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Risk identification of precipitation extremes due to climate change in the southern region of the state of Rio de Janeiro

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A B S T R A C T
The occurrence of natural disasters and extreme events caused by precipitation has been directly affecting the population of the state of Rio de Janeiro. However, studies that seek to understand and identify changes in the variability of this meteorological element are scarce for the southern region of the state of Rio de Janeiro. In this context, the aim of this study was to identify Risk of precipitation extremes due changes in the rainfall distribution in the southern region of the state of Rio de Janeiro through the application of Climate Change Indexes and Mann-Kendall test. For this purpose, daily precipitation data from 1938 to 2018 for the municipality of Resende-RJ were used. For this municipality, 8 climate change indexes were calculated seeking to identify changes in precipitation. The results obtained showed that for the last decades, the total annual precipitation and consecutive wet days have decreased, which is mainly due to increase on consecutive dry days. However, increase of extremely wet days and total maximum daily precipitation was verified, which could contribute to an increase in the occurrence of extreme precipitation events in the region.
Keywords: daily precipitation; extreme events; natural disasters

Identificação de risco de precipitação extrema devido a mudanças climáticas na região Sul do estado do Rio de Janeiro

R E S U M O
A ocorrência de desastres naturais e eventos extremos causados pela precipitação vem afetando diretamente a população do estado do Rio de Janeiro. No entanto, estudos que busquem entender e identificar mudanças na variabilidade deste elemento meteorológico são escassos para a região sul do estado do Rio de Janeiro. Nesse contexto, o objetivo deste estudo foi identificar o risco de extremos de precipitação decorrentes de alterações na distribuição das chuvas na região sul do estado do Rio de Janeiro por meio da aplicação de Índices de Mudanças Climáticas e o teste de Mann-Kendall. Para tanto, foram utilizados dados diários de precipitação de 1938 a 2018 para o município de Resende-RJ. Foram calculados 8 índices de mudanças climáticas buscando identificar mudanças na precipitação. Os resultados obtidos mostraram que, nas últimas décadas, a precipitação anual total e os dias chuvosos consecutivos diminuíram, o que se deve principalmente ao aumento nos dias secos consecutivos. No entanto, verificou-se aumento de dias extremamente úmidos e precipitação máxima diária total, o que poderia contribuir para o aumento da ocorrência de eventos de precipitação extrema na região.
Palavras-chave: desastre natural, evento extremo, precipitação diária

Introduction

Precipitation is one of the meteorological elements vital for the planet and essential for life. The knowledge of its spatial-temporal distribution becomes fundamental, mainly as a function of changes of its distribution due to climate variability and changes (Wanderley et al., 2014; IPCC

(2021)). Water availability directly and indirectly influences human society, interfering with agriculture, in its supply to cities, industries, livestock, energy generation, tourism, population well-being, among others.

The current consumption patterns of human beings have contributed to the increase in the release of greenhouse gases. The presence of these gases in the atmosphere is the main responsible for climate changes, mainly due to the increase in temperature, which contributes to modifying precipitation patterns, increasing the intensity and frequency of extreme precipitation events (Halimatou et al., 2017; Saunders et al., 2017; IPCC, 2021).

In Brazil, these changes contribute to the increase in extreme events, especially those related to precipitation, whether due to deficit or excess water. Excessive rainfall causes floods, downpours and landslides. Some of these events causes harm to society, such as significant economic losses, which can cause contamination, threat to public health and even death. For the Northeastern region of Brazil, studies such as those by Araújo and Brito (2011); Assis et al., (2012); Souza and Azevedo (2012) and Wanderley et al. (2014) have shown changes in rainfall distribution, some of these changes with statistical significance.

The Southeastern region of the country also showed changes in rainfall, with the occurrence of extreme events demonstrated by Marengo et al. (2015); Marengo and Alves (2015); Marengo et al. (2020) and Zilli et al. (2017). For the state of Rio de Janeiro and its capital, changes in rainfall distribution were also identified, along with increase in extreme events related to precipitation, and impacts on population were quantified by Aguiar and Cataldi (2021); Avila et al. (2016); Bunhak and Wanderley (2020); Ehrlich et al. (2021); Machado et al. (2010); Pereira et al. (2021). Pristo et al. (2018); Silva and Dereczynski (2014); Silva et al. (2016) and Wanderley and Bunhak (2016) showed the importance of studying precipitation, its changes and impacts.

These authors contributed with studies on extreme climatic events, with great emphasis on extreme precipitation events. The results of these studies pointed to changes in the rainfall regime in Brazil, especially in the Southeastern region, and in the state of Rio de Janeiro. These changes were indicated in annual precipitation totals, increase in the number of days without rain, reduction in the total number of rainy days, and increase in the occurrence of extreme precipitation events. A definition of disaster can be given as the result of adverse events, either natural or man-made, on an ecosystem, causing human, material and/or environmental loss and consequent economic and social damage (Kobiyama et al., 2006).

