Erosive Indices of Amparo in São Francisco – Sergipe, Brazil Related to the Phenomena El Niño La Niña

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Abstract— *Erosion is originally from the Latin, which means to corrode and, in a comprehensive way, can be considered a set of natural processes that promote the alteration of landscapes through degradation, wear and transport from one point to another of materials on the earth's surface through agents erosive. The objective is to evaluate the erosive index for the municipality of Amparo de São Francisco – Sergipe, relating them to the El Niño and La Niña phenomena. The calculation of pluvial and erosive anomalies was used, generating their respective graphs for the area under study coupled with the extreme events of large scale El Niño and La Niña to see the erosive contributions of the studied area. Erosion calculations were performed using the formulation developed by França (2021) for the study area. The rainfall erosivity indices of anomalies in the study area, taking into account the El Niño and La Niña periods, is a relevant factor for decision makers on the most adequate soil management practices, aiming at the sustainability of exploration for projects farming and fertile soil management.*

Keywords— Soil withdrawal, rainfall erosive potential, Soil conservation and loss.

I. INTRODUCTION

One of the impacts caused by water erosion is the exhaustion of soil lacking due to the loss of nutrients, organic matter, siltation and contamination of water tables, through the displacement of fertilizers and pesticides, causing direct changes in flora and fauna (BERTONI et al., 2012; PIRES et al., 2013). According to Pires et al. (2013) erosion is evaluated as a process of natural origin with the purpose of landscape formation and soil renewal.

Erosivity has been expressed as the potentiality of the erosive agent, wind and/or water, to generate erosion. As for the rainfall erosive capacity procedure, the EI30 (kinetic energy of impact of "E" drops by the maximum rainfall intensity in 30 minutes) was created and the “R” factor of the Universal Soil Loss Equation was suggested as a rainfall index (WISCHMEIER et al., 1978). FOSTER et al. (1981) dimensioned the units for the International System of Measurements, expressing in MJ.mm/h year ago. With the help of rainfall correlation and erosivity, the rainfall erosive potential of a location with the same climate type and which does not have rainfall data records is estimated (OLIVEIRA et al., 2012; TRINDADE et al., 2016).

In the northeastern semiarid region, precipitation spreads irregularly with long periods of drought. Temperatures register higher averages causing high evaporative and evapotranspiration rates (CLEMENTE, 2021; MARENGO, 2008). Precipitation in this region is a result of atmospheric dynamics, and the influence of local and regional factors, such as relief and geographic position (MARENGO et al., 2011).

Medeiros et al. (2016a) analyzed the oscillations of El Niño and La Niña and their influence on the number of rainy days in the municipality of Bom Jesus do Piauí. For the Northeast, the periods of El Niño are associated with the scarcity of rain and La Niña, in general, with abundant rainfall, while in the South and Southeast regions conditions are observed with opposite events. The El Niño south oscillation (ENOS) considerably influences the climate in places where it operates, with long periods of drought and total rainfall above historical normal’s (ROMERO, 2013).

Medeiros (2018) showed that there is a lack of studies on the correlation of rainfall with large-scale climatic phenomena, such as El Niño and La Niña. The author analyzed the influence of rainfall variability and the number of rainy days in the city of Recife - PE, and their relationship with the phenomena El Niño and La Niña. According to this author in the dry four-month period, which corresponds to October, November, December, and January, there is no interference from the El Niño and La Niña episodes in the increases and decreases in the days with rain occurrences, which are directly linked to local factors such as breeze, convective movements and line of instability. The phenomena El Niño and La Niña have little influence on the days with rain occurring in Recife - PE, because in the months with the greatest intensity of these episodes, the trend curves showed no increase or decrease. Coherent results were found in the studies by Medeiros et al. (2016) for the municipality of Bom Jesus do Piauí.

França et al. (2018) calculated the climatological water balance for the municipalities of São Bento do Una and Serra Talhada and investigated the influence of the phenomena El Niño (2012, 2016) and La Niña (2008, 2011) on the distribution of rainfall through analysis of the water balance extract. They found that the El Niño episode influenced the rainfall rates of the cities studied. In the La Niña episode, the distribution of these indices was irregular, reflecting on the water balance.

Medeiros (2014) analyzed the occurrences of extreme precipitation events in Campina Grande, with daily data covering the years 1970–2010. The extreme events analyzed were those with the highest daily precipitation intensity. The results showed that there was a change in the behavior of precipitation occurrences from the 70s onwards. There was an intensification in the maximum precipitation with a greater number of events with precipitation values greater than 80 mm. There was, in general, no direct relationship between the increase in precipitation and occurrences with ENSO events. Extreme events were evident between the months of the rainy season with 88% of occurrences, and 12% of evidence in the dry season. Medeiros et al, (2012), analyzing the climatology of precipitation in the city of Bananeiras - PB, in the period 1930-2011, as a contribution to Agroindustry, found that rain gauges are essential to agro-industrial sustainability even with activities from external events

The objective is to evaluate the erosive index for the municipality of Amparo de São Francisco – Sergipe, relating them to the El Niño and La Niña phenomena.

II. MATERIAL AND METHODS

Amparo de São Francisco is limited to the east and south by Telha, to the west by Canhoba and the state of Alagoas to the north, it is positioned at 10°08'04" south and 36°55'46" west, with an altitude of 51 meters (Figure 1)

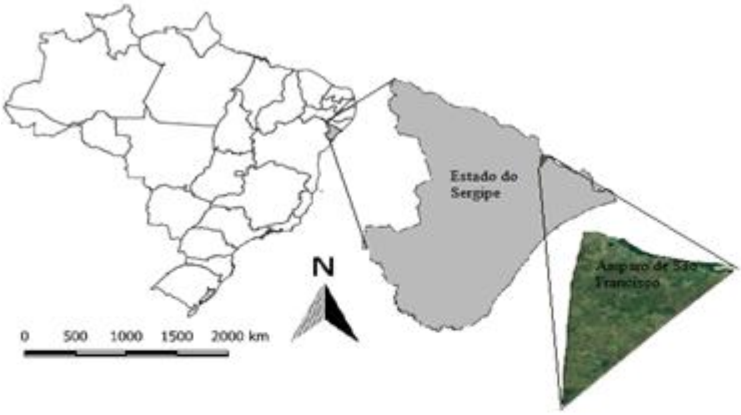

FIGURE 1: Positioning of the city of Amparo de São Francisco within the state.
Source: França (2022).

Monthly and annual rainfall data provided by the Superintendence for the Development of the Northeast (SUDENE, 1990) and the Agricultural Development Company of Sergipe (EMDAGRO - SE, 2020) between 1963 and 2019 were used.

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, flowing from September to January. According to the climate classification (KÖPPEN 1928; KÖPPEN et al., 1931; ALVARES et al., 2014), the study area has an "As" type climate (hot and humid Tropical rainy). Annual precipitation of 1138.2 mm; maximum temperature of 31.5 °C; average temperature of 25.9 °C; minimum temperature 20.9°C; annual relative humidity of 80.2% and total insolation of 2341.9 hours. (FRANÇA, 2021).

It is interesting to note that the rainy season is marked by intense and frequent rainfall in a short period of time, favoring the emergence of erosion, since due to the frequency of rain in a short period, the water cannot infiltrate into the soil and ends up carrying out solid particles.

The equation for erosive calculations in the municipality of Amparo de São Francisco – Sergipe was developed by França et al. (2021)/

$$EI_{30} = 0{,}3908(P)^{1{,}651}$$

Where

EI30- factor R (MJ mm ha^{-1} h^{-1} yr^{-1}) for the studied region;

P - Monthly or annual precipitation (mm).

The calculation of pluvial and erosive anomalies was used, generating their respective graphs for the area under study coupled with the extreme events of large scale El Niño and La Niña to see the erosive contributions of the studied area.

