

## **TENDÊNCIA DE PRECIPITAÇÃO PLUVIOMÉTRICA E IMPACTOS SOBRE PROCESSOS EROSIVOS NO SERTÃO DOS INHAMUNS: INDEPENDÊNCIA, CEARÁ**

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### **1 RESUMO**

O monitoramento das variáveis ambientais é importante para a compreensão dos processos naturais. Sob esta perspectiva, este estudo buscou avaliar a ocorrência de mudanças no padrão da precipitação pluviométrica e erosividade da chuva no semiárido brasileiro, onde foi aplicado o teste estatístico não-paramétrico de Mann-Kendall. Os resultados indicam uma tendência de queda nos valores de precipitação e erosividade, entretanto, estatisticamente não significativa, apontando uma redução na precipitação de aproximadamente 8mm por década indicando um decréscimo médio de 80mm durante a janela temporal analisada (~100 anos). Dessa forma, conclui-se que houve uma sutil mudança no padrão de precipitação da região.

**Keywords:** Variação de precipitação, Erosão, Semiárido.

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### **RAINFALL TREND AND IMPACTS ON EROSION PROCESSES IN THE SERTÃO DOS INHAMUNS: THE CASE OF INDEPENDÊNCIA, CEARÁ**

### **2 ABSTRACT**

Monitoring environmental variables is important for understanding natural processes. From this perspective, this study sought to assess the occurrence of changes in rainfall patterns and rain erosivity in the semiarid region of Brazil via the Mann-Kendall nonparametric statistical test. The results indicate a downward trend in rainfall and erosivity, although this trend is not statistically significant, indicating a reduction in rainfall of approximately 8 mm per decade and an average decrease of 80 mm over the time window analyzed (~100 years). Thus, it is concluded that there has been a subtle change in the region's precipitation pattern.

**Keywords:** Precipitation variability, Erosion, Semi-arid Climate

### 3 INTRODUCTION

The semiarid region of Brazil is characterized by a strong negative water balance, irregular rainfall and long periods without rainfall. These characteristics make water resource management a challenging task in the region (Campos *et al.*, 2016; Araújo; Güntner; Bronstert, 2006). When rainfall occurs, it plays a fundamental role in hydrology and environmental dynamics, directly influencing surface runoff and infiltration processes (Costa *et al.*, 2016).

However, this same precipitation, when concentrated in intense events, is closely related to soil erosion, a phenomenon that significantly affects the land's carrying capacity, agricultural productivity and maintenance of natural resources (Simplício *et al.*, 2021). Therefore, the importance of rainfall in the semiarid region of Ceará is clearly not restricted to water recharge.

Intense precipitation events, for example, can cause severe surface runoff since the runoff process in the region is predominantly Hortonian (Lima *et al.*, 2022; Figueiredo *et al.*, 2016), which, combined with fragile vegetation cover, results in the disaggregation of particles and consequently an increase in soil erosion. This reality is aggravated by climate change scenarios, in which a greater frequency of extreme events, such as torrential rains, which can drastically

alter precipitation patterns and modify erosion processes in the region, is expected (Figueiredo *et al.*, 2016; Alencar; Araújo; Teixeira, 2020). Therefore, studying changes in precipitation patterns and their relationships with erosion in particularly vulnerable areas, such as the semiarid region of Brazil, is relevant.

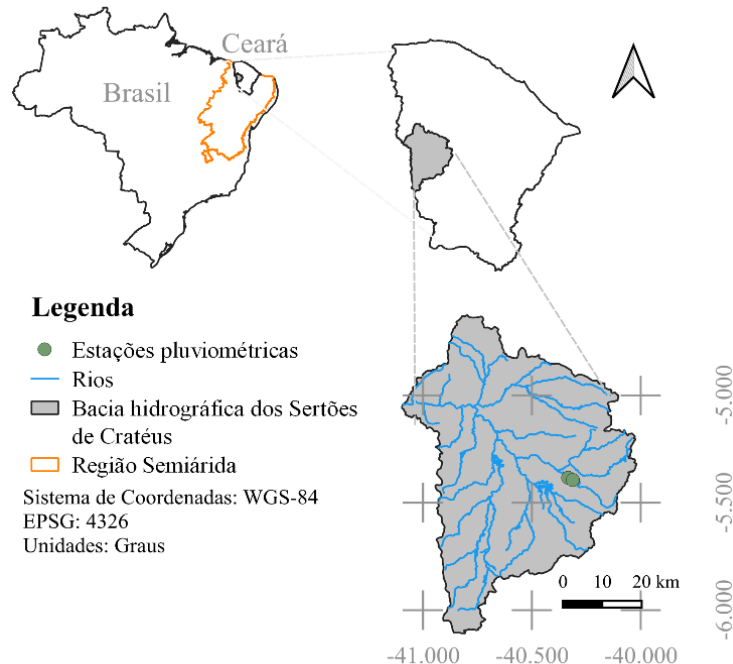
In this context, a study was carried out with the aim of evaluating the occurrence of changes in the rainfall pattern in the municipality of Independência, in the state of Ceará, which is located in the Inhamuns subregion, with more than one hundred years of rainfall data.

