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RAINFALL EROSIVITY IN THE DESERTIFICATION NUCLEUS OF CARIRI AND SERIDÓ DA PARAIBA.

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ABSTRACT

Desertification is a process of land degradation and occurs predominantly in arid, semi-arid and dry sub-humid areas. In view of this, we sought to determine the main characteristics of rainfall erosivity in the desertification nuclei of Cariri (Cabaceiras) and Seridó (Santa Luzia) in Paraiba, located in the intermediate geographic regions of Campina Grande and Patos, with these determinations being the main objectives. Using monthly and hourly rainfall data, collected from automatic meteorological stations, from these locations, the rainfall erosivity (EI), the kinetic energy of the maximum intensity of the rain, in 30 minutes (EI_{30}), the number of events with Imax and the relationships between the averages of total rainfall >100 mm and the EIs. The main results show that, in deforested areas, the erosivity of the rain potentiates the erosion process and the interstate desertification nuclei have different characteristics of rainfall regime and EI. The maximum EI_{30} occurred in the late afternoon/early evening, with lower values in Cabaceiras, where most classes were low. In Santa Luzia, 1/3 of the classes were high to very high, although predatory anthropic interventions contribute to aggravating them.

EROSIVIDADE DA CHUVA NOS NÚCLEOS DE DESERTIFICAÇÃO DO CARIRI E SERIDÓ DA PARAÍBA.

RESUMO

A desertificação é um processo de degradação de terra e ocorrem, predominantemente, em áreas áridas, semiáridas e subúmidas secas. Diante disto, procurou-se determinar as principais características da erosividade da chuva, nos núcleos de desertificação do Cariri (Cabaceiras) e Seridó (Santa Luzia) da Paraíba, localizados nas regiões geográficas intermediárias de Campina Grande e Patos, sendo essas determinações os objetivos principais. Utilizando-se dados mensais e horários de chuvas, coletados nas estações meteorológicas automáticas, das referidas localidades foram estimadas as erosividades da chuva (EI), a energia cinética da intensidade máxima da chuva, em 30 minutos (EI_{30}), os números de eventos com Imax e as relações entre as médias dos totais de chuva >100 mm e as EIs. Os principais resultados mostram que, em áreas desmatadas, a erosividade da chuva potencializa o processo de erosão e os núcleos de desertificação interestadual têm características distintas de regime pluvial e de EI. As máximas EI_{30} ocorreram no final da tarde/início da noite, com menores valores em Cabaceiras, onde a maioria das classes foi baixa. Já, em Santa Luzia 1/3 das classes foi alta a muita alta, embora às intervenções antrópicas predatórias contribuam para agravá-los.

INTRODUCTION

The energy of the impact of raindrops and surface runoff transport organic matter, nutrients, suspended soil particles, among others and, therefore, make water erosion the main responsible for soil loss (SCHICK et al., 2014). .

The spatial and temporal oscillation of rainfall is the deterministic factor for the erosion process in agricultural areas. In Africa, soil erosion, influenced by human actions, results in increasing pressure on natural resources, which leads to more intensive land use (VRIELING et al., 2010)

The rain erosivity index (EI) expresses the erosive potential of rains WISCHMEIER and SMITH (1978), that is, the potential capacity to cause erosion, being expressed through an index (HICKMANN et al., 2008).

Vegetation cover is the most important factor in controlling desertification, especially in the semiarid region. Even with very dry and twisted vegetation (deciduous), the caatinga protects the soil against the weather, reducing degradation.

Intense rainfall events, associated with low vegetation cover, to protect the soil, result in erosive impacts of great magnitude (MELO FILHO and SOUZA, 2006)

Vegetation cover is important in soil protection, because it increases the retention of intercepted water, reduces the damping (impact) of raindrops, reduces the speed of surface runoff and enhances the formation of ravines and gullies (SUERTEGARAY, 2020).

It was tried to establish the main characteristics of the erosivity of the rain, in the desertification nuclei of Cariri (Cabaceiras) and Seridó (Santa Luzia) of Paraiba, located in the intermediate geographic regions of Campina Grande and Patos, being these determinations the main objectives.

