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Analysis of the Evolution of the Brazilian Sugar-Energy Sector from 1995, 2006, and 2017 Agricultural Censuses

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ABSTRACT
Given the historical importance of sugarcane for Brazil and considering that it continues to stand out in national agribusiness, it is important to investigate the interfaces of this activity. The objective was to analyze the changes that have occurred in the productive aspects of sugarcane, comparing the data from the 2017 Agricultural Census against 2006 and 1995. The results showed that the sector continues to represent great importance for Brazilian agriculture. In addition, the Midwest has stood out as a new producing region, with emphasis on Goiás, which came to occupy the second position in the quantity produced among the states in the 2017 Census. The Southeast continues to lead the production, with more than 60% of the Brazilian total, with São Paulo standing out. Considering the references consulted and the results found, the states that are leading the sugarcane market have greater technological capacity, aiming at productive sustainability and efficiency of processes, especially in terms of agricultural yields.

KEYWORDS
Evolution, Sugarcane Agroindustry, Market

Análise da Evolução do Setor Sucroenergético Brasileiro a partir dos Censos Agropecuários de 1995, 2006 e 2017

RESUMO
Haja vista a importância histórica da cana-de-açúcar para o Brasil e levando em consideração que continua se destacando no agronegócio nacional, faz-se relevante investigar as interfaces dessa atividade. O objetivo foi analisar as modificações ocorridas nos aspectos produtivos da cana, comparando os dados do Censo Agropecuário de 2017 em cotejo com os Censos de 2006 e 1995. Os resultados demonstraram que o setor continua representando grande importância para a agricultura brasileira. Ademais, o Centro-Oeste tem se destacado como nova região produtora, com realce para Goiás que passou a ocupar a segunda posição na quantidade produzida dentre os estados no Censo de 2017. O Sudeste continua liderando a produção, com mais de 60% do total brasileiro, sobressaindo São Paulo. Considerando as referências consultadas e os resultados encontrados, os estados que estão liderando o mercado canavieiro apresentam maior capacidade tecnológica, visando sustentabilidade produtiva e eficiência dos processos, sobretudo em termos de rendimentos agrícolas.

PALAVRAS-CHAVE
Evolução, Agroindústria Canavieira, Mercado.

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1. Introduction

Sugarcane was introduced in Brazil in 1532 and became the main export product, with factors such as the adaptability to edaphoclimatic conditions, use of enslaved labour and plantation scale contributing to its expansion. The sugarcane industry still occupies a place of importance for Brazil, either due to the increase in international demand for sugar, or the domestic demand for ethanol (from Proálcool in 1975 and the introduction of the flexible-fuel vehicle in 2003). The period had also an average increase in productivity, which was necessary for the maintenance of production. At the same time, the State has undergone a process of sectoral deregulation since 1990 (Szmrecsányi, 1976; Ferreira and Vieira Filho, 2019).

The sugarcane industry in Brazil is unlike its international counterpart, as most Brazilian industries produce a high proportion of the sugarcane necessary for processing. Another characteristic is the diversity of products manufactured from sugarcane, especially sugar, ethanol, and cogeneration of energy from the burning of bagasse. The wide national geographical space and the favorable climate make it possible to produce at different times of the year, facilitating distribution logistics and internal supply (Neves, 2014; Rissardi Júnior, 2015).

In the 2018/2019 harvest, 620.8 million tons of sugarcane were produced, generating 29 million tons of sugar and 33.1 million liters of ethanol, with foreign exchange of US$5.8 billion with sugar exports and US$904.3 million with alcohol exports, being the 4th sector with the highest percentage of participation in Brazilian exports (responsible, in 2018, for 7.35% of the total exported) (UNICA, 2020b; MAPA, 2020). In addition, sugarcane planting formally employed more than 125,000 people in 2018 (MTE, 2020). Given the importance of the sector, it is justified to study its dynamics based on data from the 2017 Agricultural Census. In order to understand sugarcane production in Brazil, the main question becomes: what does the 2017 Agricultural Census data show in relation to the productive aspects of sugarcane? Thus, the objective is to analyze the changes that have occurred in the productive aspects of sugarcane, comparing the data from the 2017 Agricultural Census against 2006 and 1995.

Considering the objective of the study, the methodology used is descriptive and exploratory analysis based on data from the Agricultural Censuses of 1995, 2006 and 2017, made available by the Brazilian Institute of Geography and Statistics (IBGE); the variables used will be collected and compared between the Censuses, in order to capture changes between years.

This article is divided into four sections, including this introduction. The second section discusses aspects of the evolution of the sugarcane agroindustry in Brazil, which is necessary to understand its historical vicissitudes. The third presents the results and discussion, while the fourth section concerns the final considerations.

2. Evolution of sugarcane production in Brazil

Szmrecsányi (1976) points out that the development of sugarcane agroindustry was one of the pillars of the colonial economy. The importance of this sector was mainly established by the production of sugar, which supplied the domestic market and was, for centuries, the leader of national exports.

Sugar only lost importance in Brazil's productive agenda in the short gold cycle and in the first two decades of the 20th century, when it became the sixth export product, behind coffee, cotton, cocoa, tobacco and mate. It was from 1921 onwards that exports grew again, due to the conditions of the end of World War I (1918), reaching second place (behind coffee). Although it underwent a not-so-significant phase for exports, it is noted that much of the sugar production was destined for the domestic market and as such production still grew throughout the period (Szmrecsányi, 1976).

In 1933, a period marked by an interventionist State, the creation of the Sugar and Alcohol Institute (IAA – Instituto do Açúcar e do Álcool) sought to reconcile the incipient sugarcane production in the Centre-South with the North-Northeast production, which was undergoing period of decline in importance in the national scenario. According to (Rissardi Júnior, 2015, p. 20, our translation), with the IAA *"[...] it was imperative that the producer of sugarcane underwent a series of institutional arrangements that connected the organized interests of the sugarcane agroindustry with the state's decision-making mechanisms."*

With the two world wars, maritime trade was compromised, causing supply problems in the world, which also hit Brazil. Internally, the Centre-Southern region was destocked from sugar, which is why the IAA allowed the increase in sugarcane production to the South-eastern states (Szmrecsányi and Moreira, 1991). With this, soon the sugarcane production of the Centre-South would surpass that of the North-Northeast. This evolution, for example, points to the 1965/1966 sugarcane harvest of the Centre-South, which was almost three times larger than that of the North-Northeast. Sugar production was the driver of the sector in the period (Shikida, 2014).

Nevertheless, also in the second half of the 1960s, there was a phase of technological insertion in Brazilian sugarcane production, seeking to improve the competitiveness of the sector. One of the measures was the creation of the National Sugarcane Improvement Program (PLANALSUCAR) in 1966, as well as the promotion of mergers and incorporations of mills. When PLANALSUCAR was extinguished in the 1990s, Ridesa (Interuniversity Network for the Development of the Sugar-Energy Sector) incorporated its units and continued a process of technological advancement for the sector (Rissardi Júnior, 2015).

(Shikida, 2014, p. 47-48) points out that, in the first half of the 1970s, there was a strong state interventionism in the sugarcane sector, as well as in previous periods, "thus expanding the subventionist paradigm as model of survival [...]". Santos et al.

(2015) explored the percentage of sugar and alcohol produced from the beginning of the 1960s to the 2011/2012 harvest, and explain that, since the 1970s, the mills that produce both ethanol and sugar predominate over those that produce only one of the products. Until the first half of the 1970s, sugar production remained higher. However, the creation of Proálcool in 1975 resulted in a substantial increase in ethanol production.

Between the 1975/1976 and the 1985/1986 harvests, there was an average growth rate of 11.7% per annum (p.a.) in Brazilian sugarcane production, and ethanol led the period, with an average growth rate of 34.7% p.a., compared to 2.8% of sugar. The motivation for this significant expansion was the importance that ethanol gained in the Brazilian energy matrix, taking into account the oil crises in the 1970s and the "orchestration of interests" of the government, the sugarcane industry, the automotive industry and the machinery and equipment sector around Proálcool (Shikida, 2014).

