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Temperature versus Decadal Rainfall in Amparo São De Francisco, Sergipe – Brazil

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ABSTRACT

Rainfall and thermal distributions and variability, associated with uncontrolled human activities, have had negative consequences for local and regional socioeconomics such as agriculture, agribusiness, and human survival. The objective of this work is to study the oscillations of the decadal thermal and rainfall climatic elements between 1963-2019, aiming to identify their variability for the municipality of Amparo de São Francisco, Sergipe - Brazil.Monthly and annual rainfall data provided by the Superintendência de Desenvolvimento do Nordeste (SUDENE) and by the Empresa de Assistência Técnica e Extensão Rural do estado de Sergipe (EMATER-SE), from 1963 to 2019, were used.The thermal data were estimated by the Estima_T software for the same rainfall period. The coefficients of the quadratic function were determined, by the inverse of its distance, for the monthly average temperature, in the function of the local coordinates latitude, longitude, and altitude. An evident change in the average variability of thermal and rainfall elements was identified among the oscillations studied in the municipality of Amparo de São Francisco, causing annual rainfall increases in the first two decades and reductions in the other four decades. Decades of thermal indices showed reductions in the first two decades and increases in the next four decades. The atmospheric systems of meso and large scale followed by the regional and local systems, that influence the elements temperature and precipitation of the studied area, can provide subsidies to the government decision-makers and the planners and elaborators of projects, aiming at a better preparation of use of the water resources.

INTRODUCTION:

Braga *et al*. (2019) Studying the variability of rainy and thermal temporal series, showed that it is important to generate subsidies for creating mitigating measures for areas such as poultry, agricultural, storage, and water storage and population in general. They found that rainfall irregularities are directly linked to regional rainfall systems and the condensation factor. Local contributions, such as the Intertropical Convergence Zone, acted with intensity and caused, in most cases, rains above normality and in some decades, there were disasters of intense and moderate proportion.

In the past century, multiple studies have been carried out on climate fluctuations and their changes, using the global average temperature to establish the degree and direction of climate change (Silva *et al*., 2006).

Medeiros *et al*., (2018) carried out the analysis of the space-time variability of air temperature for the State of Pernambuco distributed by homogeneous regions. They showed that the results of the thermal fluctuations are related to the elevation and the latitude, being variables of the physiography that better explain the instability of the monthly and annual temperature in the study area. The fluctuations in the average temperature are due to the synoptic systems operating at the time of the rainy season and the dry season, as well as the impacts on the environment. There were temperature reductions under the displacement of the rainy season and the actions and/or contributions of regional and local effects.

Marengo *et al*., (2011) explain that the increase in temperature influences the loss of soil moisture, as a consequence of the increase in evapotranspiration. Souza (2006) explained that the availability of water in the soil is influenced by thermal fluctuations and the spatial distribution of rainfall.

Mello *et al*., (2015) analyzed the climatic variability of the maximum, average, and minimum temperature of the state of Pernambuco, focusing on such variations, as a means to understand future changes. They used annual temperature data from 1960 to 1990. They stated that the knowledge of the climatic characteristics of a region is important for studies of the weather forecast and mainly for agricultural planning. The delimitation of a warmer or colder period serves as a warning to federal, state, and municipal authorities when making decisions, to better plan activities.

The factors that provoke and/or inhibit rainfall can cause excess or drought (Medeiros, 2016). The understanding of the variability of precipitation can guide decisions to mitigate damages resulting from the respective natural phenomena. According to Marengo *et al*., (2011), the Intertropical Convergence Zone is the important atmospheric system that causes rain in the region, which is represented by the axis of the equatorial trough and its different variations in position and intensity that are correlated to changes in positions and intensities of the subtropical highs of the North and South Atlantic.

Medeiros *et al*., (2018) studied rainfall variability in the municipality of São Bento do Una, a strong poultry production center, due to the increase in water demand necessary for the full development of the activity. Their study can be used as a tool for planning and actions that aim to manage water resources using systems of capture, storage, and avoiding the problem of water scarcity. They also emphasize that there is a need for policies and plans for capturing and using rainwater, in addition to the efficient use of other natural resources in the region, so that socioeconomic development is not limited by low water availability.

Medeiros *et al*., (2017) observed the monthly rainfall variation in the municipality of Serra Talhada and verified the possible linear trend, identifying that the greatest precipitation variability occurred in January, February, March, and April, resulting in high rates of rainwater in the municipality. They found that the rainfall values with the lowest values are found between July, August, September, and October. They also found that local rainfall is quite irregular in space and time.

Several studies have been carried out to understand the spatial and temporal variation of precipitation, as well as its influence on local and global dynamics (Yang, *et al*., 2010; Chierice *et al*., 2014; Ishihara *et al*., 2014; Nóbrega *et al*., 2015; Lai *et al*.,2016; and Zhijia*et al*.,2016).

