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Scientific paper

Analysis of variability of climatic indexes for the state of the Paraíba – PB

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Abstract

This work had as main objective the study of spatial variation of meteorological variables (DEF, EXC, Ia, Iu and Ih) according to the available water capacity (AWC) levels of 75, 100, 125 and 150 mm obtained from water balance proposed by THORNTHWAITE (1948) in the State of Paraíba. In the execution of the water balance it was used rainfall data available at the Academic Unit of Atmospheric Sciences, Federal University of Campina Grande and an estimation of air temperature for a specified series from 1970 to 2000 based on 54 rain gauge stations located throughout the state. In the mapping of meteorological variables it was used the tools of Geostatistics for the construction of contour maps, using the technique of Kriging to obtain the homogeneous areas that enable a planning of the use and a differential agricultural management of the area. Through this analysis it was verified that it occurred small variations of these variables according to the slides studied, proven by the low rainfall coupled with high rate of potential evapotranspiration for most of that state.

Keywords: Climatic Indexes; Evapotranspiration; Water Balance; Climatic Classification.

Introduction

It is known that the period of sowing of certain crops is dependent on the occurrence of rain, temperature, among other meteorological variables and, also, that these periods range from one region to the other. Several studies have already been performed using classical procedures of statistics aiming to analyze these variables which have influence over all the phases of growth and development of the region crops (MENDONÇA, 2008; SILVA et al., 2003).

Important variables which may condition the agricultural crops are those obtained by the Water balance, which has major importance in several studies of one region, i.e., in the determination of favorable places to a certain kind of crop, climate classification, etc. Several authors (ALFONSI et al., 1990; PEREIRA, 2002; VAREJÃO-SILVA, 2005) define water balance as the water account of the soil, i.e., the statement of all the water gains and losses, together with its storage, which is verified in the considered soil or watershed. In the water balance, there are integrant as: the

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rainfall and/or irrigation, which are the great suppliers of water in sol, the superficial drift, the amount of water which was storage in this soil, the depth drainage, and, finally, the simultaneous action of evaporation and plant transpiration (considering always this vegetated soil) which is named evapotranspiration, in which the equation composed by this variables is considered so that if they are all added, the value is zero, contributing to the reasoning of the water balance.

The production depends essentially on the balance of soil humidity, which depends, by its turn, on the rainfall, temperature, evaporation, etc. Therefore, the mapping of variables which compose the water balance is of major importance for the planning of the land use and to understand, explain and prevent the growth and development of the natural resources, aiming to promote its rational use. According to CAMARGO (1971) cited by HORIKOSHI and FISCH (2007), in order to know if a region presents deficiency or excess of water during the year, it is indispensable to compare two opposed elements of the water balance: the rainfall which increases the soil humidity and the evapotranspiration which reduced the soil humidity. Several researches were developed over time using water balances, ranging according to the different objective, with example in the works performed by ZEPKA (2002), SANTANA et al. (2004), TEIXEIRA and SILVA (1999) and HORIKOSHI and FISCH (2007).

Another important meteorological variable used by the water balance is the evapotranspiration, used to express the transference of the water vapor for the atmosphere coming from surfaces with vegetation (VAREJÃO-SILVA, 2005). Works about evapotranspiration may be found in its different aims (HENRIQUE, 2006; MENDONÇA, 2008; VALIATI et al., 2003). The climatic index of: aridity (Ia), humidity (Iu) and water index (Ih) have as one of the purposes the climate characterization of a considered place. These climatic indexes represent part of this characterization of a certain region, obtained through variables of water balance, and through the potential evapotranspiration.

The state of Paraíba has its economy dependent on a much diversified agriculture which is strongly influenced by climatic conditions, during the cultivation period, mainly from the variables which compose the water balance. Under these consideration, this work has as objective to study meteorological variables in function of the behavior of the available water capacity (AWC) in the levels of 75, 100, 125 and 150 mm, aiming to identify possible alterations in all the state, and may serve currently as orientation to farmers and researchers.

