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Rainfall and its trend between the periods 1963-1982, 1983-2001 and 2002-2019 in Amparo de São Francisco - Sergipe

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Abstract

The trends of rainfall climate fluctuations in the periods 1963-1982, 1983-2001 and 2002-2019 were analyzed, seeking to understand possible variations in these fluctuations for the socioeconomic sectors and providing contributions to decision makers on possible risks. The rainfall data were from the Northeast Development Superintendence and the Technical Assistance and Rural Extension Company of the state of Sergipe, between 1963 and 2019. The periods 1963-1982 are used; 1983-2001 and 2002-2019, performing the rainfall trend for the respective months of the periods studied. Trend studies are accessible when analyzing long data series or split into 20-year sub-periods for a perfect understanding of their oscillations. The results found and discussed can be a beneficial tool for carrying out planning, monitoring and acts that point out the best way to manage rainfall rates to be used in agriculture, health, thermal comfort in cities, among other applications. The irregularity of rainfall distribution is limiting factors for the increase in agriculture and agribusiness under study.

Keywords: Rain buoyancy and distribution; Agriculture; Extreme rainfall events

1. Introduction

Agriculture is among the most important economic activities in Brazil today, being one of the few areas that keeps growing in recent years. According to [18], agriculture is the economic activity most dependent on climate variables, which is why it leads to fluctuations in agricultural production. [26] stated that meteorological factors can affect not only the metabolic processes of plants, such as photosynthesis, but also other activities carried out in the field, such as drought, flooding and others.

Some authors who worked with temporal trends of rain showing their variability and intensities [32]; [2]; [8]; [28]; [11]; [31]. [4] Reveal that the application of quantile techniques to determine extreme rainfall events in the State of Pernambuco has been causing disasters with temporal trends in almost the entire state.

[23] in their studies on the water and edaphic conditions for Bom Jesus Piauí, the future climate scenarios were taken into account. Pessimistic scenario [A_2], a 20% reduction in rainfall and an increase of 4ºC in the average air temperature. In an optimistic scenario [B_2] with a 10% reduction in rainfall and a 1ºC increase in temperature. The annual evapotranspiration value was 1.573,9 mm for the normal scenario, 1.789,1 for the B_2 scenario and 2843.7 for the A_2 scenario, which corresponds to 62.6%; 55.04% and 34.63% of annual precipitation [984.8 mm] respectively. The actual evaporation values were 928.2; 886.2 and 787.8 for the normal scenario, B_2 and A_2 respectively. These values may cause significant impacts on rained agricultural activities and water supply, if these changes in the region's climate are confirmed. There will be no water surpluses for scenarios B_2 and A_2. The water deficit will suffer a significant increase,

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which will cause water stress in most crops. Extreme rainfall events in the B_2 and A_2 scenarios could increase the intensity and worsen the erosion processes in the region. It was found that the municipal region was in the very high erosivity class, since the erosivity index (R) was 29.504,7 MJ mm ha^{-1} h^{-1} $year^{-1}$.

[19] in his studies on rainfall and thermal oscillations from 1981-2019 for Lagoa Seca, Paraíba, seeking to measure these oscillations in socioeconomic activities, and helping decision makers regarding possible climate risks. The author showed that they become more understandable when analyzing long time series, which can be divided into sub-periods of at least 30 years. Rainfall anomalies between 2000-2019 recorded ten years dry; six years very dry; three very rainy years and one rainy year, these rainfall irregularities lead us to conclude that climatic events and human actions may be contributing to the records of these scenarios on a local scale, the predominance of dry and very dry years has been causing impacts to fruit and vegetable producers which has been using longer times in irrigation.

[22] revealed that the change in the volume and distribution of rainfall has been affecting the availability of water, and that it is important to carry out an analysis of the rainfall behavior followed by a better management of water resources,

[20] observed that rainfall fluctuations in São Bento do Una, Pernambuco on the pretext of the increase in water demand essential for the expansion of poultry activities. The study is a tool to design programs and acts that manage water resources, avoiding the problem of water scarcity. The authors showed that there is a need to capture and use rainwater, in addition to the efficient use of natural resources in the region.

[21] in their studies on possible rainfall changes, investigated their possible trends and identified rainfall variability in Serra Talhada - Pernambuco, where high rates were recorded from January to April and the lowest values from July to October. The authors showed that local rainfall is irregular.

[3] analyzed the rainfall historical series and its trend for 25 municipalities and 24 farms that make up the Uruçuí Preto River area, PI (BHRUP), carried out in this study linear regression and measures of central tendency and dispersion of monthly and Yearly. Based on the results, they showed that the median is the measure of central tendency most likely to occur. The rainy season is recorded from October to April with an average value of 936.8 mm for the period, corresponding to 96% of the annual precipitation. The months with the lowest rainfall fluctuated between May and September, corresponding to 4% of the annual total, showing temporal variability characteristic of the cerrados and cerradão regions.

[24] Revealed that the analysis of precipitation behavior in large and medium-sized cities is extremely important for the management of water resources, since these are densely urbanized areas. Often, without an adequate urban structure, these cities fit perfectly in this context. They used monthly rainfall data from 1913 to 2010 in Teresina – Piauí. The results showed the recurrence of maximum annual precipitation values for the interval of 18, 11 and 8 years. In the analysis of standard deviations, the results showed a predominance of negative deviations.

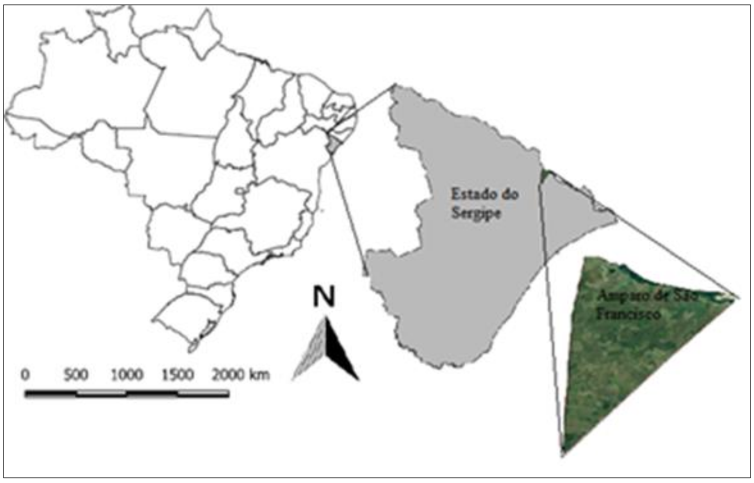
The objective is to analyze trends in rainfall fluctuations in the periods 1963-1982, 1983-2001 and 2002-2019, seeking to understand possible variations in these fluctuations in the socioeconomic sectors and providing information to decision makers about possible risks.

2. Material and methods

Amparo de São Francisco approach with the municipality of Telha to the East and South, Canhoba to the West and the State of Alagoas to the North. Altitude of 51 meters, (Figure 1).

According to the classification by [9]; [10], it has an “As” climate [hot and humid Tropical rainy], and they agree with the authors [19]; [1]. Amparo de São Francisco is located in a region characterized by two well-defined seasons, a rainy season ranging from February to August and a dry season from September to January.

The rainfall data were from the Northeast Development Superintendence [30]; Development Company of the state of Sergipe between 1963 and 2019. For this purpose, the rainfall data series was separated every 20 years, that is, the periods from 1963-1982 were characterized; 1983-2001 and 2002-2019, performing the rainfall trend for the respective months of the periods studied.



Source: França [2022].

Figure 1 Location of Amparo de São Francisco – Sergipe, Brazil.

3. Results and discussion

Figure 2 shows the rainfall trend variability for the month of January for 1963-1982 [a] 1983-2001 [b] and 2002-2019 [c] in Amparo de São Francisco - Sergipe.