The analysis of the rain characteristics becomes important since it makes it possible to detect trends or changes in the climate, at local, regional, state, national and continental scales (Silveira *et al*., 2016; Marcuzzo *et al*., 2012). According to these authors, the excess or lack of rain can be favorable or harmful to socioeconomic development, and the analysis of precipitations is extremely important when carried out over a historical period.

The objective of this research is to study the oscillations of the decadal thermal and rainfall climatic elements between 1963-2019, aiming to identify their variability for the municipality of Amparo de São Francisco, Sergipe - Brazil.

MATERIAL AND METHOD:

The municipality of Amparo de São Francisco is limited to the east and south by the municipality of Telha, to the west by the municipality of Canhoba, and the north by the state of Alagoas, with a maximum height of 51 meters at its headquarters, located with coordinates regions of 10 ° 08'04 "south and 36 ° 55'46" west (Figure 1).

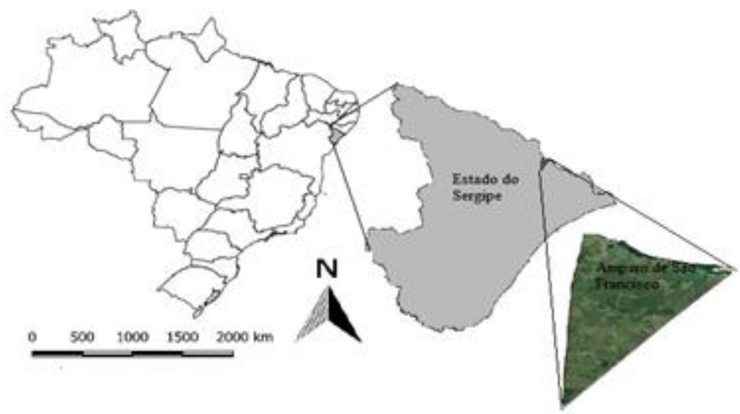

Figure No. 1: The state of Sergipe and the positioning of the city of Amparo de São Francisco

Source: França (2020).

Amparo de São Francisco is located in an area marked by two well-defined seasons, a rainy season flowing from February to August and its dry season between September to January. According to the climatic classification of Köppen (1928) and *Köppen et al*., (1931), the municipality has the “As” (hot and humid tropical rainy) climate(Medeiros, 2020; Alvares *et al*., 2014).

Monthly and annual rainfall data were provided by the Superintendência de Desenvolvimento do Nordeste (SUDENE, 1990) and by the Empresa de Assistência Técnica e Extensão Rural do estado de Sergipe (EMATER-SE, 2020), from 1963 to 2019, were used.

The thermal data were estimated using the Estima_T software (Cavalcanti *et al*., 1994; Cavalcanti *et al*., 2006) for the same rainfall period. The coefficients of the quadratic function were determined, by the inverse of its distance, for the monthly average temperature, in the function of the local coordinates latitude, longitude, and altitude (Cavalcanti *et al*., 2006) expressed by the equation:

$$T = C0 + C1\lambda + C2Ø + C3h + C4\lambda 2 + C5Ø2 + C6h2 + C7\lambda Ø + C8\lambda h + C9Øh$$

On what:

C0, C1, ..., C9 are the constants;

λ, λ2, λ Ø, λ h longitude;

Ø, Ø2, λ Ø latitude;

h, h2, λ h, Ø h height.

They also estimated the time series of temperature, adding to this the temperature anomaly of the Tropical Atlantic Ocean (Cavalcanti *et al*., 2006).

$$Tij = Ti + AATij \quad i = 1,2,3, ..., 12 \quad j = 1950, 1951, 1952, ... 2019$$

On what:

i = 1,2,3, ..., 12

j = 1950, 1951, 1952, 1953, ..., 2019.

RESULTS AND DISCUSSIONS:

Figures No. 2 to No. 12 show decadal, annual rainfall, and thermal oscillations and their anomalies.

The decadal variation (1963-1972) of precipitation shows irregularities and magnitudes differentiated month by month (Figure 2). The months with the lowest rainfall rates were October, November, and January; the months with the highest rainfall rates were recorded in April, May, and June. It is observed that between April to September there is a gradual reduction in rainfall.

The thermal variability starts to increase from the second half of August and continues until the second half of December, followed by its reduction until the beginning of August. The quarter corresponding to October, November, and December, and the cold quarter June, July, and August. It is noteworthy that the thermal fluctuations are inversely proportional to the rainfall indexes. Studies such as those by Duarte *et al.*, (2020), Marengo *et al.*,(2015), and IPCC (2014) corroborate the discussions in this article.

