

SOYBEAN PRODUCTION IN THE STATE OF MARANHÃO AND ITS RELATIONSHIP WITH THE GROSS DOMESTIC PRODUCT

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ABSTRACT: Maranhão (MA) State is among the ten largest soybean producers in Brazil and is the second largest producer in the northeastern region, with an average yield of 2,915 kg ha⁻¹, and the evolution of this production has positively influenced the Municipal Gross Domestic Product (GDP). Thus, this study aimed to characterize soybean production in MA, analyzing data from the main producing municipalities from 2010 to 2019 and relating the value of soybean production to GDP in the period. Municipal Agricultural Production and Municipal GDP data from the Brazilian Institute of Geography and Statistics were used to carry out exploratory and descriptive analyses, simple linear regression, and Pearson's correlation. To characterize the factors that influence crop yield, monthly graphs of temperature and pluviometric index were elaborated for the period of the soybean cycle in MA. The results indicated that the MA planted area evolved significantly and plantations were concentrated in the municipalities of Balsas and Tasso Fragoso, which also had the highest yields in the period, with 619,997 and 616,672 Megagram in 2018, respectively. The highest yield was observed in Buriticupu (3,900 kg ha⁻¹) in 2019. The survey showed a strong and significant relationship between the value of production and GDPs.

Keywords: agribusiness, agricultural cultivation, *Glycine max L.*

PRODUÇÃO DE SOJA NO ESTADO DO MARANHÃO E SUA RELAÇÃO COM O PRODUTO INTERNO BRUTO

RESUMO: O Estado do Maranhão (MA) está entre os dez maiores produtores de soja do Brasil e é o segundo maior produtor da região nordeste, com um rendimento médio de 2.915 kg ha⁻¹, sendo que a evolução dessa produção tem influenciado positivamente no Produto Interno Bruto (PIB) Municipal. Assim, o trabalho teve como objetivo caracterizar a produção de soja no MA, analisando dados dos principais municípios produtores no período de 2010 a 2019 e relacionando o valor da produção da soja com o PIB deste período. Foram utilizados dados de Produção Agrícola Municipal e PIB Municipal do Instituto Brasileiro de Geografia e Estatística para realização das análises exploratórias, descritivas, regressão linear simples e correlação de Pearson. Para caracterizar fatores que influenciam no rendimento da cultura, elaborou-se gráficos mensais de temperatura e índice pluviométrico no período do ciclo da soja no MA. Os resultados indicaram que a área plantada do MA evoluiu de forma significativa e os plantios concentraram-se nos municípios de Balsas e Tasso Fragoso, que também apresentaram as maiores produções no período, com 619.997 e 616.672 toneladas em 2018, respectivamente. O maior rendimento foi em Buriticupu (3.900 kg ha⁻¹) em 2019. A pesquisa evidenciou a relação forte e significativa entre o valor da produção e os PIBs.

Palavras-chave: agronegócio, cultivo agrícola, *Glycine max L.*

1 INTRODUCTION

Brazil is currently the largest producer and exporter of soybeans (*Glycine max* L.) with 37% of world production, displacing the United States, which has fallen to the second position with 29%. Brazilian soybean production occupies an area of 37 million hectares, with a production of 125 million tons and productivity of 3.379 kg ha⁻¹ in the 2019/2020 season. Production in the country is led by the states of Mato Grosso (29%), Paraná (17%), Goiás (10%), Rio Grande do Sul (10%) and Mato Grosso do Sul (9%). Maranhão is part of the MATOPIBA region, which covers part of the states of Maranhão, Tocantins, Piauí and Bahia, currently considered the main frontier for new agribusiness investments in Brazil. In the state of Maranhão, soybean cultivation is expanding its planting area and have an important role in Maranhão's agriculture. Currently, this state is the ninth largest soybean producer in Brazil and the second largest producer in the northeast, only behind Bahia (Soja, 2020).