However, there was a phase of "deceleration and crisis of the Proálcool and rupture of the subventionist paradigm (1986/1987 to 1995/1996)", in which the "bottleneck", arising from the oil crisis and fundamental to the creation and subsequent expansion of Proálcool, disappeared; the State, with a liberal tendency and affected by the fiscal and financial crisis, gradually moved away from the function of "managing" prices of sugarcane agro-industrial activity. This moment coined the era of deregulation in this sector; the automobile industry signaled the lack of interest in producing ethanol-powered vehicles, in addition to the sugar market having shown an increase in its international prices. Sugarcane production increased by 0.92% p.a., and in this phase sugar production grew 5.7% p.a. and ethanol production grew 1.4% p.a. (Rissardi Júnior, 2015). The extinction of the IAA in 1990 "[...] reflected in a shift from a subventionist paradigm to the technological paradigm, marking a new sectoral institutionality, with predominance of the free market" (Wissmann, 2017, p. 101, our translation).

The phase between 1996/1997 and 2002/2003 was marked by the continuity of sectoral deregulation, in which the State stopped intervening with expedients such as price control and marketing, establishment of production quotas, granting subsidies, among others. From this context, various strategies were adopted among the agents, in order to make the structures more competitive, through differentiation and innovation. In this period, the lowest average growth rate of sugarcane production (0.07% p.a.) was recorded since the 1940s (Shikida, 2014).

In the phase between 2003/2004 and 2012/2013, there was an average growth rate of sugarcane production of 6.7% per annum, with recovery in relation to the previous period. There was loss of participation in the Northeast and increase of the Midwest in total, which presents a reasonable contribution of technological capabilities. This increase was linked to the introduction of the flex-fuel car in 2003, and by 2014, it already exceeded 90% of the total number of cars sold in Brazil. Another important source of expansion of ethanol production was the contribution of foreign

direct investment (Andrade, 2001; Fátima Vidal et al., 2006; Shikida, 2013; Moraes and Bacchi, 2014; Meurer et al., 2015).

Despite the relatively favorable moment (sugar prices and the introduction of flex-fuel), between 2008 and 2012, more than 40 sugar and ethanol producing units ceased to operate in Brazil, 30 of which between 2011 and 2012 (Shikida, 2014). According to a survey conducted by RPA Consultoria (a technical consultancy company), 52 sugarcane agroindustries were in judicial recovery and 27 in bankruptcy, within a total of 444 units in Brazil. The main causes of this scenario were the financial deterioration resulting from the international crisis of 2008, with a decline in sugar and ethanol prices, instability in the rainfall and frost regimes, as well as a high degree of indebtedness and management errors (Ramos, 2017). Moreover, *"at the beginning of the 2010s, a policy of fossil fuel prices out of international prices was put in place in order to control inflation"*, which by "holding" the price of gasoline exerted strong pressure on the demand for ethanol (Ferreira and Vieira Filho, 2019, p. 207, our translation).

To mitigate these results, the National Biofuels Policy (RenovaBio), Law No. 13,576/2017, was instituted, in order to promote the production and use of biofuels in Brazil, contributing to the reduction of greenhouse gases and the strategic role of biofuels in the energy matrix (Brasil, 2017). This legislation pointed to sugarcane producers as an alternative to expand ethanol production, contributing to the recovery of the sector. RenovaBio is considered the largest decarbonization program of the transport matrix in the world, contributing to the Brazilian commitments made to reduce greenhouse gases by 43% by 2030 (UNICA, 2020a).

3. Results of the Agricultural Census 2017: comparisons and discussions

The information from the Agricultural Census 2017 provides an overview of the characteristics of the sugarcane economy, as follows: production, production value, harvested area, average yield, number of establishments and staff occupied. A complement is also made on two important commodities of the sugarcane agroindustry, sugar and ethanol. Sugarcane production in Brazil grew from 265 million tons in 1995 to 407 million tons in 2006, reaching 638 million tons in 2017, an increase of 53.75% from 1995 to 2006, and 56.75% from 2006 to 2017 (Table 1).

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Sugarcane production is predominant in the South-eastern region, accounting for more than 65% of the amounts produced in Brazil in the three Censuses. In 1995 and 2006, the region with the second highest production was the Northeast, producing 19.73% and 15.32% of the total. The Midwest started to occupy this position in 2017,

with 21.85%. The South and Northeast lost participation among the three Censuses (Table 1).

The Midwest production increased by more than 130% from 1995 to 2006, and by more than 200% from 2006 to 2017, behind only the North, which is has little expressivity in total production (less than 0.57%). Production in the North-eastern region grew the least from 1995 to 2006 and decreased by 36.43% from 2006 to 2017 (Table 1). The prominence of the Midwest region is indicated by (Shikida, 2013), which justifies this expansion due to the potentiality of climatic conditions, the search for renewable energies and the saturation of traditional areas.

Among the states, São Paulo has been the largest producer in the country, with participation percentages in the order of 58%, 59% and 54%, in 1995, 2006 and 2017, respectively. In 1995, São Paulo was followed by Alagoas (7.75%), Paraná (6.96%) and Pernambuco (5.78%). Since 2006, there has been a change in the positions of the states, with an increase in the participation of Goiás and Minas Gerais; the trend was followed in 2017, with the states becoming the second (11.39%) and third (10.33%) producers, respectively. In 2017, Mato Grosso do Sul began to gain relevance, which contributes, alongside Goiás, to the highlight of the Midwest in the national scenario (Table 1). According to Meurer et al. (2015), Goiás is prominent among Midwestern states in technological capacity, which contributes to its relevance in the sector.

Minas Gerais doubled its participation between 2006 and 2017, which is cited by Santos (2021) as a period of significant geographical concentration in the Triângulo Mineiro Region, with expansion in typical "cerrado" (Brazilian savanna) regions. Perosa et al. (2017) explain this expansion by the demand for diversification of agricultural income, in which farmers sought new forms of investment and the conditions offered by sugarcane mills were attractive to different farmer profiles.

The sugarcane production value data (for monetary data at different time periods) was deflated by the General Market Price Index (IGPM) for the 1995 base year, the first year of analysis. The percentage values represent the real variation, with the correction being made to the absolute values. The value of sugarcane production grew 44.52% from 1995 to 2006, and 18.69% from 2006 to 2017. Following the trend, the South-eastern region concentrated more than 60% of the total, as observed in Table 2. In 2017, the Midwest gained prominence in both amount produced and production value, occupying the second highest percentage in this latter category, 22.28%. In 1995 and 2006, the North-eastern region was in this position, with 19.29% and 16.58%, respectively (Table 2). It should be noted that the value of sugarcane production increased less than the amount produced, and thus prices have decreased, reflecting a difficult scenario for the sector.

