

# The expansion of sugarcane agroindustry in the central west Brazilian (1975-2017): a historical-economic analysis

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**Abstract:** The objective of this research was to analyze the expansion of the sugarcane agroindustry in the Center-West region (from 1975 to 2017), with emphasis on historical-economic aspects, highlighting the primary drivers, potentialities, and limits of this agroindustry. The main results indicate that the growth rate of the area harvested, the production of sugarcane, sugar, and ethanol of the region was higher than the national average, resulting in the continuous increase of the importance of this sugarcane agroindustry in the national scenario, supported by favorable conditions for its expansion (such as edaphoclimatic conditions, topography of lands propitious to the use of mechanization, among others), despite the limits indicated in the literature (transport logistics, instability in the ethanol market, and others). The national and international market projections for sugar, ethanol and cogeneration of energy are favorable to the economic consolidation of the sugarcane agroindustry in the Center-West region in the regional and national comparison.

**Keywords:** Sugar. Ethanol. Sugarcane in the cerrado.

## 1 INTRODUCTION

After almost five centuries of existence in Brazil, sugarcane cultivation remains a relevant activity for the country, either from the historical-economic or cultural perspective. The creation of the National Alcohol Program (Proálcool) in the mid-1970s brought a new impetus to the national sugarcane sector. At that time, the Brazilian State defined alcohol as an

alternative energy source to petroleum, which at the time was a hindrance for the productive sector due to the excessive dependence on this commodity and the consequent vulnerability to the high international prices and supply crises, as occurred during the international oil shocks in 1973 and 1979. The Brazilian State started to provide institutional support (initially with creation of the National Alcohol Commission) and executive (via financing, credit and tax

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incentives, subsidies and/or price incentives) to the sugarcane agro-industry to ensure the expansion of the sector's infrastructure, as well as to organize the “orchestration of interests” among the national objectives, businessmen of mills and distilleries, the machinery and equipment sector, and the automobile industry (besides consumers) in order to ensure the success of Proálcool (SHIKIDA, 1997).

It was during the second phase of Proálcool (of accelerated expansion, 1980-1985) that the Center-West region (composed by the states of Mato Grosso, Mato Grosso do Sul, Goiás and Distrito Federal), without any sugarcane tradition until then, started to attract investments from sugarcane activity and to be part of the geographical reconfiguration of the sector; the states that stood out in the absorption of Proálcool resources were: São Paulo (36.0%), Minas Gerais (10.3%), Alagoas (8.1%), Paraná (7.9%), Goiás (7.2%), Pernambuco (7.1%), Mato Grosso (3.2%), Rio de Janeiro (3.0%), Paraíba (2.7%) and Mato Grosso do Sul (2.5%) (SHIKIDA; BACHA, 1999).

Comparing the 2006/2007 and 2017/2018 harvests in the Center-West region, the sugarcane harvested area increased from 588.06 thousand to 1.858 million hectares (+ 216%), the sugarcane production from 40.95 million to 133.69 million tons (+ 226.44%), sugar from 1.88 million to 4.13 million tons (+ 119.51%), and total ethanol production from 2.22 million to 8.74 million m<sup>3</sup> (+ 294.07%). In terms of the evolution of the national participation in these crops, the region accounted for 9.25% and 18.25% of the national sugarcane harvested area, for 9.58% and 28.86% of the national sugarcane production, for 6.28% and 10.72% of national sugar production, and 12.44% and 31.4% of national ethanol production (UNICA, 2019).

The literature points to new agricultural frontier areas for sugarcane cultivation in Brazil; among them, the main one is the Center-West (MORAES, 2000; SILVA; MIZIARA, 2011; WISSMANN *et al.*, 2014; SHIKIDA; RISSARDI JÚNIOR, 2017). The statistics presented on the evolution of sugarcane agroindustry performance in this region corroborate the literature. Given this scenario, it

is crucial to know how the expansion of the sugarcane agroindustry in the region took place. With this purpose, the objective of this research is to analyze the expansion of the sugarcane agroindustry in the Center-West region from 1975 to 2017, with emphasis on historical-economic aspects, also highlighting the primary drivers, potentialities, and limits of this agroindustry in the region. The chosen period of this analysis dates from the creation of Proálcool (1975) and the sector performance statistics used are from 1980 to 2017 due to the availability of data from the Brazilian Sugarcane Industry Association (UNICA) and the Brazilian Institute of Geography and Statistics (IBGE).

For the data analysis, the following subperiods were delimited according to the classification of the literature (SHIKIDA, 1997; SHIKIDA; RISSARDI JÚNIOR, 2017): phases of the moderate expansion of Proálcool (1975-1979), accelerated expansion (1980-1985) and deceleration and crisis (1986-1995); increasing deregulation of the sector (1996/1997 to 2002/2003); resumption of ethanol production and domestic consumption (2003/2004 to 2013/2014) and recent period (2014/2015 to 2017/2018).