Material and methods

Study data and area

For the analysis of the climatic behavior of the state of Paraíba, it was used data of rainfall of 54 rain gauge stages (monthly averages) available in the Academic Unit of Atmospheric Sciences (Unidade Acadêmica de Ciências Atmosféricas - UACA) of the Universidade Federal de Campina Grande (Federal University of Campina Grande - UFCG), specifying a time series from 1970 to 2000. It was used the software named "Estima_T" (CAVALCANTI et al., 2006), developed by the Universidade Federal de Campina Grande (Federal University of Campina Grande) to estimate series of monthly air temperature mean of all the 54 rain gauges due to the absence of data in some points of the region. Figure 1 shows the spatial distribution of the rain gauges in the state of Paraíba.

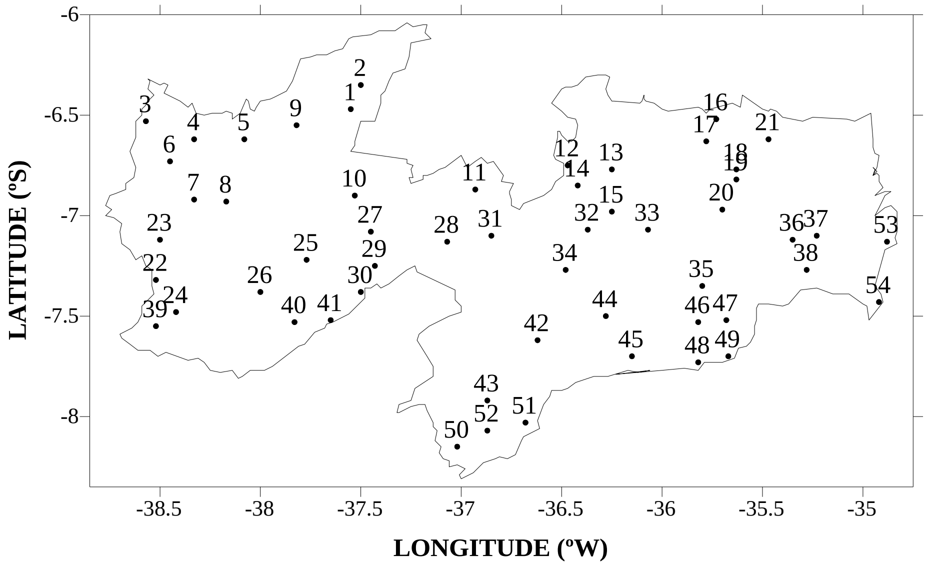

Figure 1. Location of the 54 rain gauges located in the state of Paraíba.

The study area was the state of Paraíba, located in the Northeast of Brazil between the meridians 34º 45′ 54″ and 38º 45′ 45″ of West longitude and the parallels of 6º 02′ 12″ and 8º 19′ 18″ of South latitude, with an area of approximately 56440 Km². It is limited at North, with the state of Rio Grande do Norte; at West, with Ceará; at South, with Pernambuco; and at East, with the Atlantic Ocean. It has 223 municipalities (IBGE, 2008).).

Calculation of the Potential Evapotranspiration

The estimate of the potential evapotranspiration (PET) used in this work require only data of the monthly mean temperature and of the maximum insolation. Expressed in mm/month, the potential evapotranspiration is defined in the following way, according to THORNTHWAITE (1948) cited by VAREJÃO-SILVA (2005).

$$(\mathrm{ETP})_j = F_j \cdot E_j \quad (1)$$

In which $\mathbf{E}_j$ represents the potential evapotranspiration (mm/day) which was not adjusted, summarized in the following way:

$$E_j = 0{,}533\left(\frac{10 \cdot \overline{T}_j}{I}\right)^a \quad (2)$$

In which $\overline{T}_j$ represents the monthly mean air temperature of the month j (°C); I is the annual index of heat defined trough:

$$I = \sum_{j=1}^{12} i_j \quad (3)$$

In which, i_j is the thermal index of heat in the month j given by:

$$i_j = \left(\overline{T}_j / 5\right)^{1,514} \quad (4)$$

Finally, the exponent "a" from the equation (2) is a cubic function of this annual index of heat, expressed in the following way:

$$a = 6{,}75\times10^{-7} I^3 - 7{,}71\times10^{-5} I^2 + 1{,}79\times10^{-2} I + 0{,}49 \quad (5)$$