Table 1 shows the classification and intensity of the El Niño and La Niña phenomena, for Amparo de São Francisco – Sergipe.

TABLE 1
CLASSIFICATION AND INTENSITY OF EL NIÑO LA NIÑA PHENOMENA BETWEEN THE YEARS 1963 TO 2019

years	classification	Intensity	years	classification	Intensity
1963			1992	El Niño	Forte
1964	El Niño	Fraco	1993	El Niño	Forte
1965	El Niño	Forte	1994	El Niño	Moderado
1966	El Niño	Forte	1995	El Niño	Moderado
1967	La Niña	Fraca	1996	La Niña	Fraca
1968	El Niño	Moderado	1997	El Niño	Forte
1970	El Niño	Moderado	1998	La Niña	Moderda
1971	La Niña	Moderada	1999	La Niña	Moderada
1972	El Niño	Forte	2000	La Niña	Moderda
1973	El Niño	Forte	2001	La Niña	Moderdo
1974	La Niña	Forte	2002	El Niño	Moderado
1975	La Niña	Forte	2003	El Niño	Moderado
1976	La Niña	Forte	2004	El Niño	Forte
1977	El Niño	Fraco	2005	El Niño	Forte
1978	El Niño	Fraco	2006	El Niño	Forte
1979	El Niño	Fraco	2007	El Niño	Forte
1980	El Niño	Fraco	2008	La Niña	Forte
1981			2009	El Niño	Fraco
1982	El Niño	Forte	2010	El Niño	Fraco
1983	El Niño	Forte	2011	La Niña	Moderada
1984	La Niña	Fraca	2012	El Niño	Moderado
1985	La Niña	Fraca	2013	El Niño	Forte
1986	El Niño	Moderado	2014	La Niña	Neutra
1987	El Niño	Moderado	2015	El Niño	Forte
1988	El Niño	Moderado	2016	El Niño	Forte
1989	La Niña	Forte	2017	La Niña	Moderada
1990	El Niño	Forte	2018	El Niño	Moderado
1991	El Niño	Forte	2019	El Niño	Forte

Source: CPTEC/INPE.

III. RESULTS AND DISCUSSIONS

Figure 2 shows the variability of rainfall and erosive anomalies in the La Niña period for the protection of São Francisco – Sergipe. Remember that all Figures were created by pluvial and fluvial anomalies in the study area, taking into account the La Niña periods.

The year of 1964, except for the month of April, registered erosion superior to the pluvial indices, the months of January, February and from May to December the erosive indices were inferior to the pluvial ones, therefore the year of 1964 the rains were of irregular significance and of low distribution rainwater.

In 1965, rainfall and erosive anomaly rates were negative from February to June. In the months of August to December, the rainfall indices were few causes of erosion, that is, the rains were not well distributed and did not cause erosivity as expected.

In 1967, the rainfall distribution of greater intensity and in a short period of time caused anomalous erosivity in the months of April, May and July.

FIGURE 2: Rainfall and erosive variability in the La Niña period for Amparo de São Francisco – Sergipe.

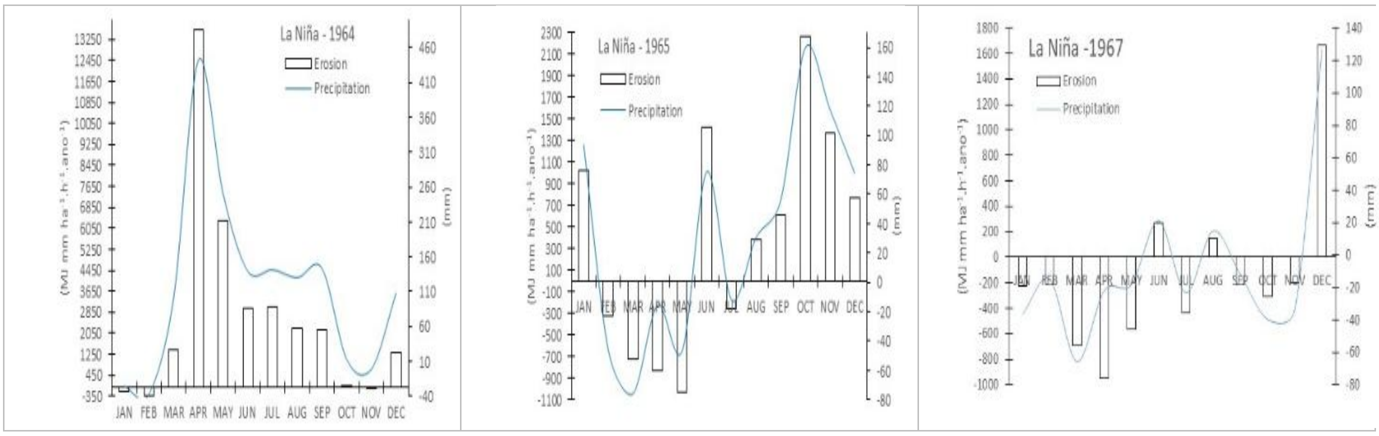

FIGURE 2 (A)
Source: França (2022).

The year 1968 registered negative anomalies for both elements under study, except for the month of May. Rainfall in the study year was below the climatological normal and its distributions were more irregular than normal.

The year 1970 registered negative anomalies in rainfall and erosivity, except in March and November. The months from April to July stand out, where both elements under study had their greatest variability due to rainfall irregularities. These irregularities are discussed in the studies (MARENGO et al., 2011; MARENGO et al., 2008 and MENEZES et al., 2011).

With positive anomalies in rainfall and less irregular distribution throughout the year, it recorded erosive indices above its normais pattern, as can be seen in 1971.

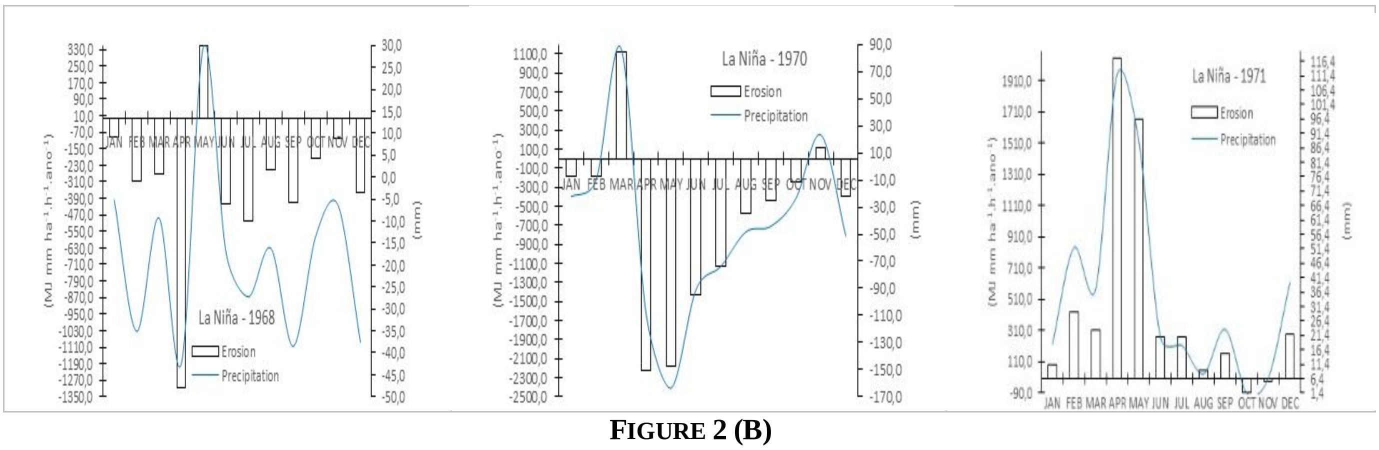

FIGURE 2 (B)
Source: França (2022).