This research is classified as exploratory/explanatory, as it provides greater familiarity with the research problem and is mostly based on bibliographic and documentary material (statistical data), considering the most varied aspects that are related to the fact studied and serving as a basis for further research in order to broaden the explanation of the investigated objective (GIL, 2017).

This article consists of four sections, including this introduction. Sections two and three portray, respectively, the historical-economic aspects and drivers, potentialities and limits of this sector evolution, and, finally, the fourth section presents the conclusions.

## 2 HISTORICAL-ECONOMIC ASPECTS OF THE EXPANSION OF SUGARCANE AGROINDUSTRY IN CENTER-WEST REGION

The advance of sugarcane agroindustry to new producing areas in the Brazilian Center-West was associated with Proálcool. This Program emerged in 1975 and lasted until 1995

in response to a hindrance in the country's productive system represented by the excessive dependence on petroleum as an energy matrix. This energy resource experienced a considerable rise in international prices due to the world energy crises of 1973 and 1979 (SHIKIDA; BACHA, 1999).

Proálcool consisted of a series of institutional support measures from the Brazilian State to spread an alternative energy matrix to petroleum, in which alcohol (now called ethanol) was chosen. Making Proálcool viable required an “orchestration of interests” between the State, plant and distillery entrepreneurs, the machinery and equipment sector, and the automobile industry. For the sugarcane businessmen, this represented the creation of a new market in the face of the constant crises of sugar activity and the technological advance of the productive park; for the machinery and equipment sector, it provided the opportunity for continued growth that began in the 1960s and peaked during the 1970s (period which is known as the Brazilian “Economic Miracle”); for the automobile industry, it consisted of the perpetuity of the road policy adopted by Brazilian development, threatened by the oil crisis (VIAN, 2015; SHIKIDA; RISSARDI JÚNIOR, 2017).

According to the periodization proposed by Shikida (1997), Proálcool presented three phases: moderate expansion (1975-1979), accelerated expansion (1980-1985), and deceleration and crisis (1986-1995). During the first phase, the National Executive Commission on Alcohol (CENAL) was responsible for the institutional support of the Program, which for its execution it was officially supported by financing, credit and tax incentives, subsidies and/or price incentives. The insertion of alcohol in the national energy matrix required massive investments in the sugarcane agroindustry in order to expand the sector's infrastructure. For Lopes (1996), from 1975 to 1980, Proálcool invested US\$ 1.019 billion, 75% from public resources and the remainder from private sources. However, these investments were mainly directed to the installation or modernization of distilleries in traditional states in the sugarcane industry (São Paulo, Alagoas, Pernambuco, and Rio de Janeiro). This phase

was guided by the use of anhydrous alcohol (gasoline additive).

In the second phase of Proálcool, of accelerated expansion (1980-1985), hydrated alcohol production as a single-fuel vehicle was intensified through independent distilleries. In this phase, the “orchestration of interests” occurred more intensely, examining measures that affected from the sugarcane industry entrepreneurs to the final consumer, benefited by the reduction of the Tax on Industrialized Products (IPI) for the purchase of alcohol-only powered vehicles, exemption from IPI for taxi drivers, and establishment of the alcohol price cap of 65% of gasoline price (SHIKIDA, 1997).

It was during the accelerated expansion phase of Proálcool (1980-1985) that the Center-West region of Brazil began to attract investments from the sugarcane agroindustry. According to Lopes (1996), about US\$ 5.406 billion was invested between 1980 and 1984, 56% from public sources, and 44% from private sources. The states that stood out in the absorption of these resources were: São Paulo (36.0%), Minas Gerais (10.3%), Alagoas (8.1%), Paraná (7.9%), Goiás (7.2 %), Pernambuco (7.1%), Mato Grosso (3.2%), Rio de Janeiro (3.0%), Paraíba (2.7%) and Mato Grosso do Sul (2.5%). There was a geographical reconfiguration of sugarcane production during this period, where Goiás, Mato Grosso, and Mato Grosso do Sul, with no tradition in the sugarcane sector, began to stand out in alcohol production.

The third phase of Proálcool, the deceleration and crisis (1986-1995), was marked by the reduction of state interference in the sugarcane sector, in a context of the advent of the neoliberal idea of reducing the size and State interference in the economy and fighting the fiscal crisis, aggravated in the 1980s. Lopes (1996) notes that there was a gradual reduction in public investments in the sugarcane agribusiness between 1985 and 1990, totaling US\$ 0.511 billion for the entire period (the lowest value among the three phases of Proálcool), of which 39% from public sources and 61% from private sources. This change in investments is how the sector moved from the old subsidization paradigm to the technological paradigm, in which companies had to prioritize

investments in innovation and modern technologies to remain active and competitive in the market (SHIKIDA; BACHA, 1999; VIAN, 2015).