MATERIAL AND METHOD

The data analysis criterion was performed on two scales: hourly, using data collected from automatic weather stations (EMAs), installed in Cabaceiras (Cariri) and Santa Luzia (Seridó) and another climatologically scale- with monthly rainfall data, provided by the Executive Agency for the Waters of the State of Paraiba (AESA), Campina Grande, PB..

The rainfall data, in the hourly scale, were collected in the automatic tipping rain gauge and stored in a Campbell Scientific data acquisition system, model CR1000, with continuous records and readings every ten minutes, being processed and stored the averages every 30 minutes, hourly and daily.

Daily rainfall data were collected in a Ville de Paris rain gauge and provided by AESA, being analyzed using criteria of climatologically and descriptive statistics.

The average monthly and annual rainfall erosivity were estimated using the equations proposed by BERTONI and LOMBARDI NETO (2005):

$$EI_{30}(MJ.mm/ha.h.mês) = 67{,}36 \times \left[\frac{\text{monthly average rain }^{\wedge}2}{\text{average annual rain}}\right]^{0{,}85}$$

To determine the water, aridity and humidity indexes related to the susceptibility of the lands to desertification, the components of the water balance were used, including rainfall and potential evapotranspiration (ETP), from the two locations; one from Cariri and the other from Seridó in Paraiba.

The aridity indices (Ia) were determined using the criteria of the climatic water balance and UNEP (1991), using the equations:

Dryness index $Ia(BHC) = \frac{\text{water deficiency}(mm)}{ETP(mm)}$

Dryness index $Ia(UNEP) = \frac{Rain(mm)}{ETP(mm)}$

The calculations and the elaboration of graphs and tables were made using an Excel spreadsheet.

RESULTS AND DISCUSSION

The characterization of heavy rains is essential in the dimensioning of rainwater, especially in the control of surface runoff, in rural and urban areas related to the process of water erosion.

Figure 1 shows the hourly distribution of maximum rainfall events, in 30 minutes, for the two representative locations of the Cariri and Seridó from Paraiba desertification nuclei

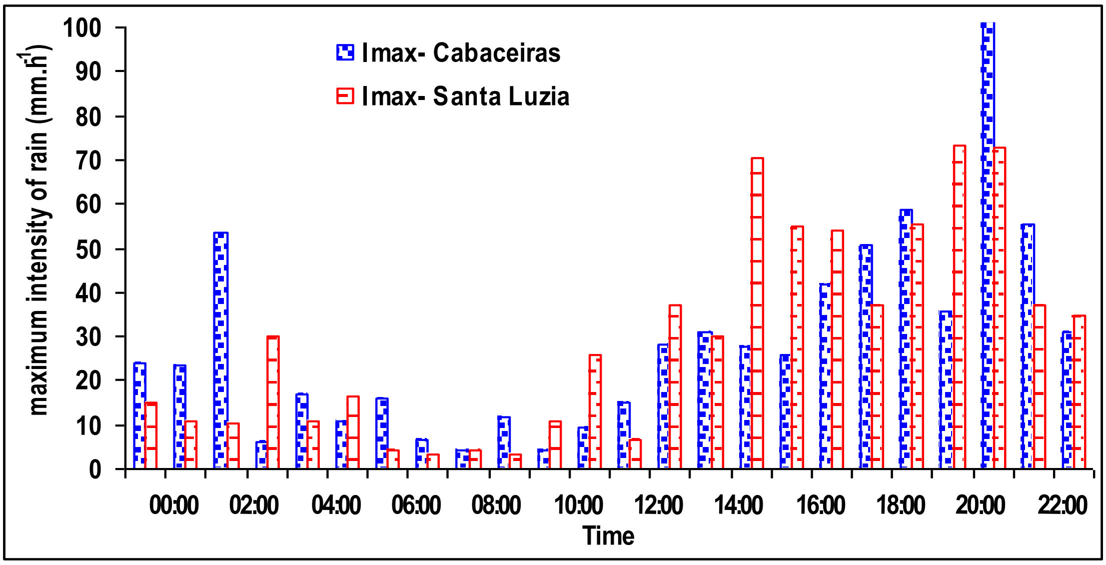

Figure 1. Maximum hourly rainfall intensities, in 30 minutes, in Cabaceiras and Santa Luzia.

