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SOIL EROSION AND ROUTES OF USE AND PRODUCTION IN THE MATOPIBA REGION, BRAZIL

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ABSTRACT

The goal was to monitor the production and soil erosion in the “MATOPIBA” region in the last 20 years. The study monitored agricultural production in the Brazilian Savanna, situated in the States of Tocantins (TO), Maranhão (MA), Bahia (BA), and Piauí (PI). The results showed that soybean occupies the largest area, corn and cotton show oscillations and coffee and sugar cane remain with values without major changes. In the production routes, the production areas present a positive correlation with k-apexes higher than 0.60 ($p<0.05$), indicating there is an increase in areas and no negative influence between the crops. The highest average erosivity rates were found respectively in the states of Tocantins and Maranhão. Conclude that the region MATOPIBA presents great potential for Brazilian agriculture requiring private and public actions to make sustainable use of the region through advanced technologies with conservation systems to avoid soil and water losses.

Keywords: Maranhão, Tocantins, Piauí, Bahia, Agriculture

INTRODUCTION

The region known as MATOPIBA, is an acronym created with the initials of the states of Maranhão "MA", Tocantins "TO", Piauí "PI", and Bahia "BA", characterized by the expansion of an agricultural frontier with high crop production that occurred from the second half of the 1980s. Mingoti et al. (2014) affirmed that the MATOPIBA region is composed of diverse and complex scenarios covering crop production in agribusiness and family agriculture with preservation areas.

The MATOPIBA region is mostly composed of the Cerrado biome, occupying about 204 million hectares of the national territory. This biome is characterized by a highly diversified ecosystem with savannas, forests, and grasslands (EMBRAPA, 2006). According to the New Brazilian Forest Code (Law No. 12.651, 05/25/2012), rural properties inserted in the Cerrado biome must preserve and protect 20% of the property with legal reserve. The great areas are covered by soil classified as Latossolo, known for high weathering and leaching degrees, representing an area of 28 million hectares (38% of the MATOPIBA region). Due to low soil natural fertility, crop productions request applications of correctives and fertilizers. However, the region presents favorable physical characteristics for agricultural use, with good permeability and high porosity (EMBRAPA, 2006). The climate is characterized by its humid, dry subhumid, and moist subhumid climate, with the rainy (from October to April) and drought seasons (from May to September) (APARECIDO et al. 2021).

Soil (erodibility) and climate conditions (erosivity) are important points for analyzing the risk of erosion and water losses. Erosivity is classified as the maximum energy of rainfall per unit of rainfall in 30 minutes. While, erodibility is soil susceptibility based on soil texture, organic matter, and soil porosity (JONES et al., 1996). Silva et al. (2019) showed that during the rainy season, the most rainfall presented an intensity between 51 and 120 mm h^{-1} with a duration of 30 minutes, and a huge capacity to cause soil erosion based on the erosive energy.

Based on these aspects, the region still faces great challenges in soil management and conservation and the implementation of integrated production systems. Although widespread in other states of the Cerrado Biome, ecological intensification systems still present great difficulties in implementation, and management over the years (BORGHI et al., 2014). Understanding erosivity and soil in the region is important to define the best time to establish soil management and conservation practices, justifying this presented here

The hypothesis was that opening new areas is promoting soil degradation in the MATOPIBA Region, requiring alternatives to agriculture with good practices to avoid soil erosion. The goal of this work was to monitor the production and soil erosion in the “MATOPIBA” region in the last 20 years.

MATERIAL AND METHODS

Study characterization

The study monitored agricultural production in the Brazilian savanna, situated in the states of Maranhão, Tocantins, Piauí, and Bahia. The climate is predominantly classified as Aw (humid and dry tropical climate or savannah), according to the Köppen-Geiger classification, with an average precipitation of 1,600 mm (750 to 2,000 mm) and temperature between 22 and 27°C.