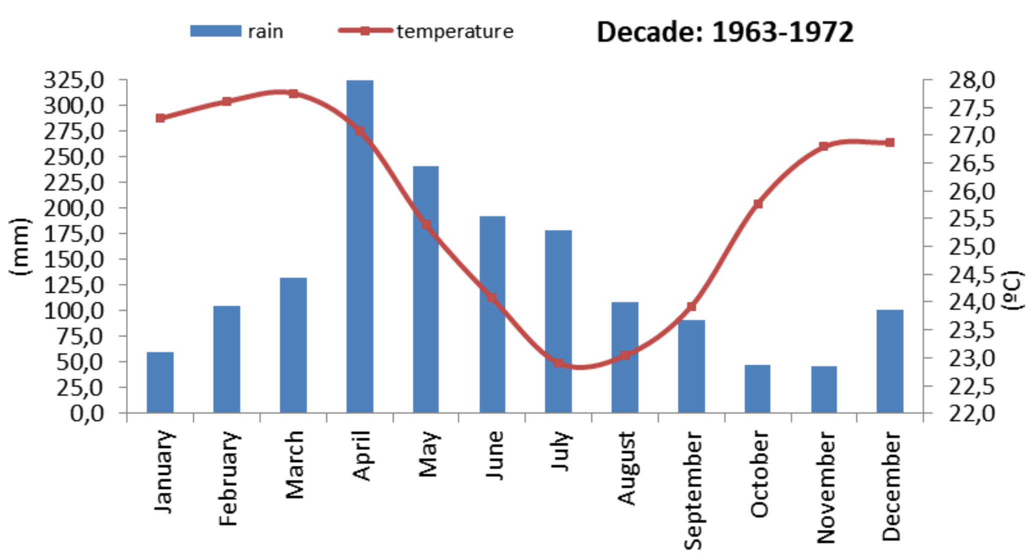

Figure No. 2: Decadal rainfall and thermal variability for Amparo de São Francisco, Sergipe.

Source: Medeiros (2021).

Figure 3 shows the decadal rainfall and thermal variability (1973-1982) for Amparo de São Francisco, Sergipe. Rainfall rates ranged from 22.2 mm in November to 231.1 mm in May. The months with the greatest rainfall variability were from April to July and those with the lowest rainfall were October, November, and January. Thermal fluctuations ranged from 22.7ºC in July to 27.6ºC in March.

Comparing the previous decade, it should be noted that the rainy and thermal conditions were much better in 1973-1982 since the micro-scale atmospheric systems and regional contributions were more active than in the past decade. These discussions have similarities with the studies by Medeiros *et al*., (2020) and by Marengo *et al*.,(2015).

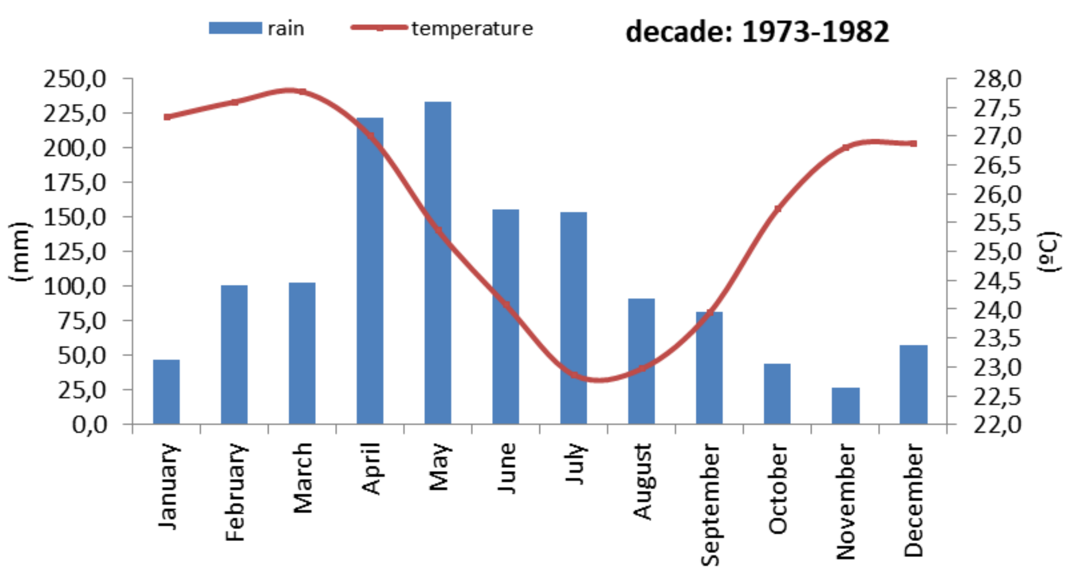

Figure No. 3: Decadal rainfall and thermal variability for Amparo de São Francisco, Sergipe.

