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Estimation of Erosivity in The Amparo De São Francisco Municipality, State of Sergipe, Brazil

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ABSTRACT

Soil degradation due to rainfall erosion is one of the serious global, regional, and local environmental problems that have been registered in different parts of the world. The objective of the present work is to compare some erosivity models for the municipality Amparo de São Francisco, Sergipe state, Brazil, aiming at the spatial and temporal variability of the erosive potential. The models were compared to each other, aiming to obtain the best results on the erosive reality of the studied location. The Leprun and Maia Neto Models present or record erosive indices of low moderation and significance. The Leite Júnior, Coelho, and Silva models can be applied to studies of the erosivity of the study area, taking into account the rainfall recorded in 30 minutes. Compared to the other models, the one from France presented plausible erosive values, recommending its application in the study area. With the results obtained, safe parameters that represent erosion with greater significance can be determined.

INTRODUCTION

In Brazil, the areas most susceptible to desertification are those in the States of the Northeast region, characterized by low rainfall and high temperatures in the semiarid climate. Santana (2007) stated that in Brazil four areas stand out as desertification nuclei, that is, areas intensely subject to erosive processes, namely: Gilbués (PI), Irauçuba (CE), Seridó (PB), and Cabrobó (PE). In all these nuclei, anthropic action, responsible for the removal of native vegetation (Caatinga), leaving the soil bare, exposed to accelerated erosion, can be highlighted as the main triggering factor for the problem.

For some authors (WEI *et al.*,2017; SILVA et al., 2009; CUTILLAS et al., 2009) the estimation of erodibility has generated wide interest in recent decades and from this, several studies have been produced to obtain the erosive index. Erosive indices are affected by intrinsic soil characteristics, such as texture, aggregate stability, shear strength, water infiltration capacity, and other chemical and organic attributes (BLANCO et al., 2008; MORGAN, 2005).

Erosivity can be expressed as the potential capacity of the erosive agent, wind or water, to cause erosion. As for the rainfall erosive capacity procedure, the EI_{30} (kinetic energy of impact of the "E" drops by the maximum rainfall intensity in 30 minutes "EI_{30}") was created and the "R" factor of the Universal Loss Equation was suggested as a rainfall index of Soil (WISCHMEIER et al., 1978). FOSTER et al., (1981) dimensioned the units for the International System of Measurements, expressing in MJ.mm/ha.h.year. With the help of rainfall correlation and erosivity, the rainfall erosive potential of a given location with the same climate type and which does not have rainfall data records is estimated, as stated by the authors Oliveira et al., (2012) and Trindade et al., (2016).

For Bertoni et al., (2012) surface erosion processes in the soil are caused by the actions of wind and water caused or generated by wind or water erosion. Water erosion is the most important and worrisome one due to the predominance of the tropical climate that transforms millions of hectares of arable land into unproductive areas, with soils of low agricultural competitiveness (BERTOL et al., 2019). As a result, productive areas suffer losses of 20 to 40 billion tons of soil per year with erosion (FAO, 2015).

For (RAI et al., 2016 and COELHO et al., 1994), land deterioration is one of the serious global, regional and local environmental problems, where all forest ecosystems present considerable changes from their original areas, mainly due to anthropic actions.

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

The objective of the present work is to compare some erosivity models for the municipality Amparo de São Francisco – Sergipe, Brazil, aiming at the spatial and temporal variability of the erosive potential.

MATERIAL AND METHOD

The municipality Amparo de São Francisco (Figure 1) 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 seat has geographic coordinates of 10°08'04" South, 36°55'46" West, and an altitude of 51 meters. It is a region characterized by two well-defined seasons, a rainy period flowing from February to August, and a dry period from September to January. The climate according to the classification of (KÖPPEN 1928 and KÖPPEN et al., 1931) is of the "As" type (hot and humid Tropical rainy). This classification is in agreement with the result of Alvares et al. (2014).

