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Rainfall and Straight Regression Trends for The Municipality Amparo De São Francisco - Sergipe, Brazil

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ABSTRACT

Rainfall monitoring is a global concern and, therefore, rain total forecasting policies have been adopted all over the world aiming at rainwater storage. In this sense, several warning mechanisms regarding the scarcity or excess of water resources are becoming more and more common, especially for the poultry and agricultural sectors. The objective of this work is to analyze the distributions of rainfall indexes between 1963 and 2019 years, by examining their characteristics and their linear trend lines (increasing or decreasing), taking into account the monthly assessment of the years, to identify the months of greatest and lowest rainfall, aiming to obtain information regarding the spatial and temporal rainfall variation, and the maximum and minimum monthly erosivity in the municipality of Amparo de São Francisco, Sergipe state, Brazil. Average monthly and annual rainfall data from the Superintendência de Desenvolvimento do Nordeste – SUDENE and from Empresa de Desenvolvimento Agropecuário de Sergipe – EMDARO, were used. The basic statistical parameters for the referred months of the years were applied and their respective graphs were plotted, followed by the monthly and annual trend lines, calculation of rainfall anomaly and polynomial trend, as well as the calculation of the moving average for five and ten years. The highest rainfall rates were recorded in the years 2002 and 2004, and the lowest rainfall rates were recorded in the years 1967, 1978, 1993 to 1995, 2007, 2014, 2015, and 2017. The month with the highest rainfall in April, while the lowest rates occur between January and August. The 10-year moving average estimates present values of greater significance than for the 5 years. The years in which the greatest anomalies were registered were 1964, 1966, and 1972, while the smallest anomalies were 2016, 2018, and 2019. Between 1993 and 2019, rainfall was below the historical average. The linear straight equation showed a negative slope in all months of the year. The histogram of the average climatological rainfall and the polynomial trend show rainfall reductions with a tendency to stabilize in the coming years.

INTRODUCTION

Rainfall monitoring is a global concern and, therefore, rain total forecasting policies have been adopted all over the world aiming at rainwater storage. In this sense, several warning mechanisms regarding the scarcity or excess of water resources are becoming increasingly common, especially for the poultry and agricultural sector. Sun et al. (2014) believe in the evidence between the distribution of meteorological variables and the modes of climate variability in different regions of the globe.

Medeiros (2016) studied the Uruçuí Preto River Basin - PI, specifically in terms of flow modeling and precipitation elements, air temperature, relative air humidity, and its climatic variability, providing technical support to decision-makers, society civil society, companies, and state and municipal governments. This author suggests to farmers and the riverside population, how the information contained in meteorological data should be used for better crop production and access to drinking water.

Excessive rainfall, together with other factors in the biophysical and geological environment, can cause floods, causing barriers to fall and road breaking. When the rains cease, these climatological impacts result in droughts and river siltation, affecting productive, socioeconomic, and environmental sectors (SOUZA et al., 2012).

Rainfall impacts are generated by the intensity of rainfall occurring in a short period, in most Brazilian cities, causing floods and landslides, gaining attention in the media, due to the high number of homeless people, in addition to the proliferation of diseases, economic losses, damages to the environment, deaths, among others (MONTEIRO et al., 2014).

The importance of analyzing and diagnosing rainfall fluctuations in the Northeast region of Brazil was shown by Medeiros et al. (2015), specifically in the State of Paraíba, especially due to its irregularity, since climate variables are fundamental to the climate approach. The results confirmed trends in reductions in rainfall, with fluctuations in rainfall throughout the series studied, showing the recurrence of maximum annual precipitation values in the intervals of 15, 12, and 7 years.

Medeiros et al. (2018), analyzing the distribution of rainfall during the period 1920 to 2016, examined the possible behaviors of the linear trend and the variability of the regression coefficient, taking into account the monthly assessment and aiming to identify the months with the highest and lower rainfall, as well as its temporal variation. This type of study can be used as a tool for planning and actions aimed at managing water resources, using catchment and storage systems, thus mitigating the problems of water scarcity.

The objective of this study is to analyze the distributions of rainfall rates between the years 1963 to 2019, examining their behavior and their linear trend lines (increasing or decreasing), taking into account the monthly assessment of the years, to identify the months of highest and lowest rainfall, seeking information regarding the spatial and temporal rainfall variation and the maximum and minimum monthly proclivities in the municipality of Amparo de São Francisco, in the state of Sergipe, Brazil.

MATERIALS AND METHODS

The municipality Amparo de São Francisco is located in the northeast region of the State of Sergipe, Brazil, and is limited to the municipality of Telha to the east and south, Canhoba to the west, and the State of Alagoas to the north. The municipal area is 39.8 km2, with the city center at an altitude of 51 meters and located in the geographic coordinates of 10°08'04" south latitude and 36°55'46" west longitude (Figure 1).

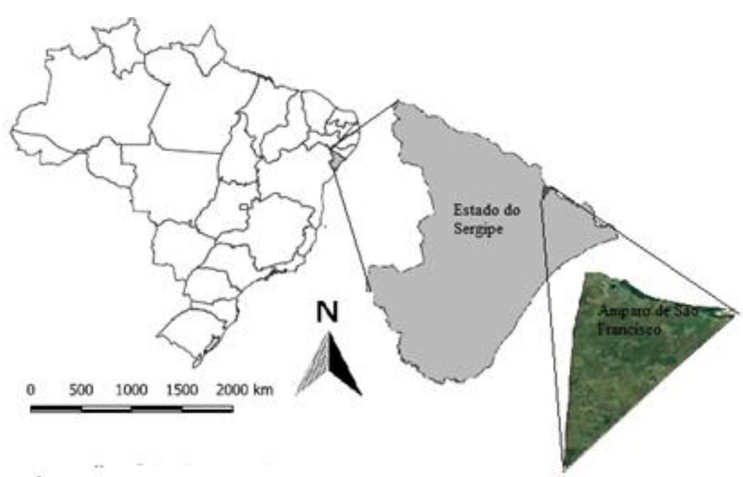

Figure No. 1: Location of Amparo de São Francisco municipality within the state of Sergipe, Brazil.