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Data on production and area were collected from the Brazilian Institute of Geography and Statistics, IBGE (IBGE, 2020), and the National Supply Company, CONAB (CONAB, 2020b). The data on the area and production of sugarcane (stalks) and cotton (herbaceous cotton; seed) were monitored on the IBGE Sidra platform. While, data on the area and production of soybean, corn, and coffee (all grains) were monitored by historical series on CONAB (2020b). Corn data considered the production in summer (1^{st} harvest) and winter (2^{nd} harvest).

Erosivity was calculated using the climate data derived from 15 cities in each state, with a 30-year climate database (from 1981 to 2010) monitored by Climatempo and the National Institute of Meteorology, INMET. The cities monitored were in Maranhão (Açailândia, Tasso Fragoso, Alto Parnaíba, Balsas, Aldeias Altas, Santa Luzia, Turiaçu, Cidelândia, Santo Antônio dos Lopes, Estreito, Miranda do Norte, Caxias, Sambaíba, São Raimundo das Mangabeiras, and Riachão), Bahia (Angical, Bom Jesus da Lapa, Baianopolis, Canapolis, Coribe, Cristopolis, Feira da Mata, Jaborandi, Paratinga, Riachão das Neves, Santa Maria da Vitória, São Desidério, Serra do Ramalho, Serra Dourada, and Sitio do Mato), Tocantins (Gurupi, Porto Nacional, Campos Lindos, Pedro Afonso, Dianópolis, Esperantina, Lagoa da Confusão, Formoso do Araguaia, Caseara, Colinas do Tocantins, Goiatins, Pium, Dueré, and Cristalândia, and Palmas), and Piauí (Uruçuí, Baixa Grande do Ribeiro, Bom Jesus, Ribeiro Gonçalves, Santa Filomena, Currais, Gilbués, Sebastião Leal, Monte Alegre do Piauí, Bertolínia, Corrente, Riacho Frio, Pio IX, São Raimundo Nonato, and Floriano).

Erosivity was calculated according to Carvalho's Equation (1994), represented by Eq 1.

Eq. 1

$$EI = 6{,}886\ x\ (\frac{P_m^2}{P})^{0{,}85}$$

Where EI is the monthly mean of the erosion index (MJ mm/h ha), P is the mean annual precipitation (mm) and Pm is the mean monthly precipitation (mm).

The quality of the dataset was tested using the data normality (Shapiro–Wilk test; $p < 0.05$) and homogeneity of variance (Bartlett test; $p < 0.05$). The routes of soil use with crops were monitored using the data of all years and states and correlated by the Pearson correlation test ($p < 0.01$), representing the results in the tree grafo (adapted). The routes between crops were linearly correlated and represented by Hamiltonian Cycle (Hamiltonian route), described as a closed grafo where every k-apex is visited exactly once. All the data analysis was performed on the R programming language (R, 2020).

RESULTS AND DISCUSSION

Production profile

In the last 20 years, soybean had occupied the largest area with an annual area of 4 million hectares. Corn and cotton show fluctuations with an average of 1 million hectares for corn and 0.5 million for cotton (Figure 1).