Agribusiness has been recognized as a crucial vector of Brazilian economic growth, with an emphasis on soybean crops. As a commodity, soybean, is a product of economic and social importance because it is a vital generator of wealth, jobs and foreign exchange, becoming one of the main vectors of regional development in the country. In three decades, soybean has become not only the most important crop of Maranhão's agribusiness, but also the most economically important agricultural product in the state (Araújo *et al.*, 2019; Sodr e *et al.*, 2019; Taherzadeh; Caro, 2019).

In this scenario, the use of reliable sources of statistics of crops, such as the survey of Municipal Agricultural Production, is essential to understand the regional productive process, facilitating measures to direct production financing and decision-making. These statistics contain information about planted area, quantity produced, average yield, and production value of agricultural crops, which are used as indicators of production and monitoring of the economy in the short term

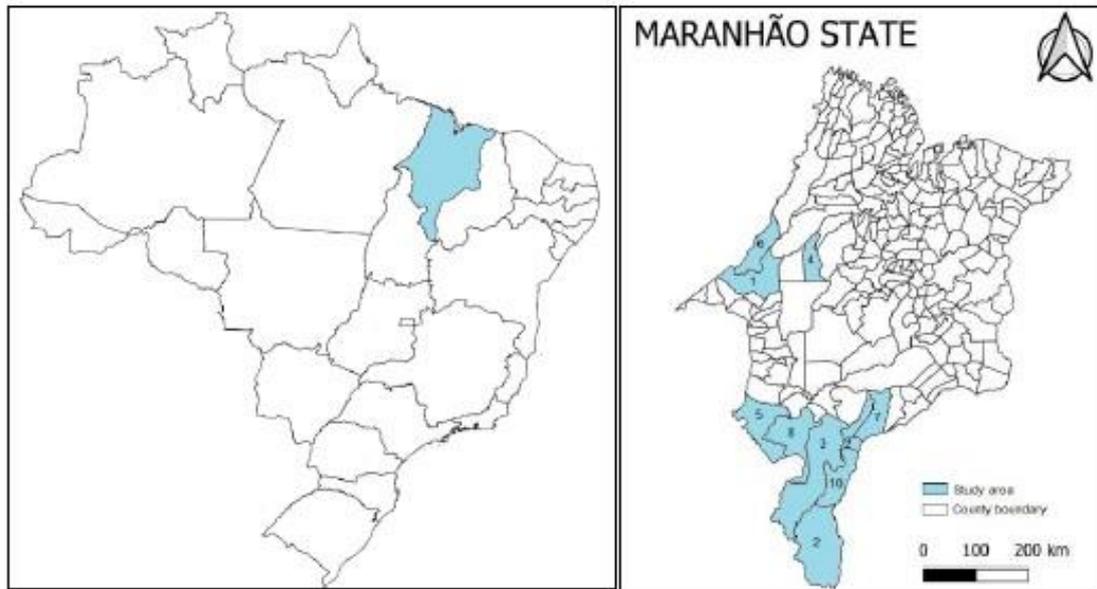
(Rizzi; Rudorff, 2005; Sentelhas *et al.*, 2015; Ceratti; Costa; Harris, 2019). Considering the importance and growing participation of soybean in the economy, it is essential to measure the influence of the crop in the economic context, where Gross Domestic Product (GDP) is the main indicator used to measure the economic growth of a region.

Therefore, to establish an idea of the future perspectives of soybean cultivation in the State of Maranhão, it is essential to analyze the evolution of crop and its relationship with GDP, considering the factors that influence this process. Thus, the main objective of this study was to characterize the production of soybean in the State of Maranhão, analyzing data from the main producing municipalities in the period 2010-2019, and the relationship between the value of soybean production and GDP in the same period.