Fator de Correção F_j

The correction factor F_j of the equation (1) is defined in function of the number of days of the month D_j (in January, $D_1 = 31$; in February $D_2 = 28$; etc.) and of the maximum insolation of the 15th day of the month j (N_j),considered representative of the average of this month, defined by:

$$F_j = \frac{D_j \cdot N_j}{12} \qquad (6)$$

For the calculation of the maximum insolation of the 15th day, it was used the following expression:

$$N_j = (2/15)[\text{arc.cos}(-\text{tg}\phi \cdot \text{tg}\delta)] \qquad (7)$$

In which: ϕ: Place latitude; δ: Declination of the Sun in degrees, for the considered day, defined by:

$$\delta = 23{,}45^o \, \text{sen}[360(284 + d)/365] \qquad (8)$$

In which is the number of order, in the year of the considered day (Julian day). The estimate of potential evapotranspiration trough equation (1) is only valid for value of mean air temperature inferior to 26.5 °C. When the average temperature of this month is equal or superior to 26.5 °C, THORNTHWAITE (1948) assumed that E_j is not dependent on the annual index of heat and uses an appropriate table for its estimate.

Calculation of the Water Balance

The model used to determine the water balance was proposed by THORNTHWAITE (1948) cited by VAREJÃO-SILVA (2005). The water balance was performed only with data of the rainfall, monthly average air temperature and a value correspondent to the available water capacity (AWC), emphasizing that for the elaboration of the water balance in all the state of Paraíba, it was used values of AWC of 75, 100, 125 and 150 mm.

The structure of the calculation used in this work of the water balance was originated from the application of the software proposed by BELO FILHO (2003), which originated the software SEVAP (Sistema de Estimativa da Evapotranspiração) developed in the Universidade Federal de Campina Grande (Federal University of Campina Grande - UFCG).

Climate indexes

One of the aims of the climate indexes: of aridity, humidity and water index is the climatic characterization of one region. In this research, they were interpolated aiming to verify possible changes in function of the AWCs as well as the climatic classification of this state.

The Index of Aridity is characterized for indicating the water deficiency expressed in percentage of the potential evapotranspiration (necessity). It is defined in function of the deficiency and potential evapotranspiration (both annual), expressed in the following way:

$$I_a = 100 \cdot \frac{DEF}{ETP} \qquad (9)$$

The index of humidity represented the water excess expressed in percentage of the necessity which is represented by the potential evapotranspiration, both annual, according to the expression:

$$I_u = 100 \cdot \frac{EXC}{ETP} \qquad (10)$$

Generally, over the year, there are seasons with excess and lack of water. Due to that, the water index is defined in the following way:

$$I_h = I_u - 0,6 \cdot I_a \tag{11}$$

Interpolation of data

In the confection of the maps of isolines and surface, several methods may be used for the interpolation of data. Some works report that the superiority of the kriging as interpolator over other methods for parameters of landscape, it was being noteworthy KRAVCHENKO and BULLOCK (2000), ZIMBACK (2001) and ANDRADE (2002). The interpolation of data has in kriging the most indicate method to represent them with fidelity, making it necessary to effect an spatial analysis trough geostatistics techniques, aiming to model the variation of data in relation to the continuity or spatial dependence in function of the distance and geometry between samples. Therefore, the data interpolation and the mapping of all the variables analyzed here were obtained through this technique of kriging for the AWCs analyzed of 75, 100, 125 and 150 mm.

Results and discussions

Water deficiency

With the data of rainfall, monthly mean air temperature and estimate of the potential evapotranspiration, it was determined the water balance proposed by THORNTHWAITE (1948) for 54 water gauges in four levels of AWCs, in which the calculation of the water balance enabled to estimate the amount of the levels of deficiency (AWC) and water excess (EXC), trough indexes of aridity and humidity. Figure 2 shows the water deficiency in several water volumes for the state of Paraíba.