Regarding each state, São Paulo obtained, for the three Censuses, more than 50% of the total value of production, despite the percentage suffering a slight decrease. The Midwestern states also gained relevance regarding the value of production in 2017,

Table 1. Amount of sugarcane produced in Brazil, regions and states, and percentage of participation and variation between censuses – 1995, 2006 and 2017 (tons)

Regions and States	1995		2006			2017		
	Total	% Brazil	Total	% Brazil	% Variation	Total	% Brazil	% Variation
Brazil	**265,016,222**		**407,466,570**		**53.75**	**638,689,872**		**56.75**
Northern Region	**182,753**	**0.07**	**1,033,775**	**0.25**	**465.67**	**3,628,795**	**0.57**	**0.57**
Rondônia	23,027	0.01	32,501	0.01	41.14	83,689	0.01	157.50
Acre	2,841	0.00	1,452	0.00	-48.89	3,988	0.00	174.66
Amazonas	8,547	0.00	34,021	0.01	298.05	270,587	0.04	695.35
Roraima	582	0.00	373	0.00	-35.91	2,445	0.00	555.50
Pará	55,596	0.02	792,816	0.19	1,326.03	913,097	0.14	15.17
Amapá	2,473	0.00	2,730	0.00	10.39	1,207	0.00	-55.79
Tocantins	89,687	0.03	169,882	0.04	89.42	2,353,782	0.37	1,285.54
North-eastern Region	**52,285,333**	**19.73**	**62,439,558**	**15.32**	**19.42**	**39,693,421**	**6.21**	**-36.43**
Maranhão	829,257	0.31	1,093,328	0.27	31.84	2,129,116	0.33	94.74
Piauí	502,434	0.19	552,826	0.14	10.03	903,201	0.14	63.38
Ceará	1,029,294	0.39	721,369	0.18	-29.92	109,625	0.02	-84.80
Rio Grande do Norte	3,183,533	1.20	1,520,191	0.37	-52.25	1,963,911	0.31	29.19
Paraíba	8,732,243	3.29	3,600,354	0.88	-58.77	5,109,030	0.80	41.90
Pernambuco	15,319,302	5.78	17,150,904	4.21	11.96	10,349,049	1.62	-39.66
Alagoas	20,545,778	7.75	34,268,175	8.41	66.79	13,625,617	2.13	-60.24
Sergipe	660,317	0.25	675,707	0.17	2.33	1,794,744	0.28	165.61
Bahia	1,483,175	0.56	2,856,704	0.70	92.61	3,709,128	0.58	29.84
South-eastern Region	**173,073,683**	**65.31**	**269,383,911**	**66.11**	**55.65**	**417,470,430**	**65.36**	**54.97**
Minas Gerais	11,812,888	4.46	20,663,104	5.07	74.92	65,984,683	10.33	219.34
Espírito Santo	1,782,898	0.67	3,796,453	0.93	112.94	2,098,740	0.33	-44.72
Rio de Janeiro	5,709,830	2.15	3,577,905	0.88	-37.34	1,702,827	0.27	-52.41
São Paulo	153,768,067	58.02	241,346,449	59.23	56.95	347,684,180	54.44	44.06
Southern Region	**20,197,769**	**7.62**	**29,542,795**	**7.25**	**46.27**	**38,358,751**	**6.01**	**29.84**
Paraná	18,442,306	6.96	28,672,287	7.04	55.47	37,805,994	5.92	31.86
Santa Catarina	518,184	0.20	145,618	0.04	-71.90	106,365	0.02	-26.96
Rio Grande do Sul	1,237,279	0.47	724,890	0.18	-41.41	446,392	0.07	-38.42
Midwestern Region	**19,276,684**	**7.27**	**45,066,531**	**11.06**	**133.79**	**139,538,475**	**21.85**	**209.63**
Mato Grosso do Sul	5,160,330	1.95	11,253,497	2.76	118.08	50,479,440	7.90	348.57
Mato Grosso	7,450,702	2.81	14,703,260	3.61	97.34	16,333,547	2.56	11.09
Goiás	6,659,013	2.51	19,102,268	4.69	186.86	72,720,538	11.39	280.69
Federal District	6,639	0.00	7,506	0.00	13.06	4,950	0.00	-34.05

Source: authors' own elaboration based on IBGE (2020) data for the Agricultural Censuses of 1995, 2006 and 2017.

Table 2. Value of sugarcane produced in Brazil, regions and states, and percentage of participation and variation between censuses - 1995, 2006 and 2017 (thousand Reais)

Regions and States	1995		2006			2017		
	Total	% Brazil	Total	% Brazil	% Variation	Total	% Brazil	% Variation
Brazil	**5,358,490.07**		**7,744,057.76**		**44.52**	**9,191,111.34**		**18.69**
Northern Region	**11,959.91**	**0.22**	**101,343.19**	**1.31**	**747.36**	**103,395.80**	**1.12**	**2.03**
Rondônia	3,924.42	0.07	936.29	0.01	-76.14	2,807.92	0.03	199.90
Acre	614.46	0.01	480.25	0.01	-21.84	680.29	0.01	41.65
Amazonas	2,071.28	0.04	9,729.93	0.13	369.75	7,503.48	0.08	-22.88
Roraima	147.06	0.00	30.62	0.00	-79.18	370.26	0.00	1,109.36
Pará	2,706.70	0.05	83,331.54	1.08	2,978.71	52,818.19	0.57	-36.62
Amapá	257.86	0.00	218.23	0.00	-15.37	221.37	0.00	1.44
Tocantins	2,238.13	0.04	6,616.33	0.09	195.62	38,994.30	0.42	489.36
North-eastern Region	**1,033,886.14**	**19.29**	**1,284,318.54**	**16.58**	**24.22**	**729,504.84**	**7.94**	**-43.20**
Maranhão	19,496.04	0.36	21,631.49	0.28	10.95	43,618.32	0.47	101.64
Piauí	12,082.86	0.23	10,113.71	0.13	-16.30	21,130.85	0.23	108.93
Ceará	30,648.81	0.57	20,728.31	0.27	-32.37	5,376.03	0.06	-74.06
Rio Grande do Norte	52,798.08	0.99	35,722.82	0.46	-32.34	38,567.56	0.42	7.96
Paraíba	121,820.06	2.27	73,794.92	0.95	-39.42	83,969.05	0.91	13.79
Pernambuco	282,111.71	5.26	298,101.03	3.85	5.67	196,949.85	2.14	-33.93
Alagoas	401,053.77	7.48	741,983.39	9.58	85.01	229,562.18	2.50	-69.06
Sergipe	20,882.98	0.39	25,306.16	0.33	21.18	24,620.57	0.27	-2.71
Bahia	92,991.84	1.74	56,936.72	0.74	-38.77	85,710.43	0.93	50.54
South-eastern Region	**3,410,191.72**	**63.64**	**4,903,407.23**	**63.32**	**43.79**	**5,773,049.55**	**62.81**	**17.74**
Minas Gerais	267,150.83	4.99	595,464.06	7.69	122.89	1,068,807.70	11.63	79.49
Espírito Santo	39,801.31	0.74	67,221.31	0.87	68.89	32,729.60	0.36	-51.31
Rio de Janeiro	86,729.06	1.62	64,436.65	0.83	-25.70	49,933.09	0.54	-22.51
São Paulo	3,016,510.51	56.29	4,176,285.21	53.93	38.45	4,621,579.16	50.28	10.66
Southern Region	**443,432.69**	**8.28**	**481,093.64**	**6.21**	**8.49**	**537,571.68**	**5.85**	**11.74**
Paraná	359,078.84	6.70	431,988.64	5.58	20.30	483,799.13	5.26	11.99
Santa Catarina	31,510.64	0.59	10,243.29	0.13	-67.49	12,533.72	0.14	22.36
Rio Grande do Sul	52,843.21	0.99	38,861.71	0.50	-26.46	41,238.83	0.45	6.12
Midwestern Region	**459,019.61**	**8.57**	**973,894.81**	**12.58**	**112.17**	**2,047,589.47**	**22.28**	**110.25**
Mato Grosso do Sul	74,643.82	1.39	225,614.78	2.91	202.26	700,407.45	7.62	210.44
Mato Grosso	203,458.87	3.80	486,868.01	6.29	139.30	266,681.07	2.90	-45.23
Goiás	180,350.95	3.37	260,915.03	3.37	44.67	1,079,720.89	11.75	313.82
Federal District	565.96	0.01	496.98	0.01	-12.19	780.05	0.01	56.96

Source: authors' own elaboration based on IBGE (2020) data for the Agricultural Censuses of 1995, 2006 and 2017. Note: Values deflated from the General Market Price Index (IGPM – Índice Geral de Preços do Mercado) for the base year 1995.

with Goiás (11.75%), occupying the second position and Mato Grosso do Sul (7.62%) the fourth (Table 2).

