºC. A partir dos dados gerados no balanço hídrico, tem-se a seguinte tipologia climática: B1w2A' (Megatérmico Úmido com déficit hídrico no inverno e na primavera) para Martins e C1dA' (Megatérmico Subúmido Seco com pequeno ou nenhum excedente hídrico) para Antonio Martins.

Palavras-chave: Clima; Semiárido; Área de Exceção.

CARACTERIZACIÓN CLIMÁTICA DE SERRA DE MARTINS – RN

Resumen

El noreste de Brasil em su mayor parte se define por un clima semiárido. Sin embargo, al analizar la regiónen una escala cartográfica más grande, es posible revelar áreas que escapan a este contexto, caracterizándo como Áreas de excepcióno enclaves húmedos. Así, esta investigación tuvo como objetivo una caracterización climática de la Serra de Martins, enel período de 1973 a 2002, comparando con el municipio de Antonio Martins, ubicado em la Depresión Sertaneja. Encuanto a los datos, EMPARN puso a disposición los datos de precipitaciones y los datos de temperatura se estimaron mediante software, siguiendoel modelo de Cavalcanti y Silva (1994), llamado *Estima_T*, que proporciona los promedios, valores máximos y mínimos basados em latitud, longitud y altitud. Después de latabulación de datos, se generóel balance hídrico climatológico, de acuerdoconel modelo propuesto por Thornthwaite y Mather (1955). Para Martins, el promedio de precipitaciones de 1230 mm y 23ºC se encontró como um promedio térmico. Antonio Martins, por su parte, encontro un valor promedio de precipitación de 693 mm y supromedio térmico es de 26 ºC. A partir de los datos generados em el balance hídrico, tenemos lasiguiente tipología climática, B1w2A'Megatherm húmedo con déficit hídrico em invierno y primavera) para Martins y C1dA' (Megatherm subhúmedo seco com poco o ningún excedente de a gua) para Antonio Martins.

Palabras-clave: Clima. Semi árido. Area de Excepción.

1. INTRODUCTION

The climate of any region is largely defined by the general circulation of the atmosphere, which ultimately results from the differential heating of the globe through solar radiation, the desymmetric distribution of oceans and continents on the Earth's surface and the topographic characteristics over the continents. (FERREIRA; MELO, 2005). According to the authors, such factors generate circulation patterns that redistribute heat, humidity and amount of movement in a heterogeneous way on Earth.

Based on this understanding, Mendonça and Danni-Oliveira (2007) define Brazil as a tropical country, as it is located in the tropical zone, giving particular aspects, such as the considerable brightness of the sky (sunshine) and the high temperatures linked to rainfall (hot and humid climate), located in one of the areas with the highest solar energy reception on the planet.

Within this context, the Brazilian Northeast region (NEB), in turn, presents extreme climatic attributes when compared to the Brazilian scenario; among these, low humidity levels, scarcity of annual rainfall, irregularity in the rhythm of rainfall over the years, prolonged periods of drought, saline soils, absence of perennial rivers and irregular rainfall, which are extremely limited to a short period, stand out. year, on average from 2 to 3 months (AB'SABER, 1974; REIS, 1976).

According to Kayano and Andreoli (2009), three climatic types are recognized in the region: Moist Coastal Climate, Tropical Climate and Semi-Arid Tropical Climate. This evidenced climatic diversity happens due to the physical mechanisms that affect the area, being responsible for the formation and distribution of the rains. Among the main factors that determine this climatic variability, we can mention the geographical position, the relief, the surface characteristics and the weather systems operating in the region, which have different spatial and temporal scales (MARENGO et al., 2011; FERREIRA; REBOITA; ROCHA, 2019).

Therefore, Ferreira and Mello (2005), point out that the main atmospheric systems that inhibit or cause rain on the NEB are: the Intertropical Convergence Zone (ZCIT), the main mechanism responsible for the precipitation that occurs in the northern center of the region from February to May, especially in the states of Ceará, west of Rio Grande do Norte and interior of Paraíba and Pernambuco; the Cold Fronts that cause rain in the south center of the NEB, from November to January; the East Waves, responsible for the rains in the NEB east between May and August; the High Levels Cyclonic Vortexes (VCANs), which occur in spring, summer and autumn (September to April), with maximum frequency in the month of January; the Lines of Instability, which cause rain, usually of the cumulus type; the Mesoscale Convective Complexes, causing heavy and short-term rains, usually accompanied by strong gusts of wind, and finally, the Sea and Land Breezes.