Trough Figure 2 it can be verified that the deficiency decreased with the increase of the available water capacity (AWC) of this soil in the volumes studied (from 75 to 150 mm), being noteworthy in Brejo, Sertão and Alto Sertão. In the other part of the state, it became constant mainly in almost all the area of Cariri/Curimataú and in a good part of the Agreste region. It must be considered that the modifications of the limits of the bands may cause behaviors of this deficiency reasonably different in some regions of this state. However, its characteristics in a general way are not compromised.

Even though the estimates were obtained through the water balance proposed by THORNTHWAITE (1948), the result of the DEF in most part of Paraíba presented here was coherent with the mapping of the same variable for the AWC of 100 mm (Figure 2b), presented by SENTELHAS et al. (2008), using the water balance from THORNTHWAITE and MATHER (1955), remembering that the estimate of the potential evapotranspiration is the same in both methods. The coherence of the results is in the fact that the lowest deficiencies are predominantly in Litoral, Brejo and Agreste; and the highest are located in the rest of the state, with exception of some regions.

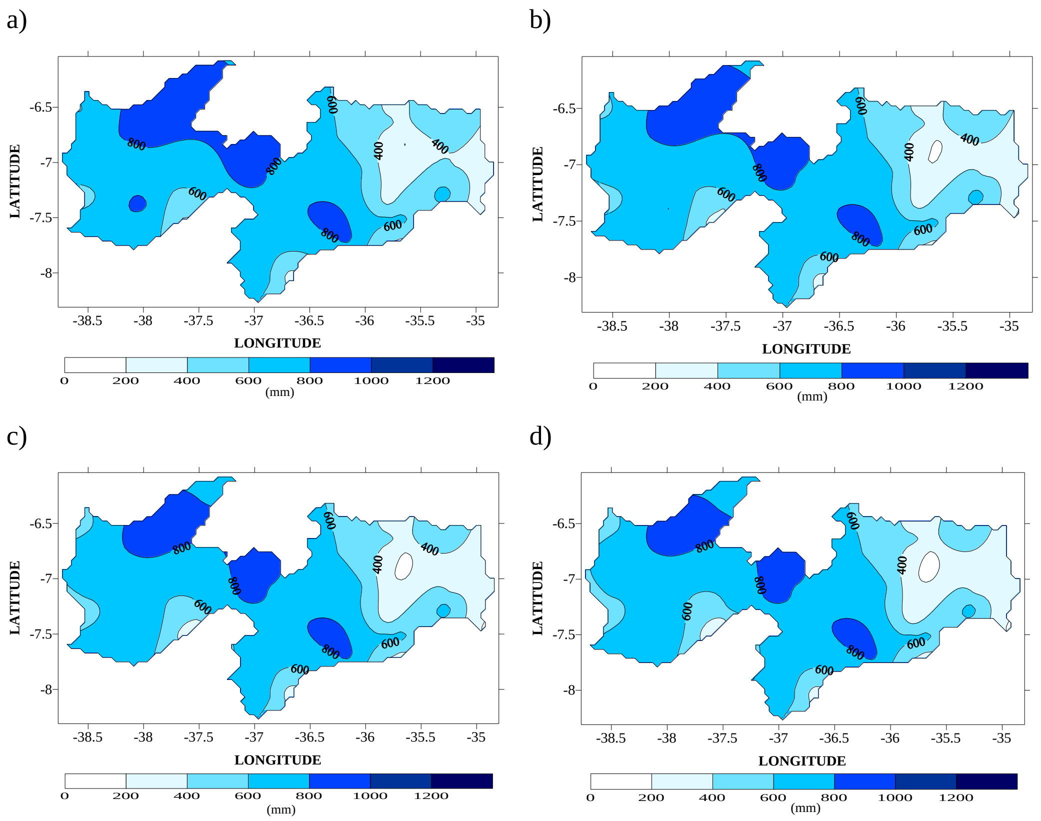

Figure 2. Water deficiency of in the AWCs of a: 75; b: 100; c: 125 and d: 150 mm.