The problem of rainfall and associated disasters is not a problem only of large urban centers. The city of São Paulo is constantly suffering from the effects of floods caused by extreme precipitation. Haddad and Teixeira (2015) estimate that floods contributed to reducing the city's growth and well-being of residents, in addition to harming both local and domestic competitiveness. Rio de Janeiro, like most Brazilian cities, is not prepared for the occurrence of extreme precipitation events, especially if these precipitation volumes occur in short periods of time. According to the State Plan for Water Resources of the State of Rio de Janeiro (2014), the year 2010 was one of the most critical, both in relation to the number of natural disasters and the damage to the population of the Médio Paraíba do Sul region.

According to the plan, the January 2000 rain led to the second highest occurrence of homeless or displaced people. The year 2010 was the only year with recognition of a State of Public Calamity decreed by the municipalities of Resende, Porto Real, Barra Mansa and Barra do Piraí, and State of Emergency recognized by the municipalities of Itatiaia, Paraíba do Sul and Três Rios. Thus, there is need for more specific studies seeking to identify changes in the precipitation regime, especially increases in its extremes and to assess whether these changes are already consequences of climate changes. However, for this understanding, it is necessary to analyze long series of data, so that the conclusions are not mistaken. Given the above, the aim of this study was to identify Risk of precipitation extremes due changes in the rainfall distribution in the southern region of the state of Rio de Janeiro through the application of Climate Change Indexes.

Material and methods

Study area and data survey

The municipality of Resende is located in the Southern region of the state of Rio de Janeiro (Figure 1), also known as Médio Paraíba region, with coordinates 22º28'08"S and 44º26'49"W. It is approximately 137 km distant from the state capital and has about 126,923 inhabitants (IBGE, 2017). Its territory borders the states of São Paulo and

Minas Gerais, in addition to other municipalities in the state. Reminiscent of the colonial Brazil era, Resende is historically considered one of the most valuable cities in Brazil, in addition to the oldest in its region.

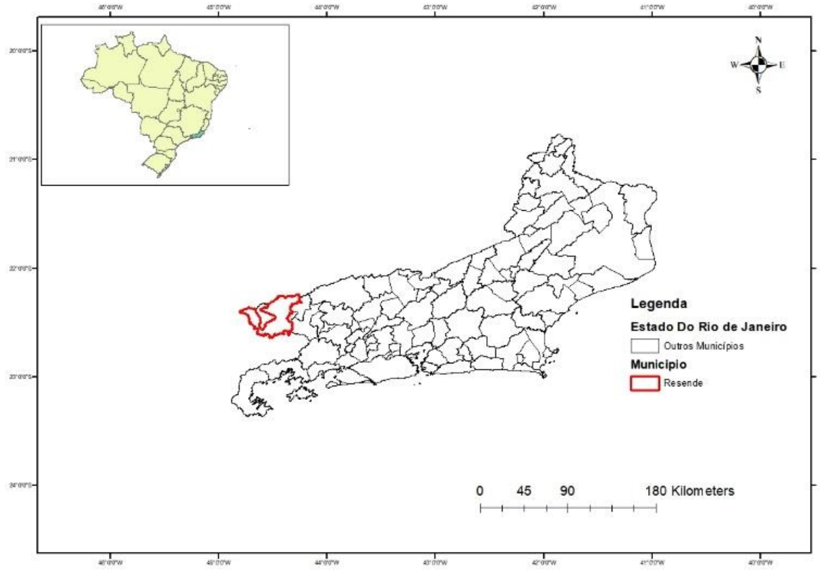

Figure 1. Geographic location of the municipality of Resende, Rio de Janeiro, Brazil.

Resende it became an important industrial, automotive, metallurgical, tourist and nuclear energy center (internationally recognized for hosting the Nuclear Fuel Factory). The municipality is also home to the second largest military complex in the world and the largest in Latin America, the Military Academy of Agulhas Negras (AMAN), the only one in the country to train combatant army officers. Located on a large plain on the banks of the Paraíba do Sul River (which has its main tributaries within the municipality), the city's relief is typical of a valley, and its climate is classified as tropical with dry season (Aw) (Banhak and Wanderley 2020). It has average annual temperature of 21ºC, minimum temperature of 12ºC in July and maximum temperature of 31ºC in February. According to INMET, the highest rainfall in the municipality occurs between the months of October and March.

The data used in this work were obtained from the National Institute of Meteorology database (INMET). The station from which data were obtained is located in the municipality and has coordinates of 22.45º S of latitude, 44.44º W of longitude and 439.89 m a.s.l. The daily precipitation totals in the municipality were used for analysis. These data refer to the historical series of 80 consecutive years, without failures, ranging from January 1938 to December 2018. Data were organized in an electronic spreadsheet to be later run in the RClimdex package of the R software.