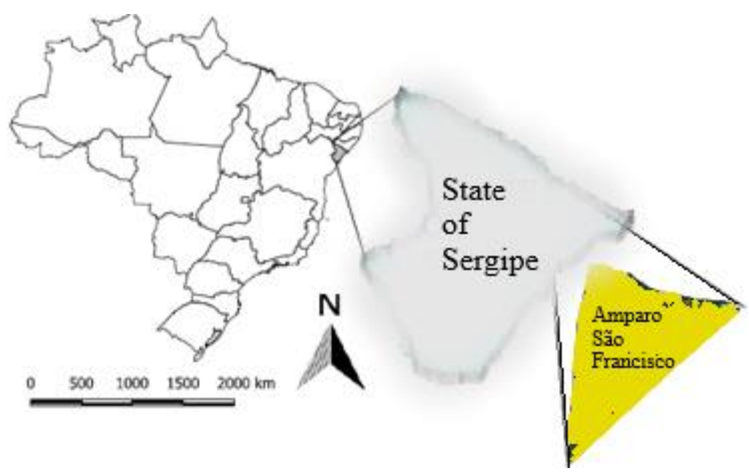

Figure 1. Positioning of the municipality Amparo de São Francisco within the state of Sergipe, Brazil.

Source: França (2021).

Daily data were performed by summing the erosivity values where monthly and annual data were obtained. The average monthly and annual erosivity values represent the monthly and annual estimates of the R Factor of the Universal Soil Loss Equation, obtained for the study area.

Annual rainfall data were acquired from the Northeast Development Superintendence (SUDENE, 1990) and the Agricultural Development Company of Sergipe (EMDAGRO - SE, 2021) corresponding to the period 1963 to 2019.

The equations (Table 1) for studies of rainfall in the Northeast of Brazil were developed in such a way that:

EI_{30}- R factor (MJ mm ha^{-1} h^{-1} yr^{-1}) of a region and/or area;

P - Monthly or annual precipitation (mm).

Table 1. Equations for calculating the EI_{30} in the Amparo area of São Francisco, Sergipe, Brazil, and its comparison with the exclusive formula for the study area.

Ordem	Equations	Referencies
1	$EI_{30} = 0,1300(P)^{1,240}$	Leprun (1981)
2	$EI_{30} = 0,3270(P)^{1,860}$	Coelho (1994)
3	$EI_{30} = 0,8522(P)^{1,461}$	Maia Neto (1996)
4	$EI_{30} = 0,2629(P)^{1,907}$	Silva (1996)
5	$EI_{30} = 0,3820(P)^{1,791}$	Leite Junior (1997)
6	$EI_{30} = 0,3908(P)^{1,651}$	França (2021)

Source: Adapted by França (2021).

The methodology developed by Carvalho (2008) was used to classify the monthly and annual rainfall erosivity for the municipality of Amparo de São Francisco, Sergipe (Table 2).

Table 2. Monthly and annual rainfall erosive classes (R) in the municipality of Amparo de São Francisco, Sergipe, Brazil.

Erosive classes	Valores de Erosividade MJ mm ha^{-1} h^{-1} yr^{-1}
Very low	$R \leq 2452$
Low	$2452 < R \leq 4905$
Average	$4905 < R \leq 7357$
High	$7357 < R \leq 9810$
Very high	$R \geq 9810$

Source: Carvalho (2008).

RESULT AND DISCUSSION

Precipitation is the driving force of the water erosion process, where the detachment and transport of sediments by surface runoff depend on the intensity, frequency, and duration of events in a given area (AMARAL et al., 2014).

Table 3 shows the months of the year, models Leprun (1981), Maia Neto (1996), Leite Junior (1991), Coelho (1994), Silva (1996), and França (2021) and their respective erosive classifications by the methodology de Carvalho (2008).

In the Leprun model (1981) the erosive indices ranged from 8.3 MJ mm ha^{-1} h^{-1} yr^{-1} in November to 85.0 MJ mm ha^{-1} h^{-1} yr^{-1}in May. Their monthly rankings according to Carvalho's (2008) methodology were of very low erosivity. According to Maia Neto's model (1996), erosivity was recorded ranging from 143.2 MJ mm ha^{-1} h^{-1} yr^{-1}in November to 2054.1 MJ mm ha^{-1} h^{-1} yr^{-1}in May. These high fluctuations from April to July are consequences of rainfall during the rainy season. The erosive rating was very low for the study period. Similar results were presented in the studies by França, et al., (2020a) and França et al., (2020b), corroborating the results discussed here.