2 MATERIALS AND METHODS

The data were obtained from the Municipal Agricultural Production (PAM) survey carried out by the Brazilian Institute of Geography and Statistics (IBGE) in the period from 2010 to 2019, totaling 10 years. We considered the planted area (ha), quantity produced (Mg), average yield (kg ha⁻¹) and value of production in real (R\$) of the ten largest municipalities producing soybean in Maranhão in 2019: Balsas, Tasso Fragoso, Açailândia, Alto Parna ba, Samba ba, Riach o, Buriticupu, Loreto, Carolina, and Itinga do Maranh o (Figure 1). The climate data for the locations were obtained from the NASA POWER platform collected automatically by script using the Python programming language and the API provided by NASA. Air temperature (T, °C) and precipitation (P, mm day⁻¹) data were collected and organized in graphs on a monthly scale. The third database was the average of the data set of GDP at current prices and Agricultural GDP of the ten largest grain-producing municipalities in Maranhão in 2019, obtained from IBGE, through the collection of the Gross Domestic Production of Municipalities (IBGE, 2020).

Figure 1. Location of the largest soybean producing municipalities in the State of Maranhão from 2010 to 2019. 1 - Açailândia; 2 - Alto Parnaíba; 3 - Balsas; 4 - Buriticupu; 5 - Carolina; 6 - Itinga do Maranhão; 7 - Loreto; 8 - Riachão; 9 - Sambaíba; 10 - Tasso Fragoso.



Source: The Authors (2020).

The data used in this study were manipulated in Excel to prepare graphs and tables. The statistical analyses employed were exploratory, descriptive, Pearson's, determination coefficients, and simple Linear Regression analysis. For the data of GDP at current prices, agricultural GDP, and production value, Pearson correlation (r), determination (R^2), and simple regression analysis were performed with the average of the values of each selected municipality.

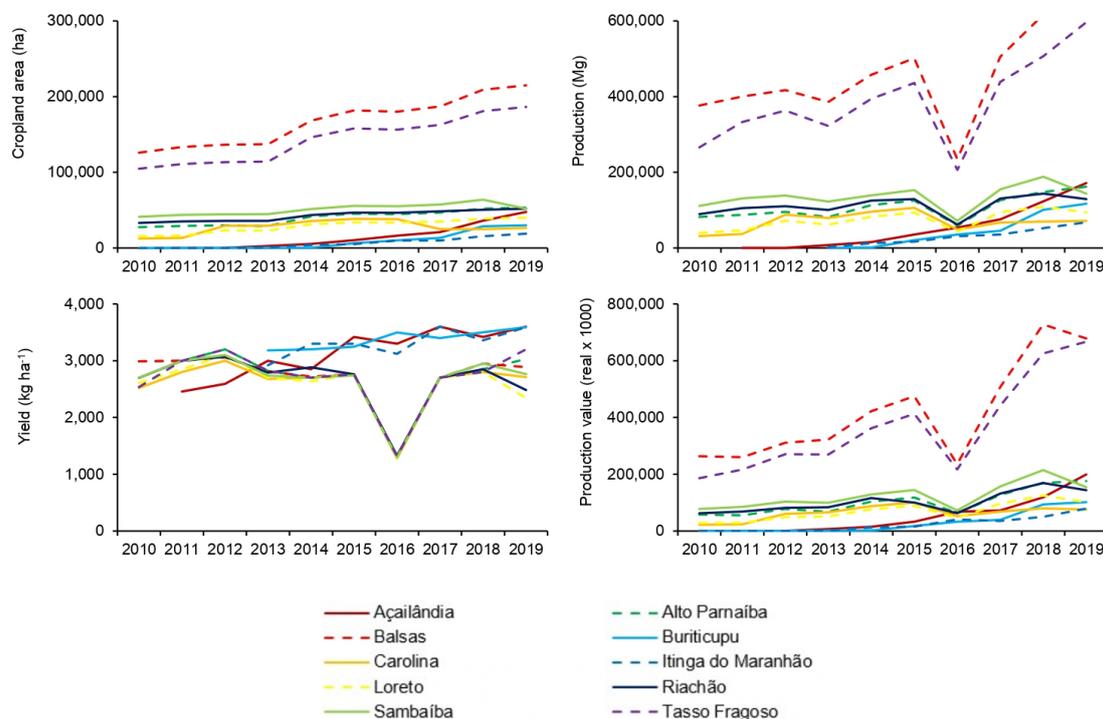
The GDPs were also correlated with the value of soybean production through linear regression, with a significance of 5%. The hypothesis of this study was: does the value of soybean production influence the GDP at

current prices and the agricultural and livestock GDP of the ten largest soybean-producing municipalities in the State of Maranhão?