Calculation of Climate Change Indexes and Statistics used

To analyze the rainfall distribution in the municipality of Resende, 8 climate change indices were calculated, described in Table I, using the RClimdex software.

The climate change indexes calculated for the annual series were submitted to the adjustment of the determination coefficient (r^2), to the Student's t test, for the angular regression coefficient with a = 0.05 significance level and standard error of estimate. The determination coefficient (r2) is a statistical measure that serves to adjust a generalized linear statistical model in relation to observed values. Its value varies between 0 and 1 and indicates in percentage how much the model can explain the observed values. The higher the r^2 value, the more explanatory the model is and the better it fits the sample. The determination coefficient is given by Equation 1:

$$R^2 = \frac{SQR}{SQT} = 1 - \frac{SQE}{SQT} = \frac{\widehat{\beta}_1 \sum_{i=1}^{n}(x_i - \bar{x})Y_i}{\sum_{i=1}^{n}(Y_i - \bar{Y})^2}, \quad (1)$$

where,
SRS - Sum of Regression Squares;
STS - Sum of Total Squares.

The regression slope (b) represents the linear regression straight line (given as its tangent) in relation to the explanatory variable. The coefficient b value is calculated by dividing the covariance of the two random variables by the variance of the independent variable, as shown in Equation 2. Knowing the b value, it is possible to identify whether a given parameter is increasing (positive coefficient) or decreasing (negative coefficient).

Table 1. Calculated climate change indices

Index	Index	Definitions	Units
PRCPTOT	Annual total wet-day precipitation	Anual total PRCP in wet days (RR >=1 mm)	mm
CDD	Consecutive dry days	Maximum number of consecutive days whit RR <1 mm	days
CWD	Consecutive wet days	Maximum number of consecutive days whit RR >1 mm	days
R95p	Very wet days	Annual total PRCP whet RR>95 th percentile	mm
R99p	Extremely wet day	Annual total PRCP whet RR>99 th percentile	mm
Rx1day	Max 1-day precipitation amount	Monthly maximum 1-day precipitation	mm
Rx5day	Max 5-day precipitation amount	Monthly maximum consecutive 5-day precipitation	mm
SDII	Simple daily intensity index	Annual total precipitation divided by the number of wet days (defined as PRCP>=1.0mm) in the year	mm/day

$$b = \frac{n\left(\sum xy\right) - \left(\sum x\right)\left(\sum y\right)}{n\left(\sum x^2\right) - \left(\sum x\right)^2} = \frac{Cov(x,y)}{Var(x)} = \frac{r_{xy}\sigma_X\sigma_Y}{\sigma_X^2} = r_{xy}\frac{\sigma_Y}{\sigma_X} \quad (2)$$

The regression angular coefficient was submitted to the Student's t test with n-2 degrees of freedom to identify a statistically significant change in this coefficient. The adopted null hypothesis (H_o), that there is no change, is rejected when the calculated t value is greater, in absolute value, than the tabulated critical value $t_{\alpha/2,\ n-2}$, at α =0.05 significance level.

The standard error of estimate (S_x) quantifies the accuracy of the regression estimate, quantifying the dispersion of sample observations in relation to the regression line. Thus, the greater the dispersion, the less accurate the estimates. This parameter helps to verify the reliability of the calculated sample mean, and can be obtained by Equation 3:

$$S_x = \frac{S}{\sqrt{n-2}} \quad (3)$$

where,
S - standard deviation;
n - sample size.

Mann-Kendall test

The climate change indices were subject the Mann-Kendall (MK) test (Mann 1945, Kendall 1975) is to statistically assess if there is a monotonic upward or downward trend of the variable of interest over time. The S-test takes the temporal series Yi of n terms ($1 \leq i \leq n$) into account, and its statistics is given by Equation (4).

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \text{sinal}\left(Y_j - Y_i\right) \quad (4)$$

where,

$$\text{signal}(Y_j - Y_i) = \begin{cases} +1 \text{se}(Y_j - Y_i) > 0 \\ 0 \text{se}(Y_j - Y_i) = 0 \\ -1 \text{se}(Y_j - Y_i) < 0 \end{cases}$$

In series with a large number of terms (n), the S-test shows a normal distribution where the mean equals zero and the variance is defined by Equation (5).

$$\text{Var}(S) = \frac{n(n-1)(2n+5)}{18} \quad (5)$$

The test presents as null hypothesis (H_o) the absence of trend in the population. To test the statistical significance of S for the alternative hypothesis (H_1), which express presence of trend, one must use a bilateral test to H_1, by which the alternative hypothesis may be rejected for large values of Z-test, in Equation (6).

$$z = \begin{cases} \frac{(S-1)}{\sqrt{Var(S)}} & se\ S > 0 \\ 0 & se\ S = 0 \\ \frac{(S+1)}{\sqrt{Var(S)}} & se\ S < 0 \end{cases} \qquad (6)$$

Results and discussion

The results of the statistical adjustment for climate change indices for the municipality of Resende showed descending linear trend and negative trend MK test z = -0.46, for consecutive dry days (CDD); however, without statistical significance (Figure 2). Furthermore, it was observed that, since the beginning of the historical series, there was reduction in CDD until the end of the 1980's and soon after, dry days began to increase. The consecutive dry and rainy days present similar signs of decreasing trends, suggesting irregularly distributed precipitation in the State (Luiz-Silva end Júnior, 2022).