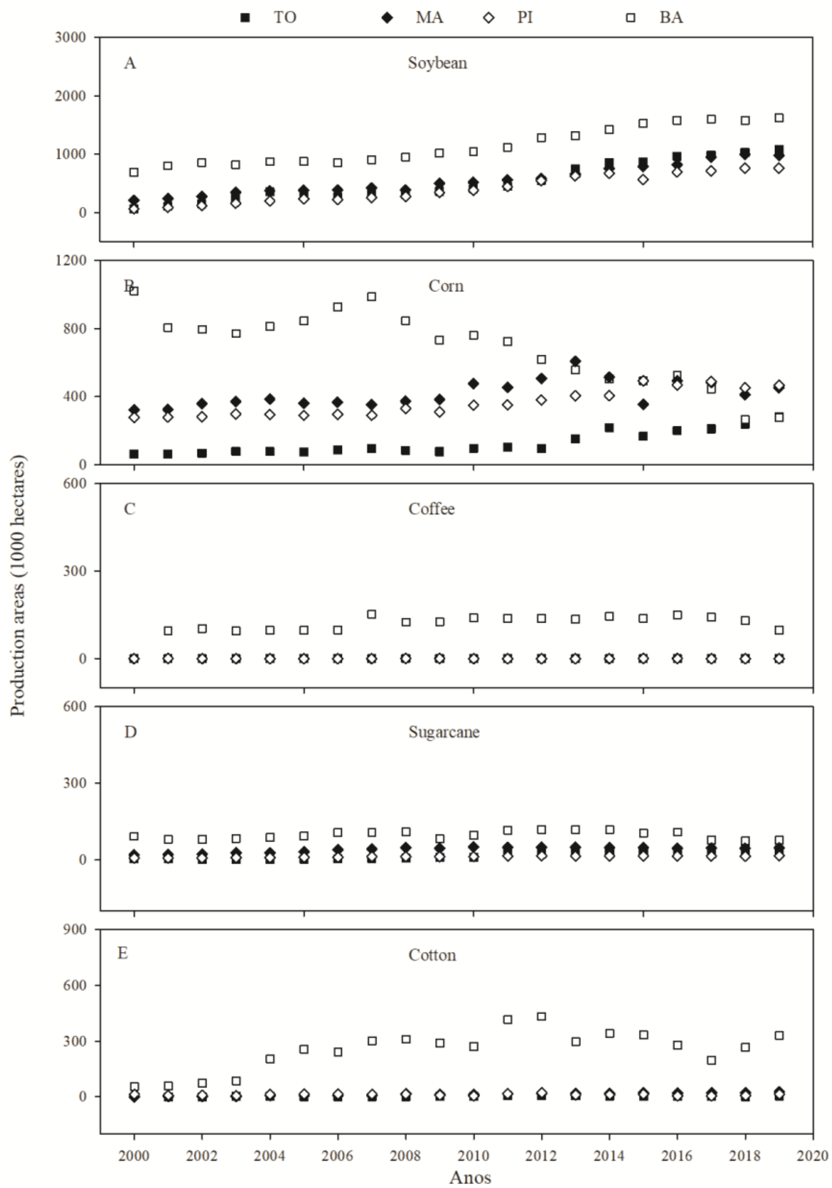

Figure 1. Soybean, corn, and cotton production area in the MATOPIBA region (Maranhão State, MA; Tocantins State, TO; Piauí State, PI; and Bahia State, BA) from 2000 to 2020.

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All states have increased the production area used for agricultural production in the last few years. Lima Filho et al. (2013) described the region as the new Brazilian agricultural frontier. According to Borghi et al. (2014) Maranhão, Piauí, and Bahia are the main producers of corn in the first harvest, where in other states the corn is produced in the second harvest.

In Bahia, cotton production increased in 2004, however, there is a significant fluctuation over the years. In Piauí also there is an increase in cotton production (Figure 1). The strengthening of the sector production chain is due to sustainable practices, quality, profitability, and the volume harvested in both states. These results are putting the region in the spotlight on the national scene.

In Bahia, there is the higher areas and production of soybean, corn, coffee, sugarcane, and cotton (Figures 1 and 2). The high production found in Bahia is explained by the use of advanced technology and irrigated planting. Landau et al. (2016) demonstrated that there is a great irrigated area in the micro-regions of Barreiras (between 50 and 71% of pivots in the MATOPIBA region) and Santa Maria da Vitória (between 15 and 28% of pivots in the MATOPIBA region) located in the middle São Francisco River.

The higher yield of soybean and corn was in Bahia State, followed by states of Maranhão, Piauí, and Tocantins explaining the higher areas of crop production in the MATOPIBA region (Figure 2). In Cerrado, Mato Grosso State is the main producer of soybean and corn represented by a linear increase from 2000 to 2020 (ALMEIDA & MOTA, 2021).