The hindrance represented by the excessive dependence on petroleum was cooled during the deceleration and crisis of Proálcool, given the fall of the international price of this commodity and the increase of its domestic production. There was a crisis of domestic alcohol supply in the 1986/1987 harvests, which reflected on the automobile industry (reduction of sales of alcohol-powered vehicles) and on consumer behavior, which faced increasingly less advantageous alcohol prices compared to gasoline, as well as the weakening of public agencies linked to the sugarcane agroindustry such as the Sugar and Alcohol Institute (IAA). In short, during this period, there was a breakdown of the “orchestration of interests” that defined alcohol as an alternative energy source to petroleum (SHIKIDA, 1997).

According to Shikida and Rissardi Júnior (2017), the upsurge in deregulation, the specific structural weakness, and the diversity of interests in the sugarcane agribusiness are characteristics that marked the period 1996/1997 to 2002/2003. According to the authors, during this period the process of deregulation perpetuated and was associated with the economic context of State reorganization (post-Real Plan), in which there was a reduction in subsidies and financing to the sugarcane agroindustry and the liberalization of anhydrous ethanol, sugarcane prices, and hydrous ethanol. Also, a wave of mergers and acquisitions in the sector dates from this period, as well as the migration of investments to sugarcane frontier areas, the main one being the Center-West.

The evolution of sugarcane production marked the structural weakness, restructuring of production units and intensification of the process of mergers and acquisitions; capital transfers to other regions (notably the Center-West); and the productive heterogeneity between the North-Northeast (at a cost and productivity disadvantage) and Center-South (with the most significant technological advance) macro-regions (VIAN, 2015).

The conflict of interest materialized between the North-Northeast producers (in favor of maintaining interventionist measures), a Center-South group that was considering deregulation, and a third group in the same macro-region, which was totally in favor of deregulation and felt harmed by the quota and marketing system. In this context, new corporatist organizations emerged, such as the Brazilian Sugarcane Industry Association (UNICA), in 1997, and others in the leading representative states of the sector in question, in addition to the creation in 2003 of the Sectional Council of Productive Chain of Sugar and Alcohol, linked to the Ministry of Agriculture, Livestock and Food Supply (MAPA).

The period 2003/2004 to 2013/2014 was characterized by the resumption of ethanol production and domestic consumption with the flex-fuel car market, the entry of Foreign Direct Investment (FDI) in the sugarcane agroindustry, and the lack of government planning, by subsidizing the domestic price of gasoline. However, in 2003, flex-fuel cars (which allow fueling of alcohol and gasoline) began to be produced in series, giving consumers the choice of which fuel to use, which was considered an innovation (SHIKIDA; RISSARDI JÚNIOR, 2017).

The federal government's lack of planning to subsidize the domestic price of petroleum-based fuels below the price paid on the international market as an instrument of inflationary control has had deleterious effects on ethanol consumption and encouraged the consumption of petroleum-based fuels, which was corroborated by the discovery of pre-salt. This political stance was considered incoherent by the corporatist organizations of the sector, both from the environmental point of view and from the Brazilian food and energy security, given the importance of the sugar-energy sector to the country. As for FDI inflows, there was an increase in foreign funding channeled to the Brazilian sugar-energy sector, given the expectation of increased world demand for biofuels, sugar, and energy, as well as investment opportunities arising from the sector deregulation that began in the 1990s. As a result, there was an intense movement of mergers and

acquisitions from 2004, raising the share of foreign capital in the sector from 3% in 2006 to 33% in 2017 (SANTOS *et al.*, 2016).

In order to guarantee the supply of raw material from the new agro-industrial units implemented in the Center-West, sugarcane planting was increased in the region. Table 1 shows the size of the evolution of the harvested area of this crop between the states and the increase of their participation in the national scenario. The statistics corresponding to the beginning and end of each analysis subperiod were presented, a procedure also maintained for Tables 2 to 4.

During the accelerated expansion phase of Proálcool (1980-1985), there was a significant increase in the Center-West

harvested area compared to Brazil. The region's share of the national sugarcane harvested area increased from 1.79% in 1980 to 4.35% in 1985 (over 128,000 additional hectares). Among the states, Goiás led the participation in national production in 1985 (2.37%), followed by Mato Grosso do Sul (1.24%) and Mato Grosso (0.74%). The average annual growth rate (by the least-squares method, considering the variables of the entire listed period, see: Hoffmann and Vieira, 2006) of the area harvested in this period for the Center-West was 30.2%, well above the national rate (8.4%). Among the states, Goiás presented the highest annual growth rate (31.18%), followed by Mato Grosso (30.47%) and Mato Grosso do Sul (29.96%).