In addition to the mechanisms mentioned, El Niño (EN) is also present, which according to Mendonça and Danni-Oliveira (2007), is a climatic phenomenon, due to the strong influence of oceanic conditions, highlighting the ocean-atmosphere interaction, mainly of the South Oscilation El Niño (ENOS). In years of EN, the equatorial convection moves to the East, changing the positioning of the Walker cell, which can inhibit the formation of clouds and moving the ZCIT to the North, favoring the occurrence of dry or very dry periods in the NEB region. (SCHMIDT, 2014).

Otherwise, in La Niña (LN) years, with the cooling of the waters of the Pacific Ocean, associated with the Negative Dipole of the Atlantic, the North Atlantic High Pressure Center (AAN) strengthens, blowing northeast winds that push the ZCIT to a more southern position. Thus, LN is generally responsible for the years considered normal, rainy or very rainy in the Northeast region.

Orographic rains also play an important role in the climatic context of the region, understood as those arising from the physical action of the relief, acting as a barrier to the free advection of the air, which is forced to descend. In this sense, a great physical barrier is identified in the NEB, the Planalto da Borborema, disposed in the South-North direction, responsible for the contrasts between the volumes of rain on each side of the mountain barrier, while interfering in the performance of forming mechanisms precipitation.

Barbosa (1998) points out that some of the driest areas of the NEB, with pluviometric indexes oscillating around 300 mm / year, constitute valleys located to the leeward of the topographic barrier that rises up to 1000 m in height, where the winds arrive dry (without moisture). On the other hand, on the windward side of the barriers, there are quite humid areas, suitable for agriculture. An explanation of this phenomenon can be found in Mendonça and Danni-Oliveira (2007, p. 71),

> the humid and hot air, when ascending close to the slopes, cools down adiabatically (...). The cooling leads to the saturation of the vapor, making possible the formation of stratiform and cumuliform clouds, which, with the continuity of the ascension

> process, tend to produce rain. Thus, the windward slopes are commonly rainier than those to the leeward, where the air, in addition to being less humid, is forced to descend, which makes it difficult to form clouds.

Through such discussions, it is essential to recognize that the understanding of the atmosphere and its phenomena is important for man to understand and use it according to his interests and needs. Promoting economic, political and social production in addition to other activities related to climatic conditions and changes in the behavior of ecosystems. Living beings, morphogenetic processes, the regime of rivers and activities carried out by man are linked to current atmospheric situations, understood, in this view, as essential to the configuration of the climate (TAVARES, 2004).

In addition to these issues, this work resolves existing gaps in the study of climate change, endowed with information that will serve as a basis for studies in the most diverse areas of knowledge, for the very knowledge of the locality and for future actions of use and management of the territory. .

Serra de Martins, despite being geographically located in the semi-arid region of northeastern Brazil, presents climatic peculiarities related to precipitation and temperature, when compared to surrounding areas, inserted in the domains of Country Depression. Considering this reality, the present article aims to develop a climatic analysis for Serra de Martins-RN, aiming to understand how the relief influences the climatic elements temperature and precipitation.

2. METHODOLOGY

The climatic characterization for Serra de Martins was based on a comparison between two different locations, with respect to altitude, Martins and Antônio Martins. The municipality of Martins has altimetric levels above 600 meters, located in the area of the Residual Plateaus and Antônio Martins, located at 270 meters of altitude, is inserted in the Depression Sertaneja (figure 1).

The data referring to the pluviometric stations, as well as the data used to estimate the temperature were as follows: Martins - latitude: 6º 5'; longitude: 37º 55'; altitude: 645 meters; and Antônio Martins - latitude: 6º 11'; longitude: 37º58'; altitude: 270 meters.