Source: Medeiros (2021).

Monitoring the region's rainfall regime in recent years has shown that scarcity of water resources accentuates socioeconomic problems, particularly at the end of each year, with rainfall totals around or below the region's average (Marengo *et al*., 2006).

In Figure 4 can be observed that the highest rainfall rates were recorded from April to August and the lowest thermal reductions occurred in the same period. The rainfall fluctuations between September and March were the lowest of the decade and the thermal indices the highest.

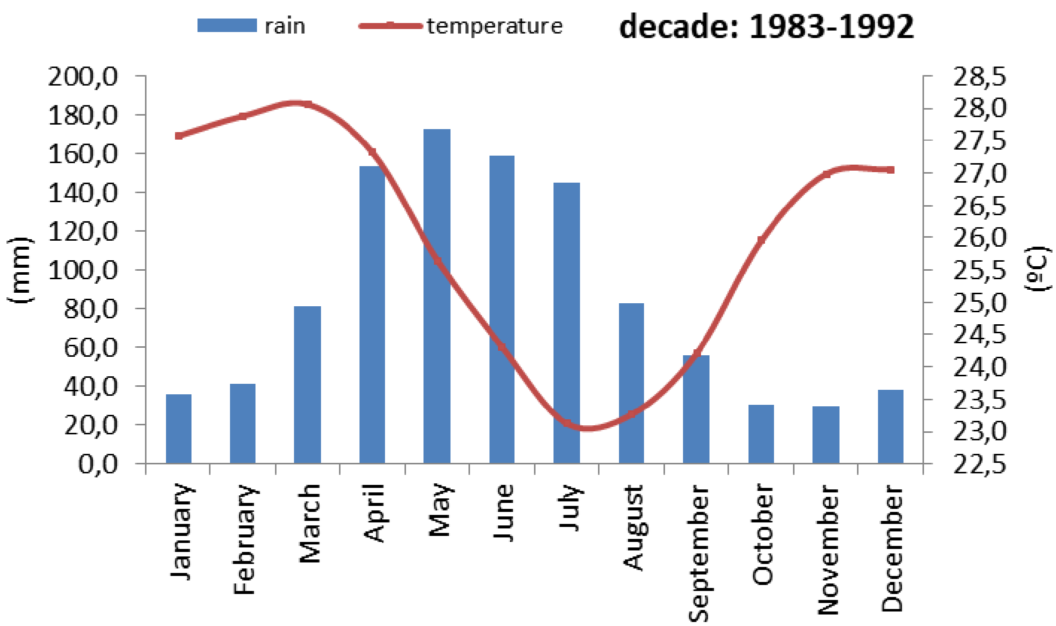

Figure No. 4: Decadal rainfall and thermal variability for Amparo de São Francisco, Sergipe.

Source: Medeiros (2021).

In the 1993-2002 decade (Figure 5), the thermal indexes began to increase and lasted until the second half of December and the rainfall rates were reduced. There are two peaks of thermal maximums in March and November and a minimum peak in July. From April to August, rainfall and thermal reductions were recorded. Similar results were recorded in the studies by Marengo *et al*. (2015) and by IPCC (2014).

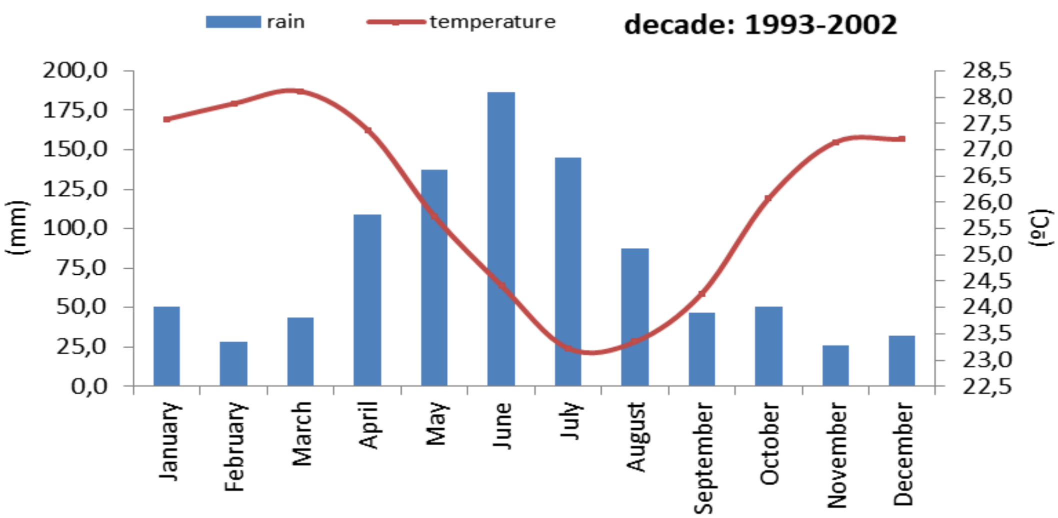

Figure No. 5: Decadal rainfall and thermal variability for Amparo de São Francisco - Sergipe.