Water exceeding

Figure 3 shows the spatial variation of the water excess for Paraíba according to interpolation performed according to the rain gauge studied. Through this figure, it is observed that the spatial variation of the water exceeding was noticed only in the Alto Sertão with the reduction of the band which goes from 250 to 500 mm for the inferior band which goes from 0 to 250 mm. In the other regions, the range practically did not exist, with predominance of the first band in almost all the State of Paraíba, i.e., all with water excess inferior to 250 mm, with exception of the Litoral (Coast), which had a higher number of this variable. When analyzing the equation to obtain the excess on the water balance, it may be seen that this low index is due to the low index of rainfall of this state (with exception of Litoral). It was also verified that the result of the EXC for the volume of 100 mm (Figure 3 b), also presented satisfactory coherence with the mapping showed by SENTELHAS et al. (2008).

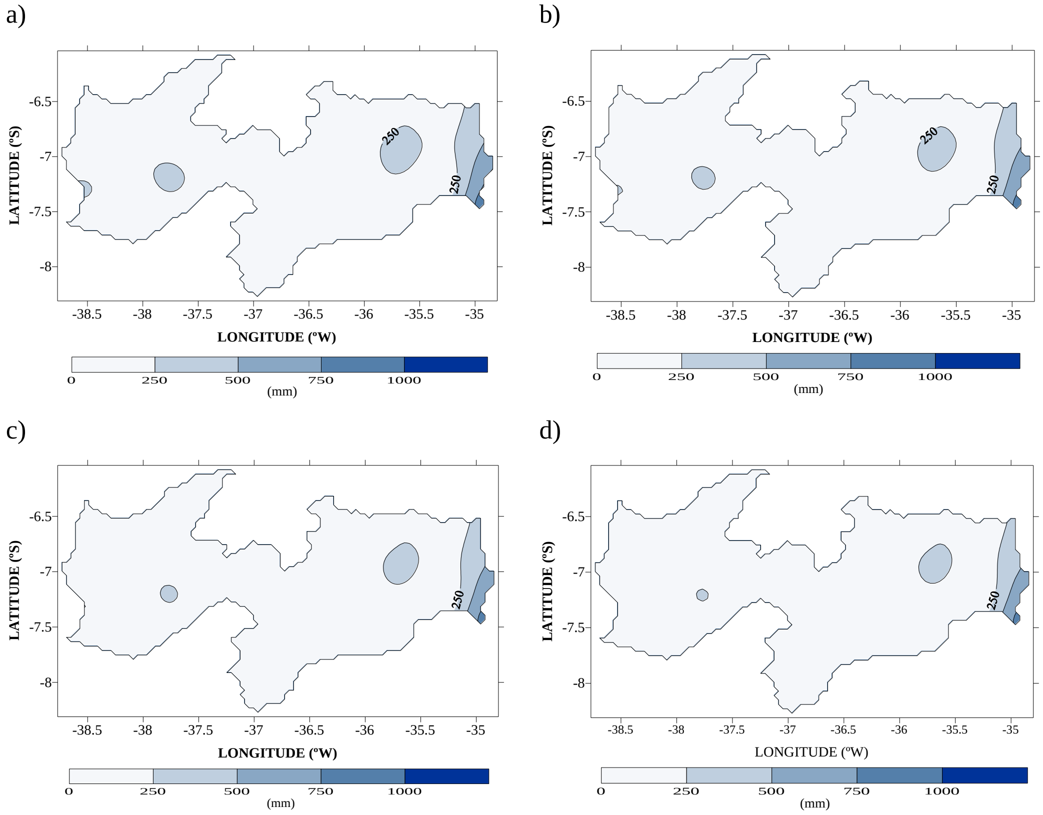

Figure 3. Water excess of Paraíba in the AWCs of a: 75; b: 100; c: 125 and d: 150 mm.