**Table 1** - Area harvested with sugar cane (1980 to 2017), in hectares, for the states of Goiás (GO), Mato Grosso (MT) and Mato Grosso do Sul (MS) in the Center-West region (CW) and participation in the Brazilian production (BR)

	GO*	MT	MS	CW	BR	Participation (%)			
						CW/BR	GO*/BR	MT/BR	MS/BR
1980	28,825	8,704	11,976	49,505	2,768,514	1.79	1.04	0.31	0.43
1985	96,765	30,192	50,705	177,662	4,084,858	4.35	2.37	0.74	1.24
1986	111,180	36,241	64,160	211,581	4,132,875	5.12	2.69	0.88	1.55
1995	104,769	98,906	74,815	278,490	4,559,062	6.11	2.30	2.17	1.64
1996	108,659	118,506	80,885	308,050	4,750,296	6.48	2.29	2.49	1.70
2002	145,425	176,666	112,100	434,191	5,100,405	8.51	2.85	3.46	2.20
2003	165,206	196,684	120,534	482,424	5,371,020	8.98	3.08	3.66	2.24
2013	860,932	282,741	642,686	1,786,359	10,165,166	17.57	8.47	2.78	6.32
2014	895,313	276,025	639,899	1,811,237	10,419,678	17.38	8.59	2.65	6.14
2017	923,192	273,273	661,906	1,858,371	10,184,340	18.25	9.06	2.68	6.50

Source: Authors, based on IBGE (2019).

\*Includes Federal District.

Specifically in Mato Grosso do Sul, Domingues and Thomaz Júnior (2012) analyzed the territorialization of sugarcane and attributed to Proálcool the main reason for the establishment of nine agro-industrial units from 1979 to 1983, due to tax and credit incentives from the federal and state spheres.

Following the analysis (Table 1), during the deceleration and crisis phase of Proálcool (1986-1995), there was little variation in the participation of the Center-West region in the sugarcane harvested area. The participation of the region concerning the country went from 5.12% in 1986 to 6.11% in 1995 (an increase of more than 66 thousand hectares). Mato Grosso was the highlight, as its share went from 0.88% (1986) to 2.17% (1995). The annual growth rates of the harvested area were -0.6% in Goiás,

10.2% in Mato Grosso, and -0.16% in Mato Grosso do Sul.

Between 1996/1997 and 2002/2003, the phase of the sugarcane agroindustry deregulation, there was an increase of over 126 thousand hectares of sugarcane harvested area in this region, whose participation in national production increased from 6.48% to 8.51%, especially Mato Grosso, whose share increased from 2.49% to 3.46%. The Center-West region grew 6.1% in the period (above the national growth of 1.32%). The states with the highest growth rates were Mato Grosso (6.69%), Mato Grosso do Sul (5.9%) and Goiás (5.59%), respectively.

From 2003/2004 to 2013/2014, marked by the creation and diffusion of flex-fuel cars and FDI inflows in the sugarcane sector, the Center-West region showed significant growth

in the sugarcane harvested area (over 1.3 million hectares), increasing its participation in national production from 8.98% to 17.57%. The participation of states in the national harvested area thus evolved: Goiás (from 3.08% to 8.47%), Mato Grosso (from 3.66% to 2.78%) and Mato Grosso do Sul (from 2.24% to 6.32%). The growth rate of the harvested area reached 14.74% for the Center-West region (higher than the national one, of 6.88%), 19.43% for Mato Grosso do Sul, 19.1% for Goiás, and 2.9% for Mato Grosso. It should be noted that the latter state had the most significant area harvested among the states of Center-West in 2003, occupying the smallest area at the end of the period, which reflected in the drop in its national participation and the lower growth rate in the period.

Although not occupying the most significant area, Mato Grosso had the highest growth rate of sugarcane harvested area in the Center-West from 1980 to 2017, 9.26%, followed by Mato Grosso do Sul (9.02%) and Goiás (8.7%). The region had a growth rate of 8.92% of the sugarcane harvested area for the

same period, higher than the Brazilian rate (3.39%).

There were no substantial changes in the recent period (2014/2015 to 2017/2018) regarding the sugarcane harvested area in Brazil and the analyzed states. Besides, it is attributed to the lower average of sugarcane harvested area in Mato Grosso due to restrictions in Sugarcane Agroecological Zoning (Sugarcane AEZ) and greater distance to the Center-South consumer market. Conversely, higher averages of sugarcane harvested areas are attributed in Goiás and Mato Grosso do Sul due to the smaller distance to the Center-South consumer market, which also concentrates the machinery and equipment industries used in the activity and the research institutes.