Soil degradation occurs mainly by the dragging of smaller particles that causes soil impoverishment by washing the surface layer, the richest in nutrients, in addition to carrying sediments to the lower parts, silting up water bodies.

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It is observed (Figure 1) that the highest peaks of rainfall intensities occur, with greater predominance in the early hours of the night and the lowest during the morning shift

Rainfall erosivity is an indicator that expresses the potential capacity to cause soil breakdown (erosion), being potentiated in areas devoid of vegetation cover, expressed by the product of the kinetic energy of the rain by its maximum intensity in 30 minutes.

The characterization of heavy rains is essential to dimension issues of interest to engineering, the environmental area and, in particular, the control of surface runoff, in rural and urban areas related to the process of water erosion.

Soil degradation occurs mainly by the dragging of smaller particles that causes soil impoverishment, through the washing of the surface layer and the richest in nutrients, in addition to carrying sediments to the lower parts, silting up the water bodies.

The Figure 2 shows the hourly distribution of the maximum rainfall event, occurring in 30 minutes (EI_{30}), distributed by class interval, for the two representative locations of the Cariri and Seridó from Paraiba desertification nuclei.

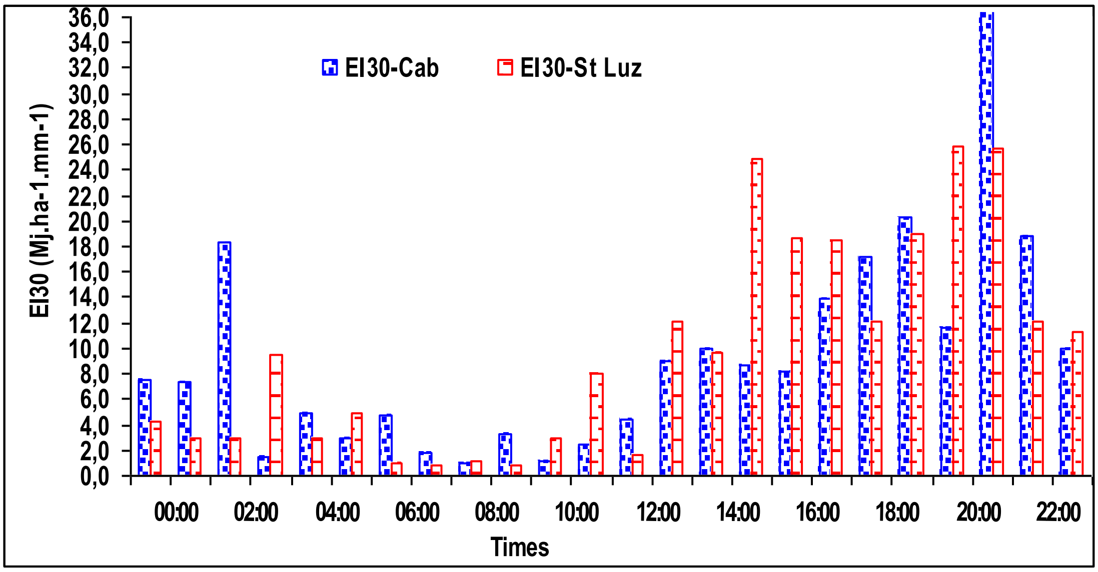

Figure 2. Hourly kinetic energy of the maximum intensity of rain observed, in 30 minutes, in Cabaceiras and Santa Luzia, PB, in the period: 01.01.2013 to 12.31.2020.

The graphic visualization of Figure 1 shows that the highest EI_{30} occurred in the late afternoon and early evening, with an absolute maximum of 36.94 $Mj.ha^{-1}.h^{-1}.mm^{-1}$ at 10 pm, in Cabaceiras, and three in Santa Luzia, of 24.81, 25.82 and 25.74 $Mj.ha^{-1}.h^{-1}.mm^{-1}$ at 16:00, 20:00 and 22:00 h, respectively.

Counting the averages of the maximum EI_{30} were 37.0 % higher for Santa Luzia, in the day shift (from 07:00 to 18:00 h), when compared to Cabaceiras, inverting, respectively, between 19:00 and 06:00 h, with 10.2 and 12.1$Mj.ha^{-1}.h^{-1}.mm^{-1}$.