Source: França (2021).

Amparo de São Francisco is located in a region characterized by two well-defined seasons, a rainy period ranging from February to August and a dry period ranging from September to January. According to the (Köppen (928; Köppen et al., 1931) climate classification, the study area has an "As" climate (hot and humid Tropical rainy), with an average annual precipitation of 1138.2 mm and an average temperature of 25.9°C (Medeiros, 2020; Alvares et al., 2014).

It is interesting to note that the rainy season is marked by frequent and intense rainfall in a short period, favoring the appearance of floods, floods, and floods, as due to the frequency of rain in a short period, the water cannot infiltrate the soil as it should.

The study area is located in the basin of the São Francisco River, where all the flow of water from this region tends to meet the main river and thus ends up shaping the terrain. The region is marked by an intense practice of cattle raising, which ends up harming the local vegetation in several points and unprotecting the soil from surface runoff.

Data on average monthly and annual rainfall for the period 1963 to 2019, acquired from the Superintendência de Desenvolvimento do Nordeste (SUDENE, 1990) and the Empresa de DesenvolvimentoAgropecuário do Sergipe (EMDAGRO-SE, 2020) were used.

The basic statistical parameters for the referred months of the years were applied and their respective graphs were plotted. Then, monthly and annual trend lines, rainfall anomaly calculation, and polynomial trend were obtained, as well as the calculation of the moving average for five and ten years.

RESULTS AND DISCUSSIONS

The precipitation trend line for January (Figure 2) for the municipality of Amparo de São Francisco - SE in the period 1963-2019, has a negative slope and R2 of low significance, showing that statistically nothing can be said about the increase or decrease in rainfall. The study by Medeiros et al. (2016) corroborates the results discussed here.

The highest rainfall was recorded in 2002 and 2004, and the lowest rainfall was recorded in 1967, 1978, 1993 to 1995, 2007, 2014, 2015, and 2017. This buoyancy is in agreement with the studies by Marengo et al. (2015) and by the IPCC (2014).

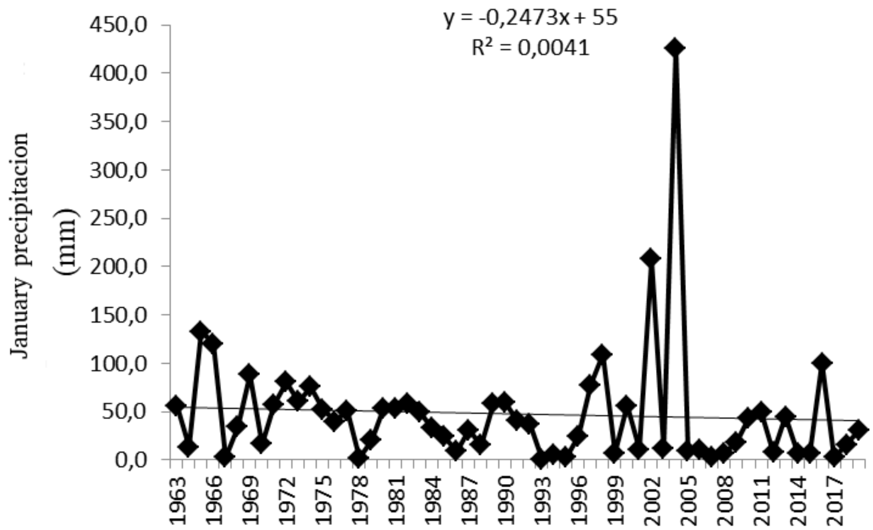

Figure No. 2: January precipitation trend line for the municipality of Amparo de São Francisco - Sergipe in the period 1963-2019.

Source: França (2021).

With a trend line presenting a low negative angular coefficient R^2, the month of February (Figure 3) registered 550.6 mm in the year 1966, 200 mm in the year 1981, and 0.0 mm in the years 1965, 1988, 1989, 1994 to 1999, 2001, 2006, 2013 and 2017.

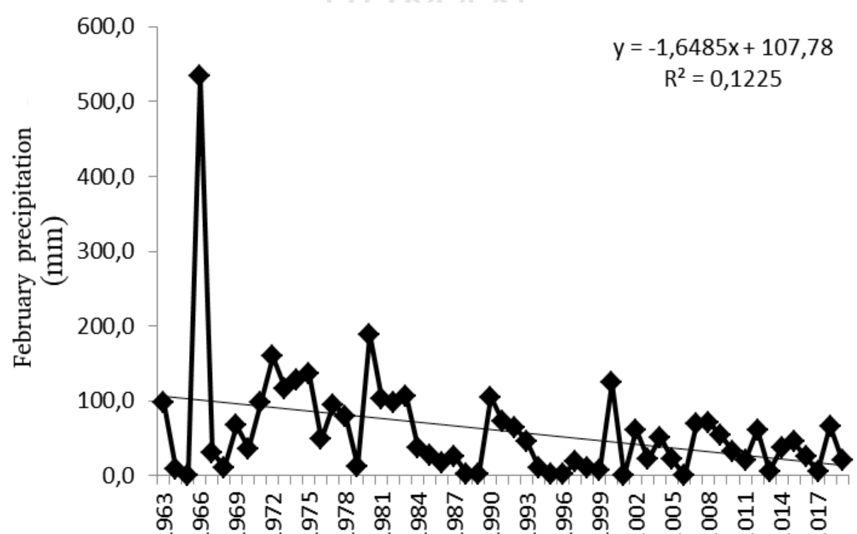

Figure No. 3: February precipitation trend line for the municipality of Amparo de São Francisco - Sergipe in the period 1963-2019.

Source: França (2021).

The integration of rainfall regimes becomes the main artifice for carrying out socioeconomic planning and conservation of the natural environment (SIMONI et al., 2014). According to Silva et al. (2011) understanding the rainfall behavior of a given region is indicated for composing the calendar and implementing agricultural projects. The analysis of rainfall distribution and climatic variability in basins is of fundamental importance for the conception of the natural functioning of water systems. Studies aimed at this purpose demonstrate an important role in human coverage, guiding measures for the rational use of water resources.