The years 1973 and 1974 show positive rainfall and erosive anomalies ranging from 30 (MJ mm/ha h year) to 4450 (MJ mm/ha h year) and rainfall flowing from 13 mm to 193 mm while fluctuations 1974 erosions occurred between -200 (MJ mm/ha h year) to 1800 (MJ mm/ha h year) and rainfall with anomalies from -30 mm to 100 mm, stand out even though in 1974 in the month August, there were negative anomalous rates of erosion and rainfall.

The erosive and rainfall variability in 1975 registered positive anomalies from January to May and negative anomalies from June to December. Expected, that is, above normal.

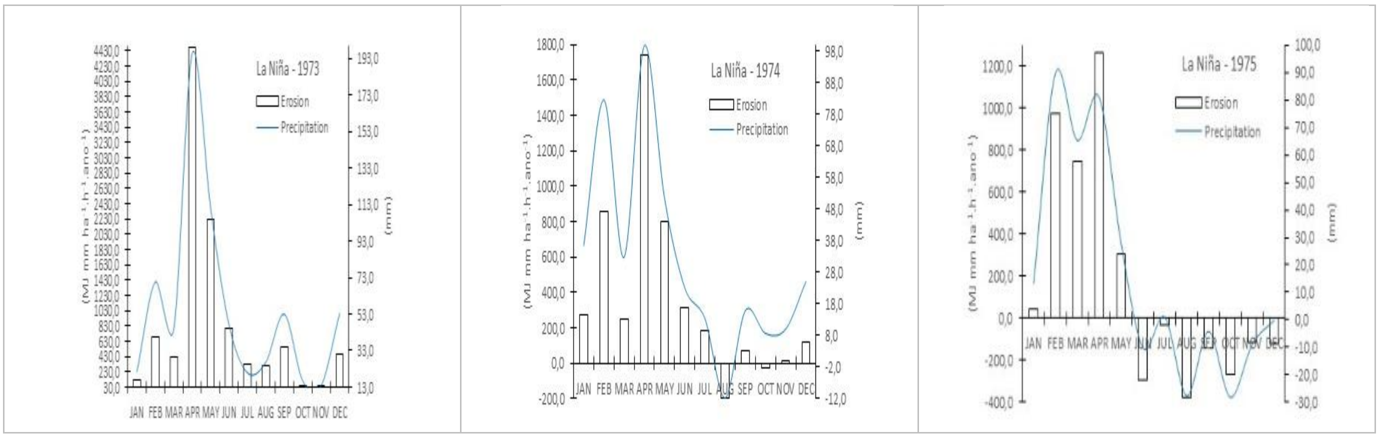

FIGURE 2 (C)
Source: França (2022).

The irregularities in the pluvial indices registered in the year 1976 also cause irregularities in the erosive indices, the months of April, May, June, August, September stand out with high incidences of negative anomalies for the elements rain and erosion.

With positive anomalies for precipitation and erosion from January to May and September. In the months of June to August and October and November there are negative anomalies of rain and erosion. The high rates of positive anomalies for rain were caused by atmospheric variability aided by the regional and local systems for the year 1983.

The anomalous erosive and pluvial indices for the year 1984 were all negative, where the rains that occurred were not necessary for many activities in the study region. The months from April to July stand out with the highest erosive and rainfall indices, while in the months from August to January these elements registered the lowest values. These fluctuations in rainfall are similar to the study by France (2021).

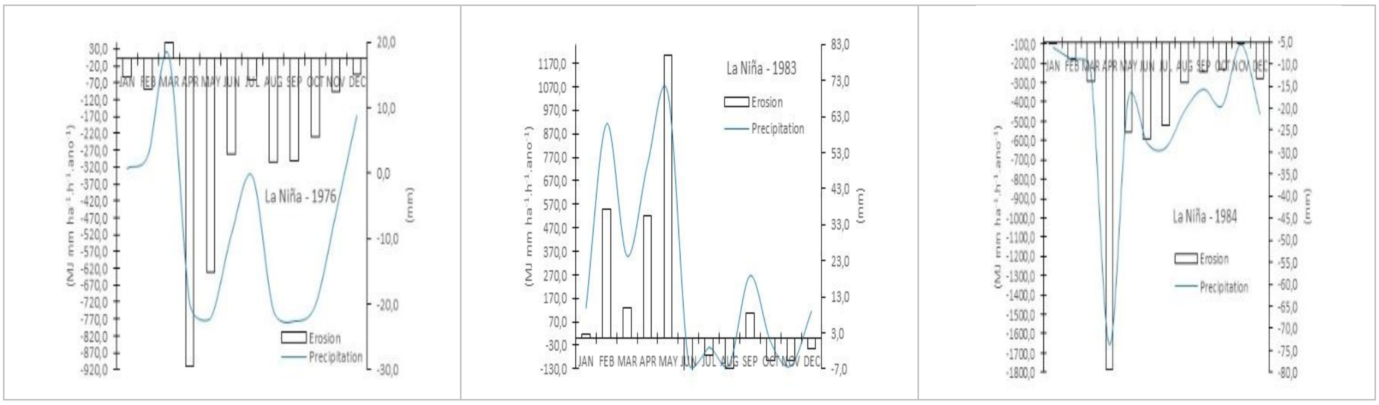

FIGURE 2 (D)
Source: França (2022).

The year 1985 was characterized by negative rainfall and erosion anomalies. The month with the highest rainfall and erosivity was April and the lowest rainfall and erosive index was November. In 1989, attention is drawn to the months from June to December, which registered positive rainfall and negative erosivity, showing that the rain did not have the necessary intensity to cause runoff and drag the soil, on the other hand, the month of March the highest indexes of these elements were registered.

The erosive and pluvial variability of 1995 show us irregularities where the month of April registered the biggest indices of pluvial and erosive anomalies, as well as the month of June the biggest positive values of the elements in studies. Such fluctuations in these years are similar to the study by França (2021).

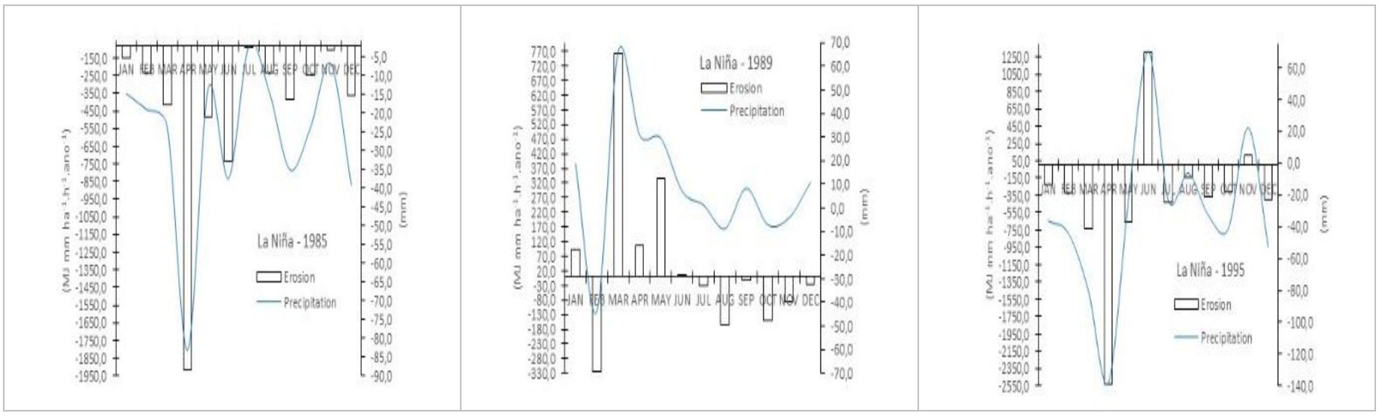

FIGURE 2 (E)
Source: França (2022).