One may take into account the Z-test analysis to accept or reject the null hypothesis (H_o) of trend absence to confirm the hypothesis of data stability, or to reject in favor of the alternative hypothesis (H_1) to admit presence of trend in the data series. The sign of the Test-Z statistics can indicate if trend is crescent (Z > 0) or decrescent (Z < 0). In a bilateral test for trend, H_1 must be accepted if $|Z| \geq Z_{\alpha/2}$, where $Z_{\alpha/2}$ is obtained in table of standardized normal distribution. The level of significance is 0.05, which interval of tabled Z is ± 1.96.

The highest occurrence of consecutive dry days was observed in the years 1939, 1940, 1950, 1975, 1988 and 1995, which presented values above 60 days. According to Luiz-Silva and Júnior (2022) the maximum number of consecutive dry days shows a gradient from the coast (about 30 days) to the State's interior (around 50 days). In the last two decades, a pattern of increase in CDD has been observed, which can lead to reduction in total precipitation. The increase in dry days in a given region can directly influence water availability for energy generation, agriculture, supply for human consumption in cities and other sectors of the economy that directly depend on water.

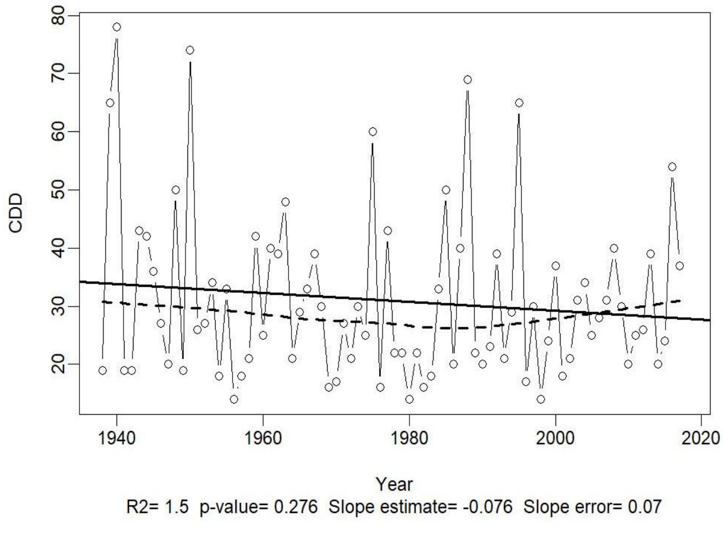

Figure 2. Maximum number of consecutive dry days (CDD) with RR* < 1mm.

Wanderley and Bunhak (2016) identified a pattern of changes presented by CDD for the study region, which occurred in the 1940s, 1960s and 1980s, with interval of approximately 20 years, indicating a possible response of local precipitation to oscillation with 20-year modulation, such as the Pacific Decadal Oscillation (PDO). In addition, the authors identified increase in the number of days without rain for almost every month analyzed. Silva and Dereczynski (2014) observed that in the state of Rio de Janeiro, there is CDD gradient oriented in the North-Southern direction, thus, areas closer to the coast have CDD of lesser durability, while in the interior of the state, CDD values are higher. This gradient is believed to occur due to the effect of sea breezes and transient systems on the coast, which transport moisture from the ocean to the continent (Silva and Dereczynski, 2014). The analysis performed by Marengo et al. (2020) showed that the number of consecutive dry days has increased.

When analyzing the number of consecutive wet days (CWD), linear trend analogous to CDD is observed, also of reduction, MK test z = -0.24 (Figure 3). However, the variation in the CWD series was almost opposite to that of CDD. Increase in wet days was observed in CWD from the beginning of the series under analysis until the mid-1970s. From this interval onwards, reduction in the number of consecutive wet days was observed.