Figure 4 shows the rainfall distribution for March and its trend line for the municipality of Amparo de São Francisco – SE in the period 1963-2019. The month understudy has a straight line with a negative slope and R^2 of low significance. The years with high rainfall levels recorded were 1966, 2007, 2008, and 2019, while the years with low rainfall were 1965, 1993, 1995, 1999, and 2017. Studies such as the one by Marengo et al. (2008), Marengo et al. (2015), IPCC (2014), and de Medeiros et al. (2016) corroborated the results discussed in this work.

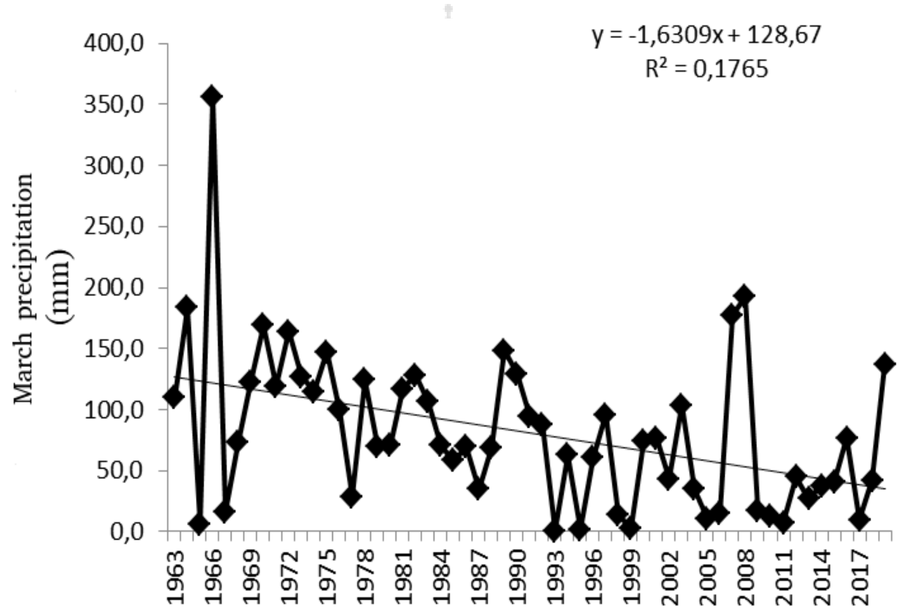

Figure No. 4: March line of precipitation trend for the municipality of Amparo de São Francisco - Sergipe in the period 1963-2019.

Source: França (2021).

With a negative trend line and low R^2 for April (Figure 5) the years of 1964, 1965, 1972, 1990, 2001, and 2011 occur with high rainfall, while in the years 1980, 1993, 1999, and 2012 there are low rainfall indices. These irregularities were caused by synoptic systems acting locally and regionally, according to the IPCC (2007; 2014), with these oscillations having similarities with those discussed in this article.

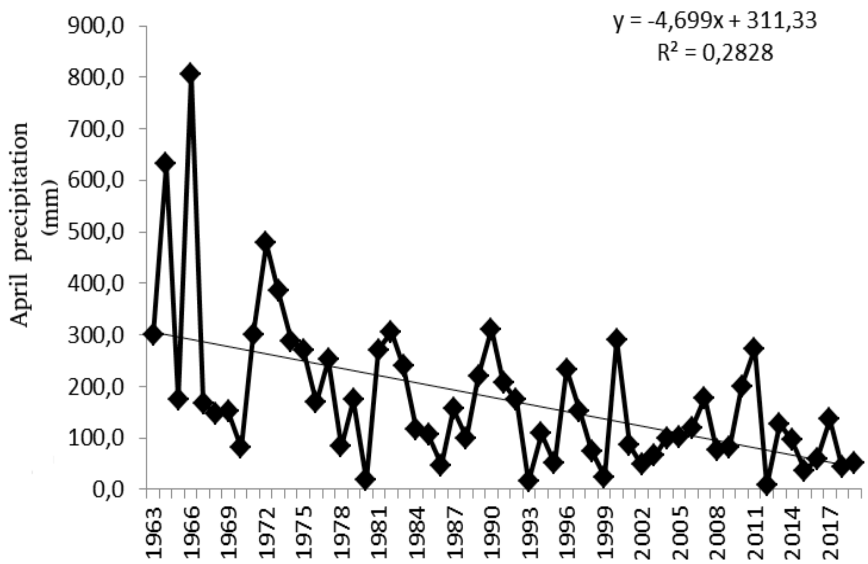

Figure No. 5. April precipitation trend line for the municipality of Amparo de São Francisco - Sergipe in the period 1963-2019.

Source: França (2021).

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Figure 6 shows the rainfall variability and its trend line for May in the municipality of Amparo de São Francisco – SE between 1963-2019. The irregularities recorded during May were caused by transient synoptic systems acting in regional and local circulations (Marengo et al., 2007; 2008; 2015) and Medeiros (2016). Maio is represented by a regression line with a negative slope and R^2 with low significance.