From 1995 to 2006 there was an increase of 30.98% in the harvested area for sugarcane, and 60.63% from 2006 to 2017 (Table 3). In Table 3, the harvested areas (hectares) for the Federal, Regional and State levels are observed regarding their percentage participations in the total of the country and variation between the Censuses.

The largest harvested area is in the Southeast, which, in this period, gained a percentage of participation in relation to the other Brazilian regions. In 1995, the Southeast had 59.24% of the harvested area; in 2006, 61.88%; and in 2017, 63.24%. In 1995 and 2006 the Northeast had the second largest harvested area, with 25.94% and 20.03%, respectively. In 2017, the Midwest held this position, with 20.44% (Table 3).

Observing the data of the harvested area of the Brazilian states, we can see a predominance of São Paulo, with 48.97% of the total in 1995, 53.60% in 2006, and 52.86% in 2017. In the 1995 Census, São Paulo was followed by Alagoas (8.47%) and Pernambuco (8.20%). In 2006, São Paulo (53.60%) and Alagoas (10.31%) held their positions, but Paraná (5.94%) took over in the third position. In 2017, São Paulo remained on top, however, the second largest area harvested became Goiás (10.32%) and the third was Minas Gerais (9.59%). Also noteworthy is Mato Grosso do Sul, which jumped from 1.81% in 2006 to 7.57% in 2017, the fourth largest area harvested among the states, contributing to the good performance of the Midwest region (Table 3).

According to the variations in the area harvested between the Censuses, it is noticed that the North (235.93%) and the Midwest (119.52%) had the highest growth between 1995 and 2006, as well as from 2006 to 2017, with 191.34% and 193.85%. Furthermore, the Midwest has greater figures in total area harvested. The growth in the Midwest region was mainly driven by Mato Grosso do Sul and Goiás, which increased the harvested area between 2006 and 2017, by 344.68% and 257.82%, respectively. From 2006 to 2017, the Northeast region showed a decrease in this variable in the order of 31.07%, as the two largest producers in the region underwent considerable reductions, i.e., Pernambuco (-28.42%) and Alagoas (-54.83%). In general, this scenario of harvested area corroborates what happened in Brazilian sugarcane production between the Censuses (Table 3).

The data for average yield (ton/ha) also strengthen the understanding of the change in the concentration pattern of sugarcane production (Table 4). In 1995, the average Brazilian yield was 61.09 ton/ha; in 2006, the value increased to 71.71 ton/ha; and in 2017, it showed a small reduction to 69.97 ton/ha. It is noteworthy that in 1995, the Midwest already had the second highest yield among the Brazilian regions, only behind the Southeast. In 2006, the Midwest occupied the third position, considering that the South reached the highest average yield recorded among the three Censuses. In 2017, the Midwest began to occupy the leadership position in sugarcane yield. This

Table 3. Harvested area of sugarcane crops for the Federal, Regional and State levels, and percentage of participation and variation between censuses - 1995, 2006 and 2017 (ha)

Regions and States	1995		2006			2017		
	Total	% Brazil	Total	% Brazil	% Variation	Total	% Brazil	% Variation
Brazil	**4,338,348.93**		**5,682,297.00**		**30.98**	**9,127,645.00**		**60.63**
Northern Region	**5,688.17**	**0.13**	**19,108.00**	**0.34**	**235.93**	**55,670.00**	**0.61**	**191.34**
Rondônia	546.37	0.01	1,189.00	0.02	117.62	2,706.00	0.03	127.59
Acre	192.28	0.00	440.00	0.01	128.84	166.00	0.00	-62.27
Amazonas	678.68	0.02	1,503.00	0.03	121.46	4,352.00	0.05	189.55
Roraima	150.02	0.00	35.00	0.00	-76.67	231.00	0.00	560.00
Pará	1,941.33	0.04	12,482.00	0.22	542.96	14,614.00	0.16	17.08
Amapá	107.71	0.00	79.00	0.00	26.66	142.00	0.00	79.75
Tocantins	2,071.79	0.05	3,380.00	0.06	63.14	33,459.00	0.37	889.91
North-eastern Region	**1,125,226.32**	**25.94**	**1,137,933.00**	**20.03**	**1.13**	**784,426.00**	**8.59**	**-31.07**
Maranhão	16,906.43	0.39	17,936.00	0.32	6.09	37,616.00	0.41	109.72
Piauí	7,987.70	0.18	9,572.00	0.17	19.83	16,808.00	0.18	75.60
Ceará	20,844.28	0.48	17,348.00	0.31	-16.77	3,730.00	0.04	-78.50
Rio Grande do Norte	67,367.97	1.55	38,371.00	0.68	-43.04	38,315.00	0.42	-0.15
Paraíba	213,760.21	4.93	80,177.00	1.41	-62.49	104,766.00	1.15	30.67
Pernambuco	355,789.18	8.20	317,328.00	5.58	-10.81	227,128.00	2.49	-28.42
Alagoas	367,451.99	8.47	585,663.00	10.31	59.38	264,557.00	2.90	-54.83
Sergipe	14,256.58	0.33	13,735.00	0.24	-3.66	38,926.00	0.43	183.41
Bahia	60,861.99	1.40	57,803.00	1.02	-5.03	52,580.00	0.58	-9.04
South-eastern Region	**2,570,228.93**	**59.24**	**3,516,110.00**	**61.88**	**36.80**	**5,771,948.00**	**63.24**	**64.16**
Minas Gerais	270,372.71	6.23	315,582.00	5.55	16.72	875,472.00	9.59	177.42
Espírito Santo	38,664.79	0.89	68,993.00	1.21	78.44	41,326.00	0.45	-40.10
Rio de Janeiro	136,692.71	3.15	85,697.00	1.51	-37.31	30,655.00	0.34	-64.23
São Paulo	2,124,498.72	48.97	3,045,838.00	53.60	43.37	4,824,495.00	52.86	58.40
Southern Region	**347,972.53**	**8.02**	**374,222.00**	**6.59**	**7.54**	**649,868.00**	**7.12**	**73.66**
Paraná	259,584.17	5.98	337,461.00	5.94	30.00	633,417.00	6.94	87.70
Santa Catarina	24,693.65	0.57	6,638.00	0.12	-73.12	3,682.00	0.04	-44.53
Rio Grande do Sul	63,694.71	1.47	30,123.00	0.53	-52.71	12,769.00	0.14	-57.61
Midwestern Region	**289,232.98**	**6.67**	**634,924.00**	**11.17**	**119.52**	**1,865,733.00**	**20.44**	**193.85**
Mato Grosso do Sul	78,346.81	1.81	155,392.00	2.73	98.34	690,995.00	7.57	344.68
Mato Grosso	118,363.28	2.73	215,862.00	3.80	82.37	232,251.00	2.54	7.59
Goiás	92,216.31	2.13	263,339.00	4.63	185.57	942,289.00	10.32	257.82
Federal District	306.59	0.01	331.00	0.01	7.96	198.00	0.00	-40.18

Source: authors' own elaboration based on IBGE (2020) data for the Agricultural Censuses of 1995, 2006 and 2017.

indicator gradually increased during the years for the Midwest and North; however, this fact was not recorded in the South, Southeast and Northeast, which reduced their average yield from 2006 to 2017 (Table 4).