The year 1996 registered positive rainfall and erosion anomalies in the months of April and August, the erosion anomalies were 400 (MJ mm/ha h year) and 900 (MJ mm/ha h year) while the anomaly indices rainfall was 400 mm and 600 mm in the months of May and November, the smallest anomalies of the elements under study are observed. The other months had negative anomalies, being September the one with the highest intensities and January the one with the lowest fluctuations.

With negative fluctuations observed from February to December (1998) in both elements of studies. It is noteworthy that the pluvial anomalies were more intense than the erosive ones, the month of January registered positive anomalies. This study is similar to the study by França et al (2021).

The positive anomalies occurred between September and November were caused by isolated synoptic systems aided by local factors causing anomalous erosion rates between 250 to 400 (MJ mm/ha h year), in the other months of that year (1999) there were negative erosion anomalies and precipitation.

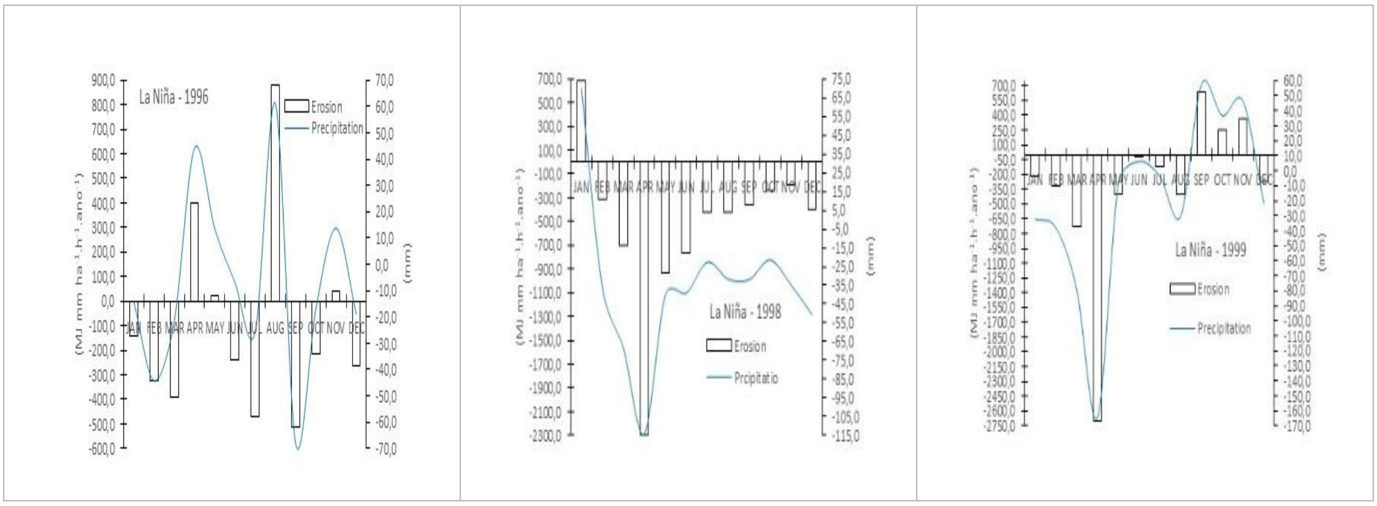

FIGURE 2 (F)
Source: França (2022).

The year 2000 was characterized by erosive anomalies and negative rainfall with fluctuations flowing between -50 (MJ mm/ha h year) to -1800 (MJ mm/ha h year), the rains recorded were not necessary to meet the water needs of the place of study. The highest erosivity and negative rainfall occurred in May and the lowest erosivity and anomalous rainfall occurred in January, February, April, June, September and December.

With irregular variability of pluvial and erosive anomalies seen for the year 2001 and with the months of June (larger), July, August (smaller), October and December positive anomalies the other months were registered negative anomalies with the months of April and May (major) and January to March (smaller).

The months of February (smaller) March (larger), May and August (2007) recorded positive anomalous indices, in the other months the anomalies of the elements in studies were negative, these variability show similarities in the studies of (SHAMSHAD et al., 2008; CARVALHO et al., 2014).

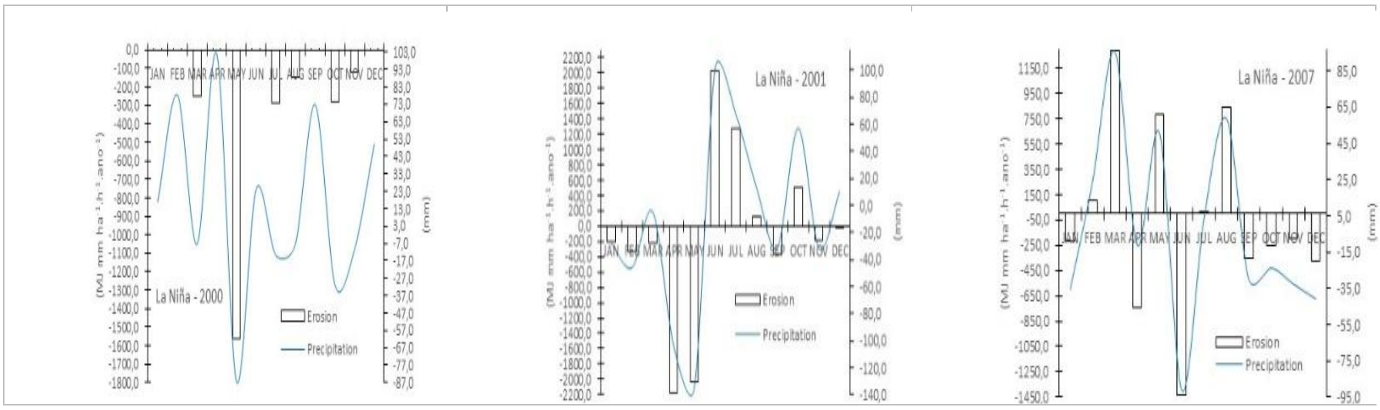

FIGURE 2 (G)
Source: França (2022).

The year 2008 registered a positive anomaly of erosivity and rainfall in the months of February and March, the positive erosive index ranged from 110 (MJ mm/ha h year) to 1500 (MJ mm/ha h year) and rainfall from 25 mm to 115 mm. In the other months, the anomalies were negative and their greatest fluctuations were registered in the months of April -2500 (MJ mm/ha h year) and -115 mm, in the month of June it was observed -1000 (MJ mm/ha h year) and -55 mm.

2010 was characterized by irregular erosive and pluvial anomalies, in negative anomalies, the highest rainfall and erosive variability was recorded in May and the lowest occurrence in January. The biggest erosive and pluvial occurrence was registered in June and the smallest occurrence in the month of July. In the year of 2010 the biggest negative fluctuation of the elements in studies was for the month of May and the smallest in January.

The biggest negative oscillation of erosion and rain occurred in the month of June and the smallest in the month of September. The month with the highest recorded high erosive and rainfall intensity, these rainfall and erosive irregularities show similarity with the studies by França et al, (2021) and Marengo et al, (2008).