Source: Medeiros (2021).

The rainfall and thermal variability in the 2003-2012 decade are shown in Figure 6. Between March and September, there was an increase in precipitation and a reduction in thermal indices, which fluctuated from 27.3ºC to 23.1ºC. From October to February the opposite occurred; the thermal indexes increased and the rainfall indexes were reduced, and these oscillations were caused by the atmospheric systems of meso and micro-scale, aided by the regional and local systems (IPCC, 2014; Marengo *et al*., 2015).

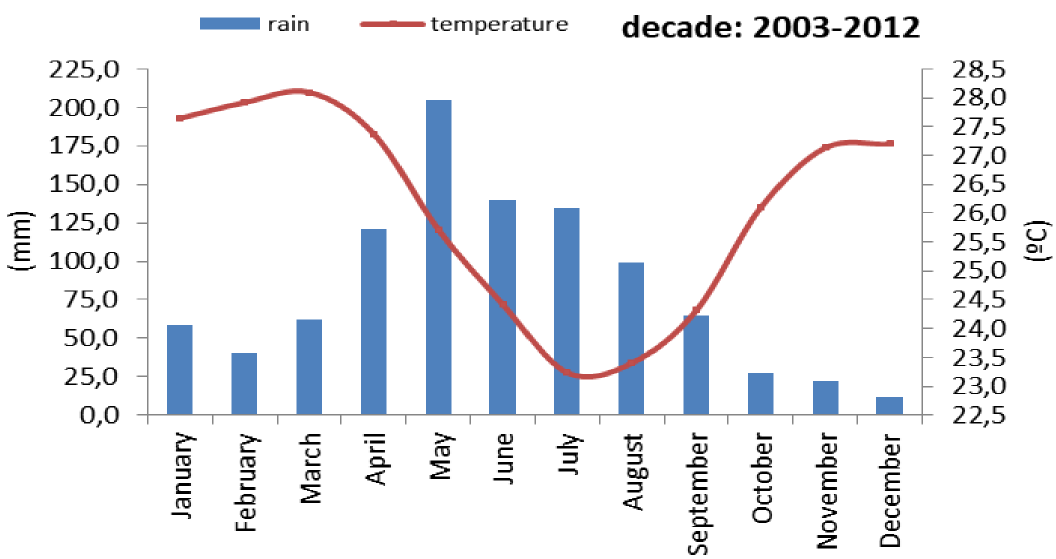

Figure No. 6: Decadal rainfall and thermal variability for Amparo de São Francisco - Sergipe.

Source: Medeiros (2021).

Figure 7 shows the decadal rainfall and thermal variability (2013-2019) for Amparo de São Francisco, Sergipe. The months of greatest rainfall and lowest thermal incidence were May, June, and July. As for thermal variability, the highest peaks recorded in March and November, and the minimum peak in July, stand out. The months of May and July stand out as those with high rainfall, and November as the one with low rainfall. With the temperature decreasing, rainfall increases; with rising temperatures, rainfall reduction occurs. Similar results were detected in the studies by Duarte *et al*., (2020).