Table 4. Average yield of sugarcane in the Federal, Regional and State levels, and percentage variation between censuses – 1995, 2006 and 2017 (ton/ha)

Regions and States	1995	2006		2017	
	Yield	Yield	% Variation	Yield	% Variation
Brazil	**61.09**	**71.71**	**17.39**	**69.97**	**-2.42**
Northern Region	**32.13**	**54.10**	**68.39**	**65.18**	**20.48**
Rondônia	42.15	27.33	-35.14	30.93	13.14
Acre	14.78	3.30	-77.67	24.02	628.00
Amazonas	12.59	22.64	79.74	62.18	174.68
Roraima	3.88	10.66	174.71	10.58	-0.68
Pará	28.64	63.52	121.79	62.48	-1.63
Amapá	22.96	34.56	50.52	8.50	-75.40
Tocantins	43.29	50.26	16.10	70.35	39.97
North-eastern Region	**46.47**	**54.87**	**18.09**	**50.60**	**-7.78**
Maranhão	49.05	60.96	24.28	56.60	-7.15
Piauí	62.90	57.75	-8.18	53.74	-6.96
Ceará	49.38	41.58	-15.79	29.39	-29.32
Rio Grande do Norte	47.26	39.62	-16.16	51.26	29.38
Paraíba	40.85	44.91	9.92	48.77	8.60
Pernambuco	43.06	54.05	25.53	45.56	-15.70
Alagoas	55.91	58.51	4.65	51.50	-11.98
Sergipe	46.32	49.20	6.22	46.11	-6.28
Bahia	24.37	49.42	102.80	70.54	42.74
South-eastern Region	**67.34**	**76.61**	**13.78**	**72.33**	**-5.60**
Minas Gerais	43.69	65.48	49.86	75.37	15.11
Espírito Santo	46.11	55.03	19.33	50.78	-7.71
Rio de Janeiro	41.77	41.75	-0.05	55.55	33.05
São Paulo	72.38	79.24	9.48	72.07	-9.05
Southern Region	**58.04**	**78.94**	**36.01**	**59.03**	**-25.23**
Paraná	71.05	84.96	19.59	59.69	-29.75
Santa Catarina	20.98	21.94	4.54	28.89	31.69
Rio Grande do Sul	19.43	24.06	23.88	34.96	45.27
Midwestern Region	**66.65**	**70.98**	**6.50**	**74.79**	**5.37**
Mato Grosso do Sul	65.87	72.42	9.95	73.05	0.87
Mato Grosso	62.95	68.11	8.21	70.33	3.25
Goiás	72.21	72.54	0.45	77.17	6.39
Federal District	21.65	22.68	4.72	25.00	10.25

Source: authors' own elaboration based on IBGE (2020) data for the Agricultural Censuses of 1995, 2006 and 2017.

The North-eastern region presented yield below the national average throughout the period, even though the literature indicated it was a region of great tradition in sugarcane cultivation. Its reduction in national participation is related to low productivity, lack of insertion of productive technologies and replacement of production by other crops (Rissardi Júnior, 2015). Shikida (2014), speaking of the technological paradigm adopted by mills and distilleries after the 1990s, proposed that their survival would be linked to the greater technological insertion in the production and processing of sugarcane, as well as its use in the generation of by-products.

Among the Brazilian states, the average yield in 1995 was led by São Paulo (72.38

ton/ha), followed by Goiás (72.21 ton/ha) and Paraná (71.05 ton/ha). For 2006, Paraná took the lead, with 84.96 ton/ha, the highest value recorded among the three Censuses analyzed, followed by São Paulo (79.24 ton/ha) and Goiás (72.54 ton/ha). Goiás obtained the highest yield result in 2017; 77.17 ton/ha, followed by Minas Gerais (75.37 ton/ha) and Mato Grosso do Sul (73.05 ton/ha) (Table 4).

Among the states that make up the Midwest region, in addition to Goiás and Mato Grosso do Sul, which occupied the first and third positions, respectively, in 2017, Mato Grosso (70.33 ton/ha) obtained the sixth best yield. Among the nine states that make up the Northeast region, six reduced the indicator from 2006 to 2017. Paraná stands out in the South, reducing the yield from 84.96 ton/ha in 2006 to 59.69 ton/ha in 2017. Furthermore, the Northern region also presented values below the national average in the three years (Table 4).

Regarding the variation in average yield, the largest increase among states, from 1995 to 2006, was Roraima, which in 1995 had the lowest yield. From 2006 to 2017, Acre had the largest increase, having the lowest yield in 2006. The national average decreased from 2006 to 2017, since in this period, 12 of the 27 Brazilian states showed reductions in yield. Only in the Midwest region all states showed growth in average yield (Table 4). It should be noted that 2017 was a year in which several sugar and ethanol producing units ceased to operate in the country, affected by the international crisis that began in 2008, the drop in sugar and ethanol prices, climate instability, indebtedness and management mistakes (Ramos, 2017).

According to the analyzed data, the number of establishments that produce sugarcane in Brazil went down from 377,000 in 1995 to 192,000 in 2006, reaching 171,000 in 2017 (Table 5). This context is in accordance with notes from the previous section, in which a phase of strength of the sector was observed after 2003, with the introduction of the flex-fuel car, and then a transition to a crisis scenario when several mills and distilleries stopped working.

Table 5. Number of agricultural establishments with sugarcane in the Federal, Regional and State levels, and percentage of participation and variation between censuses - 1995, 2006 and 2017 (units)

Regions and States	1995		2006			2017		
	Total	% Brazil	Total	% Brazil	% Variation	Total	% Brazil	% Variation
Brazil	**377,207**		**192,931**		**-48.85**	**171.348**		**-11.19**
Northern Region	**6,292**	**1.67**	**4,458**	**2.31**	**-29.15**	**13,393**	**7.82**	**200.43**
Rondônia	1,024	0.27	906	0.47	-11.52	1,204	0.70	32.89
Acre	757	0.20	746	0.39	-1.45	753	0.44	0.94
Amazonas	972	0.26	1,250	0.65	28.60	5,890	3.44	371.20
Roraima	301	0.08	37	0.02	-87.71	1,077	0.63	2,810.81
Pará	2,378	0.63	701	0.36	-70.52	1,858	1.08	165.05
Amapá	154	0.04	79	0.04	-48.70	1,008	0.59	1,175.95
Tocantins	706	0.19	739	0.38	4.67	1,603	0.94	116.91
North-eastern Region	**55,560**	**14.73**	**44,501**	**23.07**	**-19.90**	**34,574**	**20.18**	**-22.31**
Maranhão	2,316	0.61	1,019	0.53	-56.00	1,105	0.64	8.44
Piauí	2,847	0.75	1,606	0.83	-43.59	1,796	1.05	11.83
Ceará	9,501	2.52	5,119	2.65	-46.12	2,978	1.74	-41.82
Rio Grande do Norte	1,326	0.35	503	0.26	-62.07	513	0.30	1.99
Paraíba	3,588	0.95	2,591	1.34	-27.79	2,580	1.51	-0.42
Pernambuco	10,121	2.68	12,002	6.22	18.59	6,229	3.64	-48.10
Alagoas	4,942	1.31	5,641	2.92	14.14	3,109	1.81	-44.89
Sergipe	585	0.16	965	0.50	64.96	895	0.52	-7.25
Bahia	20,334	5.39	15,055	7.80	-25.96	15,369	8.97	2.09
South-eastern Region	**115,173**	**30.53**	**72,514**	**37.59**	**-37.04**	**70,256**	**41.00**	**-3.11**
Minas Gerais	80.912	21.45	43,725	22.66	-45.96	49,246	28.74	12.63
Espírito Santo	2,015	0.53	1,736	0.90	-13.85	1,512	0.88	-12.90
Rio de Janeiro	10,219	2.71	6,541	3.39	-35.99	4,496	2.62	-31.26
São Paulo	22,027	5.84	20,512	10.63	-6.88	15,002	8.76	-26.86
Southern Region	**194,802**	**51.64**	**61,750**	**32.01**	**-68.30**	**44,904**	**26.21**	**-27.28**
Paraná	24,538	6.51	7,743	4.01	-68.44	5,839	3.41	-24.59
Santa Catarina	45,047	11.94	8,461	4.39	-81.22	7,995	4.67	-5.51
Rio Grande do Sul	125,217	33.20	45,546	23.61	-63.63	31,070	18.13	-31.78
Midwestern Region	**5.380**	**1.43**	**9,708**	**5.03**	**80.45**	**8,221**	**4.80**	**-15.32**
Mato Grosso do Sul	649	0.17	2,081	1.08	220.65	1,715	1.00	-17.59
Mato Grosso	2,751	0.73	3,461	1.79	25.81	2,979	1.74	-13.93
Goiás	1,835	0.49	3,939	2.04	114.66	3,394	1.98	-13.84
Federal District	145	0.04	227	0.12	56.55	133	0.08	-41.41

Source: authors' own elaboration based on IBGE (2020) data for the Agricultural Censuses of 1995, 2006 and 2017.