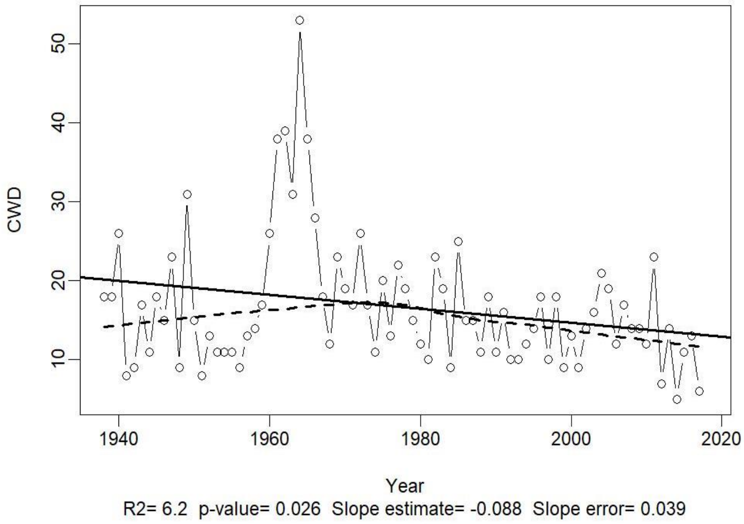

Figure 3. Maximum number of consecutive wet days (CWD) with RR ≥ 1mm.

The oscillation in CWD at this time may be a result of the response to the change in the Pacific Decadal Oscillation (PDO), where between the years 1947 and 1976, the PDO cold phase occurred. Junior and Neto (2015) found that the genesis of rainfalls in tropical climate regions point to regional and local impacts of low-frequency climate teleconnections. These results corroborate those found by Wanderley and Bunhak (2016), who showed direct influence of PDO on rainfall in the Southern region of the state of Rio de Janeiro.

In the 1960's, the years with the highest number of CWD in Resende to date were observed, including 1961, 1962, 1964 and 1965, with totals above 35 days each. According to Cambra and Neto (1997), the years 1966 and 1967 were the wettest years in Rio de Janeiro, and these associated rains caused the death of about 320 people. For the region under analysis, Bunhak and Wanderley (2020) showed that, in the summer, rainfall less than 5 mm increased, which was statistically significant. For the winter, increase in rainfall for classes from 5 to 10 mm and from 10 to 15 mm, and reduction in rainfall less than 5 mm and between 15 and 20 mm were observed; however, without statistical significance for the winter. Avila et al. (2016) show positive trends in annual and seasonal precipitation during all seasons, except for the winter in the mountainous regions of Rio de Janeiro. Total annual precipitation and the number of days with 20 mm precipitation showed significant increase during the years 1930-2019 (Marengo et al., 2020).

Changes in the subtropical Atlantic Ocean cause changes in rainfall distribution in southern and southeastern Brazil in relation to ENSO (El Niño and Southern Oscillation) and were observed between the 1950s and 1960s, and may also justify the number of days without rain in the 1960s

(Wanderley and Bunhak, 2016). The accumulated precipitation during the year is given by the PRCPTOT index (Figure 4). Figure 4 shows that this index has negative linear trend, with statistical significance. MK test also showed descending trend, no statistical significance z = -1.89. From the beginning of the historical series until the 1970s, the total precipitation did not show relevant fluctuations. After the 1970s, the trend of this index indicates reduction in precipitation. Silva and Dereczynski (2014) also found significant reduction in total precipitation for the Vale do Paraíba region.

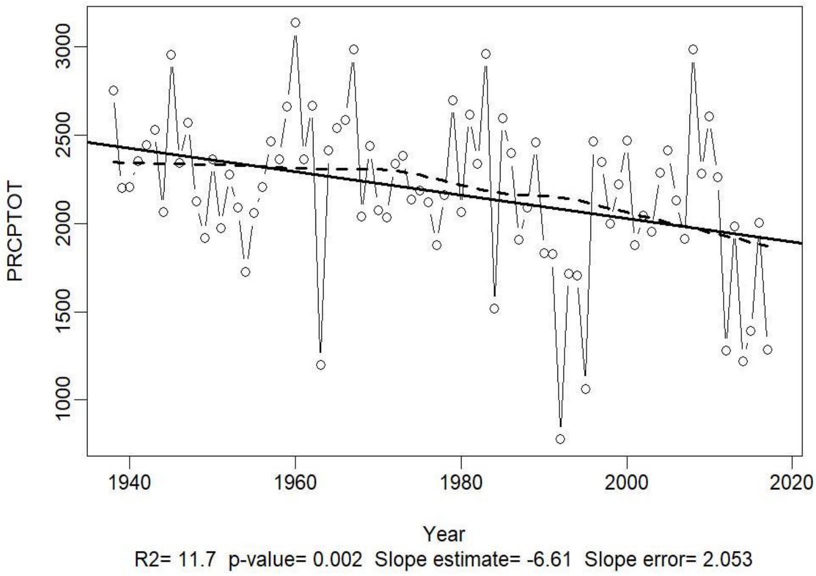

Figure 4. Annual totals of wet days (PRCPTOT) with RR* ≥ 1mm.