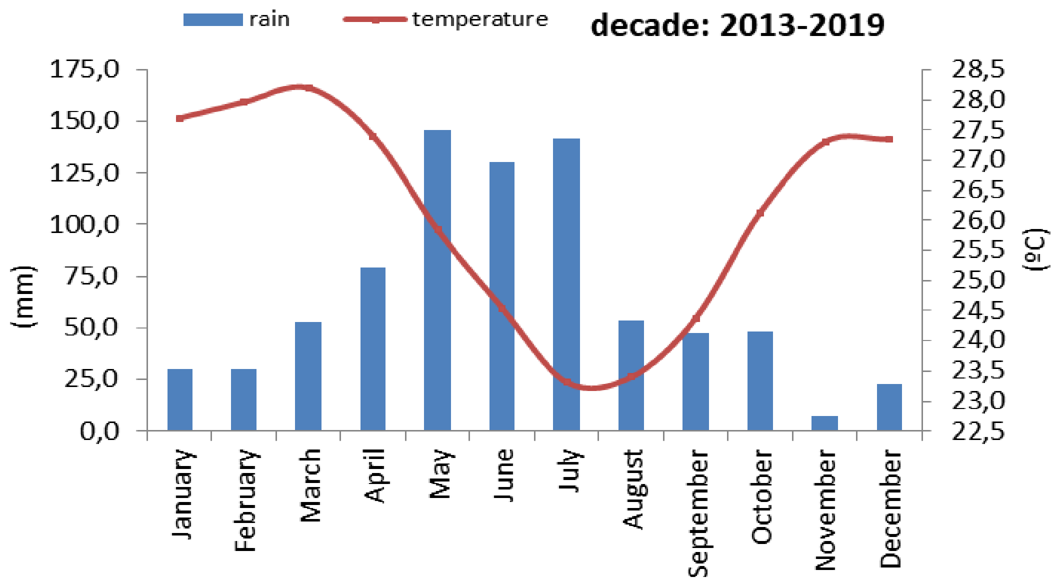

Figure No. 7: Decadal rainfall and thermal variability for Amparo de São Francisco - Sergipe.

Source: Medeiros (2021).

The thermal and rain fluctuations from the period 1963-2019 to Amparo de São Francisco are shown in Figure 8. The months of greatest rainfall variability are recorded between April and August and are also those of lower thermal fluctuations. From September to March there is a gradual increase in temperature and a reduction in rainfall. The months with the highest rainfall were April and May, and the thermals were March and July. A study as the authors of Duarte *et al*., (2020) corroborates with the discussions of this article.

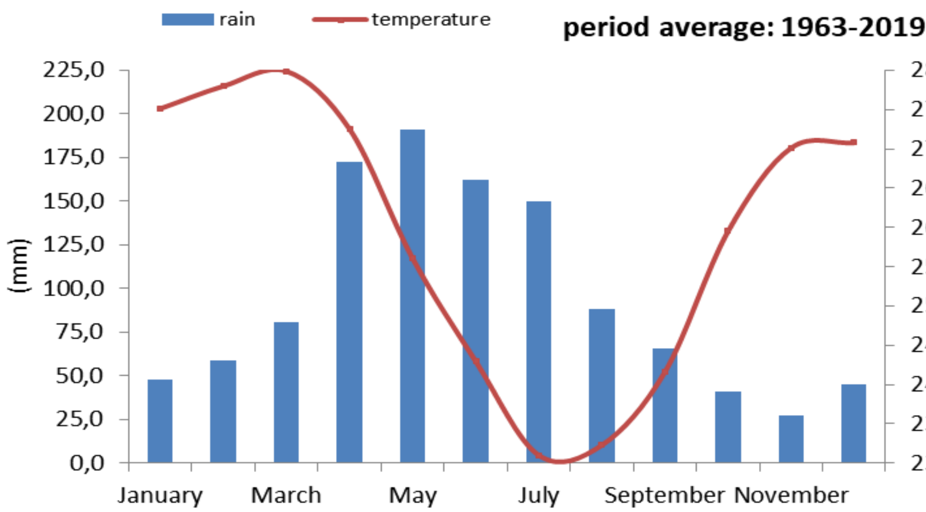

Figure No. 8: Average rainfall and thermal oscillation for the period 1963-2019 in Amparo de São Francisco, Sergipe.

Source: Medeiros (2021).

Figure 9 shows the thermal fluctuations recorded in the studied area. In the first two decades, temperatures fluctuated from 25.4ºC to 25.8ºC, registered as the low temperatures of the studied period. In the last four decades, temperatures have fluctuated between 25.9 ºC to 26.1 ºC. These increases are in line with the studies by Marengo *et al*.,(2015); Marengo *et al*.,(2008), and IPCC (2014).