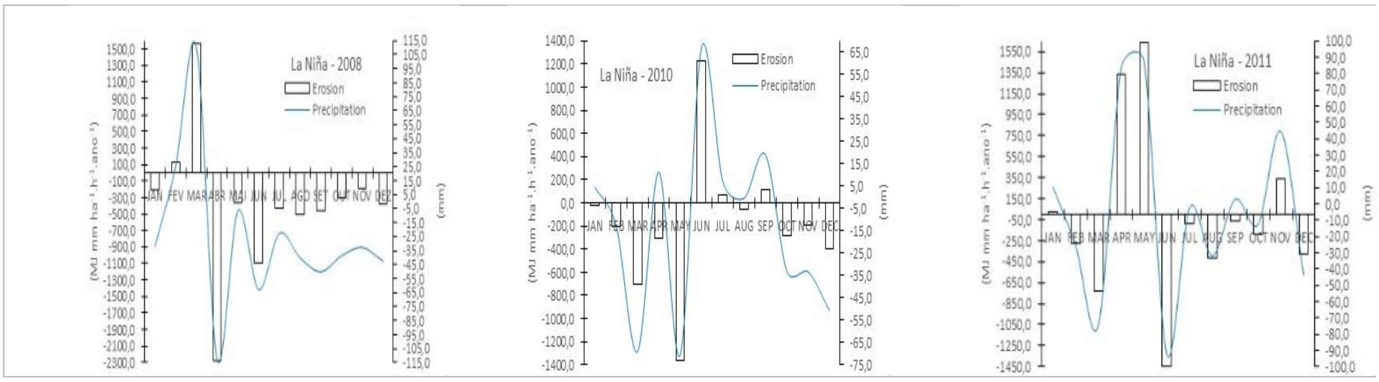

FIGURE 2 (H)
Source: França (2022).

In 2012, negative erosive anomalies were recorded, flowing from 0.0 MJ mm / ha h year to -2800 MJ mm / ha h year and negative rainfall anomalies ranging from 10 mm to -190 mm, these rainfall variations were due to isolated systems microscale and local effects that aided moderate erosivity in the study area.

The rainfall anomaly registered negative values in 10 months (2013) with the exception of July and October, which were positive, the anomaly oscillations flowed between -70 mm to 110 mm these oscillations are in accordance with the results of the studies of (MARENGO 2008; MARENGO et al., 2012; FRANCE 2021).

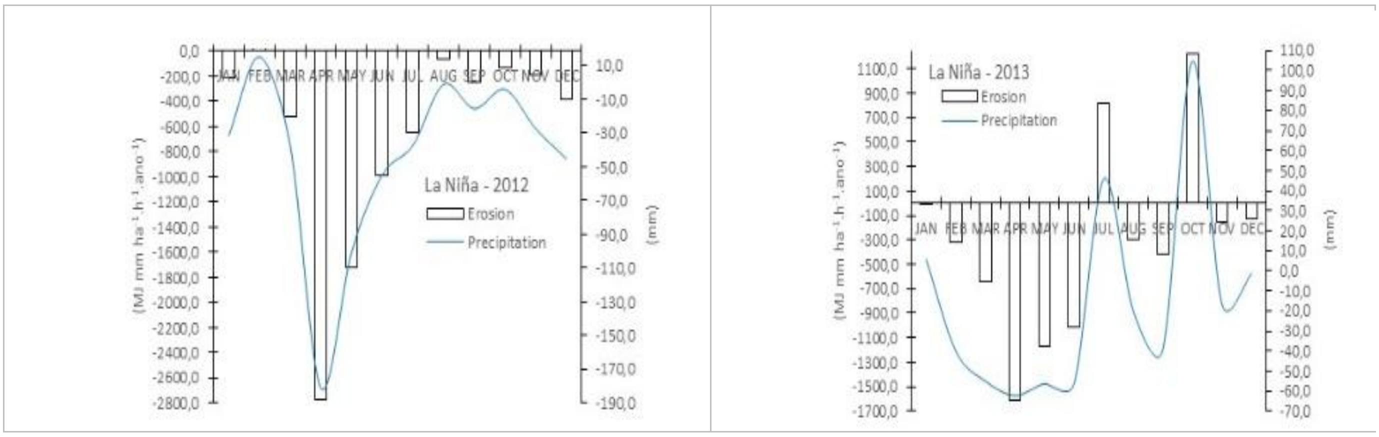

FIGURE 2 (I)
Source: França (2022).

Although monthly rainfall fluctuations and their specialties will explain a large part of the variations in erosivity (BAZZANO et al., 2010), it should be noted that these are not the only factors influencing erosive processes, where we cite the contribution of geology, pedology , relief and land use (SILVA et al., 2014).

According to the IPCC (2014), changes in the variability of rainfall distribution over the years in Northeast Brazil are largely due to large-scale climatological events, such as El Niño and La Niña, which cause heating and cooling of waters in the region. Equatorial Pacific Ocean, influencing the climate, regionally and globally.

Figure 3 shows the variability of rainfall and erosive anomalies in the El Niño period for the protection of San Francisco – Sergipe. Remember that all Figures were created by pluvial and fluvial anomalies in the study area, taking into account the El Niño periods.

With negative anomalies of medium rainfall and erosive intensity recorded in January, September and October, positive anomalies occurred in the other months of 1963. In 1966 there were negative anomalies from June to January with low to very low intensity, the months February, the largest predominated positive anomalies. The year 1969 presents irregularities in its pluviais and erosive anomalies and intensities. Erosive indices are similar to the studies by França et al (2021).

FIGURE 3: Rainfall and erosive variability in El Niño period for Amparo de São Francisco – Sergipe.

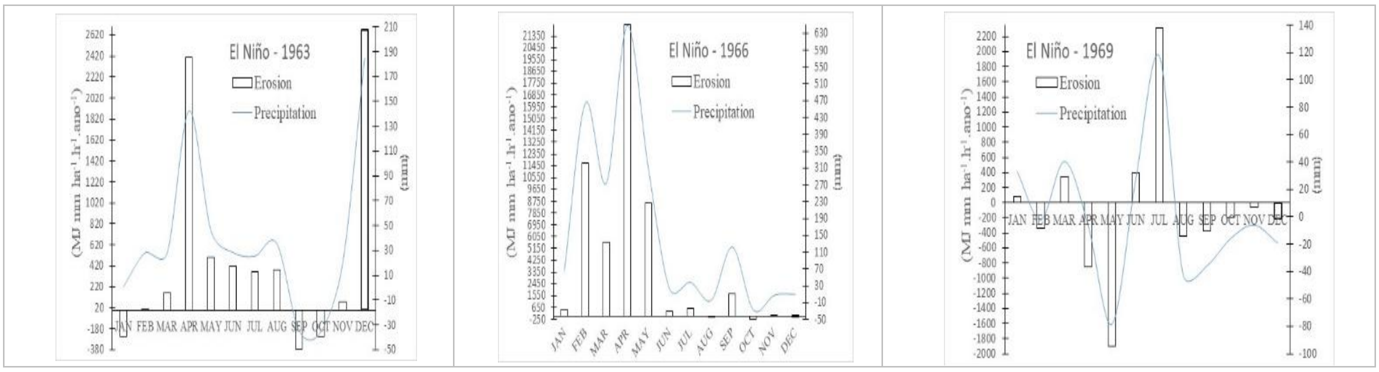

FIGURE 3 (A)
Source: França (2022).

The anomalous behavior of erosivity and rainfall in 1972 were all positive with fluctuations from 10 mm to 14 mm and from 50 (MJ mm /ha h year) to 8000 (MJ mm /ha h year). The year 1977 records rainfall irregularity and erosion in every month of the year, anomalous rainfall indices flowed from -60 mm to 140 mm and erosive indices -700 (MJ mm /ha h year) to 9700 (MJ mm /ha h year). With negative fluctuations for the months of January, February, April, June and October to December, the other months of the year the anomalous erosive and rainfall fluctuations (1978) were positive, such fluctuations corroborate França et al. (2021).