January is the end of the rains and the beginning of the pre-rainy season, in Figure 2a they show an irregular and poorly distributed interannual distribution, rainfall variations ranged from 0.4 mm (1967 and 1978) to 145.7 mm (1965). Its trend has a line with a negative angular coefficient and a gradual reduction of its indices. These variabilities are in accordance [15]; [6]; [19]. Figure 2b the rainfall indices ranging from 5.5 mm to 112.5 mm and with a positive slope trend line caused by isolated rainfall of varying magnitudes caused by local mesoscale systems such as squall line and convective clusters, these variabilities are in accordance with the results of [15]. In Figure 2c, a negative trend was registered and, on the contrary, for the rain-causing systems.

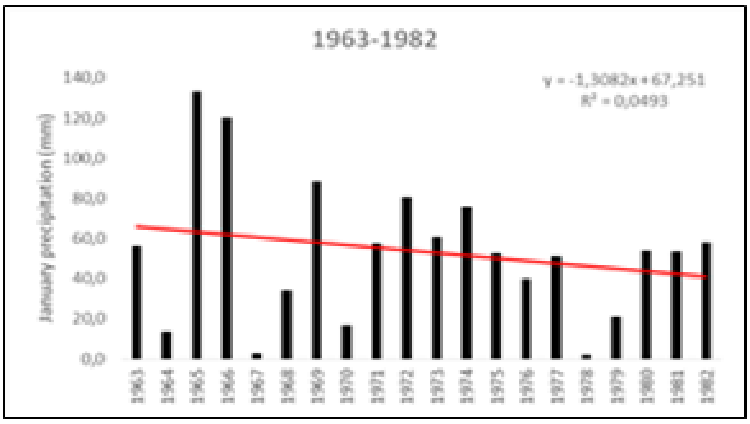


Figure 2a January precipitation trend for 1963-1982 in Amparo de São Francisco – Sergipe. Source: França (2022).

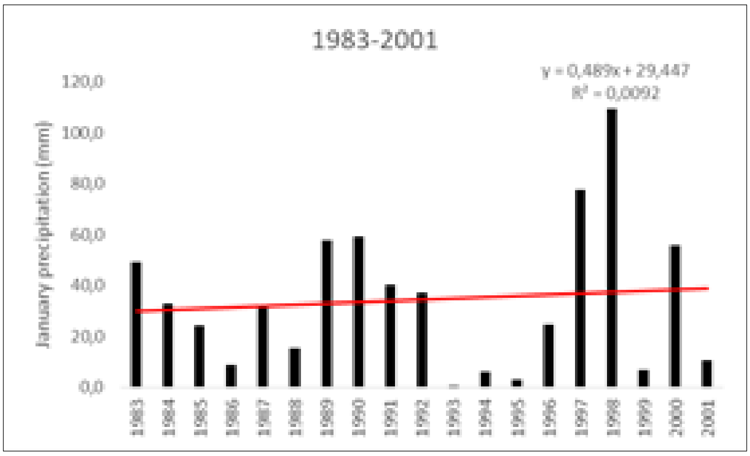


Figure 2b January precipitation trend for 1983-2001 in Amparo de São Francisco – Sergipe. Source: França (2022).

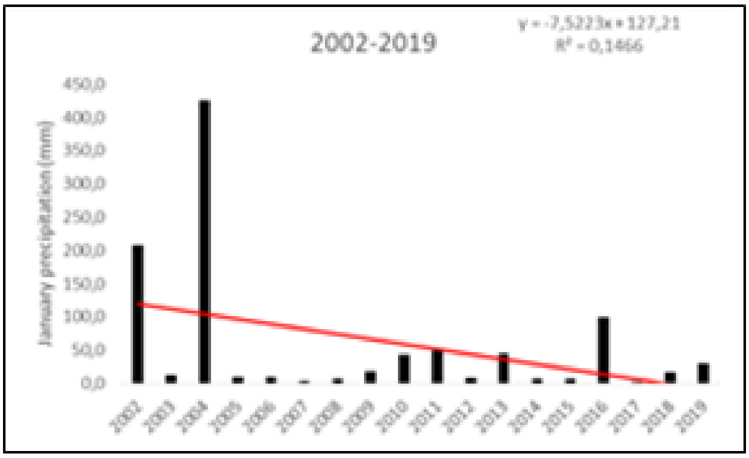


Figure 2c January precipitation trend for 2002-2019 in Amparo de São Francisco – Sergipe. Source: França (2022).

With oscillations ranging from 10.5 mm to 582 mm, and a negative trend line as occurred from 1963-1982 (Figure 3a). For Figures 3a and 3b, irregular rainfall of varying magnitudes can be observed, both with a negative trend line. The meso and microscale systems will suffer atmospheric blockages caused by the high-pressure centers of the South Atlantic, either close to the continent or away. Similar results were found by [20] and present similarities with the results discussed.

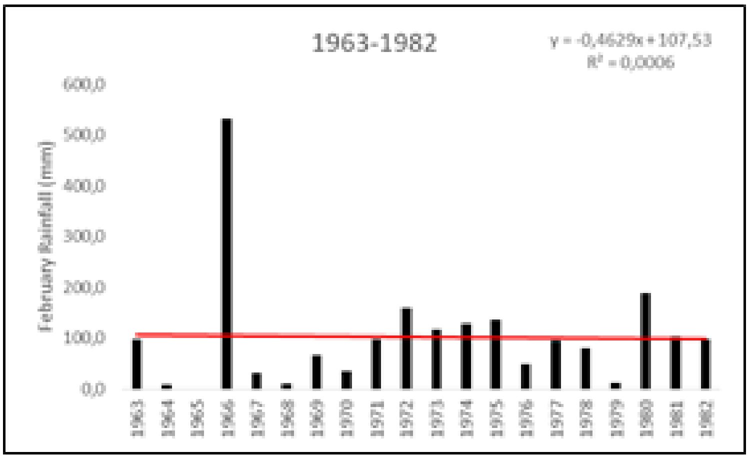


Figure 3a February precipitation trend for 1963-1982 in Amparo de São Francisco – Sergipe; Source: França **(**2022**).**

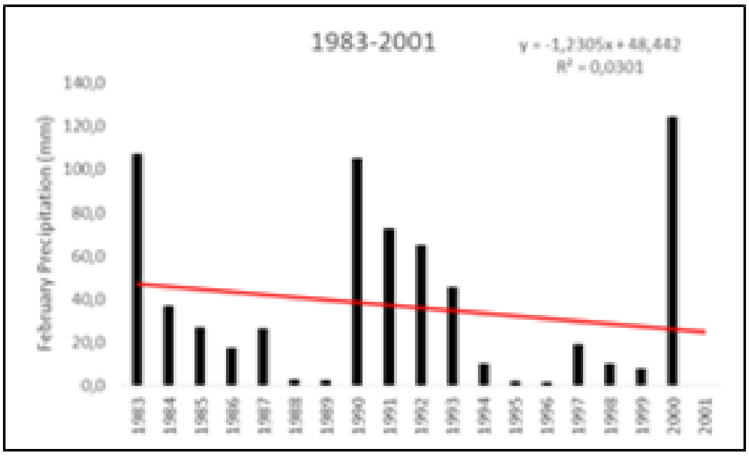


Figure 3b February precipitation trend for 1983-2001 in Amparo de São Francisco – Sergipe; Source: França **(**2022**).**