Index of Aridity

Figure 4 represents the index of aridity of all the state, with its bands following the limit of classification in the four AWCs. It is observed that basically in Paraíba two bands of subdivision of the index prevail, which would be from $(16{,}7 \leq I_a < 33{,}3)$ placed mostly in Litoral, Brejo and Agreste, followed by $(I_a \geq 33{,}3)$placed practically in the rest of the state.

They all follow this same characteristic, independent on which AWC they are using. According to the climatic subtypes according to THORNTHWAITE (1948) in function of the index of aridity, it is verified that in Paraíba (Figure 4 b) it prevails moderate to high water deficiency. In the question referent to this index in function of the AWCs it is noteworthy a center (Ia<16.7) located in the Brejo which appears from the AWC of 100 mm (Figure 4b) and increases with the other volumes, together with other center (16.7≤ Ia<33.3) which appears in Sertão from the AWC of 125 mm ©, both caused by the reduction of their bands of origin to an inferior.

Index of Humidity

The index of humidity represents the water excess expressed in percentage of the necessity which is represented by the potential evapotranspiration. Figure 5 shows the interpolation of this index in Paraíba according to the 54 rain gauges, defined trough limits determined by the climate classification of THORNTHWAITE (1948), in order to facilitate the understanding and help in the possible future classifications.

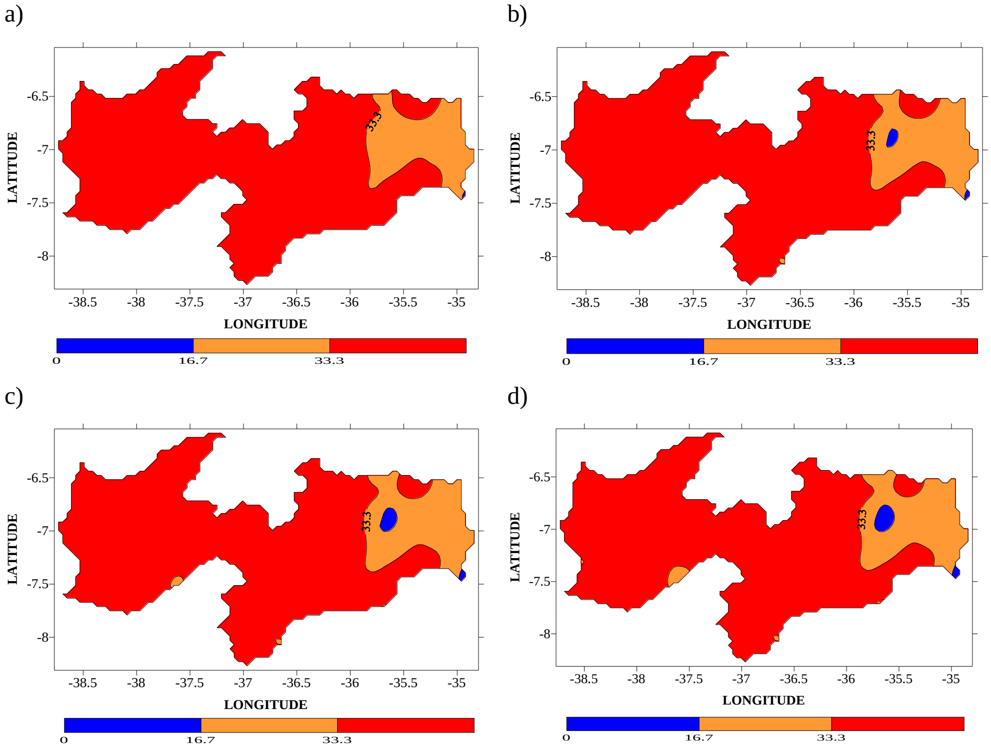

Figure 4. Index of arity in Paraíba in the AWCs of a: 75; b: 100; c: 125 and d: 150 mm.

