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RESEARCH ARTICLE

SPATIALIZATION OF MONTHLY ARIDITY INDEX FOR PIAUI STATE

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ABSTRACT

The objective of this work to estimate the monthly aridity index for the Piaui State. This index is given by the relationship between the amount of rain and reference evapotranspiration. It was used in this study daily data records of rainfall of 165 sites, 145 are located in the state of Piauí and the other in the states of Maranhão, Bahia, Ceará and Pernambuco. For the same locations was estimated monthly reference evapotranspiration by Thornthwaite Method, allowed to calculate the monthly index of aridity. The values found for the 165 sites were spatializated for Piauí State, performing slicing into six thematic classes of monthly aridity index, obtaining thus the thematic maps of monthly aridity index for the Piauí state. Between June and September, about 90% of the Piauí state area is under arid conditions. Only in February and March the rainfall exceeds the evapotranspiration, while 90% of the Piaui state is classified as humid. The spatial distribution of the monthly aridity index can identify times and places most suitable for the development of agriculture, as well as regions subject to desertification.

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INTRODUCTION

Located in Northeast Brazil, Piaui occupies an area of 252,378.49 km^2 constituting the third biggest state in extension of Brazilian Northeast. Its geo-environmental characteristics reflect the transition area between the field of condition interplanálticas depressions covered by caatingas in semiarid climates, savanna areas of the central highlands and the rainforest of the Amazon (Aquino *et al.,* 2006). The knowledge of the variables that make up the water balance as temperature, relative humidity and precipitation among others, favors agricultural planning and production control practices in order to provide information to enable producers to identify climate weaknesses, providing an essential tool for the success of an agricultural enterprise, necessary for the decision to opt or not for irrigation systems to supply water deficiency in soil (Santos *et al.,* 2010). The annual values of climatic elements are extremely variable in different regions of Piaui. The annual rainfall ranges from maximum values of 1,600 mm - 1,800 mm in the north central region 400 mm - 600 mm in the southeast. The average temperature values of the air at the annual scale, ranging from 28 ° C to 30 ° C in the center-north, and 26 ° C to 28 ° C, in the southern and eastern regions, where predominates formations plateaus and mountains, with the highest altitude of quotas, which influence the thermal behavior of Piaui. The largest humidity levels of the air (70-75%) predominate in the north-central region, and the lower (60-65%), in the Southeast, corroborating the rainfall behavior (Andrade Jr. *et al.,* 2004). The climate is one of the main barriers to the development of rainfed agriculture in the state of Piaui. Among the climatic elements, rain is the most important and which causes major losses by imposing drought to crops, due to its uneven spatial and temporal distribution. (Andrade Jr. *et al.,* 2009). Desertification is a factor to be considered by scholars, environmentalists and even the government, as one of the most serious environmental problems of today. The aridity index (AI) is used as a determinant climatic parameter to identify areas susceptible to desertification, as it recognizes the importance of the water balance parameters in optimizing agricultural productivity and consequently the economy (Aquino and Oliveira, 2013). It is common agreement among scientists using the aridity index as an indicator of susceptibility to desertification, according to the methodology developed by Thornthwaite (1948), as well as members of the Drought Polygon areas in the country. The importance of determining this rate of desertification is in fact the occurrence of this process is limited to dry areas, and the calculation of this index indicates exactly this weather condition. Although it

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is calculated and used for most jobs in annual scale, the calculation of the monthly aridity index may indicate a lesser extent to which environmental conditions, crops are subject. Thus, the aim of this work the spatial distribution of the monthly aridity index to the state of Piauí, in order to provide information for planning, programming for agricultural rainfed and management of these areas, due to the rigorous climate, present increased susceptibility to the occurrence of desertification resulting in extreme vulnerability of their environmental sustainability.

MATERIAL AND METHODS

Was used in this study data from daily records of rainfall obtained from rainfall stations in the Northeast Development Superintendence (SUDENE) and the National Institute of Meteorology (INMET) installed in 165 locations, with 145 located in the state of Piaui and other neighboring states of Maranhão, Bahia, Ceará and Pernambuco (Figure 1). Of the 165 rainfall stations have only two historical series of lower rainfall than 15 years of data, and the others have between 15 and 20 years of daily records of rainfall. From these data the wet monthly values for the same 165 locations were obtained.