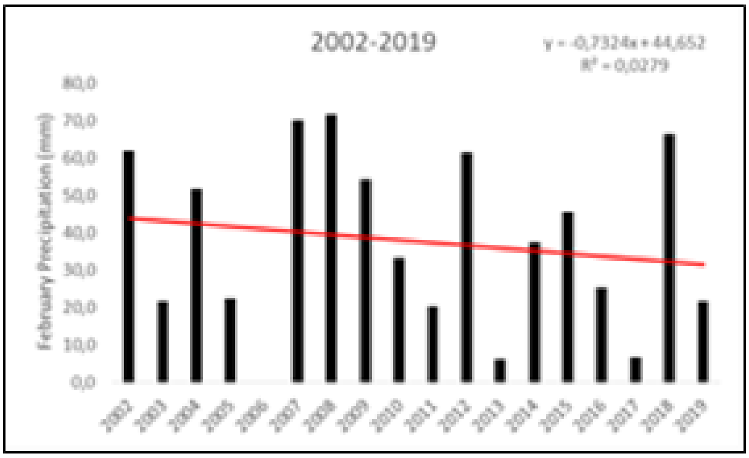


Figure 3c February precipitation trend for 2002-2019 in Amparo de São Francisco – Sergipe; Source: França **(**2022**).**

In March (Figures 4a and 4b) oscillations of diversified and irregular magnitudes and a trend line with negative angular coefficient are observed. Figure 4c shows irregular rainfall rates ranging from 10 mm to 250 mm with a negative angular trend line. The study by [27] corroborate these variability in the studied area.

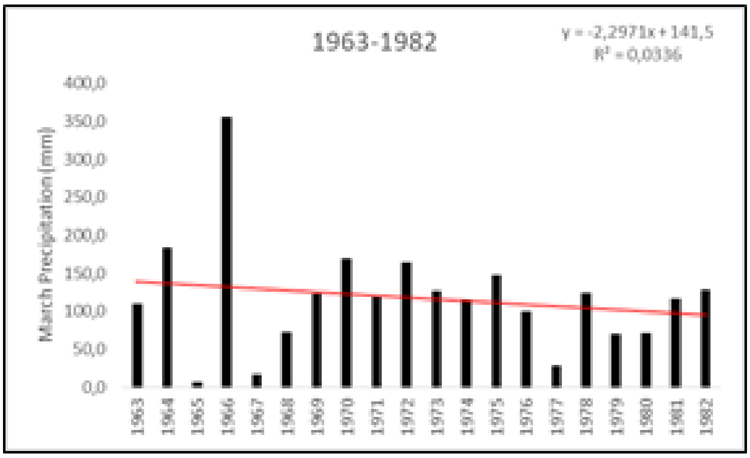


Figure 4a March precipitation trend for 1963-1982 in Amparo de São Francisco – Sergipe; Source: França (2022).

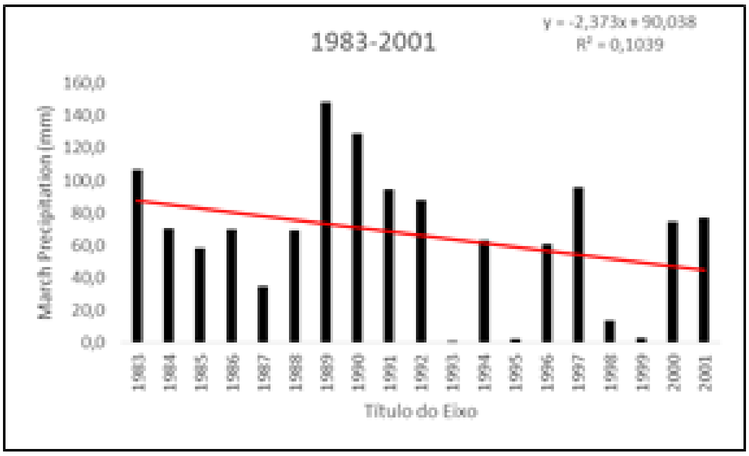


Figure 4b March precipitation trend for 1983-2001 in Amparo de São Francisco – Sergipe; Source: França (2022).

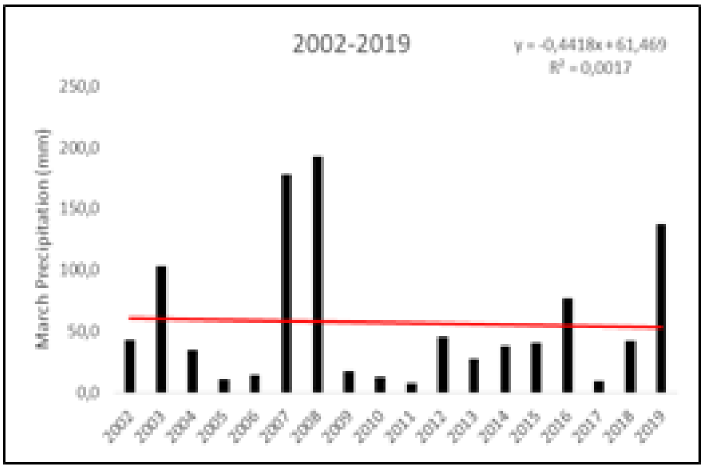


Figure 4c March precipitation trend for 2002-2019 [c] in Amparo de São Francisco – Sergipe; Source: França (2022).

In Figure 5a, you can see the oscillation of rainfall trends in April for the periods: 1963-1982 (a) 1983-2001 (b) and 2002-2019 (c) in Amparo de São Francisco - Sergipe. In Figure 5[a, b and c] there is a trend line with a negative angular coefficient and irregular inter-year rainfall fluctuations of different magnitudes caused by the synoptic systems operating in the period.

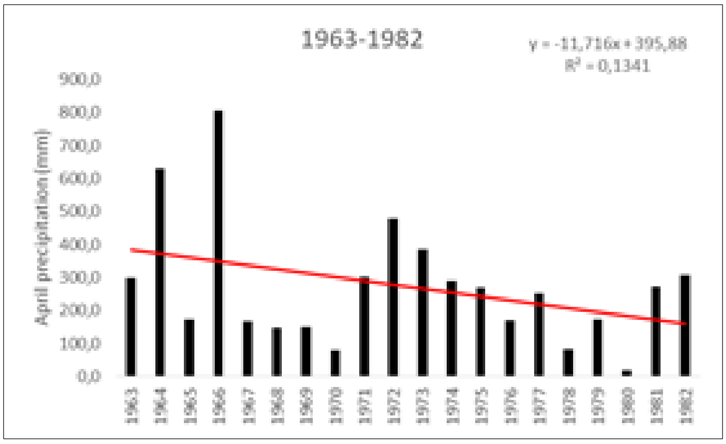


Figure 5a April precipitation trend for 1963-1982 in Amparo de São Francisco – Sergipe; Source: França (2022).

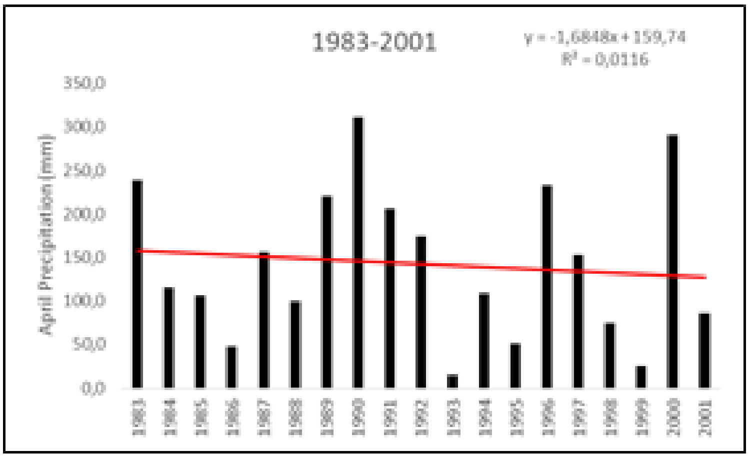


Figure 5b April precipitation trend for 1983-2001 in Amparo de São Francisco – Sergipe; Source: França (2022).