Corn was produced mainly in the first harvest before 2000, but corn is produced mainly in the second crop recently. The increase in the second crop is explained by the increase in soybean production in the first crop (occupying the same area), which presents better economic advances (MEADE et al. 2016). Moreover, adequate technologies were developed to increase corn production in the second crop (DE FARIA et al. 2019; ALTARUGIO et al. 2019).

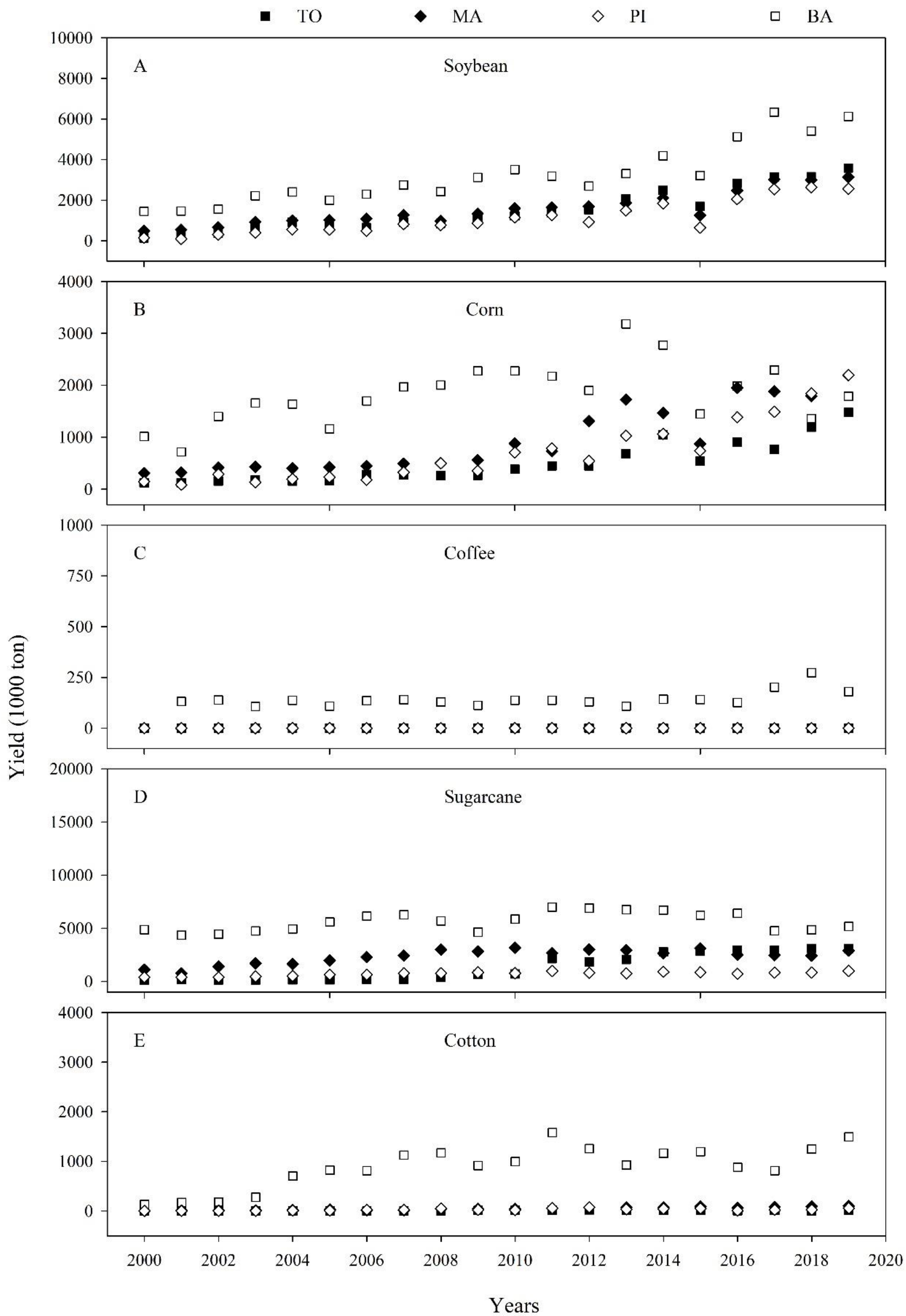

Figure 2. Soybean, corn, and cotton yield in the MATOPIBA region (Maranhão State, MA; Tocantins State, TO; Piauí State, PI; and Bahia State, BA) from 2000 to 2020.