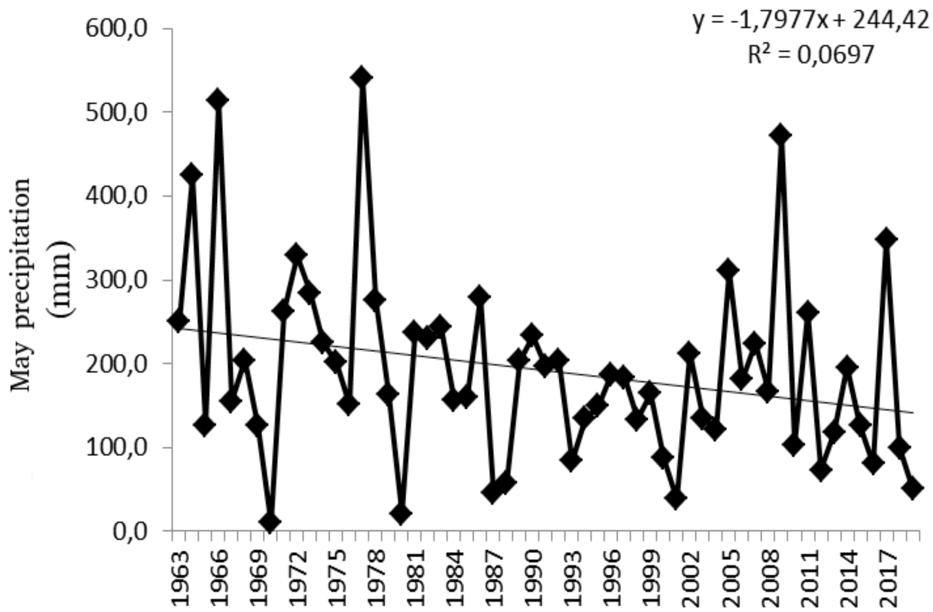

Figure No. 6: May precipitation trend line for the municipality of Amparo de São Francisco - Sergipe in the period 1963-2019.

Source: França (2021).

In June for the period 1963-2019, irregular rains of varying magnitudes were recorded (Figure 7). The highest rainfall was recorded in the years 1964, 1989, 1995, 2001, 2009, and 2017. The lowest rainfall occurred in 1969, 1980, 2007, 2011, and 2016. The months of June have a regression line with an angular coefficient negative and R^2 low.

The occurrence of extreme events of high magnitude and short time intervals is expected, as stated by Marengo et al. (2015).

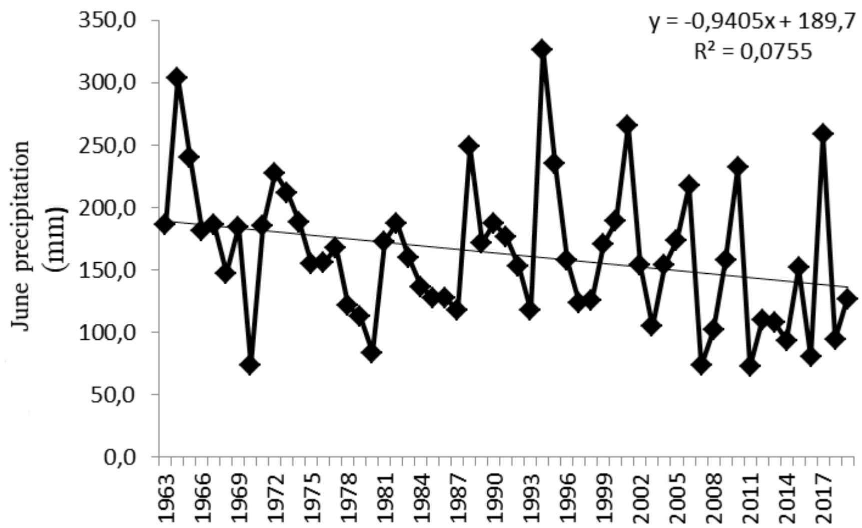

Figure No. 7: Line of the trend of precipitation in June for the municipality of Amparo de São Francisco - Sergipe in the period 1963-2019.

Source: França (2021).

In Figure 8, the precipitation trend line for July is observed for the municipality of Amparo de São Francisco – SE, in the period 1963-2019. In July, there was a straight negative trend and a low R^2. The inter-monthly rainfall oscillations showed a range of 55.5 mm to 305.8 mm.

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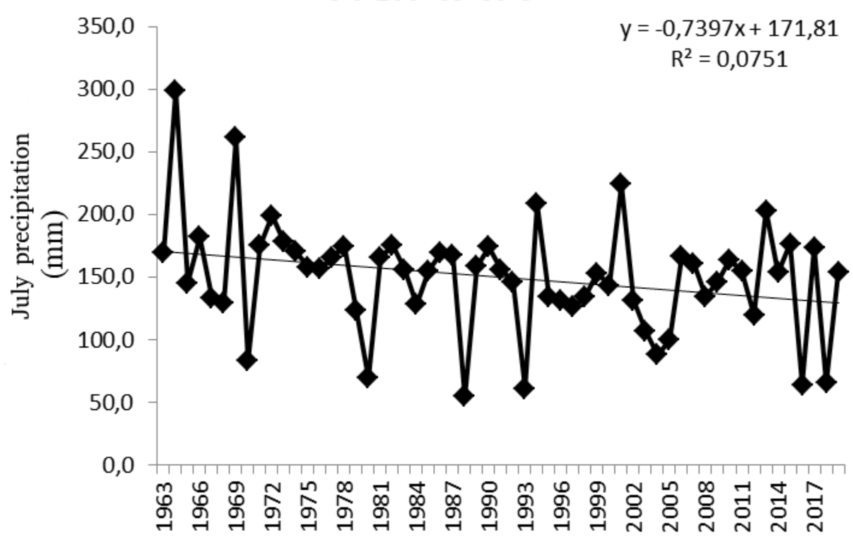

Figure No. 8: July precipitation trend line for the municipality of Amparo de São Francisco - Sergipe in the period 1963-2019.

Source: França (2021).

In August, comprised between the periods 1963-2019 (Figure 9), irregular rains and varied fluctuations were recorded. The lowest thermal indexes were registered in 1969, 1980, 1988, and 2018. The highest rainfall indexes occurred in 1964, 1966, 2008 and 2010. The trend line has R^2 of low significance and a negative slope.