3 RESULTS AND DISCUSSION

The area with soybean increased by ~100 % in Maranhão between 2010 and 2019 (Figure 2). Soybean fields were concentrated mainly in the southern region of Maranhão, especially in the municipalities of Balsas and Tasso Fragoso. The municipalities of Açailândia, Buriticupu and Itinga do Maranhão that belong to the western region of Maranhão were also highlighted.

Figure 2. Cropland area (ha), production (Mg), yield (kg ha⁻¹) and production value (Thousands of real) of soybean in the municipalities of Açailândia, Alto Paranaíba, Balsas, Buriticupu, Carolina, Itinga do Maranhão, Loreto, Riachão, Sambaíba and Tasso Fragoso, State of Maranhão, from 2010 to 2019.



Source: The Authors (2020).

The soybean production showed an average growth trend from 2010 to 2019, and this increase was 115.53% in Maranhão. The highest production recorded was 2.850.084 Mg, in 2019, and the lowest was seen in 2016, equaling 1.242.772 Mg. The municipalities with the highest soybean production in the ten years studied were Balsas and Tasso Fragoso in 2018 and 2019, respectively, coinciding with the patterns observed in the planted area of this crop in the state (Figure 2).

According to Lemos (2015) the State of Maranhão has a large area of Cerrado and the Brazilian Agricultural Research Company (EMBRAPA) has developed technologies for the cultivation of soybeans in this biome. Thus, Maranhão attracted producers from the Southeast, South and Midwest regions of Brazil, which initially settled in the south of the

State, which contributed to a larger area occupied by soybeans in the municipalities located in the south of Maranhão. The western region of Maranhão also stands out as it has a considerable planted area, even though it is traditionally a region suitable for livestock (Mesquita, 2011). This reveals that the region has great potential for soybean expansion, both in areas with degraded pastures and in systems that integrate crops and livestock (Hirakuri *et al.*, 2018).

Regarding soybean production, higher values were recorded in the ten years studied in the municipalities of Balsas and Tasso Fragoso, coinciding with the patterns observed in the planted area of this crop in the state. As can be seen in Table 1, the municipalities with the lowest production levels were Açailândia and Buriticupu.

Table 1. Average values of cropland area (ha), production (Mg), yield (kg ha⁻¹) and production value (Thousands of real) of soybean in Maranhão between 2010 and 2019.

Municipalities	Cropland area (ha)	Production (Mg)	Average yield (kg ha ⁻¹)	Production value (Thousands of real)
Açailândia	15,557	53,847	3,137.5	57,120.3
Alto Parnaíba	39,991	108,112	2,736.9	101,726.1
Balsas	167,443	451,637	2,717.7	420,365.5
Buriticupu	12,806	46,068	3,417.7	41,064.3
Carolina	27,342	69,642	2,594.6	63,509.7
Itinga do Maranhão	9,163	27,371	3,312.7	33,524.8
Loreto	29,085	73,803	2,579.2	69,232.9
Riachão	42,806	112,619	2,656.7	101,957.5
Sambaíba	51,044	135,517	2,669.4	123,833.9
Tasso Fragoso	143,396	386,381	2,704.1	366,815.2
Maranhão State	708,886	1,926,670	2,724	1,804,776

Source: The Authors (2020).