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In the production routes, the production areas present a positive correlation with k-apexes higher than 0.60 ($p < 0.05$), indicating there is an increase in areas and no negative influence between the crops. The Hamiltonian routes indicated diverse routes of soil uses in the systems of rotation and succession from 2000 to 2020 (Figure 3).

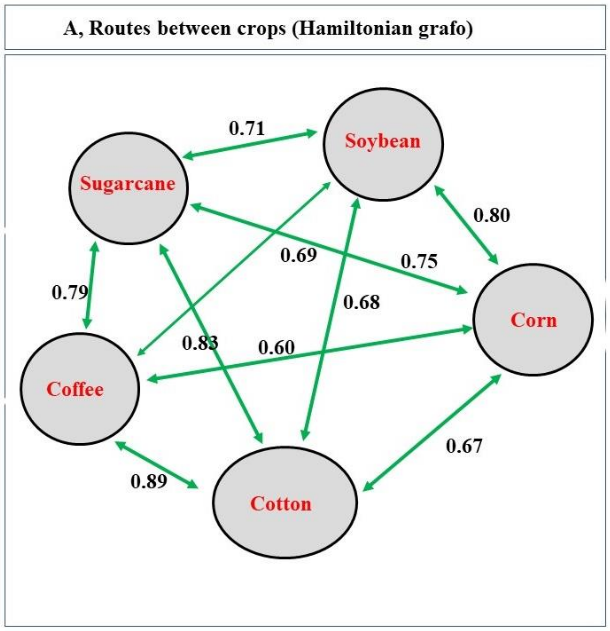

Figure 3. Routes of soybean, corn, and cotton areas in the MATOPIBA region (Maranhão State, Tocantins State, Piauí State, and Bahia State) from 2000 to 2020. Pearson correlation test ($p < 0.01$) was linearly correlated and represented by Hamiltonian Cycle (Hamiltonian route). The k-apexes were linearly correlated by the Pearson correlation test ($p < 0.01$).

The main routes were between coffee and cotton with an r-flux higher of 0.89 ($p < 0.05$), indicating that there was an increase in coffee associated with an increase in cotton areas (Figure 3). Lima and Ferraz-Almeida (2020) demonstrated that there was a negative impact of sugarcane areas that reduced the area of production of corn, soybean, beans, and tomatoes in the region of São Carlos, São Paulo. In our study, we did not notice this negative influence because the MATOPIBA is the new agricultural frontier with the conversion of pasture to crop areas with grains, mainly.

Precipitation and soil erosion

The periods with lower rainfall occur between the months of May and September, mainly in TO, PI, and BA with averages of 5, 4, and 3 mm, respectively. On the other hand, the months with the highest rainfall occurred between November and March with averages of 234, 278, 164, and 140 mm, respectively MA, TO, PI, and BA states (Figure 4). The rainfall intensity has a huge capacity to cause soil erosion based on the erosivity energy in the MATOPIBA region (Silva et al. 2019). The highest precipitation averages were in TO, which presents total precipitation values superior to the other states, highlighting the cities of Caseara and Lagoa da Confusão which presented annual precipitation above 1,900 mm (Figure 4).