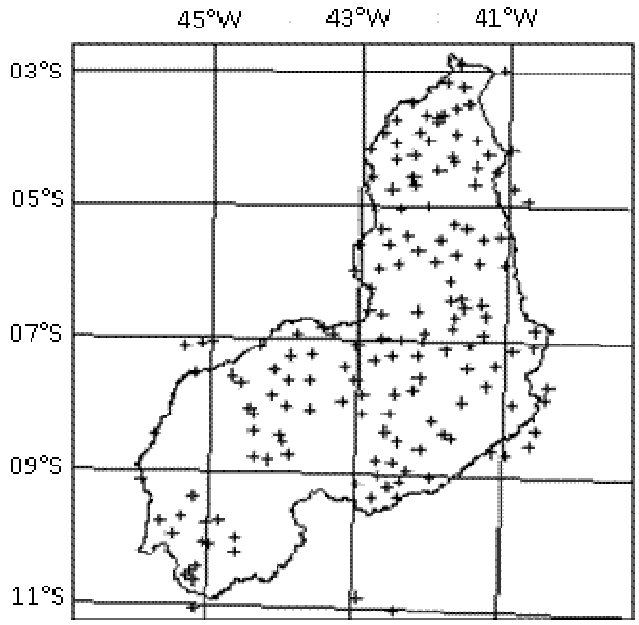

Figure 1. Geographical location of rainfall stations where daily data of rainfall were obtained

The reference evapotranspiration (ET0) in monthly basis, it was estimated 165 for the same places where the lack of the precipitation data, using the Thornthwaite method (1948). Why not have air temperature data for all locations, they were estimated using equations to estimate the average monthly air temperature to the state of Piauí proposed by Lima and Ribeiro (1998), the which are based on latitude, longitude and altitude of the location. From these equations were obtained for each month of the year the average temperatures in each of the 165 sites, it can thus estimate the monthly values of ET0. Developed by Thornthwaite (1948) and subsequently adjusted by Penman (1953), the aridity index can be calculated by dividing total rainfall for evapotranspiration, and for this study were obtained from the aridity indices in monthly scale to 165 sites. As an initial step for the preparation of thematic maps of monthly aridity index to the state of Piauí an exploratory analysis was performed AI values obtained in 165 locations. Confirmed the normality assumption, considering for performing geostatistical study the adjustment thereof to this distribution can be only approximate (Folegatti *et al.,* 2001), experimental semivariograms were generated using GS + software - Geostatistics for the Environmental Sciences (Robertson, 1998), by the estimator displayed by Journel (1989):

$$\hat{\gamma}(h) = \frac{1}{2N(h)} \sum_{1}^{N(h)} [Z(s) - Z(s+h)]^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where: $\hat{\gamma}$ (h) - semivariance; Z (s) - the variable value in the "s"; Z (s + t) - value of the variable in a position "s + h": N (h) - number of data pairs separated by a distance "h". Em que: (h) – semivariância; Z(s) - valor da variável na posição "s"; Z(s+h) - valor da variável em uma posição "s+h": N(h) - número de pares de dados separados por uma distância "h". Confirmed the spatial continuity of AI values, they were estimated for each position (s), not sampled by ordinary kriging, and, then held the spatial distribution of monthly AI values for the state of Piauí, realizing the slicing into six thematic classes monthly aridity index using Spring 5.2 software (Hall *et al.,* 1996), obtaining thus the monthly AI thematic maps for the state of Piauí. In Slicing for the preparation of maps were used climate classes, shown in Table 1, where desertification is only likely to happen in areas where the aridity index is less than 0.65.

Table 1. Climate classification according to the aridity index

Climate classes	Aridity index
Hiperarid	IA< 0,05
Arid	0,05 <IA< 0,20
Semiarid	0,21 <IA< 0,50
Dry sub-humid	0,51 <IA< 0,65
Sub-humid Humid	0,65<IA< 1
Humid	>1