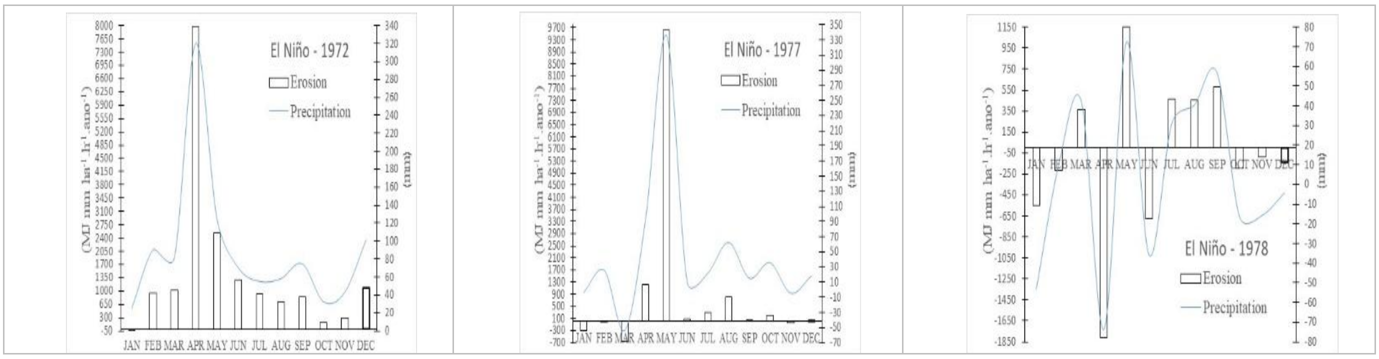

FIGURE 3 (B)
Source: França (2022).

In 1979 there were pluvial and negative anomalies flowing from -60 mm to 30 mm, the erosive anomalies were all positive and their oscillations flowed from 0 (MJ mm /ha h year) to 8000 (MJ mm /ha h year). These oscillations are similar to those found by França et al (2021).

With positive erosive fluctuations flowing between 0 (MJ mm /ha h year) to 2200 (MJ mm /ha h year) while the anomalies registered with negative and positive fluctuations ranging from -200 mm to 120 mm according to the year 1980. For 1981, erosive anomalies ranged from 100 to 4100 (MJ mm /ha h year) and rainfall anomalies were positive with variability from 10 mm to 110 mm.

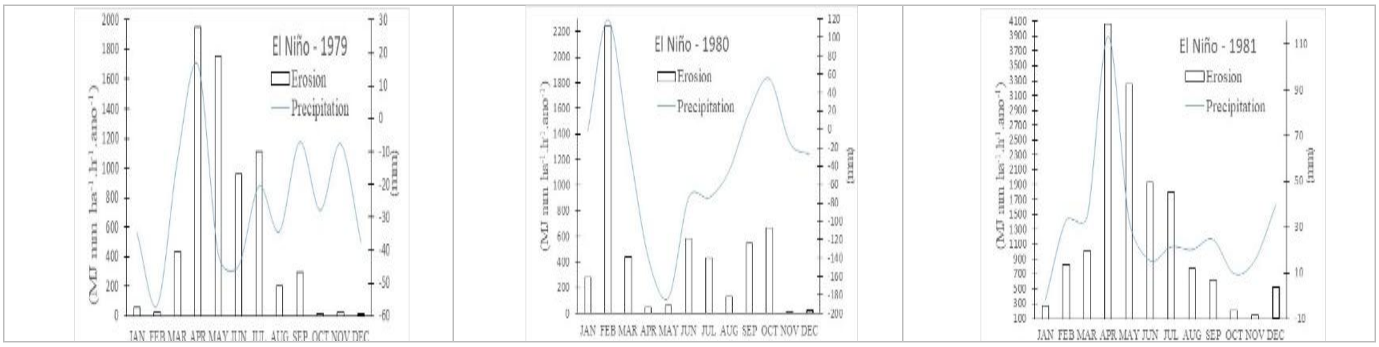

FIGURE 3 (C)
Source: França (2022).

Negative and positive anomaly indices were recorded for erosivity with fluctuations ranging from -220 (MJ mm /ha h year) to 2500 (MJ mm /ha h year), while rainfall anomalies were centered from 10 mm to 150 mm in 1982. The rainfall anomalies in 1986 ranged from -120 mm to 90 mm and erosive anomalies. The year 1987 registered positive erosive anomalies flowing from 0 (MJ mm /ha h year) to 1900 (MJ mm /ha h year) and rainfall anomalies flowed between -160 mm to 60 mm, such oscillations corroborate the results found by França et al, (2021) in their studies for the municipal area of Amparo de São Francisco.

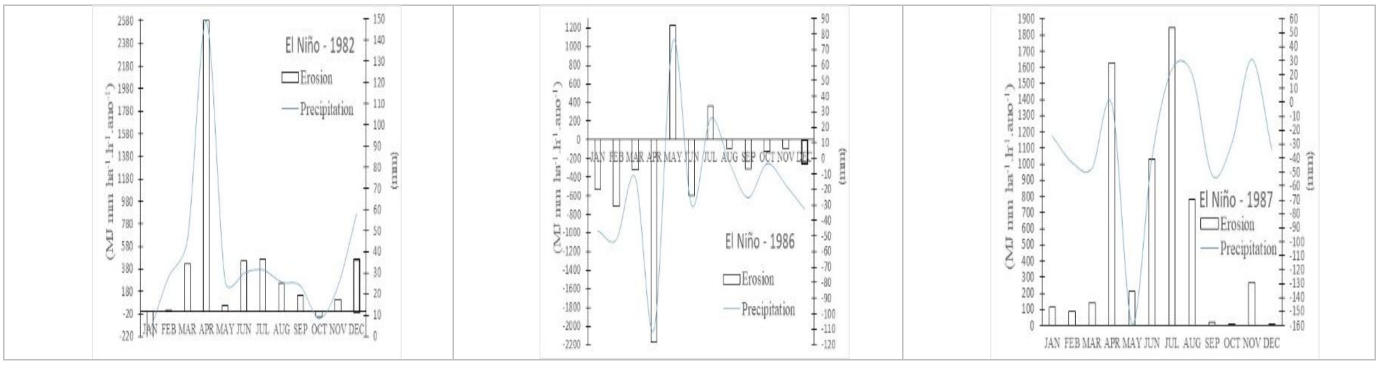

FIGURE 3 (D)
Source: França (2022).

The anomalous variability of erosion ranged from -2750 (MJ mm /ha h year) to 1650 (MJ mm /ha h year) in 1988, the greatest positive anomaly occurred in June with 1650 (MJ mm /ha h year) and in the negative anomaly it was registered in the month of May with -2750 (MJ mm /ha h year). Positive rainfall anomalies were registered in the months of June, November and December in the other months, the respective anomalies were negative.

In 1990, two months of low erosive and rainfall anomalies were recorded in the months of January and October, in the other months the anomalies studied were positive and showed strong irregularities, and these irregularities are in accordance with the studies by Marengo et al, (2007); Marengo et al (2008).

With moderate to strong rainfall irregularity and erosive variability recorded in 1991, these fluctuations are expressed in the study by França et al, (2021) and corroborate the results discussed.

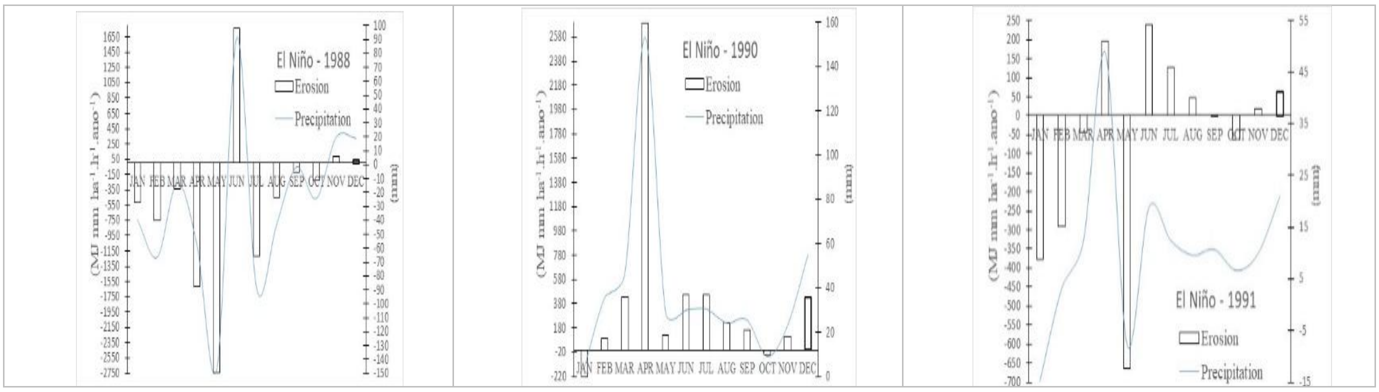

FIGURE 3 (E)
Source: França (2022).