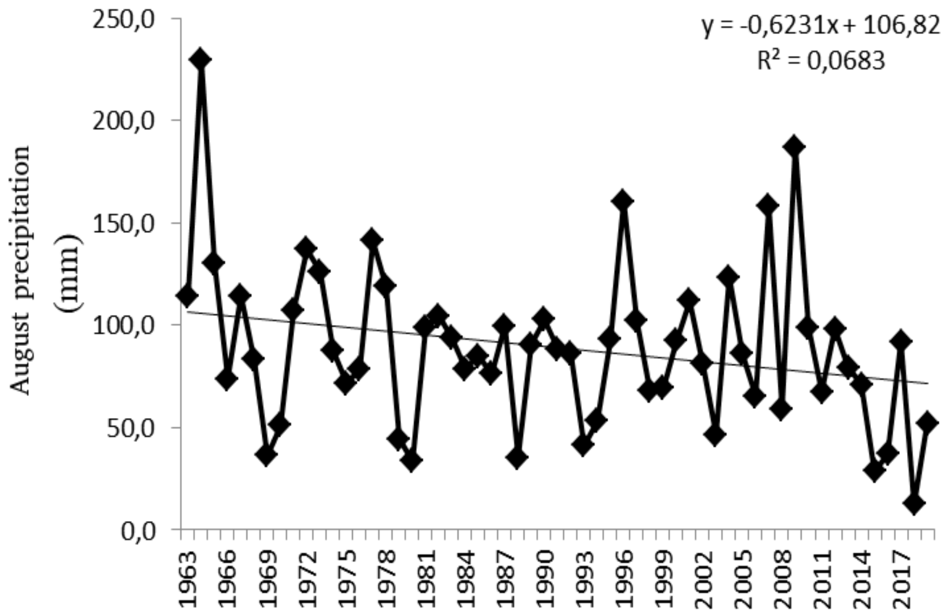

Figure No. 9: Precipitation trend line for August for the municipality of Amparo de São Francisco – Sergipe in the period 1963-2019.

Source: França (2021).

The month of September records a rainfall amplitude ranging from 0.0 mm, in the years 1966 and 1967, to 210.1 mm in the year 1964, and 210.5 mm in the year 2007. Studies by Marengo et al. (2007; 2008; 2015) and Medeiros (2016) show similarities with the discussions in this article. The month of September records a trend line with a negative slope and R2 of low significance.

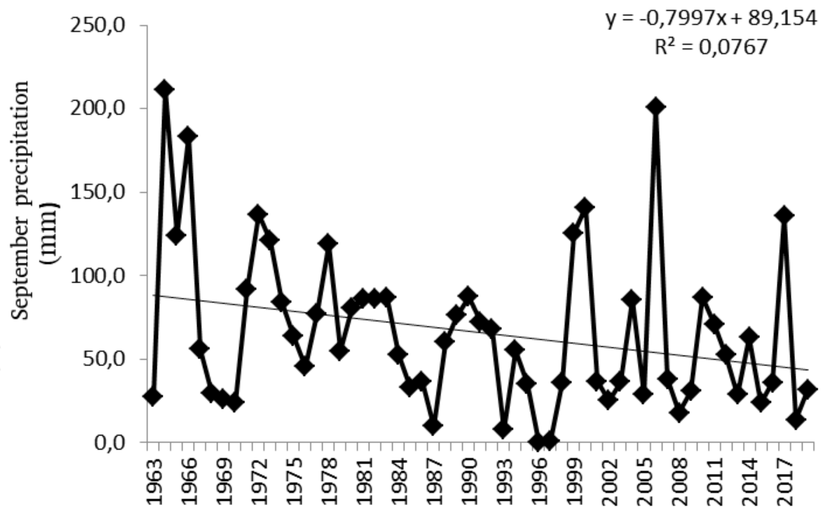

Figure No. 10: Line of trend of precipitation in the month of September for the municipality of Amparo de São Francisco - Sergipe in the period 1963-2019.

Source: França (2021).

Figure 11 shows rainfall variability for October for the municipality of Amparo de São Francisco – SE in the period 1963-2019 and its trend line with negative angular coefficient and low R2. The years with the highest rainfall were recorded in 1964, 1993, and 2014. The lowest rainfall occurred in 1963, 1967, 1997, 2004, 2005, and 2018.

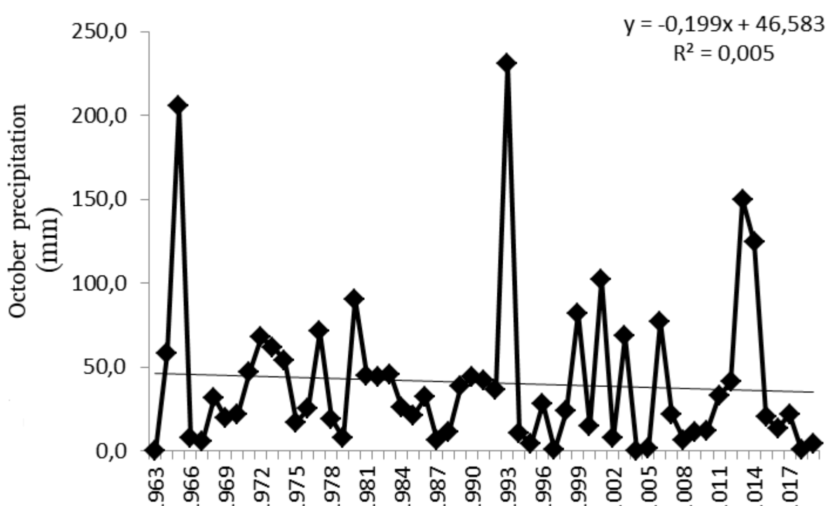

Figure No. 11. Line of the trend of precipitation in October for the municipality of Amparo de São Francisco - SE Sergipe in the period 1963-2019.

Source: França (2021).

With a trend line with a negative slope and low R2, the month of November in the period 1963-2019 (Figure 12) presents a negative trend for rainfall in the coming years. The highest rainfall in November occurred annually with the following values: 1965 it rained 158.9 mm; 1999 rained 85.2 mm; 2004 it rained 115.2 mm; and 2011 it rained 80.2 mm. The lowest rainfall rates occurred in the years 1966, 1998, 2007 to 2011 and from 2015 to 2018 and 2019 with values of 0.0 mm or close to it. These fluctuations in rainfall show similarities with the study by Costa et al. (2015).