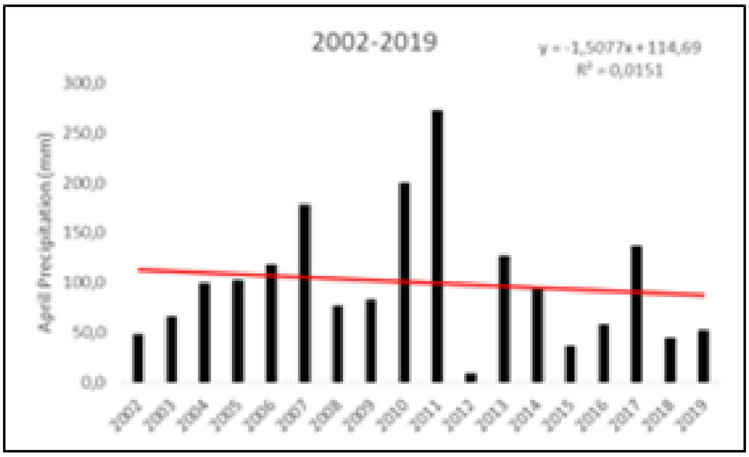


Figure 5c April precipitation trend for 2002-2019 in Amparo de São Francisco – Sergipe; Source: França (2022).

The period 1963-1982 (Figure 6: a, b and c) corresponding to the month of May presented rainfall oscillations of variable and irregulares magnitudes and their trend lines with negative angular coefficient.

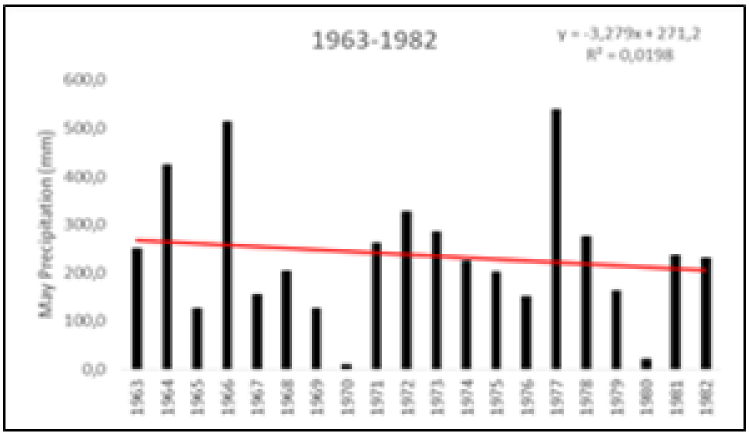


Figure 6a May precipitation trend for 1963-1982 in Amparo de São Francisco – Sergipe Source: França (2022).

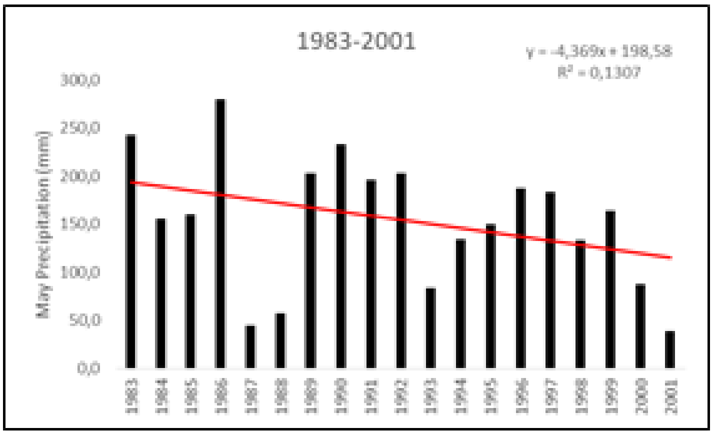


Figure 6b May precipitation trend for 1983-2001 in Amparo de São Francisco – Sergipe; Source: França (2022).

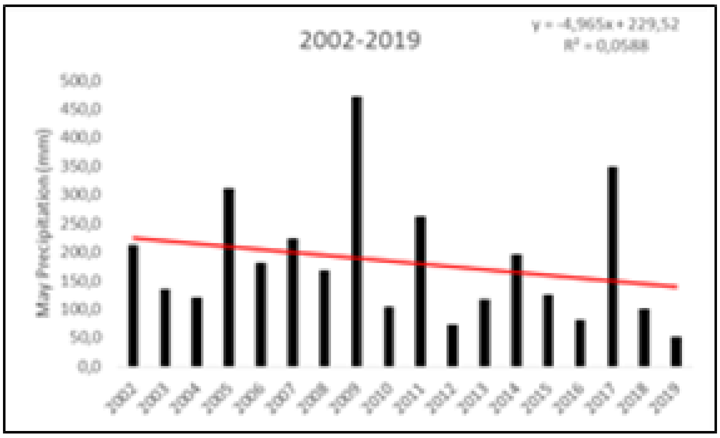


Figure 6c May precipitation trend for 2002-2019 in Amparo de São Francisco – Sergipe; Source: França (2022).

Several authors have assessed the rainfall trend observed in the Brazilian Northeast during the 20th century. [20] stated that the pluviometry analysis over South America and observed a trend of increase in the total annual rainfall over the studied area. [17] Used the indices of climatic extremes and correlated them with the Sea Surface Temperature anomalies, also demonstrating a tendency of annual rainfall increase for the states of Paraiba and Rio Grande do Norte and Ceará [19].

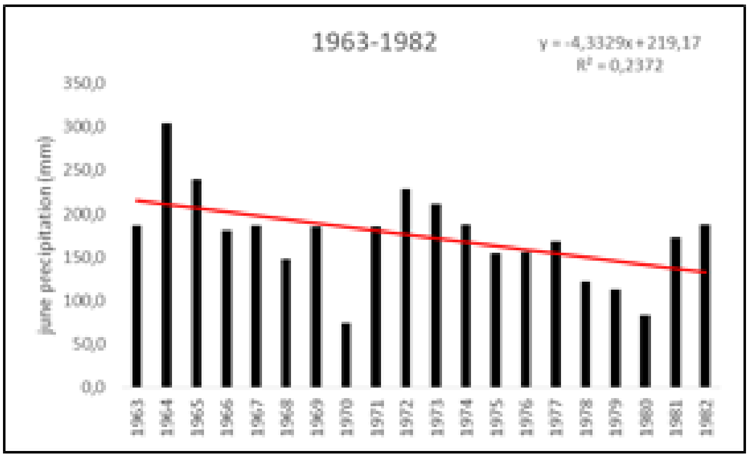


Figure 7a June rainfall trend for 1963-1982 in Amparo de São Francisco – Sergipe; Source: França **(**2022**).**

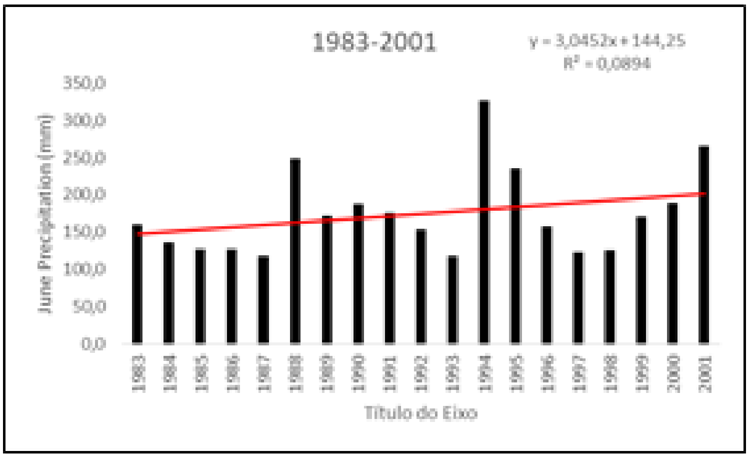


Figure 7b June rainfall trend for 1983-2001 in Amparo de São Francisco – Sergipe; Source: França **(**2022**).**