Observing the five Brazilian regions, the South had the largest number of sugarcane production establishments in 1995, with more than 50% of the total. In 2006, the Southeast occupied this position, with 37.59%; in 2017, it had 41%. From 1995 to 2006, all regions increased their participation in the number of establishments, except the South; even though the percentage variation between these two years decreased in all but nine states. The regional concentration of establishments was reduced; the Southeast, South and Northeast, which accounted for almost 97% of the properties that produced sugarcane in Brazil in 1995, reduced this percentage in 2017 to 87% (Table 5).

Among the states, in 1995 Rio Grande do Sul (33.20%) occupied the first place in the number of establishments, followed by Minas Gerais (21.45%). These positions

were held in 2006, with 23.61% and 22.66%, respectively. In 2017, the two states reversed their placements; Minas Gerais with 28.74% and Rio Grande do Sul with 18.13% (Table 5). Nevertheless, it is necessary to highlight that, in general, the number of properties that grow sugarcane is not linked to the total production of the states. As an example, São Paulo is in the fourth position in the number of establishments, but is the largest producer, with more than 50% of the national total.

The position occupied by Minas Gerais is historical, as explained by Santos (2021), the implantation of mills in the state was done in many small properties, because they aimed to supply the population contingent brought to the state in the beginning of the gold cycle. The state was slow to modernize the production process, which also influenced the maintenance of smaller mills and in larger quantity. Souza and Cleps Junior (2009) emphasize that the sugarcane expansion in Minas Gerais in the early 2000s happened, especially, from contracts signed with producers who were located near the mills, to reduce transportation costs. Thus, many small producers going through a financial crisis, seeking to diversify production, or simply to obtain greater profits from their properties, started to produce sugarcane and sell to nearby units. The long-term contracts benefited both the producers and the mills, and therefore allowed the continuity of this system of integration of the mills with the small local producers.

In turn, Rio Grande do Sul had the largest number of sugarcanes producing establishments for the 1995 and 2006 Censuses, moving to second place in 2017. This fact is explained by the EMBRAPA (2010), in which the State destines most of its production to obtain brown sugar, cachaça, molasses and animal feed. The productivity is considered low in this state and the crop is inserted mainly in family properties, because it contributes to human and animal subsistence, in addition to generating additional income. In this sense, some research has been conducted in order to enable the insertion of new varieties and technologies that contribute to increasing the productivity of the crop. Despite the advances, it is still a challenge to obtain varieties adapted to the climate of lower temperatures. Brixner (2017) agrees by stating that, historically, family farming is a producer of the sugarcane crop in Rio Grande do Sul. It still presents low technological level, which contributes to low productivity, being processed in small and artisanal industries (cachaça, brown sugar and molasses), or used without industrialization (animal feed).

As observed in Table 6, the decline in number of sugarcane-producing properties between 1995 and 2006 occurred in all classes of harvested area, except for those with less than 1 ha and those without declaration of size. The greatest reduction occurred in the group between 10 and 50 ha (-59.03%). In the group with less than 1 ha there was an increase (28.73%) in the number of sugarcane-producing establishments. From 2006 to 2017 the trend was maintained; there was reduction in the number of properties with an area between 1 ha and 500 ha (although in a smaller proportion compared to the previous period), and an increase in the number of properties

smaller than 1 ha. In 2017 the class with more than 500 ha also had an increase in the number of establishments. Considering the change that occurred between 1995 and 2017, only the group with less than 1 ha showed an increase (65.12%) in the number of sugarcane-producing establishments (Table 6).

The data in Table 3 show that the area harvested in the Southern region grew by more than 73% from 2006 to 2017, and was accompanied by an 11.74% increase in the value of production (Table 2) and growth in the quantity of sugarcane produced by 29.84% (Table 1). Whereas, the Table 5 indicates a 27.28% reduction in the number of establishments, demonstrating that there has been a concentration of the quantity produced, area harvested and value of production in fewer producing establishments.

Analyzing the area classes for the Southern region, it is possible to verify that, between 1995 and 2006, all classes had a decrease in the number of producing establishments, with the exception of the group larger than 0 and less than 1 ha. However, between 2006 and 2017, the only group that increased the number of producing establishments was the class of 500 ha and more, and the variation for the South region as a whole was -27.28%. Therefore, for the South region it can be stated that there was a concentration of production in establishments with larger total areas IBGE (2020).

Table 6. Number of agricultural establishments with sugarcane in Brazil by strata of harvested area size, and percentage of participation and variation between censuses – 1995, 2006 and 2017 (units)

Characterization of establishments	1995		2006			2017		
	377,207 (total number)	total %	192,931 (total number)	total %	% Variation	171.348 (total number)	total %	% Variation
Greater than 0 to less than 1 ha	6,314	1.67	8128	4.21	28.73	10,426	6.08	28.27
Between 1 and 2 ha	9,918	2.63	9088	4.71	-8.37	8431	4.92	-7,23
Between 2 and 5 ha	38,133	10.11	27,179	14.09	-28.73	23,906	13.95	-12.04
Between 5 and 10 ha	62,436	16.55	32,325	16.75	-48.23	28,683	16.74	-11.27
Between 10 and 20 ha	98,249	26.05	40.251	20.86	-59.03	33,546	19.58	-16.66
Between 20 and 50 ha	89,028	23.60	38,768	20.09	-56.45	34,458	20.11	-11.12
Between 50 and 100 ha	32,708	8.67	15,319	7.94	-53.16	14,050	8.20	-8.28
Between 100 and 200 ha	19,230	5.10	9,233	4.79	-51.99	7,715	4.50	-16.44
Between 200 and 500 ha	13,719	3.64	6,517	3.38	-52.50	5,347	3.12	-17.95
500 ha or greater	7,452	1.98	4,034	2.09	-45.87	4,430	2.59	9.82
No declaration	20	0.01	2,089	1.08	10345.00	356	0.21	-82,96

Source: authors' own elaboration based on IBGE (2020) data for the Agricultural Censuses of 1995, 2006 and 2017.

This dynamic of displacement of production in the South can be explained by the observations of EMBRAPA (2010) and Brixner (2017) when they emphasize the fact that it was necessary to modernize sugarcane production in the South, based on the insertion of new technologies and the development of research directed to the soil and climate conditions of this geographic context. The need to introduce new technologies may have made production on smaller scales unfeasible, for this reason the dynamics in the period was one of concentration of production in larger establishments. Observing Table 6, for Brazil as a whole, between 2006 and 2017 there was a decrease of -11.18% in the total number of establishments producing sugarcane, while the group of 500 ha and more had a growth of 9.82%, although the larger class from 0 to less than 1 ha also increased (28.28%).

Despite the dynamics presented, property distribution per total area group remains

little modified. The group between 10 and 20 ha, for example, had 20.86% of the total production sugarcane establishments in 2006; in 2017 this percentage reduced to 19.58%. Significant changes worth highlighting occur in the group with a total area of less than 1 ha, which in 1995 had 1.67% of the total, and which in 2017 came to represent 6.08%. This also occurred for the group with more than 500 ha, which went from 1.98% in 1995 to 2.59% in 2017 (Table 6).

As for the 2017 Agricultural Census (there is no such information in the other Censuses), of the total number of people employed in Brazilian agriculture, sugarcane cultivation partakes in 3.89% (Table 7).