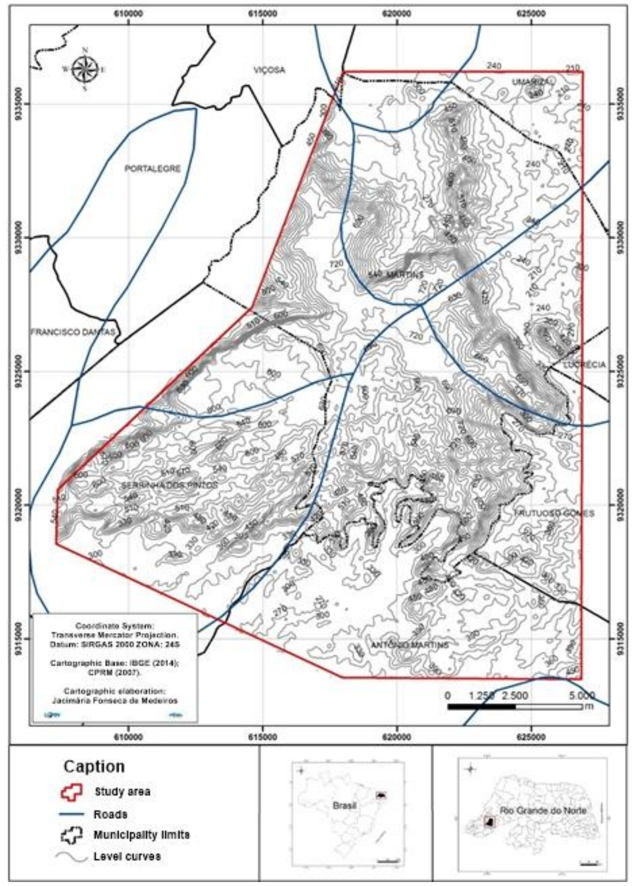


Figure 1 – Geographical location of Serra de Martins. Source: Made by the author (2016).

2.1 Data acquisition

The analysis of precipitation was based on rainfall data over a 30-year time series, from 1973 to 2002, provided by the Agricultural Research Corporation of Rio Grande do Norte (EMPARN).

With regard to air temperature, due to the absence of data for the study area and considering the need to work with them, it was decided to work with the data generated from a temperature estimation program for the states of São Paulo. Northeast region, Estima_T, created by the Department of Atmospheric Sciences (DCA) of the Federal University of Campina Grande (UFCG).

Estima_T is a software used to estimate air temperatures in the Northeast Region of Brazil, built from the model proposed by Cavalcanti and Silva (1994), and the coefficients of the quadratic function for minimum temperatures are determined for each desired location, monthly maximum and average, depending on local coordinates (longitude, latitude) and altitude. The estimate of the air temperature time series (average, maximum and minimum) is obtained by adding to the estimated average value the temperature anomaly of the Tropical Atlantic Ocean of the month (ASTM) and year considered.

Cavalcanti et al., (2006) state that the Estima_T model proved to be capable of reconstructing time series of the air temperaturer with reasonable precision for the entire Northeast of Brazil, from statistically significant correlations at the level of 1% probability between the air temperatures observed and estimated by the model.

Models of very accurate monthly and annual average temperature estimates, using geographical coordinates and altitude, have been used in different regions of Brazil, as in studies by Cargnelutti Filho et al. (2006) for the state of Rio Grande do Sul, Corraa, Terassi and Galvani (2017) for the hydrographic basin of the Rio Piquiri in Paraná, Capuchinho et al. (2019), for the state of Goiás and Menezes Filho (2020) for the Parnaíba River in Minas Gerais;

The Estima_T program generated, for the municipalities of Martins and Antônio Martins, average monthly temperature data for the period between the years 1950 to 2002, with data from the period from 1973 to 2002 being selected, which now appears as the reference period for this climate analysis, since they comprise the last 30 years of temperature generated by the program. In addition to that, according to the National Institute of Meteorology (1992), the period of 30 years is used for the delimitation of climatological normals, obeying criteria recommended by the World Meteorological Organization (WMO).

2.2 Data tabulation, treatment and analysis

The monthly average precipitation and temperature data were transferred and manipulated in a Microsoft Office Excel spreadsheet. The water balance was constructed using the method proposed by Thornthwaite and Mather (1955), using the "BHnorm" program prepared in an Excel spreadsheet by Rolim et al., (1998). As available water capacity (CAD), the value of 100 mm was used for the municipality of Martins and 80 mm for the municipality of Antônio Martins. Rolim et al., (1998) affirm that, for climatological purposes, the determination of the Climatic Water Balance (BHC) only to characterize the regional water availability, it is common to adopt values of Available Water Capacity (CAD) varying from 75 to 125 mm. Potential evapotranspiration (ETP) and real evapotranspiration (ETR) were estimated using the method of Thornthwaite (1948), according to the following formula:

$$ET_P = 16\left(\frac{l}{12}\right)\left(\frac{N}{30}\right)\left(\frac{10T_a}{I}\right)^a$$

One reads:
ETp - monthly evapotranspiration;
l - average length of the day;
N - number of days of the month;
Ta - average air temperature;
I - heat index;
a - cubic function of I.