For the erosive model established by Leite Júnior (1997), the erosive indices ranged from 249.0 (November) to 5805.7 MJ mm ha^{-1} h^{-1} yr^{-1}(May). The months from August to May were classified as having very low erosivity. The months of April and May were classified according to the Oak Table as medium erosivity, and the months of June and July were classified as low erosivity.

Table 3. Months of the year, for models: Leprun (1981); Maia Neto (1996); Leite Júnior (1991); Coelho (1994); Silva (1996) and França (2021) and their respective erosive classifications by Carvalho's methodology (2008).

Meses	Leprun (1981)	Clas	Maia Neto (1996)	Clas	Leite Júnior (1997)	Clas	Coelho (1994)	Clas	Silva (1996)	Clas	França (2021)	Clas
jan	17,0	MB	346,1	MB	809,6	MB	990,5	MB	1018,0	MB	406,1	MB
feb	22,1	MB	476,4	MB	1183,1	MB	1465,7	MB	1519,2	MB	578,8	MB
mar	30,1	MB	630,7	MB	1435,5	MB	1733,5	MB	1763,1	MB	734,0	MB
apr	77,6	MB	1942,1	MB	5805,7	M	7434,1	A	7872,1	A	2640,0	B
may	85,0	MB	2054,1	MB	5812,3	M	7337,6	M	7691,1	A	2712,6	B
jun	67,1	MB	1503,9	MB	3771,5	B	4634,1	B	4767,1	B	1855,9	MB
jul	60,7	MB	1330,5	MB	3216,5	B	3920,3	B	4010,2	B	1608,3	MB
Aug	32,0	MB	636,6	MB	1339,3	MB	1587,4	MB	1593,6	MB	709,6	MB
set	23,0	MB	451,8	MB	939,7	MB	1113,2	MB	1117,5	MB	499,3	MB
out	13,7	MB	260,8	MB	536,9	MB	636,8	MB	640,2	MB	285,6	MB
nov	8,3	MB	143,2	MB	249,0	MB	284,6	MB	279,0	MB	142,5	MB
dec	15,4	MB	303,0	MB	626,5	MB	742,3	MB	745,3	MB	333,3	MB

Caption: MB – Very Low; M - Average; B – Low; A - high.

Source: França (2021).

In Coelho's (1994) erosive model, erosive indices flow between 284.6 MJ mm ha-1 h-1 yr-1 in November to 7434.1 MJ mm ha^{-1} h^{-1} yr^{-1}in April. The months from April to July stand out, with the highest erosive indexes. The classifications for the Coelho model were as follows: between August and February the erosive power was very low; the month of April was high; may like average rating, and June and July were classified as low.

Erosive indices ranged from 279.0 MJ mm ha^{-1} h^{-1} yr^{-1}(November) to 7872.1 MJ mm ha^{-1} h^{-1} yr^{-1}(April) and their ratings were very low between August and February; high in April and May; and low between June and July.

In the model from France (2021), erosivity was recorded flowing between 142.5 MJ mm ha^{-1} h^{-1} yr^{-1}(November) to 2712.6 (MJ mm ha^{-1} h^{-1} yr^{-1})(May). The ratings were Very Low (MB) from June to March and Low (B) in April and May.

The values displayed by these models describe the greatest potential of the studied area for April to July, in which 60% of the erosive potential is concentrated, which requires the adoption of soil and water management and conservation practices in the areas arable and nonarable, to avoid environmental damage by soil degradation processes with water erosion.

Figure 2 shows the fluctuations of the monthly erosive index for the municipality of Amparo de São Francisco, Sergipe, from 1963 to 2019, using the Leprun model (1981), showing the monthly erosive variability. The lowest erosive indices are centered between October, November, and December with fluctuations ranging from 9.1 to 17.1 MJ mm ha^{-1} h^{-1} yr^{-1}. From April to July, the highest erosive indexes in the studied area are registered. Lebrun's model (1981) is not suitable for estimating erosivity in the study area as it reduces erosive rates. Amaral et al. (2014) stated that precipitation is the driving force of the water erosive process, where the detachment and transport of sediments by surface runoff depend on the intensity, frequency, and duration of events in the worked area.