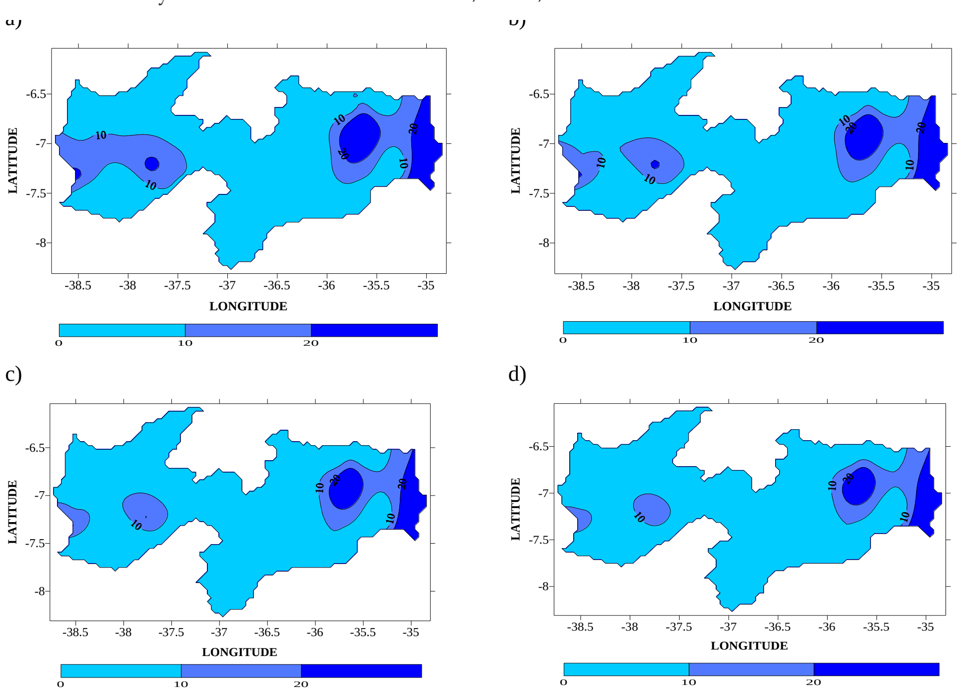

Figure 5. Index of humidity of Paraíba in the AWCs of a: 75; b: 100; c: 125 and d: 150 mm.

According to Figure 5, it can be observed that for the studied AWCs, the index of humidity of the state of Paraíba, there is a significant reduction in parts of the Sertão and Alto Sertão, in this case, since they change bands of climate subdivision, i.e., they moved to an inferior band.

The other regions did not present significant values to change the climate subdivision, although they may even have reduced this index. It can be verified that for all the state of Paraíba, it prevails an index of humidity of values approximately inferior to 10. According to the climate subtypes described by THORNTHWAITE (1948) in function of the index of humidity, it prevails low or none excess of water (Figure 5 b). It is noteworthy in Littoral, Brejo and a small part of Agreste, the good presence of the second climate subdivision that would be (10≤Iu<20) and from the third (Iu≥20), independent on which AWC is being worked, different from what happened in parts of the Sertão and Alto Sertão which had a reduction of climate subtypes, changing the climate limits, as mentioned before. Once more this result is found due to the high scarcity of rain in many parts of this state, with exception of some places mostly located in the Littoral and Brejo, together with small regions in Agreste, Sertão and Alto Sertão.

Water index

The water index is function of the indexes of aridity and humidity, as it was defined by equation (11), in which the index of aridity has a lower weight in this equation. Through it, the climate types are classified according to THORNTHWAITE (1948). Trough Figure 6, it can be noticed that different from the other indexes named previously, there are a lot of climate bands (or climate types), detailing the AWCs studied.