Table 2 presents the evolution of sugarcane production. It should be noted that during the accelerated expansion phase of Proálcool (1980-1985), the production of this grass began to be widespread in the Center-West region, given the investments received for the implantation of industrial plants in the region at this time, as pointed out in the literature.

**Table 2** - Sugarcane production in the states of Goiás (GO), Mato Grosso (MT) and Mato Grosso do Sul (MS) in the Center-West region (in thousand tons) and participation in national production - harvests from 1980/1981 to 2017/2018

Harvest	GO*	MT	MS	CW	BR	Participation (%)			
						GO*/BR	MT/BR	MS/BR	CW/BR
1980/1981	311	303	0	614	123,681	0.25	0.24	0.00	0.50
1985/1986	4,188	1,432	3,191	8,811	202,868	2.06	0.71	1.57	4.34
1986/1987	4,807	1,873	3,102	9,782	227,846	2.11	0.82	1.36	4.29
1995/1996	6,330	6,739	4,675	17,743	248,930	2.54	2.71	1.88	7.13
1996/1997	8,216	8,085	5,405	21,705	288,795	2.84	2.80	1.87	7.52
2002/2003	9,922	12,384	8,247	30,554	320,650	3.09	3.86	2.57	9.53
2003/2004	13,041	14,350	8,886	36,276	358,762	3.63	4.00	2.48	10.11
2013/2014	62,018	16,989	41,496	120,503	651,294	9.52	2.61	6.37	18.50
2014/2015	66,750	17,012	44,684	128,446	633,927	10.53	2.68	7.05	20.26
2017/2018	70,622	16,134	46,940	133,696	641,066	11.02	2.52	7.32	20.86

Source: Authors, based on IBGE (2019).

\*Includes Federal District.

In this sense, in the 1980/1981 harvest, the region's production was insignificant, and from 1985/1986 onwards, the results show particular importance in the national context, accounting for 4.34% of the total produced in the country, while national production increased over 79 million tons. It is noteworthy that sugarcane production in Mato Grosso do Sul went from 0 to 3.19 million tons (Table 2).

Despite the deceleration and crisis of Proálcool (1986-1995), sugarcane production in the Center-West continued to grow during this period, accounting for 7.13% of national production in the 1995/1996 harvest. Among the states, Mato Grosso was the one that most increased its participation in national sugarcane production in the period (from 0.64% to 2.71%). Production growth rates were: Center-West (5.93%), high above the national rate (0.46%),

Mato Grosso (15.88%), Goiás (2.33%) and Mato Grosso do Sul (1.86%). As observed in Tables 3 and 4, in the ethanol boom phases, most of the sugarcane production was directed to the manufacture of fuel, whereas in the crises of this fuel, the advantageous option was sugar production, except unfavorable circumstances. This business strategy is one of the explanations that there was no fall in sugarcane production even during the deceleration and crisis of Proálcool.

During the period in which sugarcane agroindustry deregulation was increasing (1996/1997 to 2002/2003), the participation of the Center-West region in national sugarcane production increased from 7.52% to 9.53%, with Mato Grosso accounting with the largest share (3.86% in 2002/2003). The increase in regional production in the period was over 8.84 million tons. The annual growth rate of Center-West production amounted to 4.23% (with the national rate close to zero). In the states, this growth was 6.41% for Mato Grosso do Sul, followed by Mato Grosso (4.47%) and Goiás (1.86%).

From 2003/2004 to 2013/2014 (emergence of flex-fuel cars), period characterized by the resumption of production and domestic consumption of ethanol, sugarcane production increased by more than 84 million tons (3.32 times the initial production). Participation of Center-West in the national production increased from 10.11% to 18.5%. Among the states, Goiás was responsible for the largest share in national production (9.52%) in 2013/2014, followed by Mato Grosso do Sul (6.37%) and Mato Grosso (2.61%). The annual

growth rate of Center-West production was 14.55% (higher than the national rate, 6.17%), Goiás (19.12%), Mato Grosso do Sul (19.40%) and Mato Grosso (1.39%). In the recent period (2014/2015 to 2017/2018), the growth rates of sugarcane production were not significant.

Among the federative units, the most significant shares of national sugarcane production in 2017/2018 were, respectively, Goiás (11.02%), Mato Grosso do Sul (7.32%) and Mato Grosso (2.52%). Mato Grosso do Sul led the annual growth rate in the period since the 1980/1981 harvest (22.46%), followed by Goiás (14.55%) and Mato Grosso (10.91%).