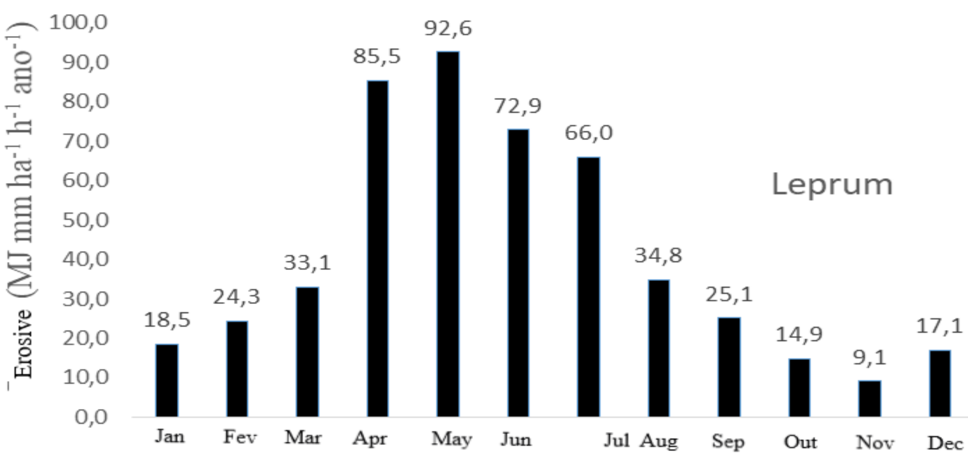

Figure 2. Monthly erosivity index for the municipality of Amparo de São Francisco, Sergipe, from 1963 to 2019, using the Leprun model (1981).

Source: França (2021).

Figure 3 shows the monthly erosive fluctuations for the municipality of Amparo de São Francisco, Sergipe, from 1963 to 2019, using the Maia Neto model (1996). In this model, it is observed that the maximum and minimum erosions are centered in April to July and from October to December. It is noteworthy that in this model the rainy months are underestimated for the calculation of erosivity and that in the dry months there are reductions for this index. Therefore, this model is not recommended for the study area.

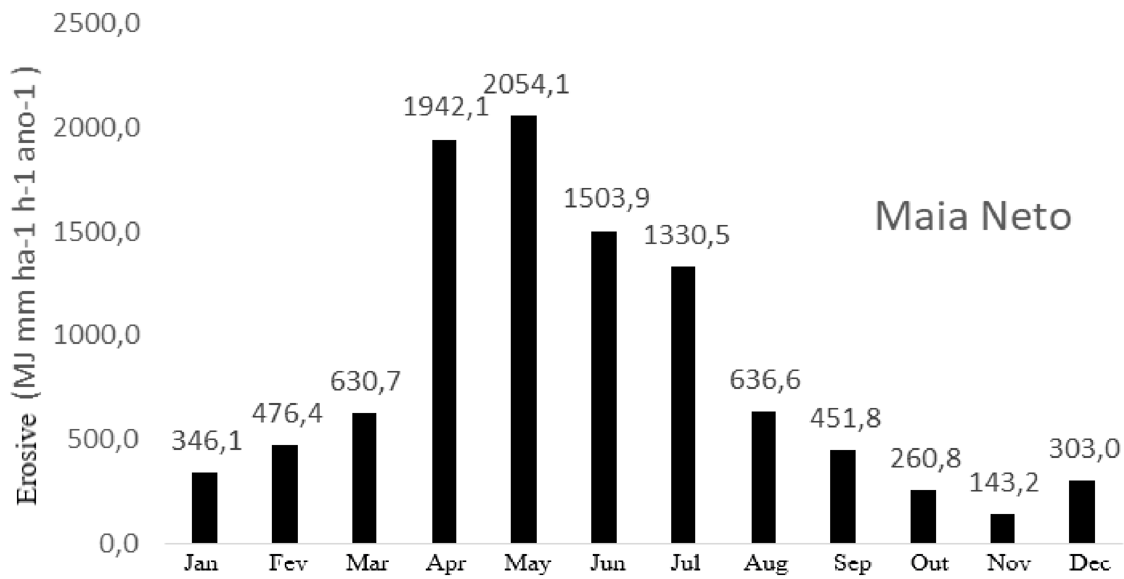

Figure 3. Monthly erosivity index for the municipality of Amparo de São Francisco, Sergipe, from 1963 to 2019, using the Maia Neto model (1996).