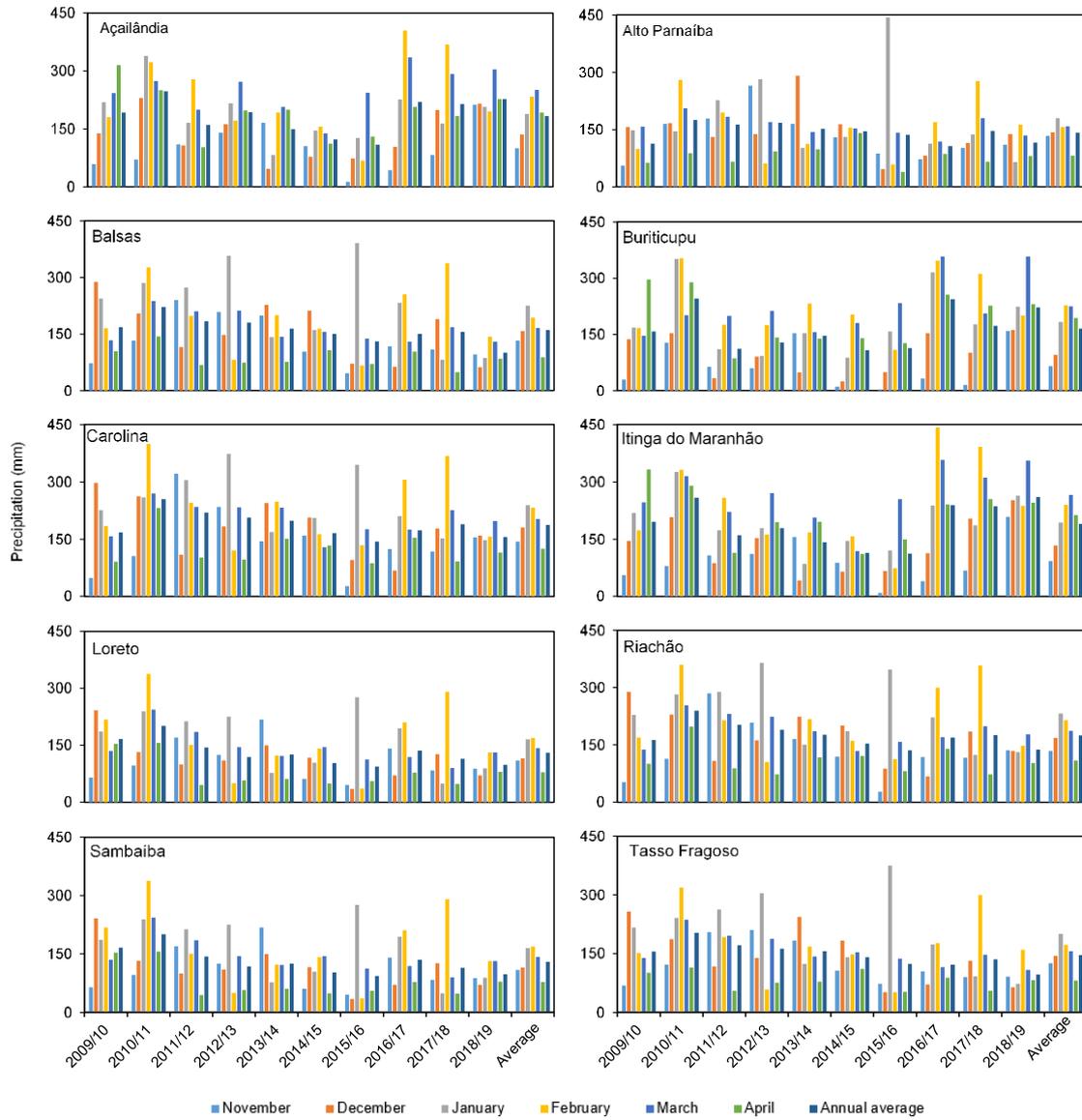
One of the main factors responsible for reducing and impacting a better harvest was the effects of weather, such as *El Niño* phenomenon, which had its strongest cycle in December 2015 and continued in early 2016 (Imesc, 2016). According to Massoquim and Azevedo (2010), *El Niño* phenomenon interferes directly with the cycle of agricultural crops, characterized by the abnormal heating of the waters of the equatorial Pacific Ocean, affecting the rainfall regime in Brazil.