### 4 MATERIALS AND METHODS

#### 4.1 Study area

This study was developed for the municipality of Independência, which is located in the Sertões de Crateús Hydrographic Basin (Figure 1). The basin has an area of approximately 10,700 km<sup>2</sup>, with an average annual precipitation of 740 mm and potential evaporation of 3,350 mm.year<sup>-1</sup> (INMET, 2024), and it is located entirely in a semiarid region. The precipitation data used come from two meteorological stations whose characteristics are described in Table 1.

**Figure 1.** Locations of the rainfall stations used in the study and the Sertões de Crateús Hydrographic Region



**Table 1.** Data from the meteorological stations used

Code	Municipality	Operator	Registration period	Latitude	Longitude
540016	Independence	DNOCS	10/1910 to 11/1985	-5.3833	-40.3333
540019		FUNCEME	03/1964 to 04/2024	-5.3936	-40.3128

Owing to the relative proximity of both (3 km) and the uniform edaphoclimatic characteristics, the data from station 540016 (interrupted in 1985) were filled with those from 540019 (present until 2024).

The data used in this study cover the period from 1911–2023, from two rainfall stations. The data from 2024 were excluded because of the occurrence of significant failures during the rainy season. As an exclusion criterion, only years without failures in the rainy season (January–May) were considered. For years with failures in the dry season, the historical average was used to fill in the missing values, since, at this time of year, rainfall tends to be very low, with averages close to zero. This approach ensured a consistent and representative database for the period analyzed, totaling 111 years.

## 4.2 Trend analysis

Trend analysis was conducted via the nonparametric Mann–Kendall test (Kendall, 1948; Mann, 1945), which is a statistical method recommended by the World Meteorological Organization (WMO) to assess the occurrence of trends in time series of hydrometeorological variables. To determine the significance of the results, a significance level of 5% ( $p < 0.05$ ) was adopted; i.e., only trends with a probability of less than 5% of having occurred were considered statistically significant. In addition, the magnitude of variation over time (rate of variation) was estimated via the Sen method (Sen, 1968), which consists of determining the angular coefficient after adjusting a nonparametric linear regression.

### 4.3 Erosivity

In the universal soil loss equation (USLE),  $R$  is the rainfall erosivity factor ( $\text{MJ.mm. ha}^{-1}.\text{h}^{-1}.\text{year}^{-1}$ ), and in this work, it was calculated via Equation 1, developed by Lombardi Neto and Moldenhauer (1992). To calculate the annual rainfall erosivity, the values calculated for each month must be added (Equation 2).

$$R_m = 68,73 \left( \frac{P_m^2}{P_a} \right)^{0,841} \quad (1)$$

$$R = \sum_{n=1}^{12} R_m \quad (2)$$

where  $R_m$  = average monthly erosion in  $\text{MJ.mm. ha}^{-1}.\text{h}^{-1}.\text{month}^{-1}$ ;  $P_m$  = average monthly precipitation in mm;  $P_a$  = total annual precipitation in mm.

The data were classified according to the criteria proposed by the International Soil Reference and Information Center, as shown in Table 2.