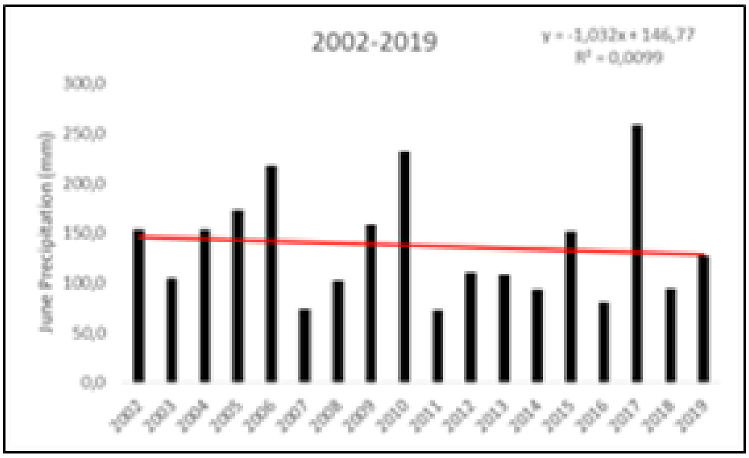


Figure 7c June rainfall trend for 2002-2019 in Amparo de São Francisco – Sergipe; Source: França **(**2022**).**

In Figure 7a, there is a negative trend line and its rainfall oscillations flowing irregularly between the years, a fact caused by the transient systems that predominated over the studied period; these similarities corroborate the results of the studies by [19]. With irregular interannual precipitation and a positive slope trend line for the period 1983-2001 (Figure 7b), these variabilities corroborate the studies by [19] and, [27]. Figure 7c shows irregulars inter-annual rainfall rates with a negative trend.

[12] showed that regional climatology is covered from the climatic oscillations and atmospheric fluctuations of a given sample of a climatic element [23a]; [15]. Climatology studies are characterized with the initial purpose of differentiating areas or comparing areas. Whether the study of climate or a constituent element, a climatology is characterized in a certain portion of space and allows the scholar to understand the space-climatic fluctuations in the distribution of its elements that act or form in a region.

With a rainfall rate ranging from 75 mm to 300 mm (Figure 8a), the trend line has a negative angular coefficient and irregular inter-year variability. The periods 1983-2001 and 2002-2019 showed a straight line of positive trends and their irregular rainfall variability (Figures 8b and 8c).

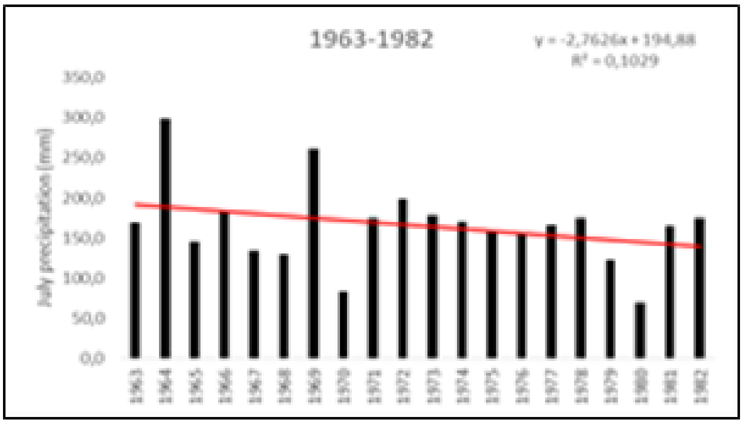


Figure 8a July rainfall trend for 1963-1982 in Amparo de São Francisco – Sergipe; Source: França **(**2022**)**.

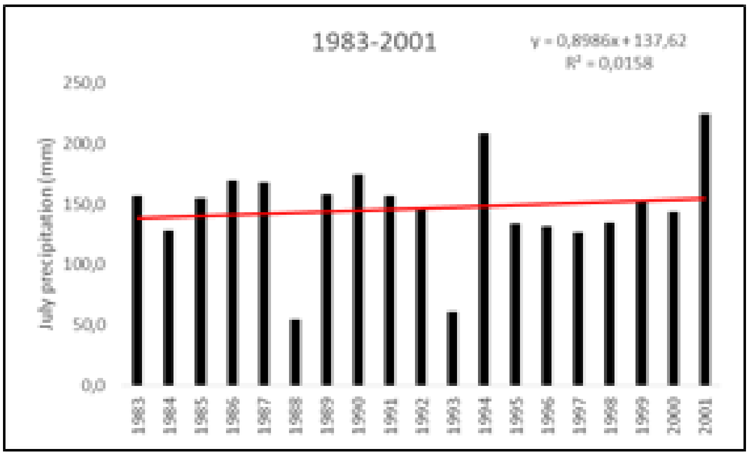


Figure 8b July rainfall trend for 1983-2001 in Amparo de São Francisco – Sergipe; Source: França **(**2022**)**.

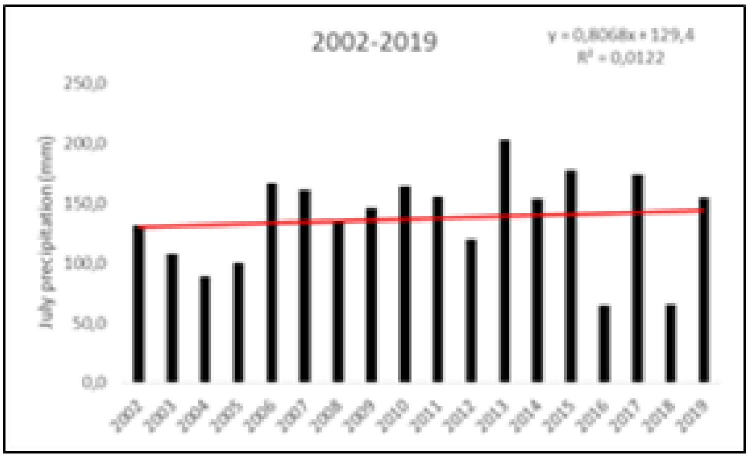


Figure 8c July rainfall trend for 2002-2019 in Amparo de São Francisco – Sergipe; Source: França **(**2022**)**.

The month of August (Figure 9a) in the studied area is one of the months that register the highest rainfall rates due to the predominant atmospheric activities, in these months there was a line of negative angular tendency and rainfall irregularity. With a positive trend line and rainfall irregularities between years (Figure 9b). Figure 9c shows rainfall irregularities of varying magnitudes and a trend line with a negative angular coefficient, the study is similar to the authors [13] and [19].

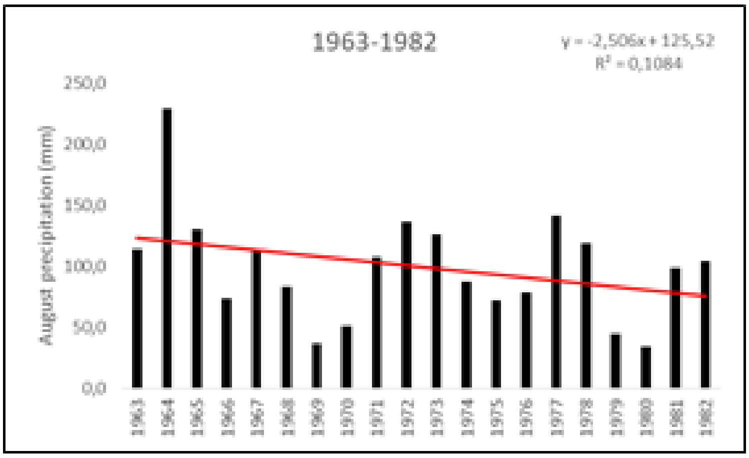


Figure 9a August precipitation trend for 1963-1982 in Amparo de São Francisco – Sergipe; Source: França (2022).