The Southeast has most of the Brazilian workers in sugarcane production, 51.03%. However, this crop employs only 9.40% of the total agricultural workers in this region. This percentage is mainly due to the power of the State of São Paulo, which employs 26.95% of the total agricultural workers in the production of sugarcane. In this same sense, Alagoas has 15.78% of the agriculture personnel working with sugarcane cultivation. This percentage is 8.41% in Mato Grosso do Sul and 7.5% in Goiás (Table 7).

São Paulo represents 38.24% of the national total of workers in the sugarcane sector, followed by Minas Gerais (11.26%) and Alagoas (8.79%). Despite the reduction in production, harvested area and yield in the Northeast in 2017, we can observe that 28.98% of the total sugarcane workers are in the region, and represent 2.67% of the total agricultural workers of the Northeast. This fact demonstrates that the sector is still important in generating income and jobs in this region, especially in more traditional states, such as Alagoas and Pernambuco (Table 7).

Table 7 also shows the amount produced per worker in the sugarcane sector for 2017. It can be seen that the Midwest region has the highest value with 2140.68 tons/worker, taking into account that the average for Brazil is 1087.70 tons/worker. The three states of the Center-West region also have the highest values among the states, with the exception of the Federal District. The Southeast region has the second highest production value per worker (1393.34), of which São Paulo is the most representative and the fourth highest among the states, with 1548.60. It is also noteworthy that the Northeast region, traditional and historical sugarcane producer, has the lowest income per worker among the regions, 233.30.

The data show that the number of sugarcane-producing establishments in Brazil decreased by 54.57% among the censuses analyzed (Table 5), but despite this, the amount produced increased by about 141% in the same period (Table 1). This demonstrates that there was a process of concentration of production in units that follow the technological paradigm.

The variables mentioned attest that the South and Northeast regions reduced their importance in the national sugarcane production percentage, the former in a smaller proportion than the latter. The decline in the participation of these regions is mainly

Table 7. Personnel employed in agricultural establishments in Brazil and in the cultivation of sugarcane (worker), percentage participation in total and total sugarcane, amount of sugarcane produced (tons) and amount produced per worker in the cultivation of sugarcane (tons/worker), in regions and states, 2017

Regions and States	Sugarcane (worker)	Total in agriculture (worker)	% total in agriculture	% Sugarcane	Amount of sugarcane produced (tons)	Amount produced per worker in the sugarcane (tons/worker)
Brazil	**15,105,125.00**	**587,192.00**	**3.89**		**638,689,872**	**1,087.70**
Northern Region	**2,010,291.00**	**4,849.00**	**0.24**	**0.83**	**3,358,208**	**692.56**
Rondônia	270,812.00	474.00	0.18	0.08	83,689	176.56
Acre	126,514.00	385.00	0.30	0.07	3,988	10.36
Amazonas	330,719.00	*	-	-	X	X
Roraima	67,070.00	165.00	0.25	0.03	2,445	14.82
Pará	979,648.00	1,835.00	0.19	0.31	913,097	497.60
Amapá	31,098.00	125.00	0.40	0.02	1,207	9.66
Tocantins	204,430.00	1,865.00	0.91	0.32	2,353,782	1,262.08
North-eastern Region	**6,376,764.00**	**170,141.00**	**2.67**	**28.98**	**39,693,421**	**233.30**
Maranhão	692,870.00	7,395.00	1.07	1.26	2,129,116	287.91
Piauí	670,321.00	5,376.00	0.80	0.92	903,201	168.01
Ceará	928,646.00	3,444.00	0.37	0.59	109,625	31.83
Rio Grande do Norte	213,883.00	6,868.00	3.21	1.17	1,963,911	285.95
Paraíba	424,116.00	13,728.00	3.24	2.34	5,109,030	372.16
Pernambuco	779,727.00	49,822.00	6.39	8.48	10,349,049	207.72
Alagoas	326,913.00	51,588.00	15.78	8.79	13,625,617	264.12
Sergipe	234,161.00	8,438.00	3.60	1.44	1,794,744	212.70
Bahia	2,106,127.00	23,482.00	1.11	4.00	3,709,128	157.96
South-eastern Region	**3.187.377,00**	**299.618,00**	**9.40**	**51.03**	**417,470,430**	**1,393.34**
Minas Gerais	1,836,353.00	66,108.00	3.60	11.26	65,984,683	998.13
Espírito Santo	357,258.00	2,779.00	0.78	0.47	2,098,740	755.21
Rio de Janeiro	160,571.00	6,216.00	3.87	1.06	1,702,827	273.94
São Paulo	833,195.00	224,515.00	26.95	38.24	347,684,180	1,548.60
Southern Region	**2,340,866.00**	**45,172.00**	**1.93**	**7.69**	**38,358,751**	**849.17**
Paraná	846,642.00	31,958.00	3.77	5.44	37,805,994	1,182.99
Santa Catarina	501,811.00	3,301.00	0.66	0.56	106,365	32.22
Rio Grande do Sul	992,413.00	9,913.00	1.00	1.69	446,392	45.03
Midwestern Region	**1,189,827.00**	**65,182.00**	**5.48**	**11.10**	**139,533,525**	**2,140.68**
Mato Grosso do Sul	254,971.00	21,443.00	8.41	3.65	50,479,440	2,354.12
Mato Grosso	422,453.00	7,675.00	1.82	1.31	16,333,547	2,128.15
Goiás	490,612.00	36,064.00	7.35	6.14	72,720,538	2,016.43
Federal District	21,791.00	*	-	-	X	X

Source: authors' own elaboration based on IBGE (2020) data for the Agricultural Census of 2017. * Amounts not disclosed by the source.

due to the growth in the participation of production in the Midwest. Although the Northeast region is traditional in sugarcane production, it lost space in the total national production in recent decades. Andrade (2001) investigated the motivation for this fact in the 1990s, presenting a chain of challenges in the region such as the lack of credit that led to the bankruptcy of mills and distilleries and, consequently, transfer of capital from this region to others, such as the Midwest. In addition, the climatic conditions of the region were severe for many years, which reduced production and productivity. A highly competitive environment, especially with other Brazilian states, may also be an explanation. Fátima Vidal et al. (2006) add that the production of the Central-South region was favored by standing out in the technological aspects; the North-eastern production processes were, in turn, late.

In general, sugarcane yields increased from 1995 to 2006; however, it decreased from 2006 to 2017. This was linked to the international crisis of 2008, in addition to a decrease in the prices of its commodities, climate instability, indebtedness and management mistakes. However, according to data from UNICA (2019) and CONAB (2019), there is a trend of increased productivity for the coming decades.

Although this is not in the Census, it is necessary to supplement this article with some notes on two commodities of the sugarcane agroindustry, sugar and ethanol. According to the CONAB (2019), for the 2015/2016 harvest the amount of sugarcane used in sugar production was 269 million tons, which corresponds to 40.4% of the total produced. From this number, 33.49 million tons of sugar were produced, a value 5.8% lower than that of the previous harvest. The Northeast showed a decrease in sugar production, especially Alagoas, with a reduction of 34.6%, and Pernambuco, with 24.4%.