Source: Funceme, 2007

RESULTS AND DISCUSSION

As expected, the stations with the highest annual rainfall have a higher index of aridity, all above the maximum level for that index is 1, so being in the wet classification, while the stations with lower rainfall have lower levels of aridity. The changes in weather patterns could result in the triggering or accelerating processes of desertification in most vulnerable areas (Galvíncio *et al.,* 2011). The highest values of aridity index are located north of the state, providing this region less arid character. This fact is mainly related to rainfall that these stations have, that among the selected points correspond to those with a higher annual rainfall, due also to its proximity to the sea. The lower occurrence of rain, observed mainly in the southern and southeastern regions of Piaui State, may be justified, among other factors, by its geographical location where cold fronts can't come up with great intensity, not being able to cause rainfall. Some atmospheric perturbation systems operating in Piauí also prevent more precipitation, as follows: the squall lines, the intertropical convergence zone and even traces of the cold front, combined with mesoscale convective complexes seconds Aquino and Oliveira (2013). You can see detail in Figure 2, the monthly variation of aridity index for the state of Piauí. During the month of January, 68% of the state are under the wet condition and 30% moist sub-humid and only a narrow strip is in the dry sub-humid classification.

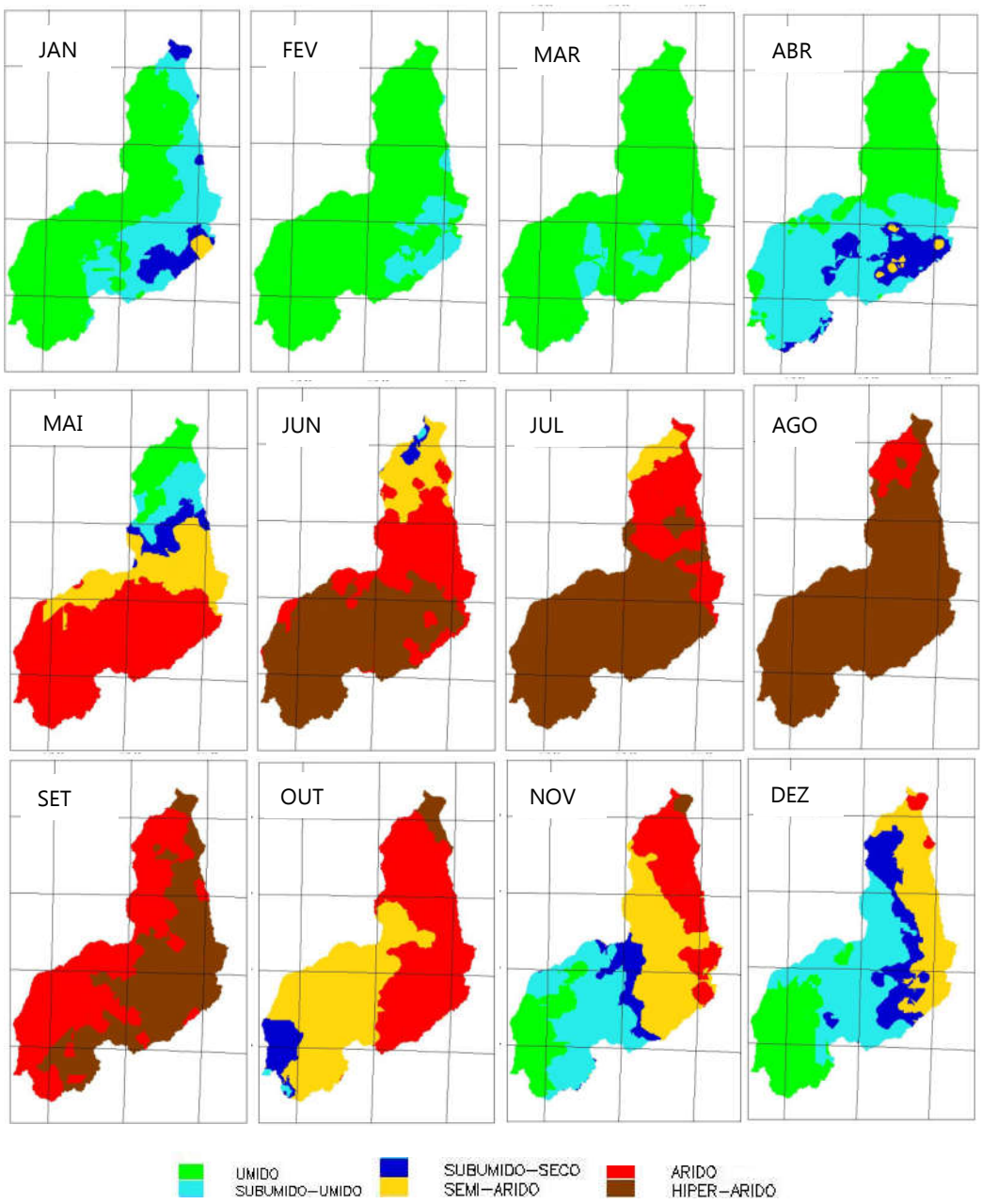

Figure 2. Thematic maps Monthly aridity index for the state of Piauí

The month of February as well as March, marking the peak of the rainy season in the state, appears with 90% of Piauí area in wet conditions. Subsequently, the month of April already has half of the Piauí state to pair, especially the south and southeast portions in the humid sub-humid, however, no region of the state this month is within the semiarid classification. You can see clearly the concentration of rainfall in the first half of the year, showing an irregular annual distribution, spatially heterogeneous but clearly similar in terms of location of the total rainfall each year. With the decrease in rainfall and rising temperatures and consequently evapotranspiration, the month of May already has 56% of the state classified as arid area, although still hold narrow bands in other climatic classes, among them, humid and sub-humid and humid. In June and July, the rains are scarce and the state is divided between arid and hiperárido, with a small portion of the semi-arid north of the state. In these months, the south and southeast are the most affected with the low level of aridity. In August, the weather conditions are more critical of the drought, ranging from arid to the hiperarid, resulting in 93% of the state area classified as hiperarid.