The years in which it rained the most were 1945, 1960, 1967, 1983 and 2008. The years with the lowest incidence of rain were 1963, 1992 and 1995, in response to the occurrence of weak, strong and moderate EL Niño intensities, respectively. Wanderleyet al. (2019) showed average increase in minimum (maximum) air temperature of +0.73 °C (+0.90 °C) and intense El Niño event in 2015-2016 and change in the rain (Veiga et al., 2022). According to results obtained by the CDD and CWD indexes, it was found that over the years, the total annual precipitation and consecutive wet days have decreased, which can also be observed by the simple daily intensity index (SDII), while the number of consecutive dry days increased (Figure 5). However, this reduction can only be observed in the southern region of the state of Rio de Janeiro, as the total annual precipitation on wet days increased widely in the mountainous regions of Rio de Janeiro, with positive trends in ~60% of analyses (Avila et al., 2016).

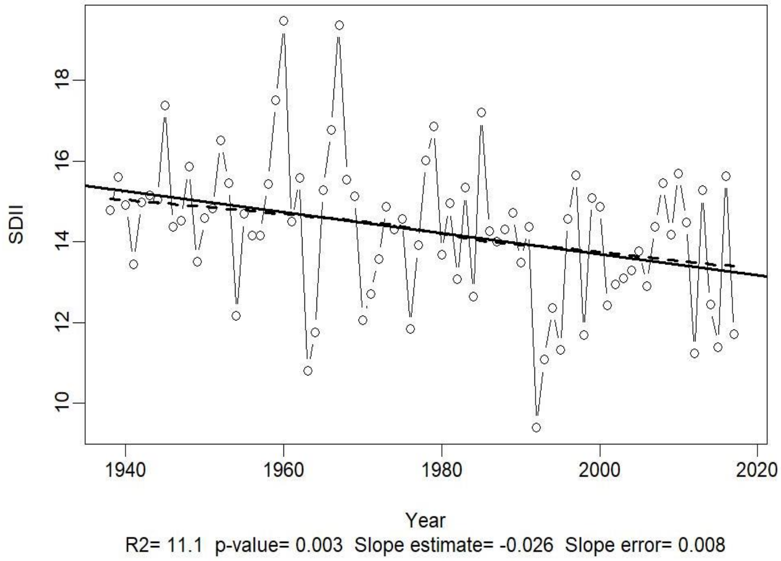

Figure 5. Simple Daily Intensity Index (SDII).

The simple daily intensity index (SDII) also showed linear reduction trend, and MK test negative trend MK test z = -3.18, which was statistically significant. SDII is given by the total annual precipitation divided by the number of wet days, with rain ≥ 1mm (consecutive or not). In view of this and based on results of previous indexes, the decrease in annual precipitation is causing the SDII to decrease, as the number of consecutive wet days is also decreasing. The variation of this index was similar to that of PRCPTOT, with greater intensity being observed for years with higher precipitation and less intensity for years with less precipitation.

The years in which the SDII index had the highest values were 1960 and 1967, and the years with the lowest values were 1963 and 1992. The reduction in precipitation also includes very wet days, with precipitation above the 95th percentile (R95p) (Figure 6). The results showed that rainfalls of low and high magnitude are decreasing. Similar results were also found by Souza and Azevedo (2012) when calculating R95p. Very wet days increased from the beginning of the historical series until the mid-1970s, decreasing since then until the present day. However, extremely wet days showed increase. These results can be verified by the 99th percentile index (R99p), with MK test z = 1.21 (Figure 7).