The anomalous erosive and pluvial behaviors of 1992 registered the month of August with low positive index and the other months with moderate to strong oscillations of the elements under study. For the years 1993 and 1994, predominant negative anomalies were observed with moderate intensities and isolated months of positive anomalies for both years studied.

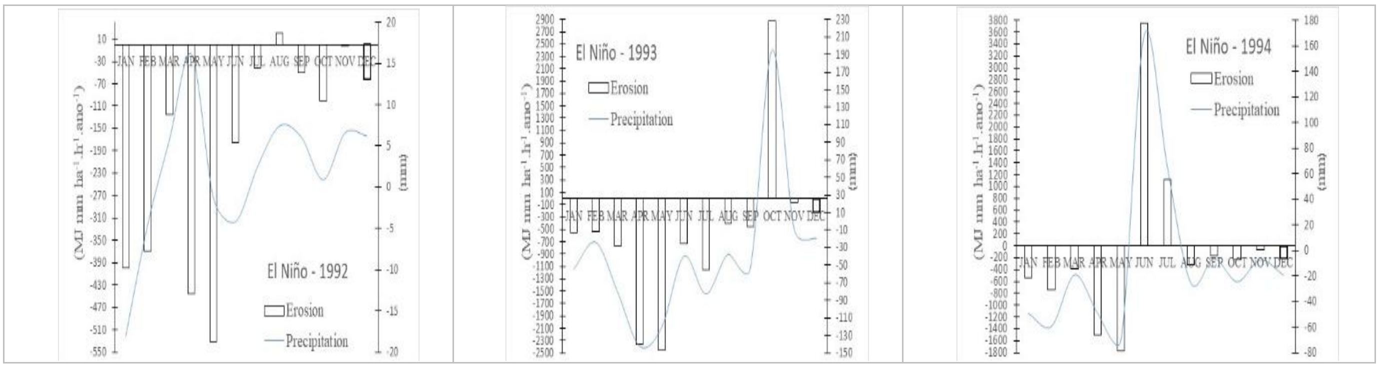

FIGURE 3 (F)
Source: França (2022).

The years 1997, 1998 and 2002 record large anomalous irregularities of rainfall and erosion, most of them being negative anomalies with moderate to strong intensity, these variations have similarities with the study by França et al, (2021).

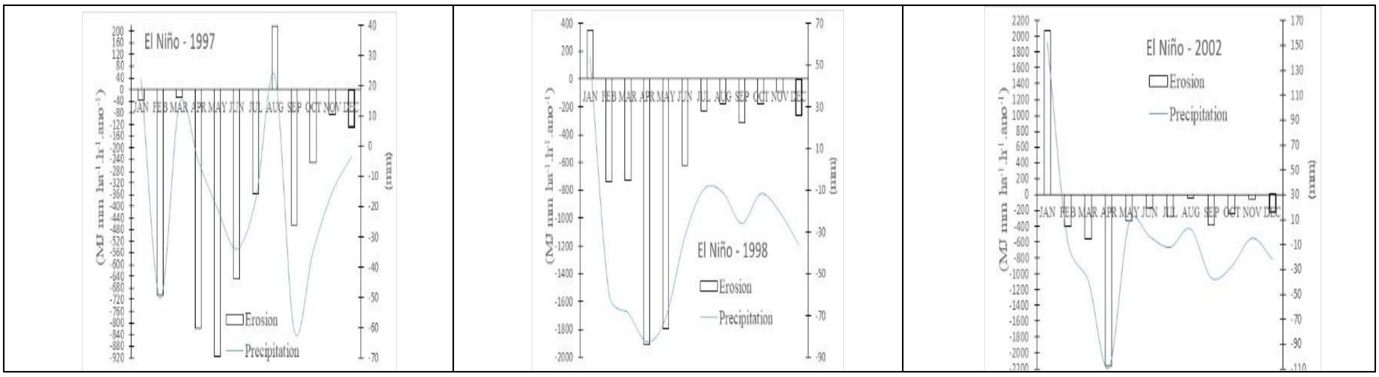

FIGURE 3 (G)
Source: França (2022).

With negative anomalies registered in the months: January, February, April to September and December. The months of April and May had the biggest anomalies and the smallest negative anomaly in December. The months of March, October and November had positive anomalies of weak to moderate intensities for the year 2003.

With a very strong intensity of positive erosion and rainfall anomalies occurring in January, and low intensity in August and September, in the other months of 2004, both elements under discussion were negative anomalies. These erosive fluctuations are similar to the studies by França et al, (2021) and rainfall variations corroborate the results of Marengo et al, (2007) and Marengo et al (2008).

The year of 2005 registered negative pluvial and erosive anomalies in ten months of the year and positive anomalies in the months of May and June, the erosive anomalies were registered between -1500 (MJ mm /ha h year) to 2000 (MJ mm /ha h year), while rainfall anomalies ranged from -80 mm to 120 mm.

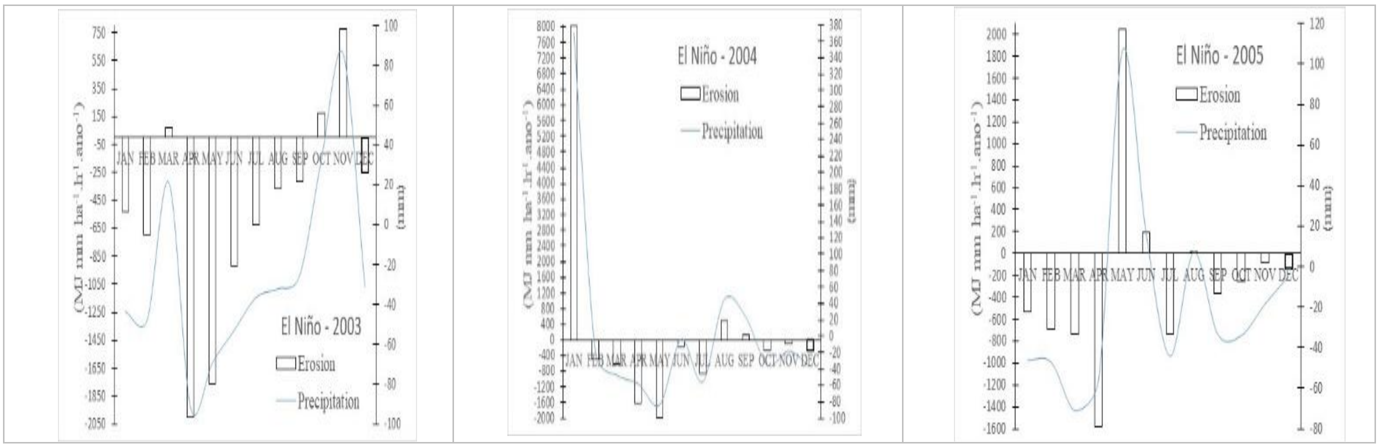

FIGURE 3 (H)
Source: França (2022).

In the figure of the years 2006, 2009 and 2014 the anomalous oscillations of erosivity and positive rain registered four months, two months and two months respectively and in the other months the anomalies were negative, both intensities were from moderate to strong.