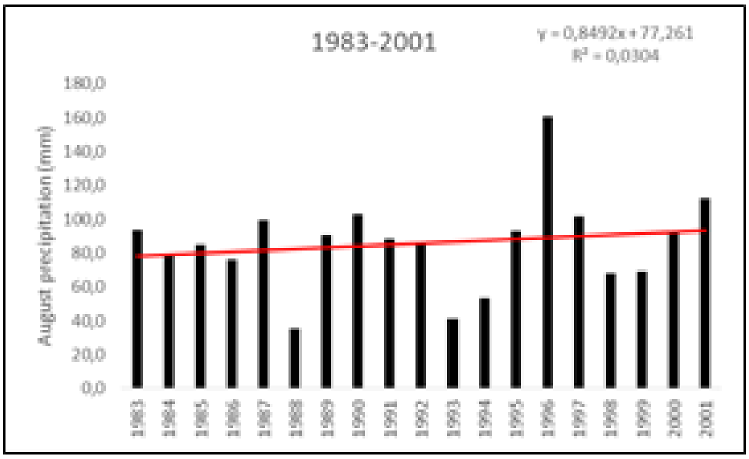


Figure 9b August precipitation trend for 1983-2001 in Amparo de São Francisco – Sergipe; Source: França (2022).

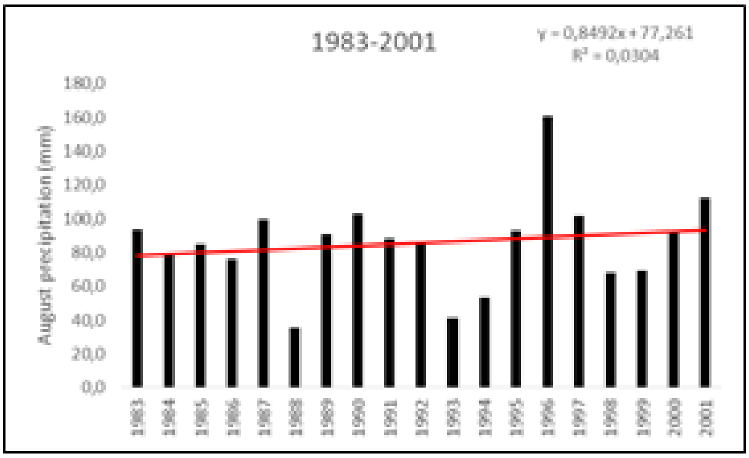


Figure 9c August precipitation trend for 2002-2019 in Amparo de São Francisco – Sergipe; Source: França (2022).

According to [15], the Northeast region of Brazil (NEB) is naturally characterized with a high potential for water evaporation due to the great availability of solar energy and high temperatures. Temperature increases associated with climate change resulting from global warming, regardless of what may happen with the rains, would already be enough to cause greater evaporation from lakes, dams and reservoirs and greater evaporative demand from plants. That is, unless there is an increase in rainfall, water will become a scarcer commodity, with serious consequences for the sustainability of regional development.

With rainfall fluctuations ranging from 26.0 mm to 212.0 mm and being characterized as the month of the end of the rainy season and beginning of the dry season, a trend line with negative angular coefficient is recorded (Figures 10a and 10c). In Figure 10b the representation of the trend line has a positive slope.

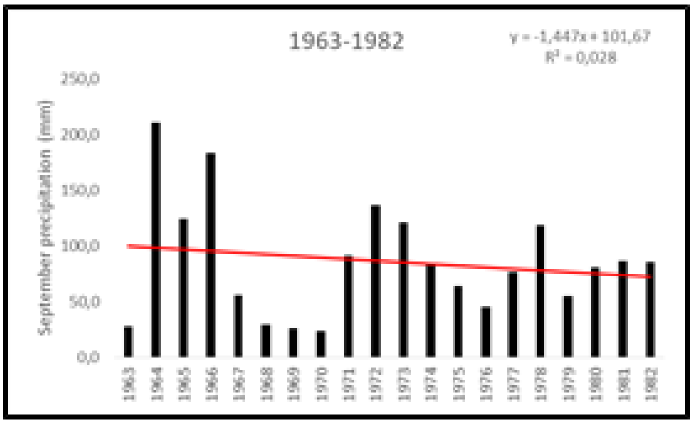


Figure 10a September rainfall trend for 1963-1982 in Amparo de São Francisco – Sergipe; Source: França (2022).

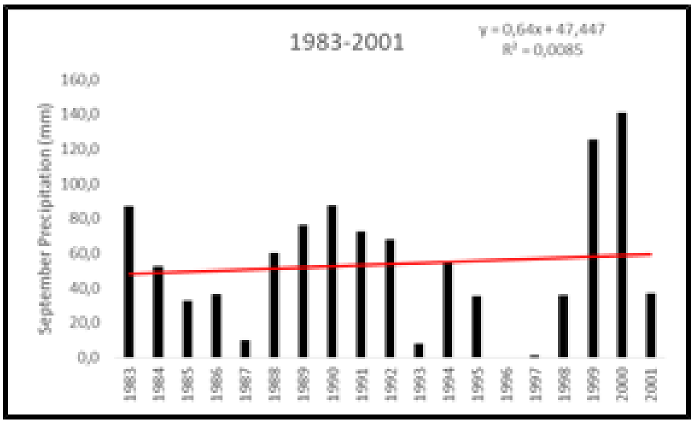


Figure 10b September rainfall trend for 1983-2001 in Amparo de São Francisco – Sergipe; Source: França (2022).

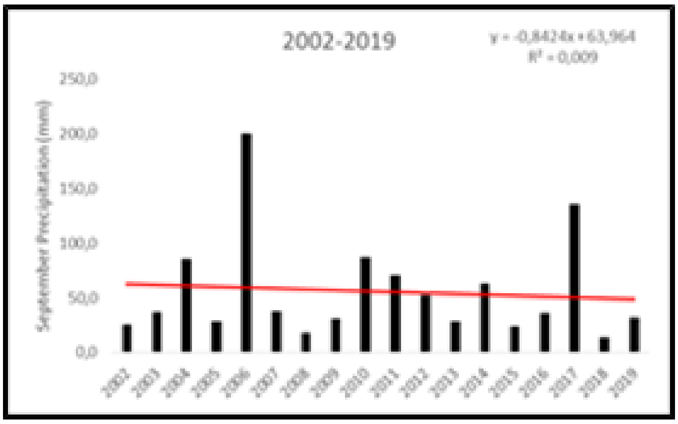


Figure 10c September rainfall trend for 2002-2019 in Amparo de São Francisco – Sergipe; Source: França (2022).

Figure 11a records rainfall variability caused by transient synoptic systems at the end of the rainy season, in this Figure the negative trend line and low magnitudes for their annual rainfall indices. In Figures 11b and 11c there is a positive angular coefficient and low rainfall magnitudes due to atmospheric blockages during the dry period.

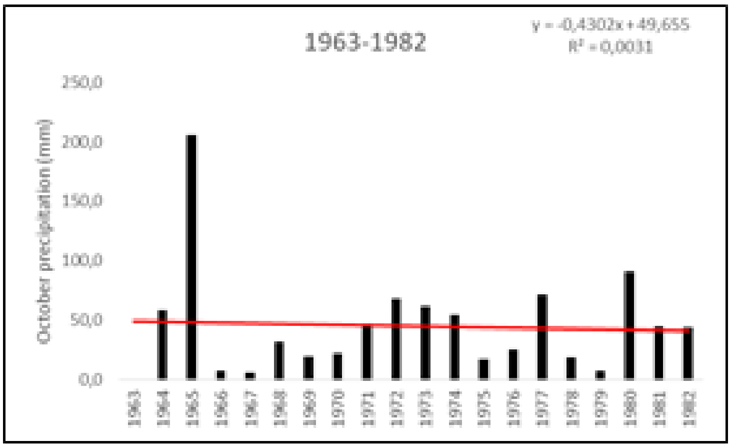


Figure 11a October rainfall trend for 1963-1982 in Amparo de São Francisco – Sergipe; Source: França (2022).