As a result, the water balance provided estimates of actual evapotranspiration (ETR), water deficiency (DEF), water surplus (EXC) and water availability.

Subsequently, the climatic classification was elaborated using the method proposed by Thornthwaite (1948). Using the water balance data for both locations, the humidity index was initially determined, which is the percentage ratio between excess water and potential evapotranspiration, which is:Im = ((100.EXC) anual - (60.D) anual) /EP

Next, the aridity index, which expresses water deficiency as a percentage of potential evapotranspiration, ranges from 0 to 100. It is calculated using the formula below:Ia = ((DEF)anual / (ETP)anual)100

The thermal efficiency index (ETP) is the numerical value of potential evapotranspiration, and is a direct function of temperature and photoperiod. It is presented with a capital letter with an apostrophe and, with or without, a subscript algorithm.

3. RESULTS AND DISCUSSION

3.1 Local rainfall characterization

Serra de Martins showed great variations in rainfall, with the values of 2523 mm, maximum rainfall in 1974, and 433 mm, minimum rainfall in 1993, with an annual average of 1230 mm, being identified during the study period. For the town of Antônio Martins, we found a maximum rain precipitation of 1478 mm in 1974, a minimum of 149 mm in 1983, and an average of 693 mm for the analyzed period. By analyzing the rainfall data of the studied municipalities, it was possible to identify the maximum and minimum rainfall found, which correspond respectively to the wetter and drier periods.

Figure 2 shows elements for the understanding that the years 1974, 1977, 1985, 1986 and 2000 are the most expressive in terms of maximum rainfall for the municipalities in question. In the years 1983, 1987, 1990, 1993 and 1998, low rainfall averages were evidenced.

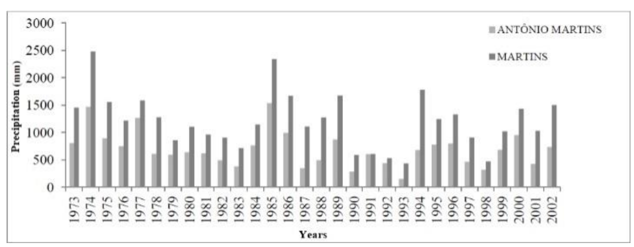


Figure 2: Historical rainfall series for the municipalities of Antônio Martins and Martins-RN. Source: prepared by the author based on EMPARN data, 2016.

In this sense, the years 1974, 1977, 1983, 1985, 1986, 1987, 1990, 1993, 1998 and 2000 were the most expressive in relation to the extreme events for the series worked on. It should be noted, therefore, that, despite the same behavior found in the two municipalities, both present a contrasting reality when it comes to rainfall values.

It is also important to carry out a more detailed analysis of extreme levels of precipitation and drought, linking them to the performance of current meteorological systems. As for the phenomena of oceanic influence, data can be linked extremos data in their majority, to the performance of El Niño and La Niña.

According to Monteiro et al. (2012), El niño presented itself as weak (in the years 1991, 1994, 2002, 2003, 2005), moderate (in the years 1987, 1993, 1995, 2002, 2003) and strong (in 1982, 1983, 1992, 1997, 1998). The oceanic phenomenon La Niña, on the other hand, presented a moderate to weak variation (for the years 1985, 1988, 1989, 1999, 2000, 2001, 2006, 2008, 2009).

As for the monthly distribution of rainfall over the period studied (figure 3), it can be seen that the rains are concentrated in greater quantities in five months of the year, with the rainy season being concentrated in the period from January to May. The driest months comprise the period from July to December, with the critical period being identified in the months of August, September, October and November. The distribution of precipitation during the studied series revealed the presence of a monomodal rainfall regime, that is, with a single peak of the rainy season, in the months of March and April. It is noticed that the municipalities have similar dynamics in terms of the distribution of rainfall throughout the year, concentrating them generally in the first months of the year, a period between the months of January to June. The second semester, from July to December, is characterized by low rainfall.