Torrential rains (of greater intensity) have higher potentials (risks) to aggravate the process of water erosion. The Figure 2 summarizes the relationships between the numbers of events with maximum rainfall intensity, in $mm.h^{-1}$, grouping them into four class intervals, and the respective maximum intensity values (Imax).

Comparing the histograms with maximum intensity and their respective frequencies, it is observed that the number of repetitions were higher, for any interval, in Santa Luzia than in Cabaceiras.

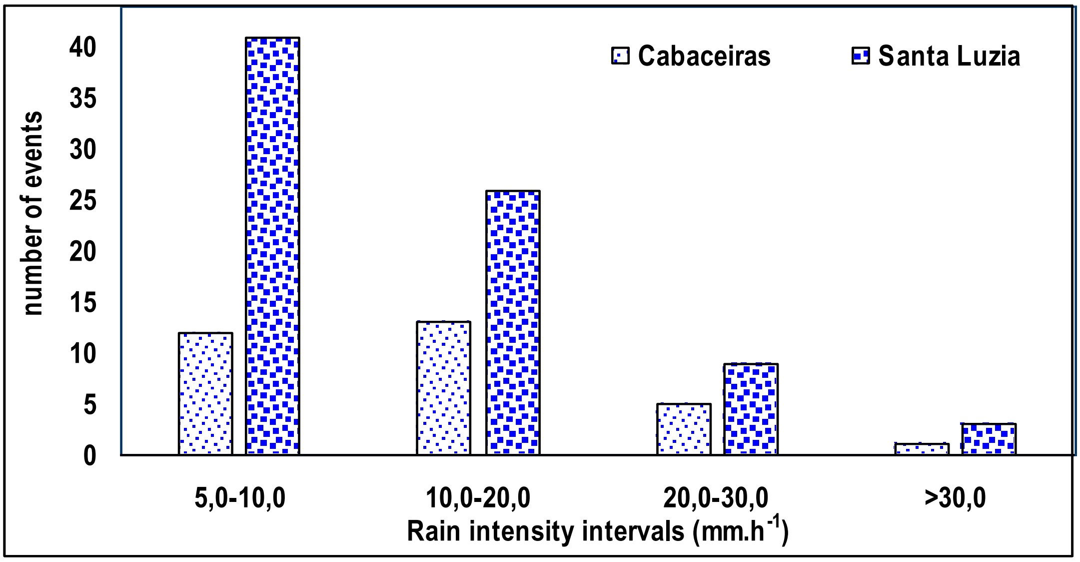

Figure 3. Number of events with maximum rainfall intensities (mm.h^{-1}), by class intervals, in Cabaceiras and Santa Luzia, PB, in the period: 01.01.2013 to 12.31.2020.

The event with the absolute Imax, in 30 minutes, took place on March 17, 2020 in Cabaceiras (100 mm) at 21:00 h and three in Santa Luzia, of 70.6, 73.0 and 73.2 0 mm, on 05/10/2014 (15:00 h), 03/25/2015 (20:00 h) and 04/17/2014 (21:00 h).

Rain erosivity is another important feature to study the potential for water erosion, existing in the Cariri and Seridó from Paraiba desertification nuclei (Figure 4).