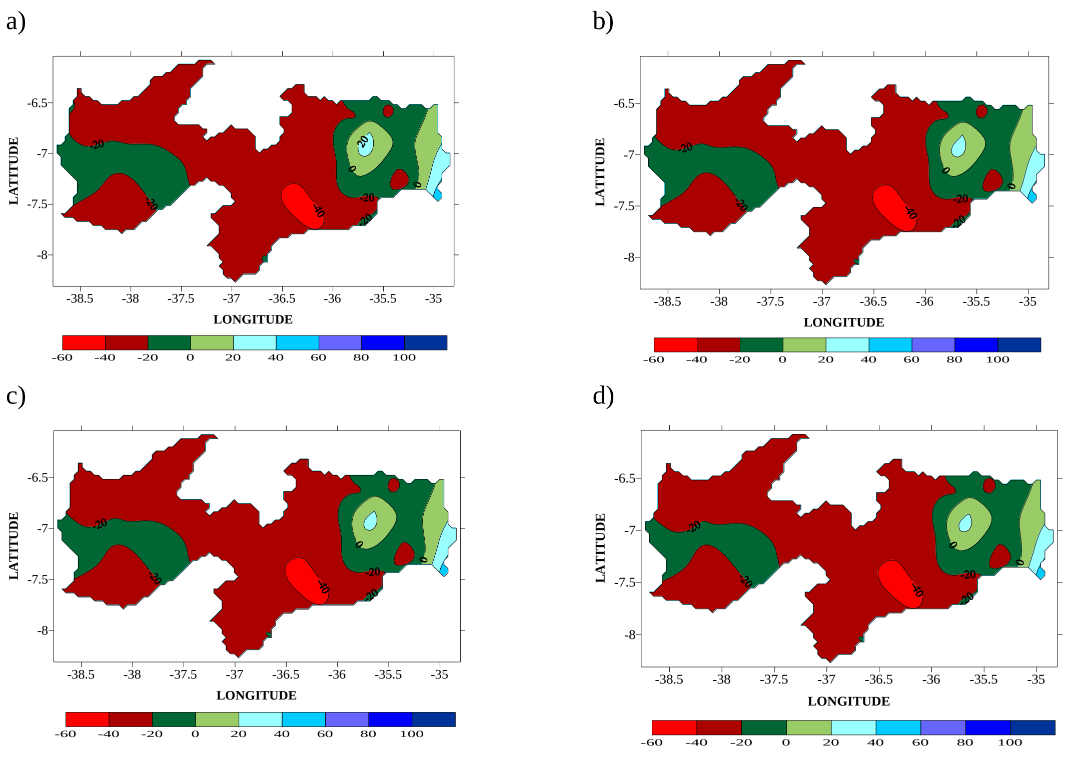

Figure 6. Water index of Paraíba in the AWCs of a: 75; b: 100; c: 125 e d: 150 mm.

This, in a general way, is consequence of the presented values of index of aridity and humidity, as it was estimated. In Paraíba, it prevails (Figure 6 b) the climates: semi-arid (-40≤Ih<-20), followed by dry and sub humid (-20≤Ih<0), and humid and sub humid (0≤Ih<20). As it was expected, in the Littoral it occurred a predominance of positive water indexes, in regions favored for being close to the Atlantic Ocean, with atmospheric conditions favorable to rainfall. Finally, it is still noteworthy a small center correspondent to the arid climate (-60≤Ih<-40), which is located in Cariri/Curimataú.

It can be explained the center located in the Brejo through two factors which may contribute to the appearance of bands referent to the climate humid and sub humid (-20≤Ih<0), together with the band (20≤Ih<40), correspondent to the climate humid. This type of climate may be due to the favoring of the rainfall in the place together with the altitude of the studied stations, in which there is the reduction if the air temperature and, consequently, the potential evapotranspiration in function of the altitude.

Conclusions

The deficiency decreased with the increase of the available water capacity of this soil (AWC), becoming most notable in Brejo, Sertão and Alto Sertão.

The spatial variation of the water excess was considered significant only in the Alto Sertão;

In the variation of the index of aridity in function of the AWCs, it was noteworthy a center located in Brejo appearing from the AWC of 100 mm together with other center, appearing in Sertão from the AWC of 125 mm;

In the index of humidity it was seen that it occurred significant reductions in parts of the Sertão and Alto Sertão;

When analyzing the water index it was verified that there was practically no ranges between them in function of the AWCs studied.

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