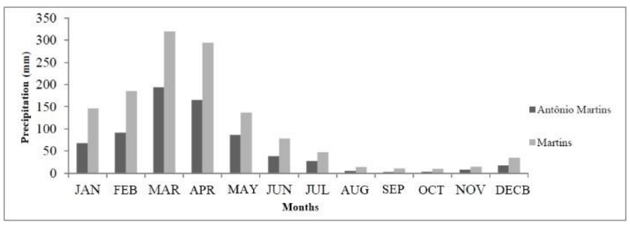


Figure 3: Distribution of average monthly rainfall in the municipalities of Antônio Martins and Martins-RN, from 1973-2002. Source: made by the author based on EMPARN data, 2016.

Schmidt (2014) points out that, in the western region of Rio Grande do Sul, rainfall is concentrated from mid-February to May, with the Intertropical Convergence Zone being the main rain-providing mechanism, as well as orographic rains, Mesoscale Convective Complexes, High Cyclonic Vortexes Levels and Lines of Instability mainly in the northern portions of the mesoregion act with less expression in the precipitated volumes. The rains practically cease from May, due to the migration of the ZCIT, which no longer influences in the interior regions of the state, even though small precipitated volumes may still occur for a few more weeks depending on the atmospheric configuration in which the region is found. However, it is noteworthy that the rainy events that occur between the months of June and July originate from the East Waves. The author also emphasizes that the orography found in this mesoregion, specifically in the extreme West, where the Serra de Martins is located, causes precipitation at other times of the year, caused mainly by orographic rains, this being the main mechanism responsible for the precipitated values in the period of transition between the dry and the rainy season, from December to February.

The dissonance verified between the municipalities occurs in relation to the average values of the pluviometric precipitations, being the data referring to the municipality of Martins greater than the data presented for the municipality of Antônio Martins. The biggest differences are identified in the rainy season, that is, in the period from January to May.

Despite the small geographical distance between the rainfall stations, it is necessary to consider that the climatic dynamics is governed by a close relationship between the elements and the geographical factors of the climate. In this case, the relief acts as a diversifying factor of the climatic pattern, causing greater precipitations with the orographic rains, arising from the physical action of the relief, acting as a barrier to the free advection of the air, which is forced to descend.

Seluchi et al. (2011) and Liebmann et al. (2011) reinforce the understanding of the behavior of areas located windward and leeward at high altitudes, emphasizing that the orographic rains are originated from the influence of the relief, where the air that goes towards the elevated areas, windward slope, is forced to ascend and condense, due to the adiabatic reduction in temperature, with the occurrence of rain of greater intensity and volume in the area being common. When crossing the elevated areas, the air devoid of moisture, descends and heats adiabatically.

In this sense, from the understanding of the precipitation dynamics of the two municipalities inserted in different geographic features, it is understood that the Serra de Martins acts as a physical barrier, presenting favorable conditions for the development of orographic rains, responsible for the contrasts between the volumes of rain identified there (higher rainfall values) and the surrounding areas located in the Depression Sertaneja, represented by the municipality of Antônio Martins, with lower rainfall values).

3.2 Local thermal characterization

The municipality of Martins presented an average air temperature of 23º C. It was evidenced that there is no great oscillation between the temperature data throughout the year, varying from 21ºC to 24ºC, that is, a difference of 3ºC. The June-July-August quarter is characterized by the lowest average air temperatures, around 21º C, thus being the coldest months. The highest averages of air temperature, above 24º C, were verified in the November-December-January quarter, being the hottest months.

In the municipality of Antônio Martins, the average air temperature found was 25.98º C, with the maximum average being 27.90º C in the month of January, which together with the months of February and November, form the hottest months. The average low was 23.83º C in June, which opens the coldest quarter, with averages around 24º C.

It is noticed that the cities of Martins (640 m of altitude) and Antônio Martins (240 m of altitude) have, respectively, average temperatures of 23º C and 26º C, configuring an average vertical gradient of approximately 0.7 ºC / 100 m (figure 4).