Source: França (2021).

In Figure 4, the Leite Júnior (1997) model was used to estimate the monthly erosive index of Amparo de São Francisco between 1963-2019. The erosive values of the dry and rainy periods in this model show more coherent values than those of Leprun and Maia Neto. The month of November stands out, with 249.0 MJ mm ha^{-1} h^{-1} yr^{-1}, and the months of April and May with the highest erosive indexes for the region. The Leite Júnior model already presents good erosive results for both periods with and without rain. The model proposed by Wischmeier et al., (1978) corroborates the results discussed in this work.

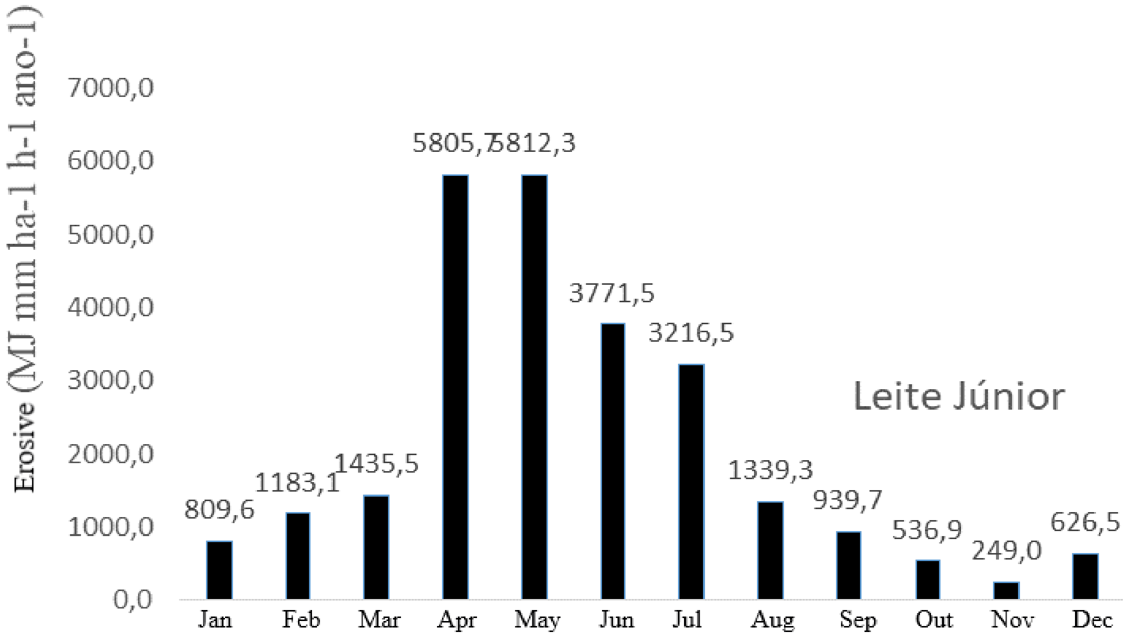

Figure 4. Monthly erosivity index for the municipality of Amparo de São Francisco, Sergipe, from 1963 to 2019, using the Leite Júnior (1997) model.

Source: França (2021).

Figure 5 shows the monthly erosivity index for the municipality of Amparo de São Francisco, Sergipe, from 1963 to 2019, using the Coelho model (1994). This model shows us more consistent erosive values than the Leprun and Maia Neto models, except for November, which registers an erosive index well below normality, and the months of June and July with their reduced indexes. These reductions are by the pluvial indices and their variability referenced by Menezes et al., (2011).