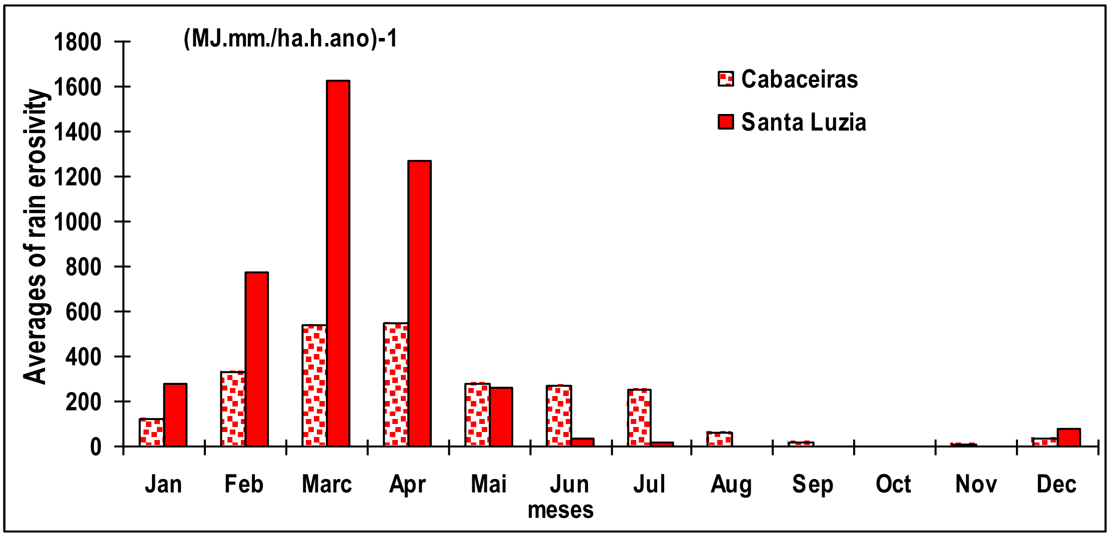

Figure 4. Monthly averages of rainfall erosivity in the desertification nucleus of the State of Paraiba.

Rainfall erosivity is an important characteristic to study the different erosion potentialities - monthly averages - in the two desertification centers of Cariri and Seridó in Paraiba (Figure 4). The monthly averages of erosivity in Figure 4 resulted in the different classes, described, with very high, high, medium, low and very low (Table 1).

Table 1. Monthly averages of the rain erosivity classes in the Cariri and Seridó from Paraiba desertification nuclei.

Classes/places	J	F	M	A	M	J	J	A	S	O	N	D
Cabaceiras, PB	MB	B	M	M	B	B	B	MB	MB	MB	MB	B
Santa Luzia, PB	B	A	MA	MA	B	MB	MB	MB	MB	MB	MB	A

MA= Very High; A=High; M= Mean; B= Low and MB= Very Low

O índice de aridez é o principal indicador e classificador de terras secas em (árida, semiárida e subúmida seca) como também, mensura o grau de susceptibilidade a desertificação.

Os indicativos percentuais da relação entre os índices de aridez (IA) estimados pelos métodos da UNEP e do balanço hídrico climatológico (BH) são apresentados na Figura 5.