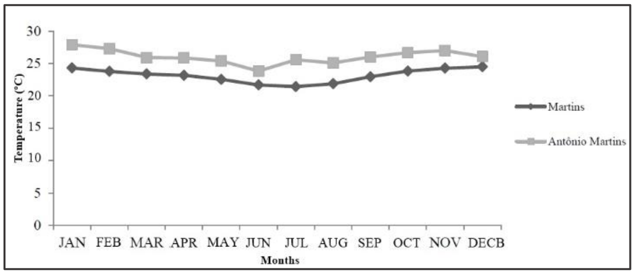


Figure 4: Distribution of the average monthly air temperature in the municipalities of Antônio Martins and Martins, from 1973 to 2002. Source: prepared by the author based on data from the DCA-UFCG.

The municipalities of Martins and Antônio Martins are located within the same latitude, with a difference of only 6 minutes, which represents a small geographical distance between them, around 20 km. In this case, discarding the action of latitude as a geographic factor of the climate, the difference in the temperature gradient is attributed mainly to altitude.

The weather conditions are influenced by several factors, among them, the altitude and relief configuration, added to the geographical position, favoring the occurrence of orographic rains with pluviometric averages higher than the Depressões Sertanejas (MACIEL, 2012; SANTOS; NASCIMENTO, 2017), such as this is the case in the study area.

Tubelis and Nascimento (1984, p. 51) point out that surfaces with different orientations and inclinations receive different amounts of sun radiation, when compared to a horizontal surface, in the same location and time of year. The authors point out that the production of plant matter is conditioned by the availability of solar energy.

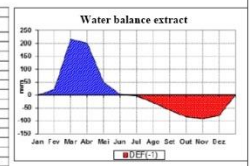
Thus, it is clear that vegetation also plays an important role as a temperature regulator for the municipalities in question. The municipality of Martins, according to Medeiros (2016), presents Savanna-Estépica Arborizada, Savana-Estépica Florestalada and Semideciduous Seasonal vegetation, while Antônio Martins, the reality is quite different, limited only to Savanna-Estépica Arborizada. It is understood that vegetation acts as a geographical factor of the climate, with regard to temperature in the municipality of Martins, as the crowns act as a barrier to direct solar radiation, decreasing the availability of energy that heats the air, decreasing the temperature.

3.3 Local water balance

Through the method proposed by Thornthwaite and Mather (1955), it was possible to arrive at the water balance for the municipalities of Martins and Antônio Martins (figure 5).

Martins - RN water balance extract

Tempo	T	P	ETP	P-ETP	NEG-AC	ARM	ALT	ETR	DEF	EXC
MESES	oC	mm	Thornthwaite 1948	mm		mm	mm	mm	mm	mm
Jan	24,30	145,93	114,5	31,4	-112,4	32,5	31,4	114,5	0,0	0,0
Fev	23,78	184,84	96,7	88,1	0,0	100,0	67,5	96,7	0,0	20,6
Mar	23,37	319,10	100,8	218,3	0,0	100,0	0,0	100,8	0,0	218,3
Abr	23,17	294,28	93,8	200,5	0,0	100,0	0,0	93,8	0,0	200,5
Mai	22,54	136,65	88,5	48,2	0,0	100,0	0,0	88,5	0,0	48,2
Jun	21,68	78,26	76,1	2,2	0,0	100,0	0,0	76,1	0,0	2,2
Jul	21,43	46,96	76,0	-29,1	-29,1	74,8	-25,2	72,2	3,8	0,0
Ago	21,87	13,53	81,0	-67,5	-96,6	38,1	-36,7	50,2	30,8	0,0
Set	22,95	10,38	90,9	-80,5	-177,1	17,0	-21,1	31,4	59,5	0,0
Out	23,83	9,41	105,8	-96,4	-273,5	6,5	-10,5	19,9	85,9	0,0
Nov	24,27	14,04	109,5	-95,3	-368,8	2,5	-4,0	18,0	91,3	0,0
Dez	24,50	34,75	117,0	-82,3	-451,0	1,1	-1,4	36,1	80,9	0,0
OTAIS	277,7	1288,1	1150,5	137,6			0,0	798,3	352,1	489,8