The low rainfall was notorious in the months of the soybean crop cycle between 2015 and 2016 in the largest producing municipalities in the state (Figure 3), which negatively impacted soybean cultivation, mainly in November and December. The soybean crop is highly vulnerable, largely conditioned by its phenological sensitivity to water availability throughout its cycle, in relation to water deficit (Berlato; Fontana,

2003; Sentelhas *et al.*, 2015). In this way, the availability of water is fundamental, mainly because approximately 90% of the weight of the soybean plant is constituted by water, which acts in practically all the physiological and biochemical processes of the plant, whose demand intensifies mainly in two periods: germination-emergence and flowering-grain filling (Ferrari; Paz; Silva, 2015).

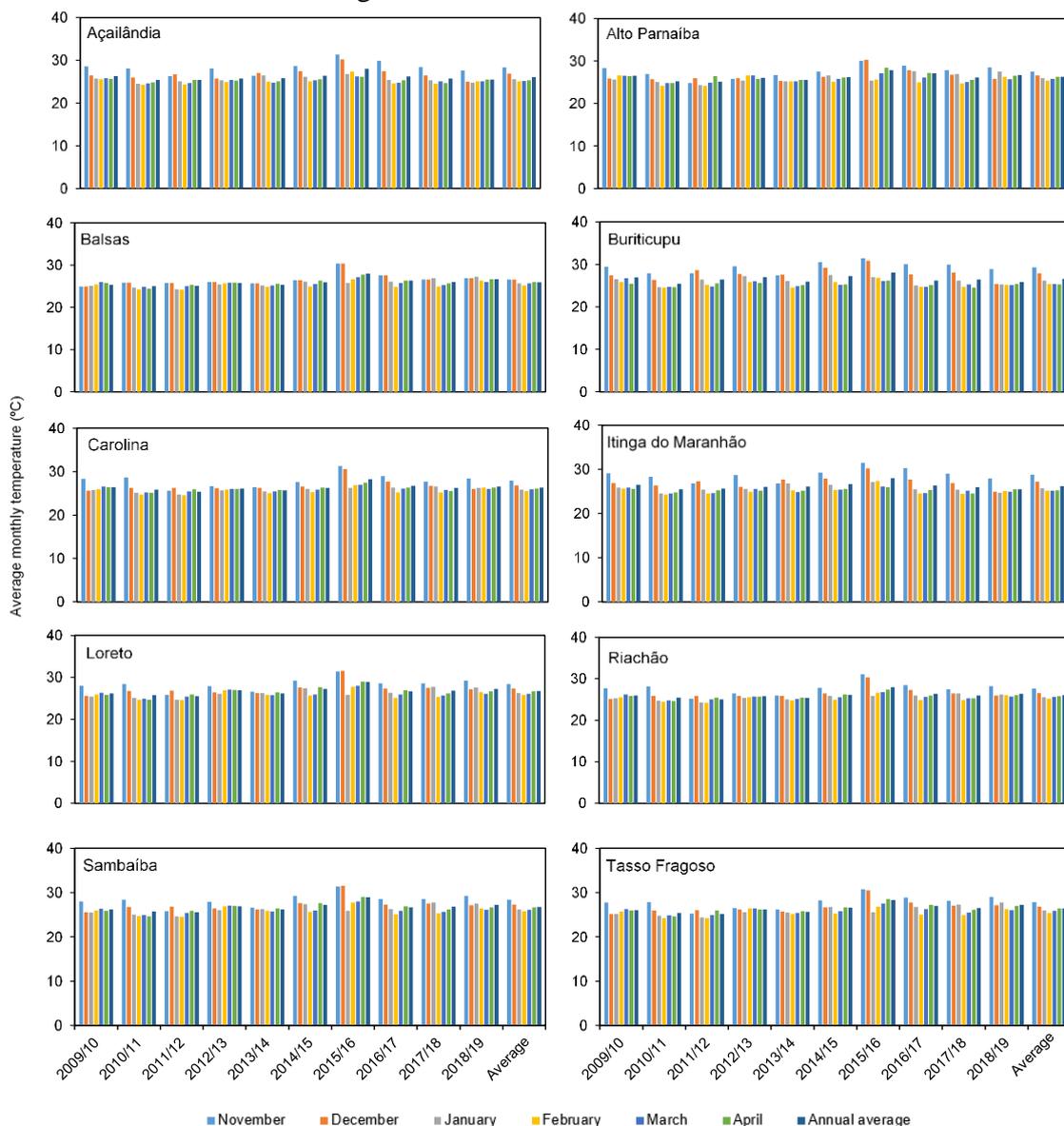
As for the average temperature in the months of November to April of the municipalities from 2010 to 2019, it was verified that the occurrence of *El Niño* phenomenon in 2015 and 2016 was associated with low precipitation, generally in the northeast region, resulting in high temperatures (Figure 4). Farias, Nepomuceno and Neumaier (2007) stated that both air temperature and photoperiod are factors influencing soybean growth and development.