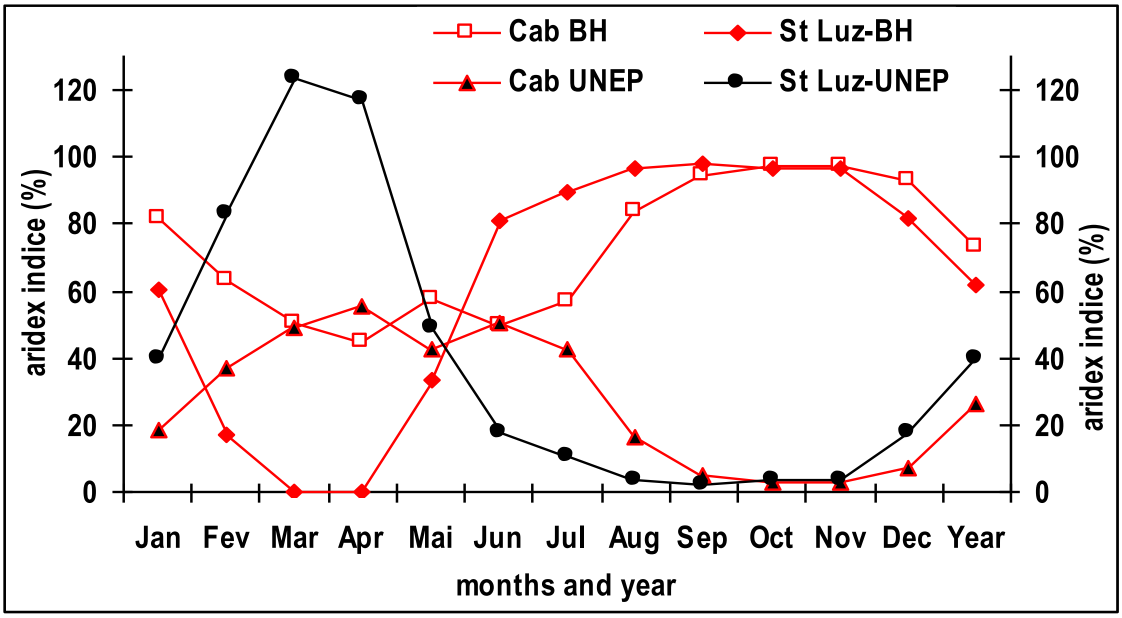

Figure 5. Relationship between the aridity index (AI), using the average climatic water balance (BH) and UNEP methods, for Cabaceiras (Cab) and Santa Luzia (St Luz), PB.

Comparing the aridity index curves using the UNEP method, it can be seen that the IA of Santa Luzia is higher than that of Cabaceiras, only during the rainy season (from January to April), justified, in almost its entirety, by due to 62% more rain

There are, however, some characteristics that differentiate the aridity index estimated by the UNEP method in relation to the climatologically water balance. The first is the ratio (P/ETP) itself, as an indicator of aridity, justified by the fact that potential evapotranspiration is the necessary rainfall, although ETP, by definition, refers to the loss of water by evapotranspiration of a low-growing crop in development and without any water restriction, conditions very different from those that occur in the semiarid region.

The aridity index, estimated by the climatologically water balance, differs from the IA UNEP, as it results from water accounting (input-output) in a volume of soil occupied by at least 80% of the root system.

The inversion of the two AI curves (BH and UNEP) in Santa Luzia and, especially, in the rainy season months, also justifying its continuity in the other months, that is, showing semi-aridity by the UNEP method and humid sub-humid by the water balance .

It is noteworthy, however, that although Cabaceiras is the least rainy locality, when compared to Santa Luzia, it has the lowest erosivity ratings, ranging from medium, low to very low, while Santa Luzia has two classes in the high range (high and very high) in 1/3 of the months (December, February, March and April).

CONCLUSIONS

The erosivity of rain potentiates the process of soil erosion in areas devoid of vegetation cover. The maximum intensities of rain, in 30 minutes (EI30), occurred in the late afternoon and early evening.

The rain erosivity indicators were higher in Santa Luzia than in Cabaceiras, where most of the erosivity classes are low, while in Santa Luzia, 1/3 of them are classified as high to very high.

In the rainy season, in both locations, the aridity indexes of UNEP were higher than those of the water balance and lower in the other months, although those of Cabaceiras are twice as high as those of Santa Luzia.

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REFERÊNCIAS

BERTONI, J.; LOMBARDI NETO, F. soil conservation. 5. ed. São Paulo: Ícone, 2005.

BLAIN, G. C.; BRUNINI, O. Quantification of agricultural drought by the standardized index of real evapotranspiration (IPER) in the State of São Paulo. Bragantia (Brazil), v. 65, p. 517-525, 2006.

CARVALHO, N. O. Practical hydrosedimentology. 2.ed. Rio de Janeiro: Interciência, 599p, 2008.

HICKMANN, C.; FOLETTO, F. L.; CASSOL, E. E. A.; COGO, C. M. Rainfall erosivity in Uruguaiana, RS, determined by the EI30 index, based on the period from 1963 to 1991. Revista brasileira de ciência do solo, v. 32, n. 2 p. 825-831, 2008.

MELO FILHO, J. F.; SOUZA, A. L. V. 2006. Soil management and conservation in the semiarid region of Bahia: challenges for sustainability. Bahia Agrícola, Salvador, v. 7, n. 3, p. 50-60.

SUERTEGARAY, D. M. A. ARENIZATION: INTERPRETATIVE SKETCH. William Morris Davis - Revista de Geomorfologia, v. 1, n. 1, p. 118-144, 2020.

VRIELING, A.; STERK, G.; DE JONG, S. M. Satellite-based estimation of rainfall erosivity for Africa. Journal of hydrology, v. 395, n. 3-4, p. 235-241, 2010.

WISCHMEIER, W.H.; SMITH, D. D. Predicting rainfall erosion losses: a guide to conservation planning. Washington: USDA, 58p, 1978.