Antônio Martins - RN water balance extract

Tempo	T	P	ETP	P-ETP	NEG-AC	ARM	ALT	ETR	DEF	EXC
MESES	oC	mm	Thornthwaite 1948	mm		mm	mm	mm	mm	mm
Jan	27,90	67,66	127,8	-60,1	-823,5	0,0	0,0	67,7	60,1	0,0
Fev	27,30	91,35	158,8	-67,4	-891,0	0,0	0,0	91,4	67,4	0,0
Mar	25,93	193,53	130,4	63,1	-19,0	63,1	63,1	130,4	0,0	0,0
Abr	25,86	165,02	123,2	41,8	0,0	80,0	16,9	123,2	0,0	24,9
Mai	25,40	85,98	117,8	-31,8	-31,8	53,7	-26,3	112,2	5,6	0,0
Jun	23,83	38,27	90,0	-51,7	-83,5	28,2	-25,6	63,8	26,1	0,0
Jul	24,58	26,88	103,6	-76,8	-160,3	10,8	-17,4	44,3	59,4	0,0
Ago	25,29	4,60	115,6	-111,0	-271,3	2,7	-8,1	12,7	102,9	0,0
Set	26,02	2,35	125,4	-123,0	-394,3	0,6	-2,1	4,5	120,9	0,0
Out	26,67	3,02	126,4	-123,3	-517,6	0,1	-0,5	3,5	122,9	0,0
Nov	27,01	7,77	132,4	-127,6	-645,2	0,0	-0,1	7,9	127,5	0,0
Dez	26,06	16,88	135,1	-118,2	-763,5	0,0	0,0	16,9	118,2	0,0
OTAIS	311,9	703,3	1489,4	-786,0			0,0	678,4	811,0	24,9

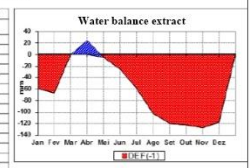


Figure 5 - Extract Graph of the Climatological Water Balance in the municipalities of Antônio Martins and Martins-RN, according to THORNTHWAITE & MATHER (1955), period: 1973-2002. Source: prepared by the author based on EMPARN data; DCA-UFCG.

The municipality of Martins presented a considerable water surplus in the first semester of the analyzed period, with values ranging from 2 mm to 218 mm, reaching 489 mm. It should be noted that in the first semester there is a gradual decrease in temperature, which significantly decreases from 24ºC in January to 21ºC in June, which contributes to the reduction of potential evapotranspiration. As for rainfall, the period between the months of January to June is characterized by the most significant data, marked by an increase for the period from January to April and a decline for the months of May and June.

As for the maximum and minimum water surplus values, it is clear that April was the month with the maximum water surplus value (218 mm) and the month of June is characterized by the minimum water surplus value (2 mm). Seeking to establish an association with the climatic elements temperature and precipitation, the month of April is characterized by the most significant rainfall average identified, 294 mm, and the average air temperature of 23º C. The month of June presents an average rainfall of 78 mm, and average air temperature of 21º C, the second lowest average temperature of the analyzed period.

The average water deficit in the period totaled -353mm, distributed in the second half of the period, with values ranging from -3 mm to -91 mm. It should be noted that the second semester is characterized by high average air temperatures, which gradually increase from 21º C in July to 24º C in December, which enhances potential evapotranspiration. The data referring to the average of pluviometric precipitation for the second semester reveal very modest values that oscillate from 9 mm to 46 mm, what contributes to the water deficit.

As for the relationship between the maximum and minimum deficit values and the climatic elements temperature and precipitation, the following reality exists: the maximum deficit was identified in the month of November (-91 mm) and the minimum value in the month of July (-3 mm). The month of November is characterized by low average rainfall (14 mm) and average air temperature of 24º C, the second highest temperature found in the analyzed period. In July, the situation is as follows:

low average precipitation (46 mm) and low average air temperature (21º C).

It is important to highlight the interface period in the water balance that appears in the month of January, explained as a period of water replacement, in which there is no water deficit or surplus.

The real evapotranspiration (ETR) reached 798 mm, being distributed throughout the year. It should be noted that the months of January, February, March and April concentrated around 45% of the total. During this period, high average rainfall is evident, as well as the average air temperature is close to the average of the analyzed period (1973-2002), around 23º C. The lowest ETR values were observed in the months of October and November, being linked to low average rainfall and a slight increase in average air temperature.