Figure 3. Monthly precipitation in the agricultural years in the municipalities of Açailândia, Alto Paranaíba, Balsas, Buriticupu, Carolina, Itinga do Maranhão, Loreto, Riachão, Sambaíba and Tasso Fragoso, State of Maranhão, from 2010 to 2019.



Source: The Authors (2020).

Figure 4. Average monthly temperature of the agricultural years in the municipalities of Açailândia, Alto Paraíba, Balsas, Buriticupu, Carolina, Itinga do Maranhão, Loreto, Riachão, Sambaíba and Tasso Fragoso, State of Maranhão, from 2010 to 2019.



Source: The Authors (2020).

Maranhão had an average yield of 2,724 kg ha⁻¹. The highest average yield was recorded in 2018 (2,969 kg ha⁻¹) and the lowest in 2016 (1,586 kg ha⁻¹). At the municipal level, the highest average yields were observed in 2019 in Buriticupu (3,900 kg ha⁻¹) and 2017 in Itinga do Maranhão (3,600 kg ha⁻¹). The lowest values were recorded in 2016 in Carolina (1,280 kg ha⁻¹) and Loreto (1,290 kg ha⁻¹).

The total water requirement of the crop to obtain maximum yield varies between 450 and 800 mm cycle⁻¹, depending on weather conditions, crop management, and the duration

of its cycle (EMBRAPA, 2013). Therefore, water availability during the growing season is the main limitation to the expression of crop yield potential and the major cause of the variability in grain yields observed from one year to another (Farias; Nepomuceno; Neumaier, 2007). When scaled in terms of reduced grain yield, the sensitivity of soybean plants to water deficiency tends to increase with the advancement of the crop cycle. However, the occurrence of water deficit in the vegetative phase can compromise grain yield due to the plant's limited vegetative development.

(Mundstock; Thomas, 2005). According to Ruíz-Nogueira, Boote and Sau (2001) and Specht *et al.* (2001), under moderate or intense water deficit, soybean crops normally accelerate maturity and shorten the grain-filling phase, which, consequently, may cause limitations in the productive potential of the crop, as shown by Sentelhas *et al.* (2015).

According to Sentelhas *et al.* (2015), excess water associated with heavy rainfall penalizes productivity, as it favors the occurrence of certain diseases, as well as grain quality, when it coincides with the harvest period. During the crop cycle, a high average temperature, mainly in November and December, with values equal to or greater than 30°C was observed. The optimum air temperature range for soybean growth and development is from 20 to 30°C. Sentelhas *et al.* (2015) stated that in producing regions located at low latitudes, such as Maranhão, the phenological phases and soybean crop cycle are affected by the thermal sum, and high temperatures promote damage to flowering.