Analyzing the evolution of sugar production in the Center-West (Table 3), during the accelerated expansion phase of Proálcool (1980-1985), concomitantly with increases in harvested area and sugarcane production, sugar production progressed little until the 1986/1987 harvest, whose share of regional production in the national scenario corresponded to 0.44%; a similar trend was observed in domestic production. It is essential to highlight that ethanol production had a significant increase during Proálcool's accelerated expansion period, suggesting that sugarcane production was mainly directed to ethanol production, an integral strategy of Proálcool that, since its second phase, directed efforts towards hydrated alcohol production to supply the growing fleet of vehicles powered by this fuel (SHIKIDA; BACHA, 1999). The annual growth rate of regional production was -5.6%, while national production was 0.46%. Mato Grosso grew -16.44%, Goiás (-8.17%), and in Mato Grosso do Sul, the growth was nil.

**Table 3** - Sugar production in the states of Goiás (GO), Mato Grosso (MT) and Mato Grosso do Sul (MS) in the Center-West region (in thousand tons) and participation in national production - harvests from 1980/1981 to 2017/2018

Harvest	GO*	MT	MS	CW	BR	Participation (%)			
						GO*/BR	MT/BR	MS/BR	CW/BR
1980/1981	21	20	0	42	8,254	0.26	0.24	0.00	0.51
1985/1986	12	36	1	49	8,033	0.15	0.45	0.01	0.61
1986/1987	11	23	1	36	8,157	0.14	0.29	0.01	0.44
1995/1996	226	265	135	626	13,513	1.67	1.96	1.00	4.63
1996/1997	309	301	192	802	14,828	2.08	2.03	1.29	5.41
2002/2003	577	546	374	1,497	22,567	2.56	2.42	1.66	6.63
2003/2004	668	579	403	1,650	24,919	2.68	2.33	1.62	6.62
2013/2014	1,891	418	1,368	3,676	37,594	5.03	1.11	3.64	9.78
2014/2015	1,997	405	1,391	3,793	35,571	5.61	1.14	3.91	10.66
2017/2018	2,235	411	1,492	4,137	38,596	5.79	1.06	3.86	10.72

Source: Authors, based on IBGE (2019).

\*Includes Federal District.

During the period of deceleration and crisis of Proálcool (1986-1995), there was a jump in sugar production at national (over 5.3 million tons) and regional (590 thousand tons). Annual production growth rates were high for both the Center-West (38.04%) and the states; however, that the region's production was still considered incipient.

From the 1995/1996 harvests of the sector's deregulation (1996/1997 to 2002/2003), the production of sugar in the Center-West began to have national representation (4.63%) and, since then, the region was growing (except for some periods), according to the literature that states that there is a migration of investments from the sector to the Center-West (SHIKIDA; RISSARDI JÚNIOR, 2017). In the period, regional production increased by 695 thousand tons, national production by 7.73 million tons, and regional participation in national totaled 6.63% at the end of the period. The annual growth rate of regional production was 9.9%, above the national one (5.93%).

As was cited above, from 2003/2004 to 2013/2014, there was a resumption of ethanol production and domestic consumption due to the massive production of flex-fuel cars. However, regional sugar production increased by 2.02 million tons, accounting for 9.78% of national production at the end of the period. Goiás had the highest national representation (5.03%). The annual growth rate was 10.92% for the Center-West (above the national rate, of 4.47%), 17.49% for Mato Grosso do Sul, 12.98% for Goiás, and -3.17% in Mato Grosso. In 2014/2015 to 2017/2018, the annual growth rate of national and regional production was 3.75% and 4.47%, respectively.

The Center-West produced 4.137 million tons of sugar in the 2017/2018 crop (10.72% of national production), with Goiás (5.79% of national production) as the leading producer. However, it was Mato Grosso do Sul that had the highest annual growth rate of production in the full period of the analysis (25.31%), followed by Goiás (18.03%) and Mato Grosso (11.94%). Production in the Center-West grew by 16.95% annually, above the national rate of 5.43%.

Table 4 presents the evolution of ethanol production in the region. It is possible to observe the production impetus that occurred during the accelerated expansion phase of Proálcool (1980-1985), in which the production grew more than 13 times in the region. Among the states, production grew more than 34 times in Goiás, more than seven times in Mato Grosso, and more than eight times in Mato Grosso do Sul. During the deceleration and crisis of Proálcool (1986-1995), Brazilian production increased little (10.50 million m<sup>3</sup> to 12.61 million m<sup>3</sup>); however, production in the Center-West advanced in a more substantial proportion, from 652 thousand m<sup>3</sup> to 1.035 million m<sup>3</sup>, corresponding to 8.21% of national production, mainly driven by Mato Grosso (increased from 1.07% to 2.99% in national production, with the highest growth rate in the period, 46.15%). Despite the unfavorable scenario for alcohol, the regional annual growth rate (3.51%) was higher than the national one (1.39%).