The main driver of these conditions is the high rate of evapotranspiration coupled with low rainfall totals. You can see that the spatial variation of rainfall over the Piaui state follows the mainland coast sense, proving the oceanic influence in increased rainfall in closer to the coastal areas. In September the state of Piaui is divided between the conditions of arid and hiperárido, being the southeast ranked hiperárida in a range that goes from north to south of the state. In October, the state sets a condition of arid and semi-arid region, evidencing the condition of the southeast region of the state. In November, the state has classified areas at all levels, and the moist semi-arid and sub-humid the larger stay, 29 and 27% of the total of Piauí area, respectively in December, with the beginning of the first rains and lower evaporation, weather conditions are concentrated in the category of moist sub-humid, represented by 36% of the state area, and 23% humid and semiarid region. Considering the annual scale, where, according to the National Integration Ministry, 34% of Piauí area is under semi-arid area and 40% in the dry sub-humid, these results are quite different depending on the observation

scale. The northern region of the state presents itself as the rainiest in Piauí remaining the first five months of the year classified as wet coming up dry in the warmer months - July, August, September and October. In contrast, the Southeast region is the one with the lowest values of the aridity index, through the months of May to October arid and hiperarid and only January and February humid and sub-humid moist. These behaviors deficit or surplus water are directly related to the rainfall recorded by each season, but also receive influence of temperature values and potential evapotranspiration.

The agro-climatic zoning identifies major areas and smaller climate risks into account the time of year, areas with higher yield potential beyond the climatic potential for the establishment of agricultural crops. Through agro-climatic zoning of the culture of guava (Sousa *et al.,* 2013) and hose (Portela *et al.,* 2008) to the state of Piauí, it was found that it can be said the states do not have any climate restriction for commercial cultivation in both species, with the temperature ranging between 25 ° C and 30 ° C, ideal for most crops. According to Chaves *et al*. (2007), the Brazilian semiarid soils, due to high temperatures and sparse cover and plant density of species, and worsening drought soil, increased runoff, increased wind erosion, decreased rainfall, increased range daily temperature and decreased Relative humidity (RH) of the air, resulting in changes in weather patterns and consequently desertification. These behaviors deficit or excess water are, first, directly related to the rainfall recorded by each season, but also receive influence of temperature values and potential evapotranspiration according to data found by Barros (2010). According Portela *et al*. (2008) for a more detailed analysis should be considered in addition to the air temperature and precipitation values, the combination of the various meteorological parameters, that is, relative humidity, wind, light, altitude and latitude.

Conclusions

Between the months of June and September, about 90% of Piauí state is under arid and hiperarids conditions. Only in February and March the rainfall exceeds the reference evapotranspiration, with 90% of Piauí state classified as humid. The spatial distribution of the monthly aridity index identifies times and more apt sites for development of rainfed agriculture, as well as those more prone to the occurrence of desertification processes.

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