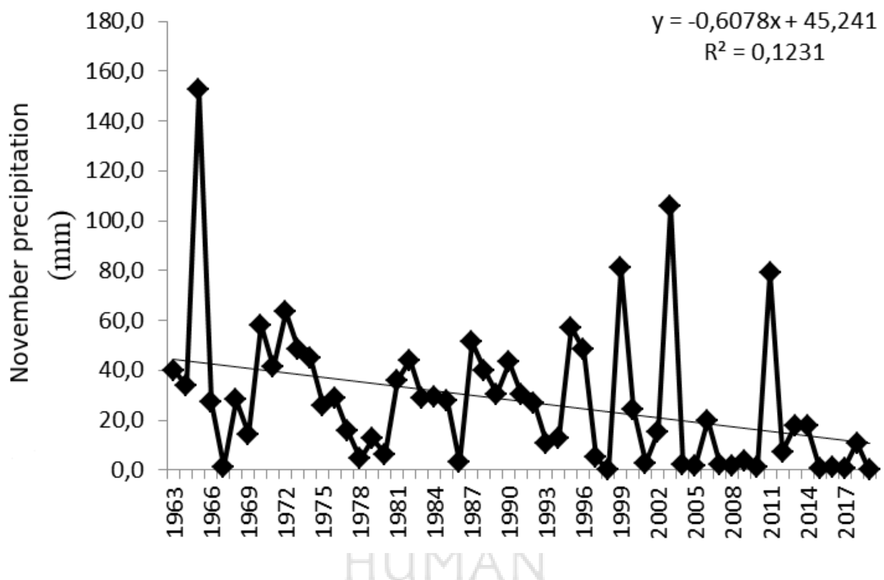

Figure No. 12: November precipitation trend line for the municipality of Amparo de São Francisco - Sergipe in the period 1963-2019.

Source: França (2021).

Figure 13 shows the rainfall variability of December and its trend line for the municipality of Amparo de São Francisco – SE in the period 1963-2019. It is noteworthy that in 1963 rainfall rates of 238.5 mm were recorded and their reductions to 10.5 mm in December 2019. This variability of reductions is predicted and highlighted in the studies by Marengo et al. (2008; 2015) and by the IPCC (2014). The month of December presents a trend line with a negative slope and R^2 of low significance.

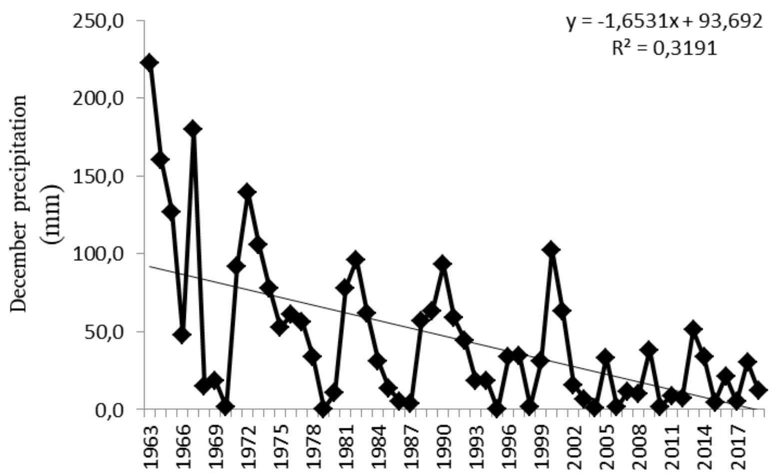

Figure No. 13: December precipitation trend line for the municipality of Amparo de São Francisco - Sergipe in the period 1963-2019.

Source: França (2021).

Figure 14 shows the variability of the annual precipitation trend line for the municipality of Amparo de São Francisco – SE in the period 1963-2019. The amplitude oscillation demonstrates how irregular the rainfall in the studied area is. Between the years 1963 to 1993 the occurrences of amplitudes were more spaced and of moderate magnitudes. In the years 1994 to 2019, this magnitude is reduced from its smaller magnitudes. Such oscillations were caused by changes in rainfall patterns caused by meso and micro-regional scale systems. Studies such as those by the authors Costa et al. (2015), Medeiros (2019), and Medeiros et al. (2020) corroborate the results discussed in this article.

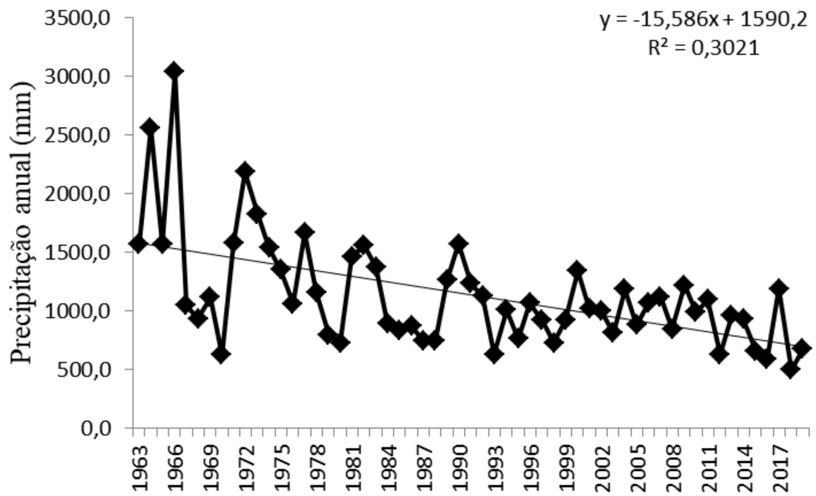

Figure No. 14: Annual precipitation trend line for the municipality of Amparo de São Francisco - Sergipe in the period 1963-2019.

Source: França (2021).

Moving Average for Five and Ten Years

Figure 15 shows the variability of observed rainfall and its estimated rainfall by moving averages for 5 and 10 years for the municipality of Amparo de São Francisco - SE in the period 1963-2019.

The observed precipitation performance follows the estimates of the moving average for 5 and 10 years and the rhythm of the observed precipitations with reduction of amplitude and flattening between years. The 10-year moving average estimates show values of greater significance than for the 5-year ones. Similar studies were carried out by Galvíncio (2000) on the precipitation of the São Francisco River for some sectors of the upper and middle course of the river.