Regarding the discussions on water stored in the soil (ARM), whose variation is due to the difference between the water inflows and outflows in the system, it is clear that, in the first six months (January to June), this value was significant, which can be proven from the evaluation of equal values for ETP and ETR. This period was also initially defined as the period in which the highest rainfall averages are concentrated. Otherwise, in the second semester (July to December), the ARM value is not very significant, which, in turn, generates a difference between the ETP and ETR values, the latter being to a lesser extent.

The municipality of Antônio Martins presented water deficit data for almost the entire period analyzed, totaling 811 mm. The only exception noted for the period occurred in the month of April, which presented a water surplus (24 mm) generated from a high rainfall average (165 mm) and an average air temperature of 25 ºC. In view of the water deficit being dominant in this municipality, the discussion will be made from the months of maximum and minimum deficit.

In the period between the months of March to June (04 months), the minimum values of water deficit are evident. The period between the months of July to February (08 months) is configured as a critical period, when it comes to the values of maximum water deficit, reaching up to 127.5 mm. In the period of minimum water deficit, that is, the period from March to June, there are significant rainfall averages, with emphasis on the months of March and April, which had 193 mm and 165 mm, respectively. The average air temperature in these months decreased from 25º C in March to 23º C in June, the latter being the lowest average air temperature identified. As for the months of maximum water deficit, related to rainfall, it should be noted that these were insignificant, with the exception of the months of January and February, which had 67 mm and 91 mm, respectively. The average air temperature for the period presented a gradual growth of 24º C in July until reaching 27º C in February. The interface period appears in the month of March, which is responsible for the replacement of the system, characterized by a month in which there is no water deficit or surplus.

The real evapotranspiration (ETR) in this municipality reached 698.40 mm, poorly distributed throughout the year, concentrating around 75% of the total in the first five months of the year. During this period, high rainfall averages for the municipality and an average air temperature of around 26º C are evident.

The data referring to the water stored in the soil (ARM) show a worrying reality, since only the months of March, April and May were satisfactory (with water surplus), characterized by a quarter in which the values of ETP and ETR presented in the same situation, as well as the rainfall averages were the most significant. However, in the remaining nine months, from June to February, the ETR was lower than the ETP.

3.4 Climatic typology

Applying the data in figure 4, it can be seen that, considering the average rainfall in the period from 1973 to 2002, the municipality of Martins fits into the Humid climate typology, B1 symbolism, according to the climatic classification of Thornthwaite and Mather (1955), with an Effective Aridity Index of 30%. Through the aridity indices (Ia), the subtype “w2, with water deficit in winter and spring, was determined. As for the thermal factor, it was found that the municipality of Martins is of the Megatérmico type (A '), with an average annual potential evapotranspiration greater than 1150 mm. Thus, the climatic formula for the municipality of Martins is B1w2A’, that is, wet Megathermic type with water deficit in winter and spring.

With respect to the municipality of Antônio Martins, it is classified in the dry Subhumid climate type, C1, according to the climatic classification of Thornthwaite and Mather (1955), presenting an Effective Humidity Index of -30.99%, with subtype d, characterized by small or no water surplus and with type A 'thermal factor, Megatérmico. The municipality of Antônio Martins is characterized by the climatic typology C1dA’, dry sub-humid Megatérmico type with little or no water surplus.

4. CONCLUSION

The municipalities of Martins (640 meters high) and Antônio Martins (240 meters high), in terms of rainfall, are characterized by two seasons: one dry and the other rainy, with average rainfall of 1230 mm and 693 mm, respectively. This contrast is justified by the fact that the Serra de Martins acts as a physical barrier to moisture that rises by convection, causing orographic rains.

The orography and vegetation influence the average temperatures of the municipalities, being verified 23º C in Martins and 26º C in Antônio Martins, which configures an average vertical temperature gradient of approximately 1.2º C / 100 m.

The differences evidenced in the elements precipitation and temperature are directly reflected in the water balance, which, in the municipality of Martins, presents a balance between the months of water deficit and surplus, unlike what occurs in the municipality of Antônio Martins, characterized by water deficit rates throughout the year, with the exception of April alone.

In this sense, it is possible to admit that the Serra de Martins is an Exception Area or humid enclave in the middle of the Semi-arid domain, and can be defined in the perspective of a Brejo de Altitude.

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