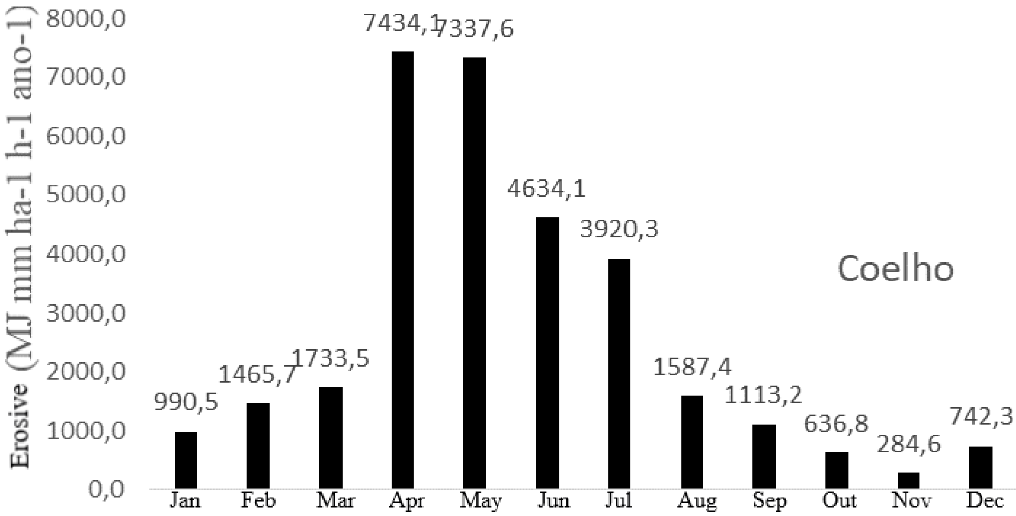

Figure 5. Monthly erosivity index for the municipality of Amparo de São Francisco, Sergipe, from 1963 to 2019, using the Coelho model (1994).

Source: França (2021).

The erosive indices according to Silva's model (1996) for the study area present coherent values for the dry and rainy periods, except for November, which registers values well below its normality. In April and May, there are high erosive peaks and are influenced by synoptic rain systems with extreme events of maximum rainfall and in a short period (Figure 6).

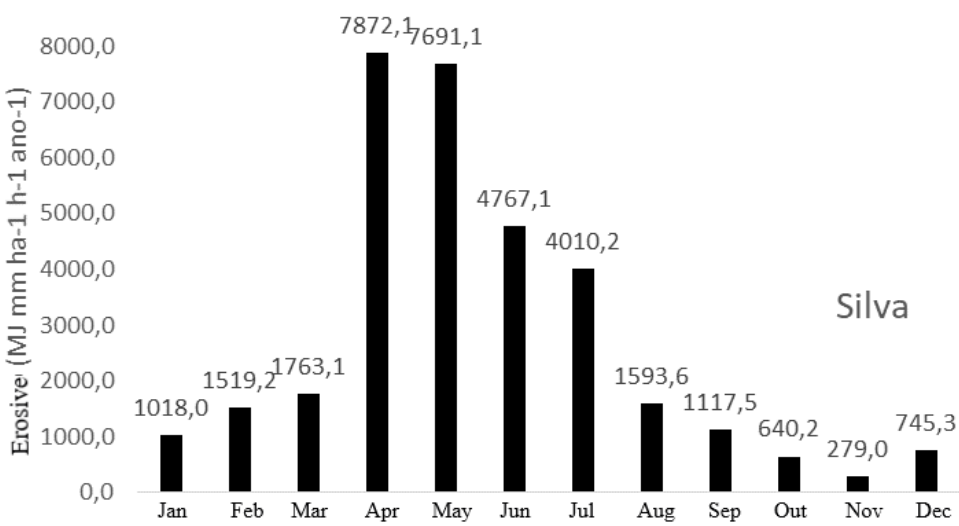

Figure 6. Monthly erosivity index for the municipality of Amparo de São Francisco, Sergipe, from 1963 to 2019, using the Silva model (1996).

Source: França (2021).

The monthly erosivity indices for the municipality of Amparo de São Francisco, Sergipe, in the period 1963 to 2019, using the França model (2021), (Figure 7), demonstrate moderate erosive incidences when compared to the other models studied and already referenced. The months from April to July are the ones with the highest erosivity, and November with a low incidence of erosive. A similar study was carried out by França et al., (2021) and corroborates the results discussed here.