In the period of increasing deregulation of the sector (1996/1997 to 2002/2003), regional ethanol production increased by 319,000 m<sup>3</sup>, while national production decreased by 1.77 million m<sup>3</sup>, resulting in an increase in regional participation in the sector from 8.39% to 12.1%. The annual growth rate of regional production was around 1.16% (while the national one was -4.28%). Mato Grosso do Sul had the highest annual growth (3.75%), followed by Mato Grosso (2.80%) and Goiás (-3.17%).

During the diffusion period for flex-fuel cars and the resumption of ethanol consumption and production (2003/2004 to 2013/2014), regional production increased by 5.29 million m<sup>3</sup> (while the national production was 12.73 million m<sup>3</sup>). The share of regional production in the national scenario increased from 13.02% to 26.26%, with Goiás being the most representative state (14.12% of national production in 2013/2014), followed by Mato Grosso do Sul (8.12%) and Mato Grosso (4.02%). The latter lost the position of central producing state prevailing in the previous phase. The annual growth rate of the regional production was 15.61% (higher than the national one, of 6.41%), constituted by the production



growth of Goiás (21.90%), Mato Grosso do Sul (18.6%) and Mato Grosso (2.57%). In this period, the Center-West showed the highest

growth rate of ethanol production, after the period of accelerated expansion of Proálcool, in which the sugarcane agroindustry was incipient.

**Table 4.** Ethanol production (in thousand m<sup>3</sup>) in the states of Goiás (GO), Mato Grosso (MT) and Mato Grosso do Sul (MS) in the Center-West region and participation in national production – harvests from 1980/1981 to 2017/2018

Harvests	GO*	MT	MS	CW	BR	Participation (%)			
						GO*/BR	MT/BR	MS/BR	CW/BR
1980/1981	9	10	28	47	3,706	0.25	0.27	0.75	1.27
1985/1986	307	77	233	617	11,829	2.59	0.65	1.97	5.21
1986/1987	331	112	209	652	10,505	3.15	1.07	1.99	6.21
1995/1996	366	377	292	1,035	12,611	2.90	2.99	2.32	8.21
1996/1997	452	468	288	1,208	14,395	3.14	3.25	2.00	8.39
2002/2003	455	654	418	1,527	12,623	3.61	5.18	3.31	12.10
2003/2004	646	792	480	1,919	14,736	4.39	5.38	3.26	13.02
2013/2014	3,879	1,104	2,231	7,214	27,476	14.12	4.02	8.12	26.26
2014/2015	4,211	1,169	2,507	7,887	28,480	14.79	4.10	8.80	27.69
2017/2018	4,618	1,499	2,632	8,749	27,859	16.58	5.38	9.45	31.40

Source: Authors, based on IBGE (2019).

\*Includes Federal District.

In the recent period (2014/2015 to 2017/2018), regional ethanol production increased by 862 thousand m<sup>3</sup> (national decreased by 622 thousand m<sup>3</sup>), making an annual growth rate of 2.56% (the national one was -1.60%). Mato Grosso had the highest annual growth rate (6.66%), followed by Goiás (2.10%) and Mato Grosso do Sul (1.16%).

Contrary to what happened with sugarcane and sugar production, ethanol production in Mato Grosso was increasing in the period, both in absolute and relative terms. The annual growth rates of the 1980/1981 to 2017/2018 harvests were 12.20% (Goiás), 11.94% (Mato Grosso), 10.15% (Mato Grosso do Sul), and 11.17% (Center-West), while Brazil grew 4.23% in the same period. The national production of ethanol grew more than seven times in the period, while the regional one more than 185 times.

According to Sauer and Pietrafesa (2012), there was a euphoria in the sugarcane sector in areas of the Cerrado during the 2000s, with the installation of new production units, financed mainly by significant foreign investments in the purchase of industrial units and land, aiming at potential European markets that have decided to replace gasoline consumption by renewable fuels by up to 10% by the year 2025. However, most of Brazil's ethanol production has been consumed internally, meeting the demand for flex-fuel cars. Also, the authors point out that at the end of 2008, the international financial crisis, together with restrictions on imports of Brazilian ethanol by the United States and the European

Community countries, and the high international sugar prices caused the slowdown in investments in the sector.

The data corroborate the assertion of the literature that the Center-West is constituted as a sugarcane border area (SILVA; MIZIARA, 2011; MORAES, 2000; WISSMANN *et al.*, 2014; SHIKIDA; RISSARDI JÚNIOR, 2017). The growth of sugarcane harvested area, sugarcane production, sugar, and ethanol was higher than national growth in all subperiods of analysis, especially during the Proálcool (1980-1985) accelerated expansion period and from 2003/2004 to 2013/2014 - characterized by the resumption of production and domestic consumption of ethanol (production of flex-fuel cars), entry of FDI into the sugarcane agro-industry and lack of federal government planning in subsidizing the price of gasoline. It is worth noting that the growth rate of sugar production was higher during the periods of retraction in ethanol production (deceleration and crisis of Proálcool, 1986 to 1995) and from 1996 to 2002 (increasing deregulation of the sector), reflecting business strategies in the sector to adapt the sugarcane processing to the most profitable product on the market at the time, either sugar or alcohol.