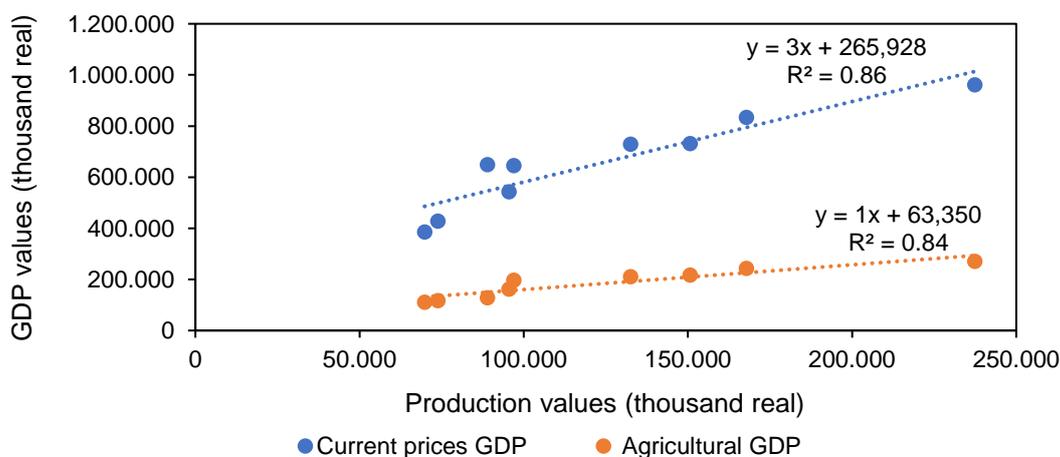
The value of soybean production in the state of Maranhão had a significant growth in recent years, with an increase of 230% between 2010 and 2019, from R\$ 928,342.00 to R\$ 3,068,163.00 real. The highest recorded value

was R\$ 3,152,954.00 real in 2018. The highest municipal production value was observed in Balsas in 2018.

The GDP data at the current and farming prices and soybean production values were considered normal. The Pearson correlation for the GDP at current prices was 0.92 and 0.91 for the Agricultural GDP, which indicates the existence of a good correlation between the values of soybean produced in the ten largest producing municipalities in the state of Maranhão and the values of GDPs presented over the years evaluated. An R² of 0.86 and an adjusted R² of 0.84 for the GDP at the current price and an R² of 0.84 and an adjusted R² of 0.82 for the Agricultural GDP (Figure 5).

According to Castro, Miranda and Lima (2015) there is a significant relationship between soybean-producing municipalities and their positive economic balance, denoting a possible interconnection between soybean production and GDP, corroborating the results found in this research. This information is relevant for municipal and state governments as it can help in the development of policies to improve GDPs by encouraging soybean cultivation through rural financing and technical assistance programs, for example.

Figure 5. Correlation between the GDPs (at current price and agribusiness) and the value of soybean production of the ten largest producing municipalities in the State of Maranhão from 2010 to 2019.



Source: The Authors (2020).

4 CONCLUSIONS

Soybean production in the State of Maranhão has increased considerably in recent years by 115.53%, due to the increase in the planted area and the amount produced, which shows the potential for growth of agribusiness in the region for soybean production, despite the bad weather in some years of cultivation. The municipalities with the largest planted areas and production were Balsas and Tasso Fragoso, which belong to the southern region of Maranhão. Higher yields were found in Buriticupu and Itinga do Maranhão, which belong to the western region.

Based on the results obtained from the correlation analysis, a strong and positive correlation was found between the value of production and the GDP at current prices ($r = 0.93$), as well as the Agricultural GDP with a value of $r = 0.91$. The production value was significant in explaining the behavior of both GDPs. The linear regression confirmed that the value of soy production is representative and explains 86 and 84% of the GDP at current prices, and agricultural, respectively.

Despite the positive results in relation to soybean production and GDP in the municipalities analyzed, even more studies related to this issue are needed. The heterogeneity found among the ten municipalities in the State of Maranhão shows that there may be other factors that are related to GDP, which are possibly influenced by activities that are as or more important than soy for local economic development.

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