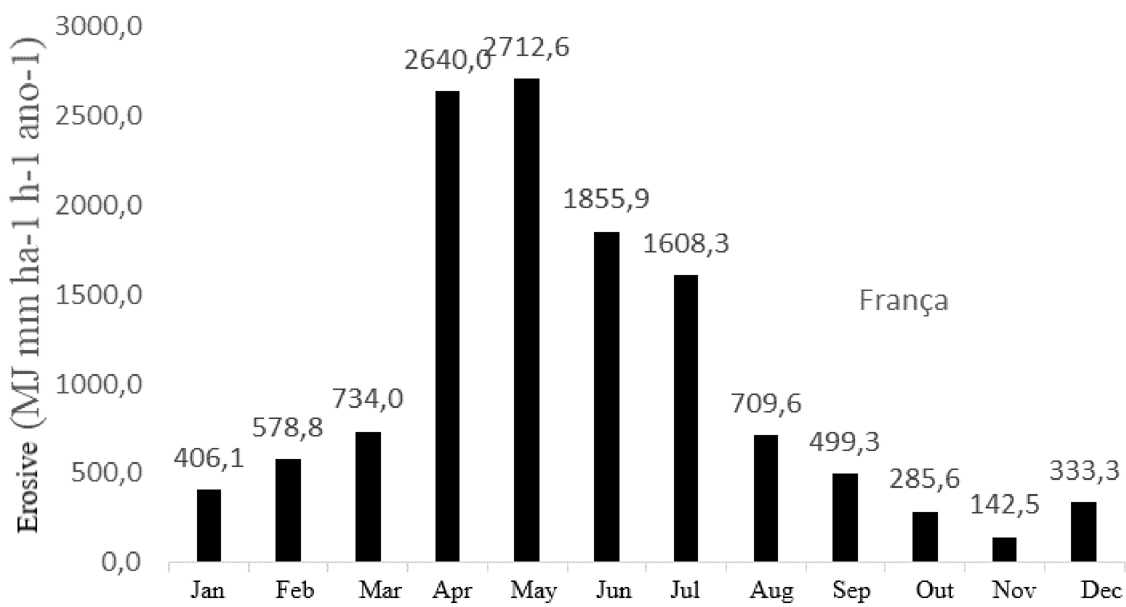

Figure 7. Monthly erosivity index for the municipality of Amparo de São Francisco, Sergipe, from 1963 to 2019, using the França model (2021).

Source: França (2021).