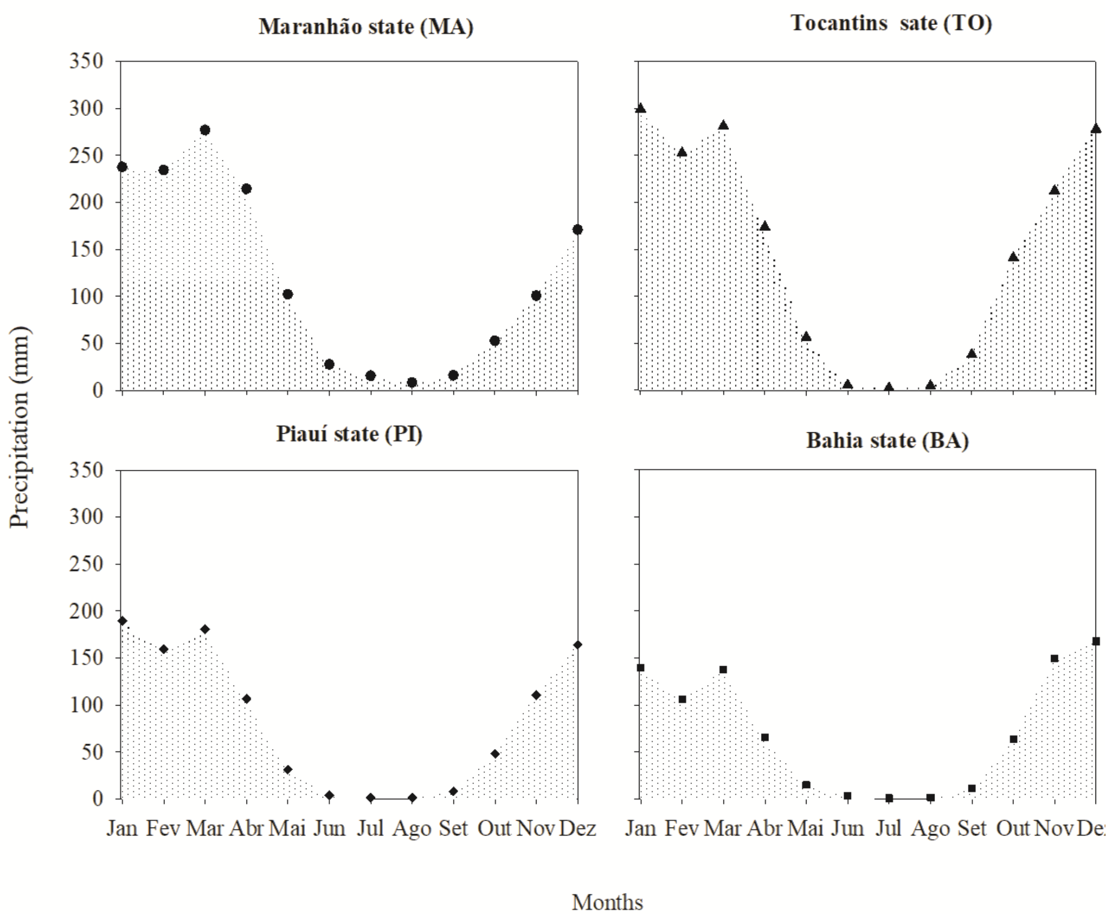

Figure 4. Mensal Precipitation (mm) in the MATOPIBA region (Maranhão State, Tocantins State, Piauí State, and Bahia State) from 2000 to 2020.

The highest average erosivity rates were found respectively in the states of Tocantins (948.6 MJ mm h ha year^{-1}) and Maranhão (814.0 MJ mm h ha year^{-1}). While the lowest average erosivity

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rates were found in Piauí (629.6 MJ mm h ha year^{-1}) and Bahia (553.3 MJ mm h ha year^{-1}), Figure 5. The city with the lowest erosivity rate found in this study was Paratinga (BA), with rainfall rates very close to zero for five months (May/September) and relatively low rates for the rest of the year. In contrast, the city of Lagoa da Confusão (TO) was the city analyzed that obtained the highest average erosivity, which, despite presenting three months (June/August) with low values, presented high values for the region for the rest of the year, increasing the final result of erosivity (Figure 5).