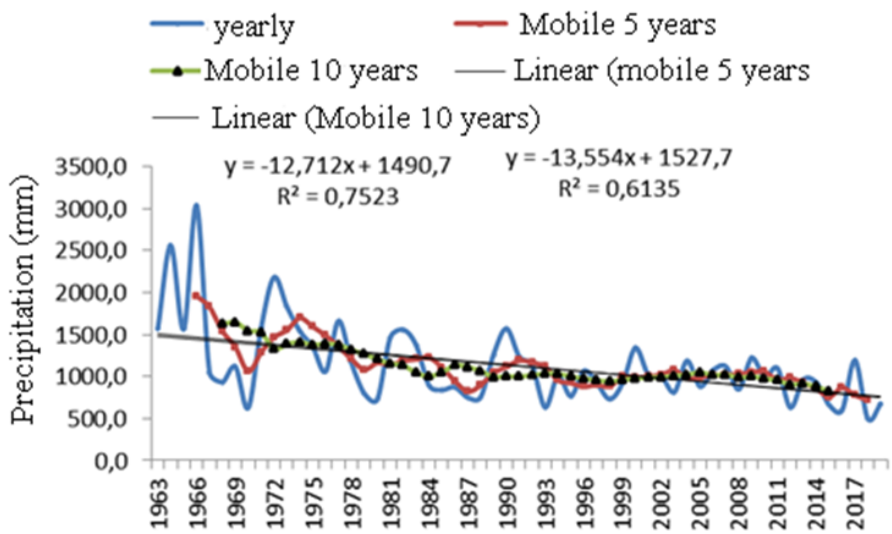

Figure No. 15: Annual precipitation trend line and moving average for 5 and 10 years for the municipality of Amparo de São Francisco – Sergipe in the period 1963-2019.

Source: França (2021).

Figure 16 shows the variability of the annual precipitation anomaly for the municipality of Amparo de São Francisco – SE in the period 1963-2019. The years in which the greatest anomalies were registered were 1964, 1966 and 1972, while the smallest anomalies were 2016, 2018 and 2019. Between 1993 and 2019, rainfall was below the historical average, that is, it rained below the average expected. Studies that presented similar data can be observed in the studies by Medeiros et al. (2018) and Marengo et al. (2015).

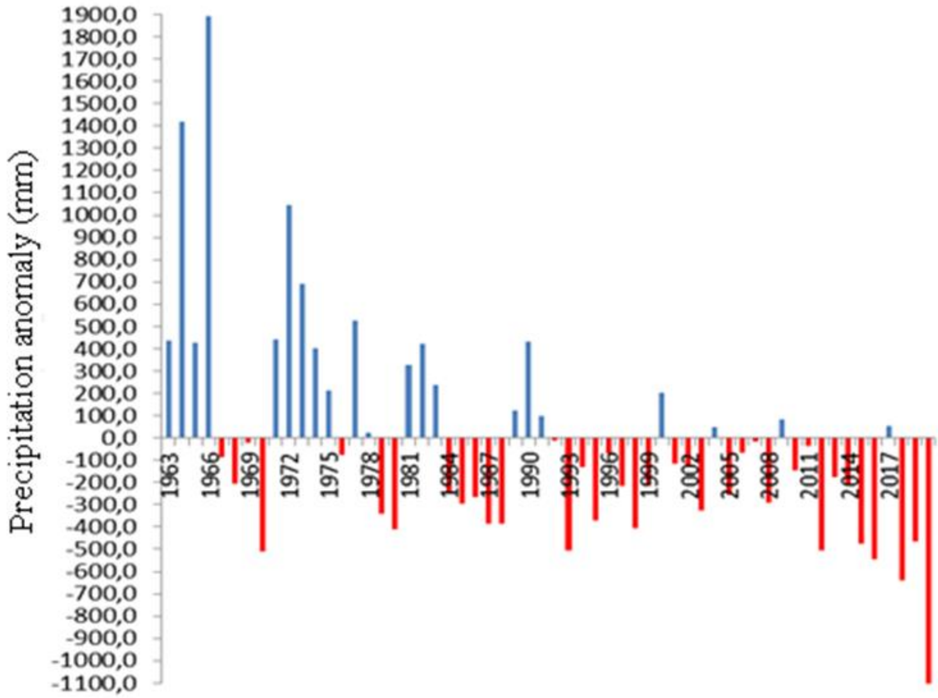

Figure No. 16: Annual rainfall anomaly for the municipality of Amparo de São Francisco – Sergipe in the period 1963-2019.

Source: França, (2021).

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Statistical analysis

In Table 1, it is observed that the mean and median values were unrelated, showing that discordant extreme values were recorded in the sample. The month with the highest rainfall was April, while the lowest rates occurred between January and August. It is also notable that the monthly averages surpass the median values in some months. Therefore, the median provides a higher probability of occurrence than the average, in accordance with the results found by Almeida et al. (2007).

Galvani (2011) stated that the standard deviation is of paramount importance as it generates information on the degree of dispersion of rainfall values in relation to the average value. The coefficient of variance is used to make comparisons in relative terms and expresses the variability of each data set normalized to the mean, as a percentage.

Table No. 1: Statistics of average precipitation, standard deviation, coefficient of variance, absolute maximum and minimum and median (mm) for the municipality of Amparo de São Francisco - Sergipe in the period 1963-2019.

Months	Average	Standard deviation	Coefficient of variance	Absolute maximum	absolute minimum	Median
Jan	47,8	64,1	1,340	425,8	0,7	59,4
Fev	60,0	78,2	1,304	533,2	0,0	105,3
Mar	81,4	64,4	0,792	355,9	1,1	129,2
Abr	175,1	146,7	0,838	806,1	8,5	310,8
Mai	192,3	113,0	0,588	540,1	10,3	233,3
Jun	162,4	56,8	0,350	326,2	72,5	187,6
Jul	150,4	44,8	0,298	299,0	54,8	174,5
Ago	88,8	39,6	0,446	229,4	12,8	103,0
Set	66,0	47,9	0,726	211,4	0,0	87,5
Out	40,8	46,6	1,142	230,7	0,0	44,6
Nov	27,6	28,8	1,041	152,5	0,0	43,5
Dez	45,8	48,6	1,062	222,7	0,0	93,0
Anual	1138,2	470,7	0,414	3032,8	498,8	1571,7

Source: França, (2021).