Jan Feb Mar Apr May Jun Jul Aug Sep Out Nov Dec

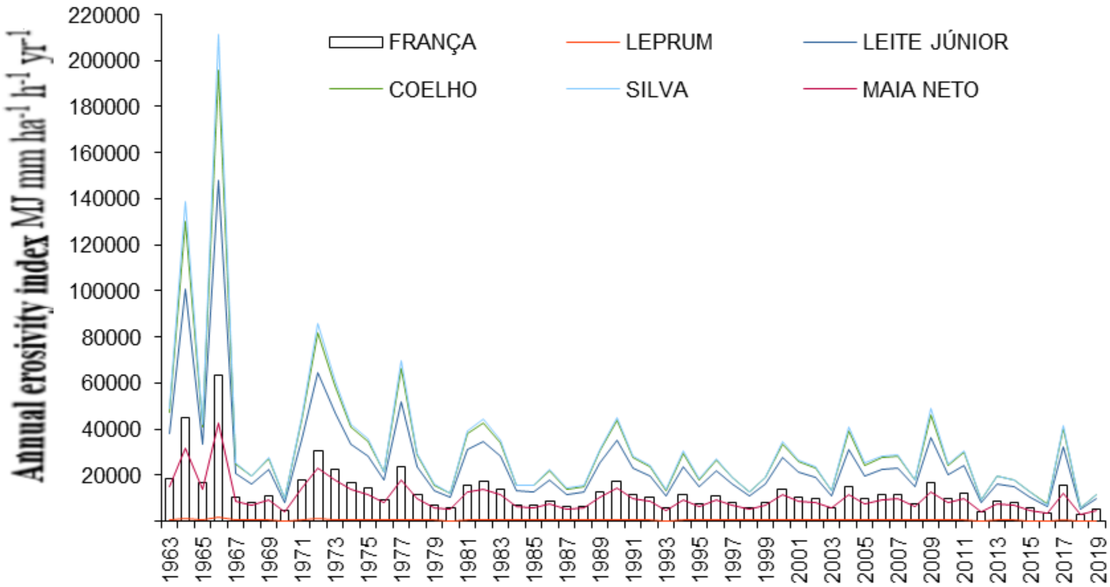

Figure 8. Annual erosivity index and its comparison for the municipality of Amparo de São Francisco, Sergipe, from 1963 to 2019.

Source: França (2021).

Figure 9 shows the rainfall rate, annual erosivity and its standard errors for the municipality of Amparo de São Francisco, Sergipe, from 1963 to 2019, using the models studied. Rainfall rates are the same for all models. Erosive fluctuations gradually increase. The models of Leprun and Maia Neto stand out as those with the lowest erosive indexes. The Coelho and Silva models are practically equal in erosive values, and the França model underestimates the erosive values of the studied area. Standard errors follow the upward trend for erosive indices. This factor is affected by the intrinsic properties of the soil, such as texture, aggregate stability, shear strength, water infiltration capacity and other chemical and organic attributes (Blanco et al., 2008; Morgan, 2005).

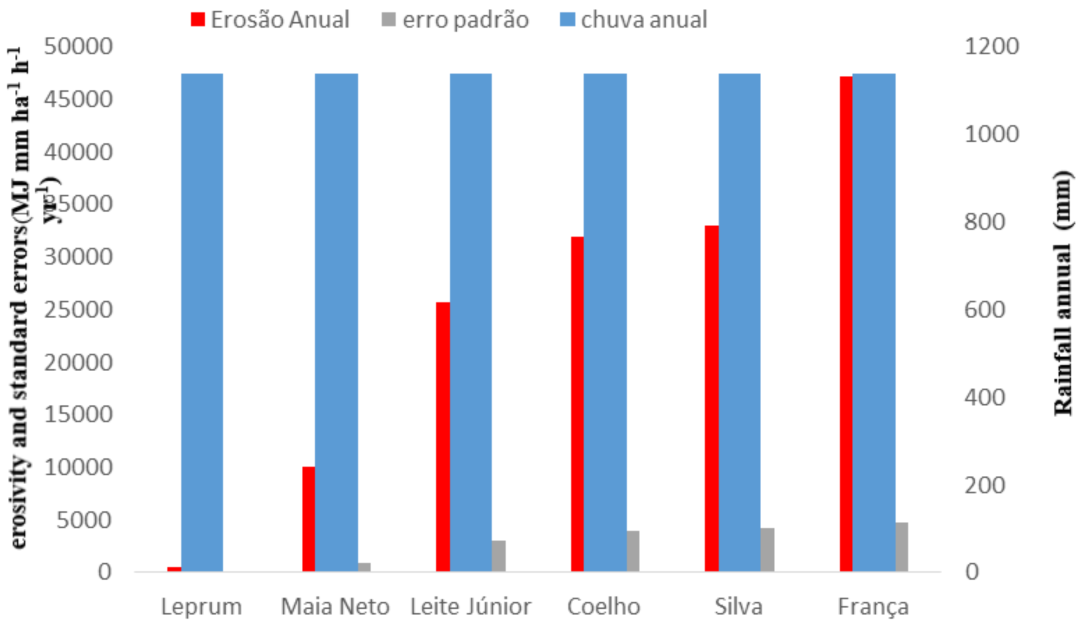

Figure 9. Rainfall rate and annual erosivity and its standard errors for the municipality of Amparo de São Francisco, Sergipe, from 1963 to 2019, using the studied models.

Source: França (2021).

CONCLUSIONS

The Leprun and Maia Neto models record erosivity indices of low moderation and significance.

The models Leite Júnior, Coelho, and Silva can be applied to studies of erosivity in the area, taking into account the rainfall recorded in 30 minutes.

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