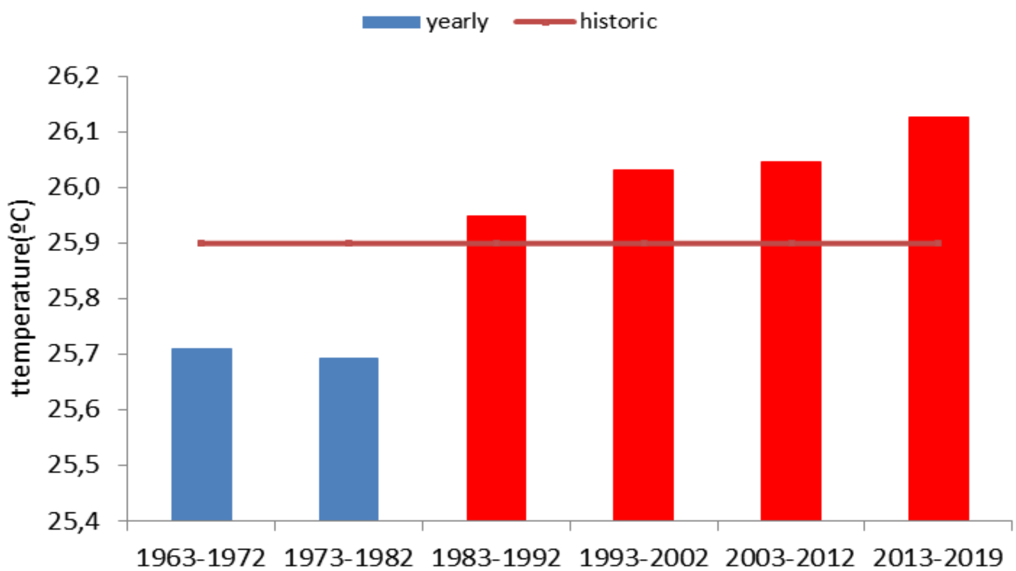

Figure No. 9: Decadal annual temperature and its historical average for Amparo de São Francisco, Sergipe.

Source: Medeiros (2021).

Figure 10 shows the oscillation of the annual decadal temperature anomaly for Amparo de São Francisco, Sergipe. In the first two decades, temperature reductions occurred and in the other decades, there was a gradual increase in the element under study. Studies such as the IPCC (2014), IPCC (2007), Marengo *et al*. (2015), Marengo *et al*. (2007), and Marengo *et al*. (2008) corroborate the results discussed here in this work.

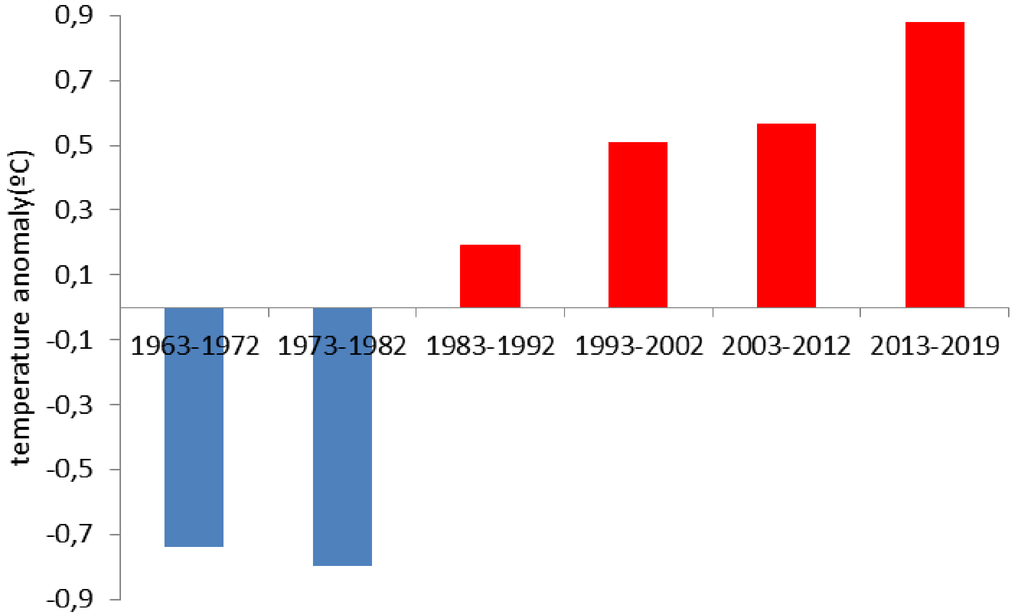

Figure No. 10: Anomaly of the annual decadal temperature for Amparo de São Francisco, Sergipe.

Source: Medeiros (2021).

Figure 11 shows the fluctuations in the annual decadal rainfall and its historical average for Amparo de São Francisco, Sergipe. With an average annual rainfall of 1138.2 mm, it shows that in the first two decades it rained above the historical average and in the other decades there was a reduction in rainfall, compared to the historical average. These reductions are following local and regional atmospheric systems and corroborate the results of the studies by Duarte *et al*., (2020).