**Table 2.** Rainfall Erosivity Classification

Erosivity	Class
$R \geq 1250$	High
$800 < R < 1,250$	Average
$R \leq 800$	Low

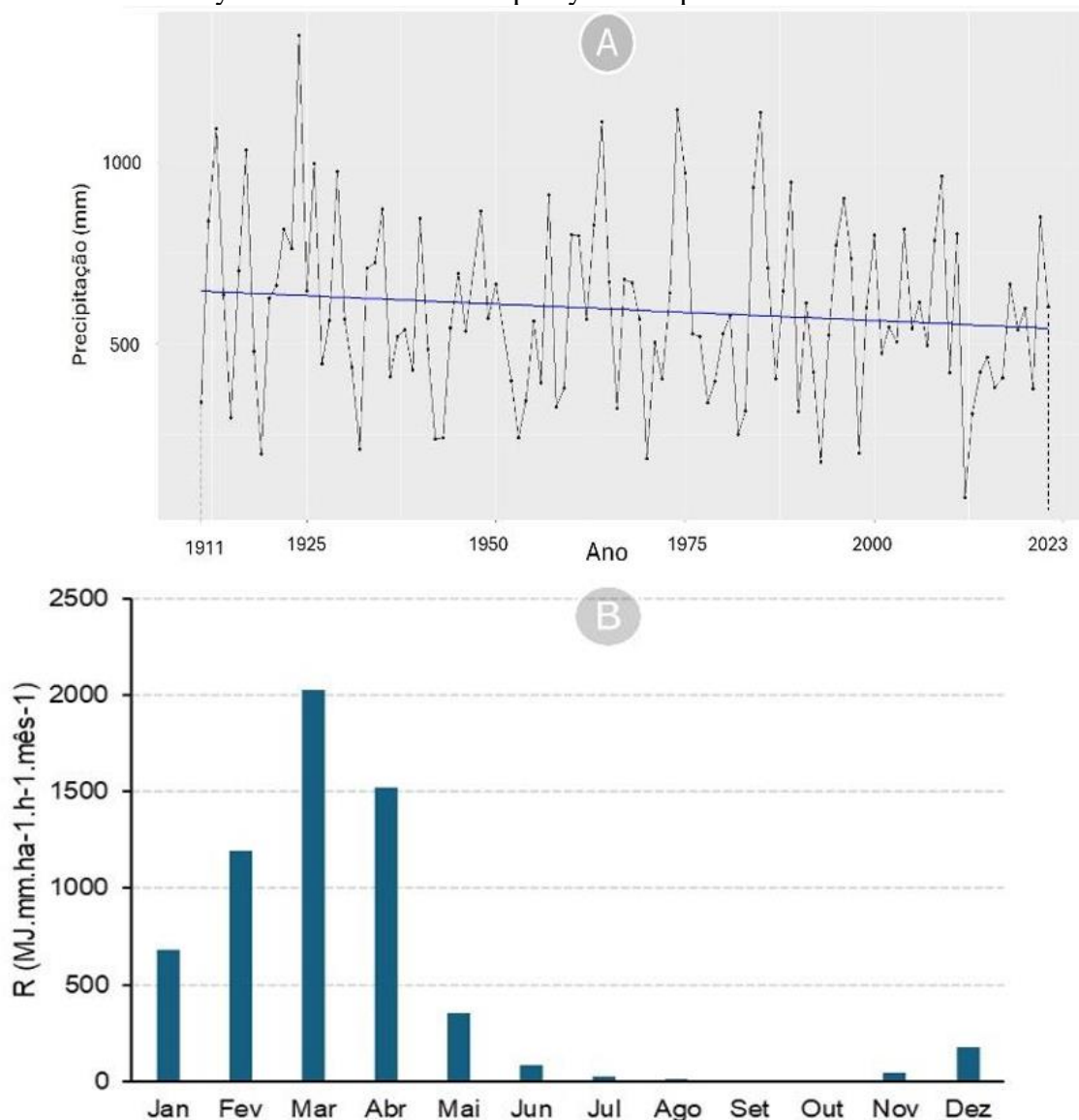
**Source:** International Soil Reference and Information Center (1996)

## 5 RESULTS AND DISCUSSION

The results did not indicate significant changes in the rainfall pattern over the analyzed period. The Mann–Kendall test suggested a possible downward trend in rainfall values ( $z = -1.149$ ), but the magnitude of this variation was small, which

reveals a weak trend. The  $p$  value obtained (0.25) reinforces the absence of a statistically significant trend. However, the calculation of the Sen (1968) slope indicated a slight reduction in rainfall over time ( $\sim 8 \text{ mm.decade}^{-1}$ ), although this decline was not significant.

**Figure 2.** (A) Annual precipitation trend for the municipality of Independência; (B) estimated monthly erosion for the municipality of Independência



This result corroborates that obtained by Soares *et al.* (2024), who reported a downward trend in rainfall during the rainy season in a semiarid basin; however, this trend was not significant (p value: 0.58); however, the authors reported that there was a trend toward a longer dry and rainy season.

Figure 2b shows the average monthly erosivity obtained, where it is considered high for the months of March and April (ISRIC, 1996), which are considered to have high precipitation in different basins in the state (Alencar; Araújo; Teixeira, 2020; Medeiros; Araújo, 2014). Heavy rainfall at

short intervals has high erosive power, even with low annual precipitation (Medeiros; Araújo, 2014). Therefore, there is no guarantee that the reduction in annual precipitation (even if statistically not significant) has less erosive power.

In this study, the average annual erosivity was approximately 6,114 MJ.mm.ha<sup>-1</sup>.h<sup>-1</sup>, a common value in some basins in the state (Araújo, 2003). High rainfall erosivity is associated with high soil degradation, enabling the creation of gullies (Alencar; de Araújo; Teixeira, 2020) and even desert areas (Simplício *et al.*, 2021).

Eroded material usually tends to be deposited at the bottom of local valleys, where dams are usually built. Therefore, erosion directly impacts the silting of reservoirs and consequently water availability (Araújo, 2003; Araújo; Güntner; Bronstert, 2006).

Although the results indicate a statistically nonsignificant downward trend in precipitation over the years, these findings may highlight the need for continuous monitoring of rainfall, providing valuable support for the formulation of strategies aimed at soil conservation and mitigating the effects of climate change.

## 6 CONCLUSION

Although the downward trends in precipitation and rainfall erosivity are not statistically significant, the average reduction of 80 mm over 100 years points to possible subtle changes in the region's climate pattern. Although the data are not conclusive, such findings may serve as a warning to reinforce continued monitoring and stimulate further studies to assess possible long-term impacts on the region's hydrological dynamics and water resource management.

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