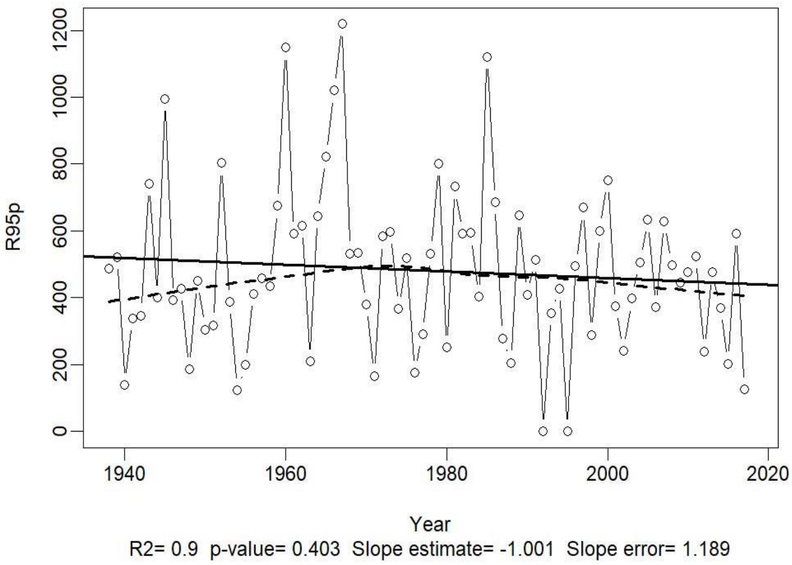

Figure 6. Total annual precipitation when RR > 95th percentile

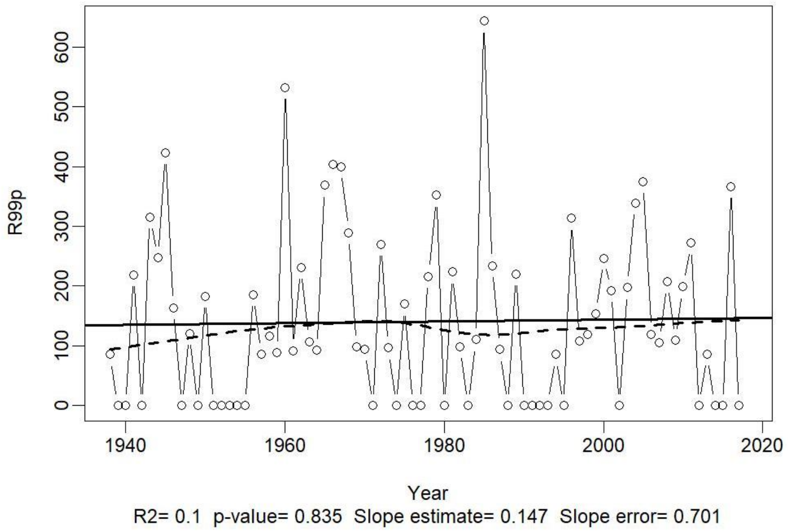

Figure 7. Total annual precipitation when RR > 99th percentile

According to Araújo and Brito (2011), R95p and R99p indexes are related to precipitation extremes that characterize the amount of rain concentrated in rainy events, indicating rainfall associated with flooding in rivers and reservoirs. The thermodynamics and dynamics have comparable contributions to the intensified precipitation extremes. Changes in thermodynamic scaling contribute to a spatially uniform increase pattern, while changes in dynamic scaling dominate the regional differences in the increased precipitation extremes (Chang et al., 2022).

As the region under analysis showed increase only for R99p, the impacts caused by the increase in this precipitation have the potential to cause major natural disasters associated with precipitation extremes, as already observed in the Vale do Paraíba region. Mass movements are among the main problems related to natural disasters in the state of Rio de Janeiro. The cities that suffer most from these events remain on alert during each rainy season. In addition to rainfall, negative events are also characterized by local geology, mainly due to soil properties (Silva et al., 2016). Araújo and Brito (2011) found positive trend for R95p and negative trend for R99p. The research carried out by Souza and Azevedo (2012) identified reduction in wet and extremely wet days.

Wet extremes are confirmed by analyzing the maximum amount of daily precipitation, verified by the Rx1day index (Figure 8). The analysis of this index showed positive linear trend and MK test z = 0.91, indicating increase in days with maximum extreme precipitation. The monthly maximum rainfall in 1 day has increased since the beginning of the time series, suffering a small drop around the 1970s and increasing again from the 1980s.

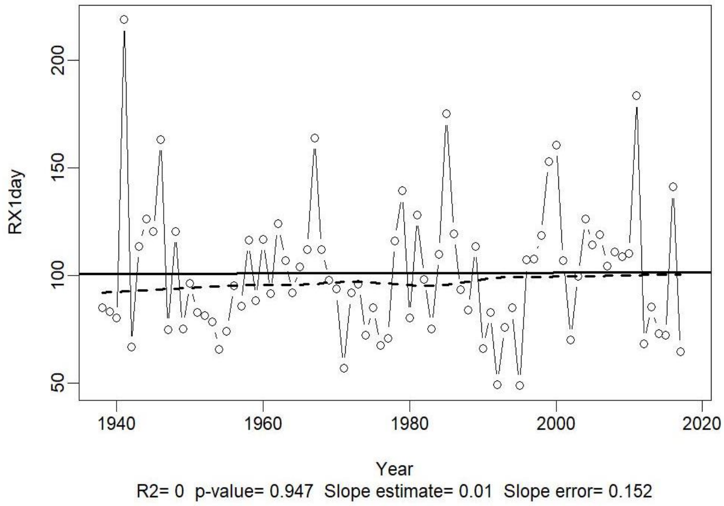

Figure 8. Maximum amount of precipitation in 1 day (Rx1day).

This index reflects the daily precipitation of greater magnitude that occurred in the year, indicating the intensity of rain that can cause sudden downpours and floods. According to Dereczynski et al. (2017), precipitation extremes in Rio de Janeiro are increasing. The positive trend in annual precipitation is mainly due to the increase in the frequency of extreme precipitation events and the number of days with precipitation, mainly for rainfall of 100 mm or more (Marengo et al., 2020). The occurrence of heavy rains causes natural disasters, which is one of the major problems in Rio de Janeiro (D'orsi et al., 2016; Maia 2012).