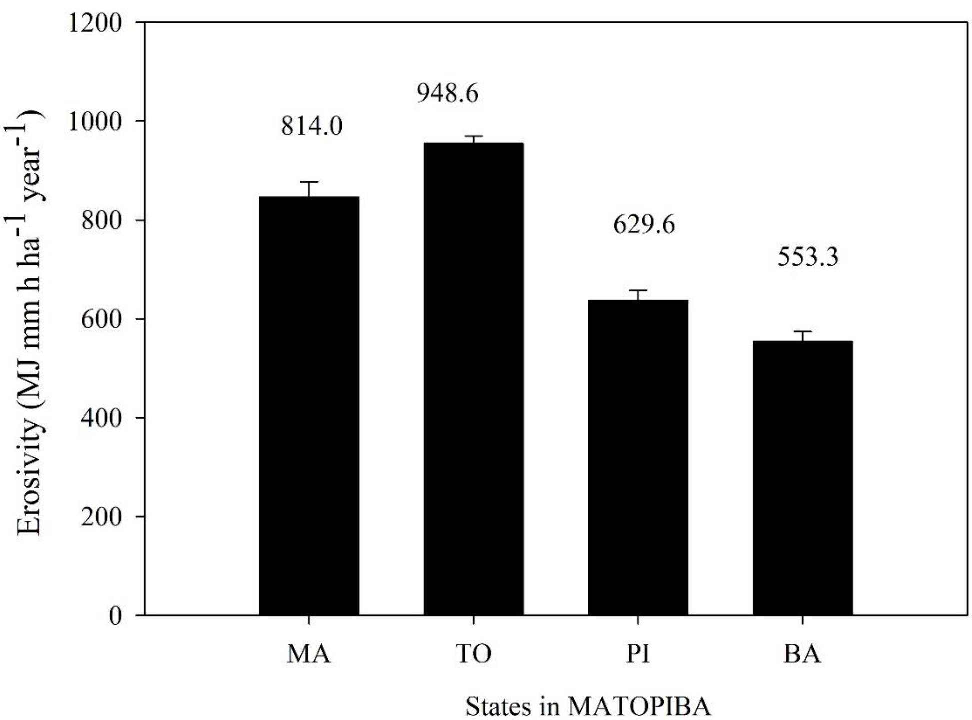

Figure 5. Mensal Erosivity in the MATOPIBA region (Maranhão, Tocantins, Piauí, and Bahia).

The erosivity caused by rainfall can be defined as its potential capacity to cause erosion; therefore, we can infer that, as the erosivity factor is directly related to the rainfall index, in periods of lower rainfall, the erosivity will also be lower (Figure 5). In the MATOPIBA region, there is moderate erodibility in areas with Ferralsols and Leptosols and low erodibility in areas with Arenosols (SILVA et al., 2019).

Using the same methodology and database used to obtain the precipitation averages, we can conclude that the statement made previously is valid, because from mid-Spring (October), through Summer (December/March) to the beginning of Autumn (April). The erosivity rates are more expressive due to the higher rainfall in these seasons. During the rest of the period (May/September), the rates are low, which results in little soil erosion. The use of cover crop and conservation systems is important to avoid soil and water losses in the region. Pereira et al. (2021) demonstrated that conventional tillage presented the lowest water infiltration, the largest runoff, and soil losses in the MATOPIBA region. While the largest infiltration water and the smallest run-off occurred in the minimum tillage and no-tillage.

CONCLUSION

The MATOPIBA region is consolidating itself as an important Brazilian agricultural frontier for Brazil. There was a great growth in production and planted area in the years 2000 to 2020, where the production of soybean and corn stands out. In the production routes, the production areas present a positive correlation, indicating there is an increase in areas and no negative influence between the crops. The highest average erosivity rates were found respectively in the states of Tocantins and Maranhão recommend the use of cover crop and conservation systems to avoid soil and water losses in the region. Concluding that the region MATOPIBA presents a great potential for Brazilian agriculture requiring private and public actions to make sustainable use of the region through advanced technologies with conservation systems to avoid soil and water losses.

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