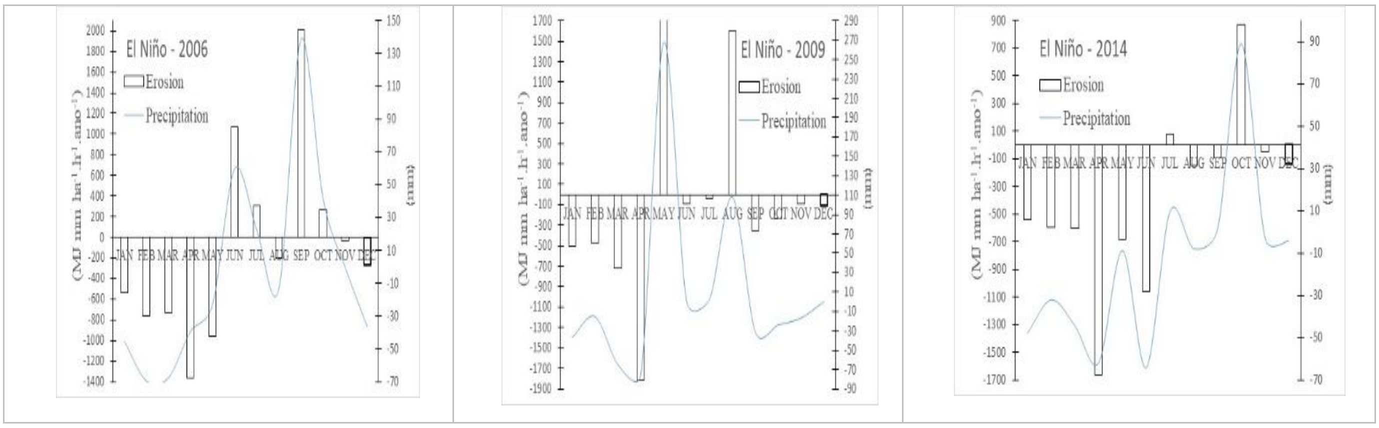

FIGURE 3 (H)
Source: França (2022).

The year 2015 registered eleven months of negative anomalies for erosion and rainfall with fluctuations ranging from -2200 (MJ mm /ha h year) to -100 (MJ mm /ha h year) and rainfall anomalies oscillating from -20 mm to -100 mm. The month of July registers positive anomalies.

With negative rainfall and erosion anomalies between February and December. Its biggest anomalies occurred in the months of June and July and the smallest anomalies were registered in November. January being the only month that there were positive anomalies of the elements studied for the year 2016.

Negative anomalies predominated between November and April and positive anomalies flowed from May to October in 2017. These erosive variables are similar to the studies by França et al, (2021) and rainfall variations corroborate the results of Marengo et al, (2007) and Marengo et al (2008).

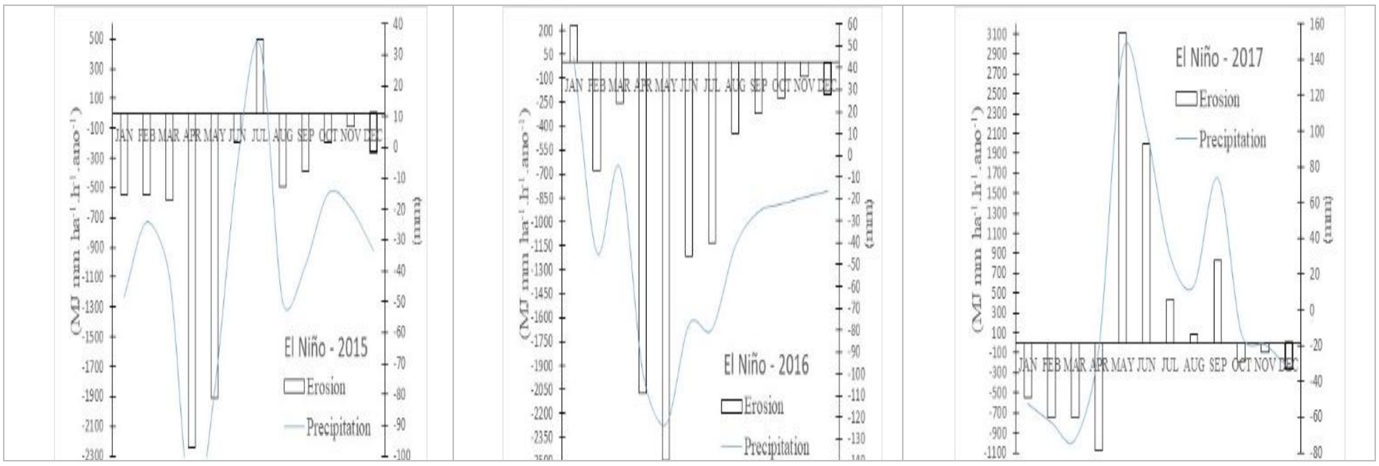

FIGURE 3 (I)
Source: França (2022).

With negative rainfall and erosive rates between March and September 2018, with fluctuations from 1300 to -2100 (MJ mm /ha h year) in erosivity and with oscillation from -115 mm to 10 mm for the rainfall anomaly. The months from October to March registered positive rainfall anomalies and negative erosive indices, showing that rainfall anomalies were not necessary to cause erosion.

The year 2019 registered negative anomaly rates for the elements in studies, except for the month of March, which were positive.

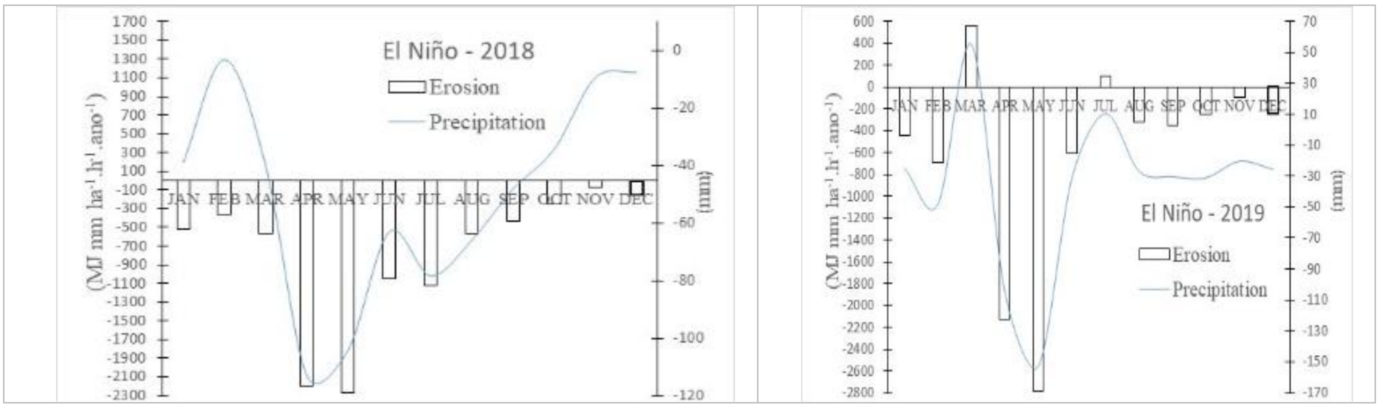

FIGURE 3 (J)
Source: França (2022).

IV. CONCLUSIONS

The anomalous variability of erosion and rainfall against large-scale El Niño and La Niña phenomena did not show large isolated activities in years of their occurrence, since in isolated years both events presented equal intensities in the elements under study.

The erosivity and rainfall indices of anomalies in the study area, taking into account the El Niño and La Niña periods, is a relevant factor for decision makers on the most adequate soil management practices, aiming at the sustainability of exploration for agricultural projects and fertile soil management.

The information provided in the study should serve as a support for the area's conservation planning, where it will be possible to follow strategies to recover and prevent damage to environmental resources and increase the property's productive capacity, contributing to socioeconomic development.

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