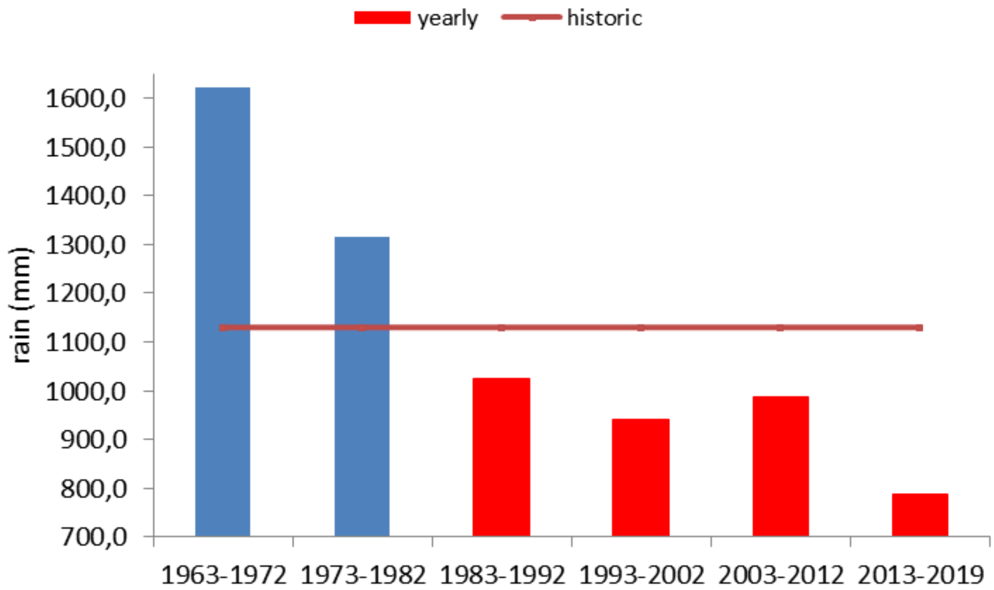

Figure No. 11: Decadal annual rainfall and its historical average for Amparo de São Francisco, Sergipe.

Source: Medeiros (2021).

Figure 12 shows the distribution of the annual decadal rainfall anomaly for Amparo de São Francisco, Sergipe. The decades 1963-1972 and 1971-1982 registered positive anomalies of 42.51% and 15%, respectively. In the decades of 1983-1992, the negative anomalies were -10; in the decade of 1993-2002 it was registered a negative anomaly of -17.2; in the decade of 2003-2012 there was a reduction of 13.3% and in the decades of 2012-2019, there was an anomaly of -30.8%, about the historical average (1138.2 mm).

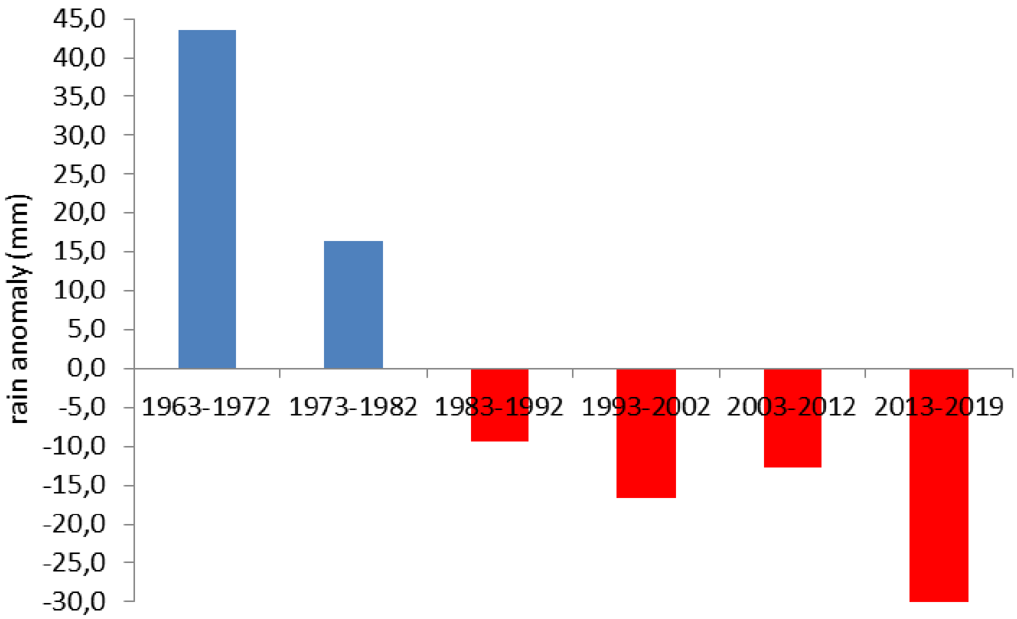

Figure No. 12: Anomaly of annual decadal precipitation for Amparo de São Francisco, Sergipe.

Source: Medeiros (2021).

CONCLUSION:

An evident change in the average variability of thermal and rainfall elements was identified among the oscillations studied in the municipality of Amparo de São Francisco, causing annual rainfall increases in the first two decades and reductions in the other four decades. Decades of thermal indices showed reductions in the first two decades and increases in the next four decades.

The atmospheric systems of meso and large scale followed by the regional and local systems, that influence the elements temperature and precipitation of the studied area, can provide subsidies to the government decision-makers and the planners and elaborators of projects, aiming at a better preparation of use of the water resources. For better thermal variability or oscillation, it is recommended to implement reforestation in the areas surrounding lakes, ponds, rivers, weirs, streams, and in areas of grain-producing properties, so that the experienced thermal sensation is alleviated and greatly protects the soil, with a consequent reduction in thermal indices.

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