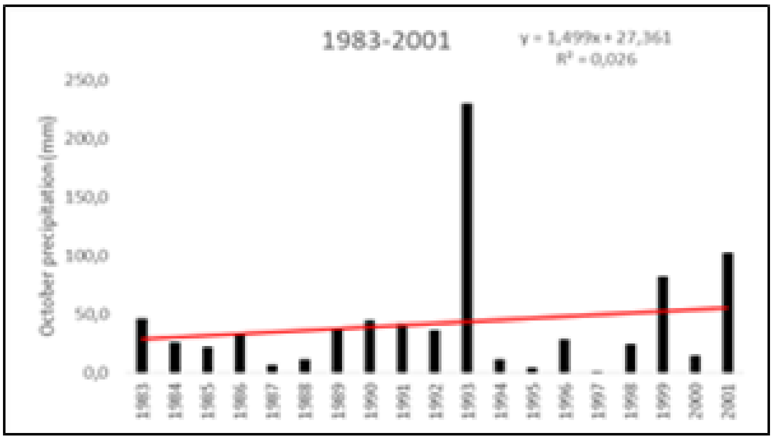


Figure 11b October rainfall trend for 1983-2001 in Amparo de São Francisco – Sergipe; Source: França (2022).

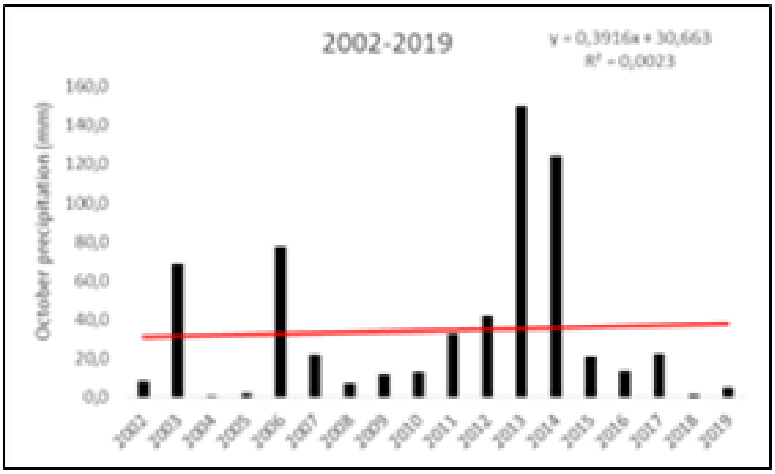


Figure 11c October rainfall trend for 2002-2019 in Amparo de São Francisco – Sergipe; Source: França (2022).

In Figures 12a; 12b and 12c for the month of November, referring to the periods under study, shows negative trends and low inter-year indexes.

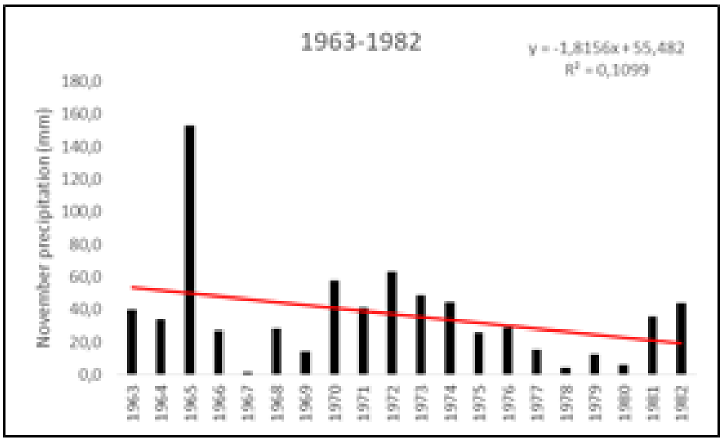


Figure 12a November rainfall trend for 1963-1982 in Amparo de São Francisco – Sergipe; Source: França (2022).

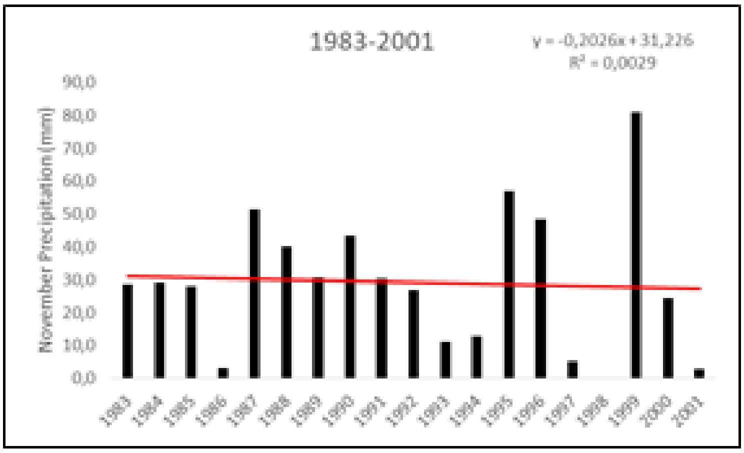


Figure 12b November rainfall trend for 1983-2001 in Amparo de São Francisco – Sergipe; Source: França (2022).

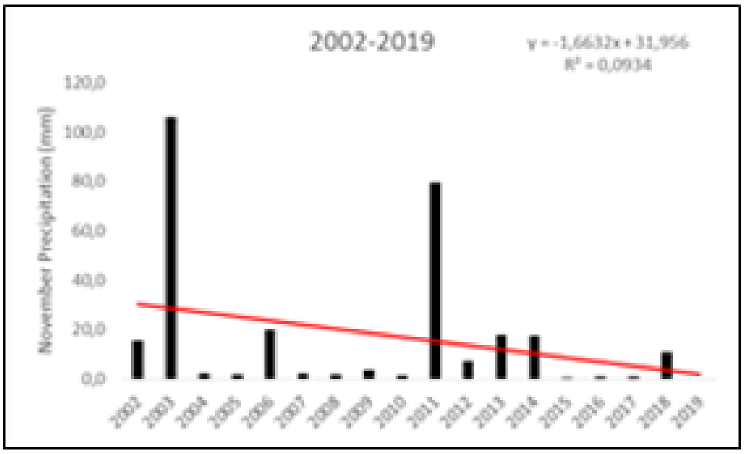


Figure 12c November rainfall trend for 2002-2019 in Amparo de São Francisco – Sergipe; Source: França (2022).

In Figures 13a and 13b, referring to the month of December of the period under study, a trend line with a negative angular coefficient and its trend can be observed. In Figure 13c, the slope and its trends are positive.

According to the Intergovernmental Panel on Climate Change, these trends in Climate Change observed in the recent past are highly likely to continue in the same direction in the 21st century [7] and [6].