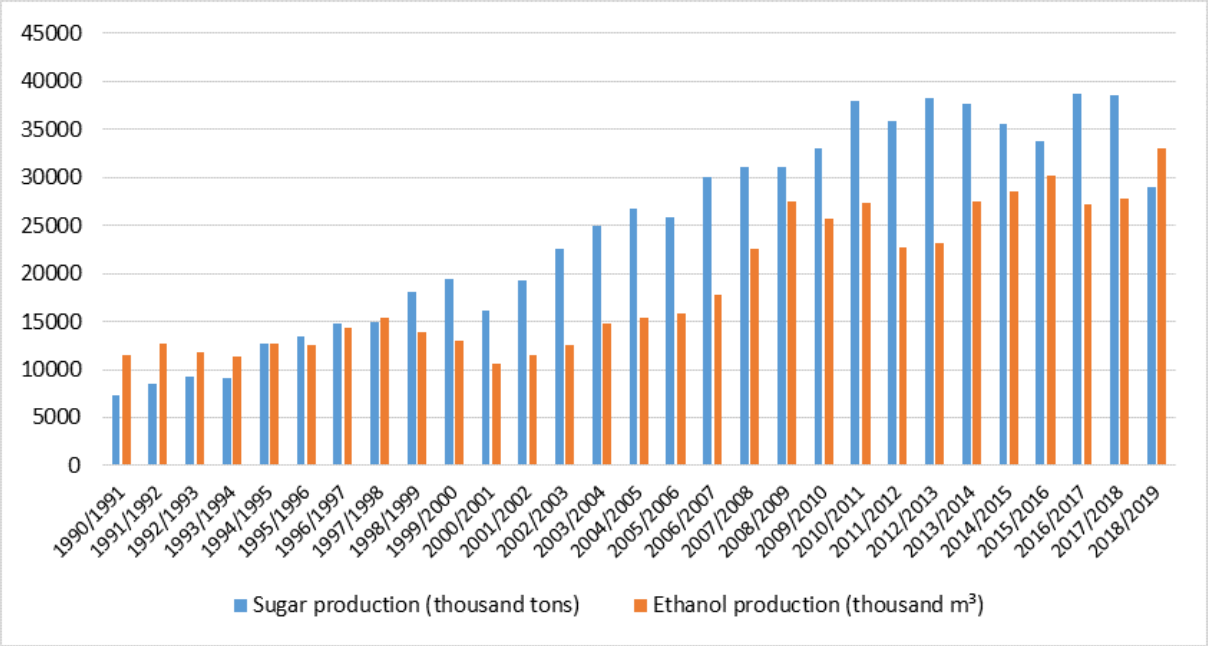
For the 2018/2019 harvest, sugar production was 29.04 million tons, about 24.75% lower than the 2017/2018 harvest. In this harvest approximately 91.28% of sugar production was concentrated in the Midwest, South and Southeast, and only São Paulo produced 62.57% of the total (UNICA, 2020b).

Ethanol production in the 2015/2016 harvest was 30.64 billion liters, an increase of 6.3% compared to the previous harvest. About 59.6% of the total sugarcane production was destined for ethanol production (CONAB, 2019). For the 2018/2019 harvest there was an increase in ethanol production by 18.82% compared to the previous harvest. This production was also concentrated in the Midwest, South and Southeast regions (93.5% of the total).

Figure 1 illustrates the evolution of the production of these commodities (1990/1991 to 2018/2019), where there is a period of instability in ethanol production until the 2000s; then with the introduction of flexible-fuel vehicles (2003) there was a growth until 2008/2009, to an oscillation period between increases and decreases in ethanol production (the average annual geometric rate of growth in the period was 4.11%)[1].

[1]On the calculation of the average annual geometric rate of growth see Hoffmann and Vieira (1987).

Figure 1. Evolution of sugar and ethanol production in Brazil, 1990/1991 to 2018/2019



Source: authors' own elaboration based on data from UNICA (2019).

Sugar, on the other hand, shows a trend better adjusted for growth, with some oscillations due to particular crop failures or market preferences (the average annual geometric growth rate was 5.85%) (Figure 1).

It is also noteworthy that corn ethanol production has expanded in recent years and for this reason it should be given deserved importance in the national energy scenario. The advantages of cereal are focused on the fact that its production can happen in the sugarcane and soybean off-season, and that it can be stored for further industrialization. Crop integration provides efficiency without the need to increase agricultural boundaries (Valle Lozano, 2018).

Milanez et al. (2014), researching the mills that process both sugarcane and corn, concluded that the risk in investing this type of facility is relatively low. In addition, they emphasize that technological level increases a given mill's profitability. Moreover, the option of this production expands the competitiveness in places that might absorb the co-products, as is the case of the Midwest, a meat-producing region.

According to estimates by CONAB (2019), Brazilian corn ethanol production is expected to grow between 2018/2019 and 2019/2020, approximately by a rate of 114%, from 791 million to 1.693 billion litres. The Midwest will be responsible, in this last harvest, for about 95% of the production of domestic corn ethanol. Mato Grosso

To obtain the rate, a linear regression is estimated using the ordinary least squares method, where lnY is the dependent variable, while the independent variable X is the time period for which the rate is desired. From the estimated parameter for the independent variable, the antilog is calculated, which will represent the geometric growth rate of the estimated series. In addition, the t-test was used to determine whether the estimate was statistically significant.

is the largest Brazilian producer, and its production will more than double in the 2019/2020 harvest. One of the activities observed was the integration of livestock production and mills, enhancing the absorption of co-products and avoiding losses in corn runoff for export. According to MAPA (2019) projections, corn cultivation is expected to grow mainly in Mato Grosso and Paraná, especially due to the increase in the production of corn from the 2nd harvest. This interest is related to the expansion of the corn ethanol industry in the Midwest, besides being also a supply of animal feed for cattle, pigs and poultry. According to Taheripour et al. (2010), the DDG (Distillers Dried Grains) – a by-product extracted during the process of distillation of corn ethanol – can be used as animal feed and mitigates the price impacts of biofuel production, reducing the demand for arable land.

4. Final remarks

This research was motivated by the importance of sugarcane agroindustry in Brazil. As such, the objective was to analyze the changes that have occurred in the productive aspects of sugarcane, comparing the data from the 2017 Agricultural Census with those from the 2006 and 1995 Censuses, in order to promote a dialogue about the dynamics that have occurred in the sector in the last two decades.

We can highlight that there was a decline in the number of producing sugarcanes establishments in Brazil among the three Censuses; however, production increased in the period by about 141%. There is indication that there was a concentration of production, for the analysis between 2006 and 2017 in the Southern region, it was possible to observe that there was a concentration of production in larger establishments. The South-eastern region continues to have the highest production among the regions, especially the state São Paulo – accounting for 54% of the total sugarcane produced in the country, in the 2017 Census.

Nevertheless, the Midwest gained prominence, with Goiás being the second largest national sugarcane producer, with 11.39% of the total. The region stood out in the increase in the number of establishments, in the harvested area and in production, among the three Censuses analyzed. As of the 2017 Census, the region became the second largest producer, behind the Southeast. Regarding yield, the Southeast, South and Midwest stood out in relation to the other regions, and for the 2017 Census the Midwest reached the highest average yield. Besides these data, the Midwest obtained the highest amount produced per worker and, among the states, the three states in this region (except the Federal District) also had the three highest values.

The sugarcane sector has historical and current importance in generating income, jobs, exports and the dynamics of some Brazilian regions. It is important to analyze the evolution of this raw material in Brazil to understand the functioning of its production, as well as to verify changes that have occurred and future trends. The findings of this study indicate the Center-West region as rising on the national scene in many

of the variables analyzed, although the Southeast region remains in the production leadership. On the other hand, the South and Northeast regions have reduced their importance in percentage terms, the Northeast in greater proportion.

The analysis of the evolution of sugar and ethanol production also shows that, despite oscillations, the two productions have tended to grow over time, especially after 2000. Both are the main byproducts of sugarcane production and are important to the national energy and food matrix.

In summary, data from the 2017 Agricultural Census emphasized the stable trend of production in regions and states. Furthermore, the results reaffirm the importance of the general and specific analysis, the multidimensionality of the sugarcane production chain, the impact of the changes that have occurred in the sector during the decades, in addition to the fact that the mills and distilleries that are surviving in this sector have greater technological capacity.

We mainly indicate the need for joint analysis, medium and long-term planning, verification of microeconomic data of mills and distilleries, in order to contribute to the direction of the efficiency and competence of this important sector in the national economy. Organization and planning are fundamental elements that provide the prediction and sustainability of a productive branch.

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