Future Monthly and Annual Trends

Table 2 shows that the variability of the coefficients of determination of the regression did not show the significance for all months, and this oscillation is due to the diversified complex of rainfall seasonality in the studied area.

The linear equation of the straight line showed a negative slope in all months of the year, showing that the trend of rainfall indices is towards reductions for the near future, reducing the days with precipitation and favoring the occurrence of extreme events of high intensity and a short period.

Table No. 2: Months, linear equation, regression determination coefficient (R^2), the monthly historical average for the municipality of Amparo de São Francisco - Sergipe in the period 1963-2019.

Months	Linear equation	R^2	Average
Jan	Y=-0,2473x + 55,00	0,0041	47,8
Fev	Y=-1,6485x + 107,78	0,1225	60,0
Mar	Y=-1,6309x + 128,67	0,1765	81,4
Abr	Y=-4,6990x + 311,33	0,2828	175,1
Mai	Y=-1,7977x + 244,42	0,0697	192,3
Jun	Y=-0,9405x + 189,70	0,0755	162,4
Jul	Y=-0,7397x + 171,81	0,0751	150,4
Ago	Y=-0,6231x + 106,82	0,0683	88,8
Set	Y=-0,7997x + 89,15	0,0767	66,0
Out	Y=-0,1990x + 46,58	0,0050	40,8
Nov	Y=-0,6078x + 45,24	0,1231	27,6
Dez	Y=-1,6531x + 93,69	0,3191	45,8
Anual	Y=-15,586x +1590,20	0,3021	1138,2

Source: França (2021).

In Figure 17, it can be seen that between March and August are concentrated 74% of the annual rainfall, and between September and February, the rainfall index is 26% of the historical average value. With an average of showing that over time the temporal variability is characteristic of the Brazilian semiarid region, it is evident that there is no possibility of the annual increase in rainfall.

The histogram of the average climatological rainfall and the polynomial trend show rainfall reductions with a tendency to stabilize in the coming years. A study such as those by Medeiros et al. (2018) and Marengo et al. (2015), corroborate the results discussed here.

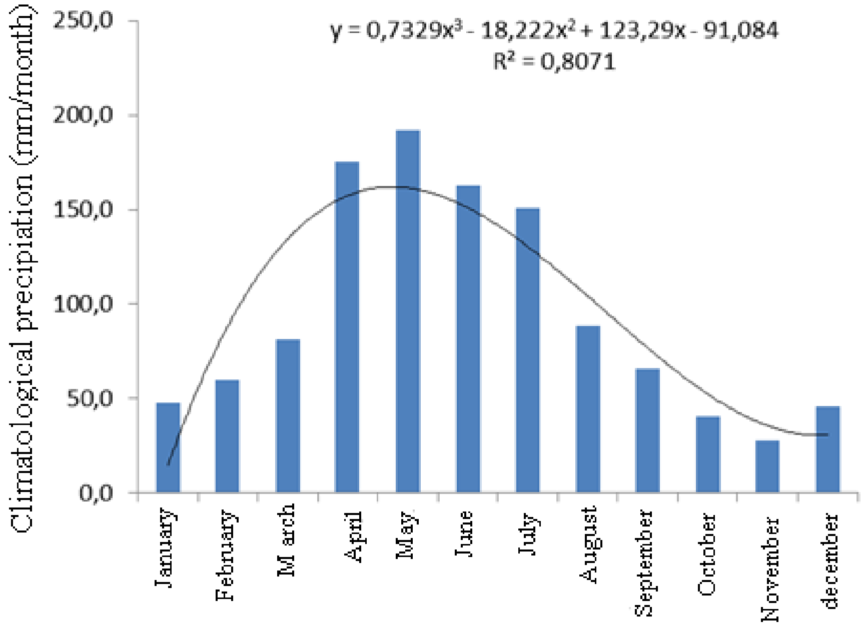

Figure No. 17: Histogram of climatological rainfall average and polynomial trend for the municipality of Amparo de São Francisco in the period 1963-2019.

Source: França, (2021).

Negative trends in precipitation cores demonstrate an increase in times without rain over the years, both in the rainy season and in the dry season. Subsequent studies did not assess whether there is an increasing or decreasing trend in precipitation acuity and the number of extreme events for the semiarid region of northeastern Brazil. This makes clear the need to explore further studies, especially when it comes to a semi-arid region such as the Northeast of Brazil, which coexists with prolonged periods of drought, as stated by Costa et al. (2015).

CONCLUSIONS

The highest rainfall rates were recorded in the years 2002 and 2004, and the lowest rainfall rates were recorded in the years 1967, 1978, 1993 to 1995, 2007, 2014, 2015 and 2017. The month with the highest rainfall is April, while the lowest rates occur between January and August.

The 10-year moving average estimates present values of greater significance than for the 5 years.

The years in which the greatest anomalies were registered were 1964, 1966 and 1972, while the smallest anomalies were 2016, 2018 and 2019. Between 1993 and 2019, rainfall was below the historical average, that is, it rained below the average expected.

The linear straight equation showed a negative slope in all months of the year, showing that the trend of rainfall indices is towards reductions for the near future, reducing the days with precipitation and favoring the occurrence of extreme events of high intensity and short period of time.

The histogram of the average climatological rainfall and the polynomial trend show rainfall reductions with a tendency to stabilize in the coming years.

Positive anomalies are recorded in seven municipalities while negative anomalies occur in eighteen municipalities. Rainfall fluctuations provide a proportional aid to decision makers to reduce climate impacts for the inhabitants.

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