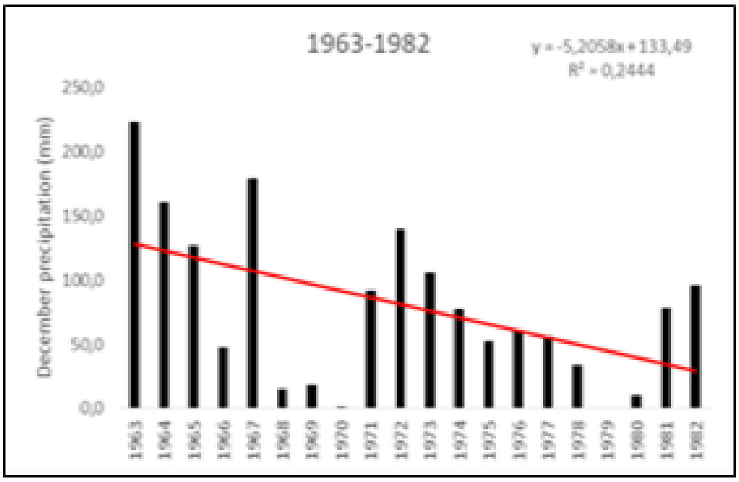


Figure 13a December precipitation trend for 1963-1982 in Amparo de São Francisco – Sergipe; Source: França **(**2022**)**.

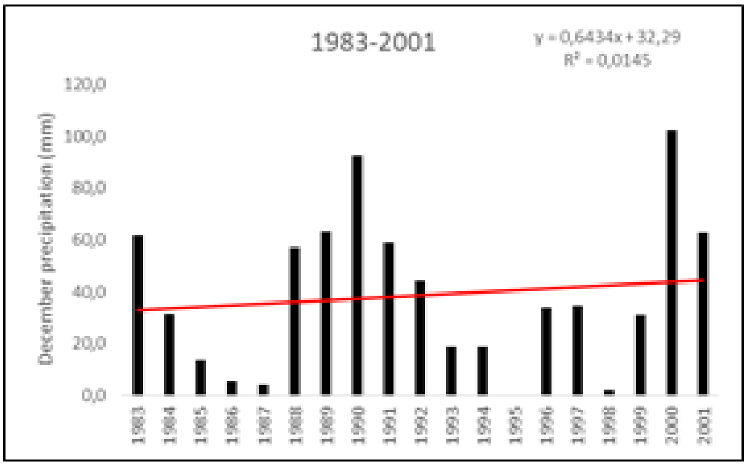


Figure 13b December precipitation trend for 1983-2001 in Amparo de São Francisco – Sergipe; Source: França (2022).

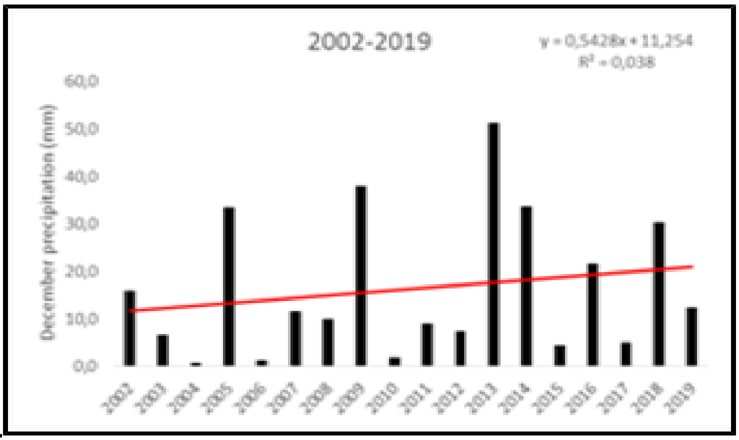


Figure 13c December precipitation trend for 2002-2019 in Amparo de São Francisco – Sergipe; Source: França **(**2022**)**.

The tables below show the summaries of each period for the trend line, it should be noted that the R^2 values were not expressed in the text, as they are not significant. We highlight the average rainfall values for the periods under study, with a view to giving a better understanding to the reader and decision makers.

Table 1 shows that the best regression determination coefficients (R^2=0.2444; 0.1099; 0.1084; 0.2372) for the months of April, June, July, August, November and December, the worst regression determination coefficients were for the other studied months. Meaning that when the value is higher, it indicates the degree of approximation of the model to the averages, while when the value is lower, it indicates the degree of distance of the model from the averages.

Table 1 Months, linear equation, regression determination coefficient (R^2), monthly historical average of precipitation from 1963 to 1982 in Amparo de São Francisco- Sergipe

Months	Linear equation	Coef. Detail Reg R^2	Average rainfall 1963-1982
January	y = -1,3082x + 67,25	0,0493	53,5
February	y = -0,4629x + 107,53	0,0006	102,7
March	y = -2,2971x + 141,50	0,0336	117,4
April	y = -11,716x + 395,88	0,1341	272,9
May	y = -3,2790x + 271,20	0,0198	236,8
June	y = -4,3329x + 219,17	0,2372	173,7
July	y = -2,7626x + 194,88	0,1029	165,9
August	y = -2,5060x + 125,52	0,1084	99,2
September	y = -1,4470x + 101,67	0,0280	86,5
October	y = -0,4302x + 49,655	0,0031	45,1
November	y = -1,8156x + 55,482	0,1099	36,4
December	y = -5,2058x + 133,49	0,2444	78,8

Caption: Coef. Detail Reg R^2= Regression determination coefficient R^2

Table 2 Months, linear equation, regression determination coefficient (R^2), monthly historical average of precipitation from 1983 to 2001 in Amparo de São Francisco- Sergipe.

Months	Linear equation	Coef. Detail Reg R^2	Average rainfall 1963-1982
January	y = 0,4890x + 29,48	0,0092	34,3
February	y = -1,2305x + 48,44	0,0301	36,1
March	y = -2,3730x + 90,04	0,1039	66,3
April	y = -1,6848x + 159,7	0,0116	142,9
May	y = -4,3690x + 198,6	0,1307	154,9
June	y = 3,0452x + 144,2	0,0894	174,7
July	y = 0,8986x + 137,6	0,0158	146,6
August	y = 0,8492x + 77,23	0,0304	85,8
September	y = 0,6400x + 47,45	0,0085	53,8
October	y = 1,4990x + 27,36	0,0260	42,4
November	y = -0,2026x + 31,23	0,0029	29,2
December	y = 0,6434x + 32,29	0,0145	38,7

Caption: Coef. Detail Reg R^2= Regression determination coefficient R^2

In the Table, you have the equations of the positive lines in the months of January; June to October and December, in the months of February, March, April, May and November their angular coefficients are negative. All regression determination coefficients have low significance; they are in the table for better understanding of the readers.

The comments and interpretations of the contents of Table 3 are explained in the two Tables described above.

Table 3 Months, linear equation, regression determination coefficient (R^2), monthly historical average of precipitation from 2002 to 2019 in Amparo de São Francisco- Sergipe

Months	Linear equation	Coef. Detail Reg R^2	Average rainfall 1963-1982
January	y = -7,5223x + 127,210	0,1466	55,8
February	y = -0,7324x + 44,652	0,0279	37,7
March	y = -0,4418x + 61,469	0,0017	57,3
April	y = -1,5077x + 114,69	0,0151	100,4
May	y = -4,965x + 229,52	0,0588	182,4
June	y = -1,032x + 146,77	0,0099	137,0
July	y = 0,8068x + 129,4	0,0122	137,1
August	y = -3,1856x + 110,57	0,1534	80,3
September	y = -0,8424x + 63,964	0,0090	56,0
October	y = 0,3916x + 30,663	0,0023	34,4
November	y = -1,6632x + 31,956	0,0934	16,2
December	y = 0,5428x + 11,254	0,0380	16,4

Caption: Coef. Detail Reg R2= Regression determination coefficient R^2

4. Conclusion

Climate trends become more accessible when considering 20-year time series for a better understanding of their buoyancy.

The results found and discussed can be a beneficial tool for carrying out planning, monitoring and actions that point out the best way to manage rainfall rates to be used in agriculture, health, thermal comfort in cities, among other applications.

The irregularity in the temporal distribution of rain is limiting factors for the development of agricultural production and agribusiness in the region.

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