The consequences of precipitation extremes have caused major impacts due the accumulated precipitation in 5 consecutive days (Rx5day). The monthly maximum rainfall in 5 consecutive days showed results opposite to the previous index, presenting negative linear trend, but positive trend MK tent z = 1.37, non-significant (Figure 9). The same results were found by Araújo & Brito (2011), who observed positive trend for the Rx1day index and negative trend for the Rx5day index. However, Assis et al. (2012) found decreasing trends for the Rx1day and Rx5day indexes.

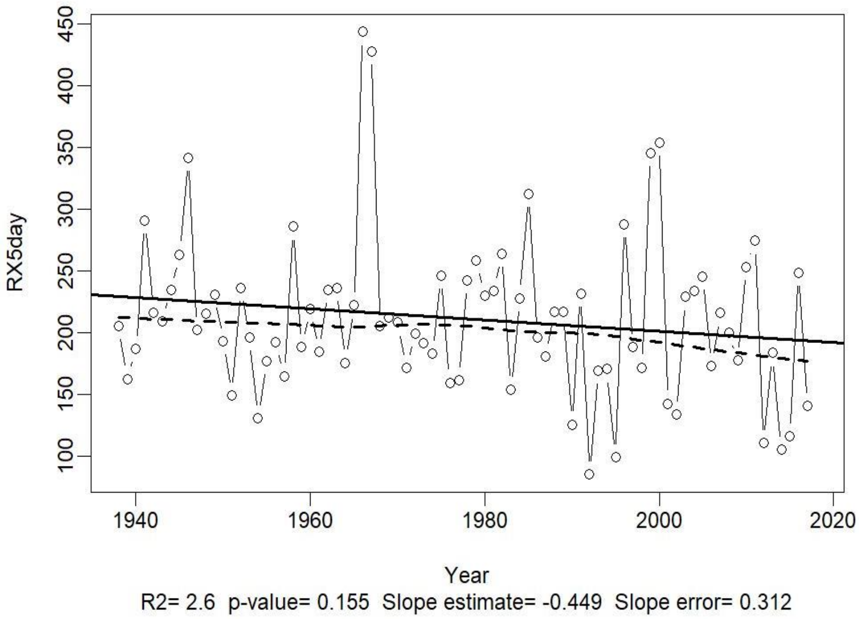

Figure 9. Maximum amount of precipitation in 5 consecutive days (Rx5day).

Rx5day is an indicator for the possibility of landslide occurrence, as it represents the maximum rainfall accumulated in 5 consecutive days. According to Luiz-Silva and Júnior (2022) the highest values of consecutive days with expressive rainfall (more than 150 mm in 5 days). The consecutive extreme precipitation events increase in most regions, nearly doubling for some (Raymond et al., 2022).

Even if the rain intensity is not high, the precipitation accumulated on these days can cause great impacts to society, as the waterlogged soil tends to rupture, causing land movement. This fact can be aggravated by the irregular occupation of hills and slopes. Some regions of cities are more susceptible to landslides than others due to differences in rainfall, geology, geomorphology and type of occupation (Ehrlich et al., 2021).

Climate projections for the remainder of the century show a continued intensification of daily precipitation extremes. Increases in total and extreme precipitation in dry regions are linearly related to global temperature change, so the spread of projected global warming explains, in part, the intensification of precipitation in these regions towards the end of the 21st century. An over 4 mm anomaly of RX5day and >20 mm R95pTOT is projected in Brazil (Sun et al., 2022).

This intensification has implications for the risk of floods as the climate becomes warmer (Donat et al., 2016). Zhang and Villarini (2017) found that the frequency of strong annual rainfall on a global scale increase between 1.5 and 2 °C until about 2070, after which the trend magnitudes become much weaker or even negative. Overall, the annual frequency of heavy rainfall across the globe is similar between 1.5 ° and 2 °C. Wanderley et al. (2019) found average increase in minimum (maximum) air temperature of +0.66 °C (+1.21 °C), between 1961 and 2010 for the city of Rio de Janeiro, which may indicate increase in temperature for other regions of the state.

Conclusion

The study of the rainfall distribution in the southern state of Rio de Janeiro showed that the rainfall distribution, during the period under analysis, presented oscillation due to the modes of variability and climatic oscillations that influence the rainfall variability in the Southern Hemisphere. However, the application of climate change indexes shows that the rainfall distribution in recent decades may be changing no longer as a result of these fluctuations. The application of climate change indexes indicates reduction in the annual rainfall distribution and its daily intensity. It was evidenced that this reduction is due to the increase in the number of consecutive days without rain and the reduction in the number of consecutive wet days for the last two decades under analysis. Change in the number of very wet days and maximum rainfall in 5 consecutive days was also found. However, extremely wet days and maximum total daily precipitation increased, which may contribute to the increased occurrence of extreme precipitation events in the region and eventual natural disasters associated with them.

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