### 3 DRIVERS, POTENTIALS, AND LIMITS OF SUGARCANE AGROINDUSTRY IN BRAZILIAN CENTER-WEST

Based on the literature, this section points out the main explanatory factors and limits to the expansion of the sugarcane

agroindustry in the Brazilian Center-West, as well as its potential sources of growth in the sector.

Shikida (2013) lists the following factors as favorable and explanatory of the expansion of the sugarcane agroindustry in the Center-West: i) national and international context of the search for food security and sustainable energy; ii) saturation of traditionally producing areas and consequent increase in land costs; iii) decay of northeastern regions of secular tradition in the sector; iv) favorable soil and climate conditions for sugarcane cultivation; v) conducive topography to the use of mechanization (low slope flatlands); vi) availability of large and continuous extensions of land, which optimizes agronomic processes; vii) agroecological zoning of sugarcane favorable to crop expansion (potential for use of anthropized areas); viii) availability of fertile land not occupied by extensive livestock and land whose fertility can be corrected with fertilization; (ix) Center-West agricultural tradition and high rates of sugarcane crop productivity; x) possibility of agroindustry diversification between sugar and ethanol production, reducing the risk to crises of these commodities; xi) expectation of improvements in transportation infrastructure, especially the construction of an alcohol pipeline linking the region to export terminals.

In addition to previous conditions, the exploration of the by-products market derived from sugar and alcohol production, the alcohol chemistry (polyethylene, polyvinyl chloride and ethyl, acetaldehyde, among others) and the use of sugarcane bagasse and straw in bioelectricity generation (GOES; MARRA; SILVA, 2008).

Another debate in the literature refers to the possible adverse impacts of sugarcane advances on other food crops (soybean, corn, beans, cassava, and wheat) and on areas dedicated to livestock, bearing in mind the concern with food security. Specifically in Goiás, Sauer and Pietrafesa (2012) suggest that the expansion of sugarcane crops occurred mainly in areas previously occupied with grains (maize, rice, and beans), rivaling the poultry and pork meat agro-industry, generating adverse results on food availability and causing a land dispute that raised the prices of this factor of production in the affected regions.

However, the finding by Sauer and Pietrafesa (2012) is not a consensus in the literature, especially among empirical studies. Souza *et al.* (2007) analyzed the substitution effect of soybean, corn, sugarcane, and grazing areas in Brazil, through the Cobb-Douglas function, and there is no evidence that sugarcane is replacing areas of livestock and soybean, only of corn. Aguiar and Souza (2014) presented similar conclusions by using the shift-share model for the eight largest national sugarcane producers (including the Center-West) and found a robust expansion of sugarcane and soybean acreage, partly explained by the expansion respective production systems (possibly by incorporating pasture areas) and partly by replacing areas dedicated to rice, bean, and corn food crops. However, these impacts were small on food production (except rice) due to the productivity growth of these crops, which offset the effects of area substitution.

Verão, Costa and Forest (2016) used the shift-share model and analyzed the expansion of sugarcane cultivation in Mato Grosso do Sul against soybean, corn, and others (rice and beans), concluding that sugarcane did not replace the other crops in the state, but the area occupied by it grew at a faster rate than other crops. Using the same method and study area, but in two subperiods between 2006 and 2013, Defante, Vilpoux and Sauer (2018) found that in the first subperiod, sugarcane advanced over pasture areas, and, in the second, it was soybean that advanced over the pasture. However, none of the activities showed a reduction in production, and the advance of crops generated positive externalities on cattle ranching because it pressured ranchers to obtain productivity gains. Therefore, there is empirical evidence that the evolution of the sugarcane agroindustry has not compromised the food and energy security of the country.

Besides the land production factor, another relevant element of sugarcane evolution in Brazil and the Center-West is innovation. Vian (2015) argues that during the accelerated expansion of Proálcool (1980-1985), critical technological innovations emerged that altered the dynamics of the sugarcane agro-industry, such as the payment of sugarcane due to sucrose content and juice purity, new varieties of

sugarcane, adaptation of vehicle engines to hydrated alcohol, and later the reuse of sugarcane bagasse for power generation.

Technological advances continued after Proálcool, as in the phase of the sugarcane sector deregulation (1996/1997 to 2002/2003), in which the adoption of the technological paradigm was crucial for agro-industries to remain competitive in the liberalized market. Producers sought new varieties of sugarcane, advances in agricultural, industrial and harvesting techniques (such as fertigation, mechanization), modernization of work and organizational structure, and corporatist coordination mechanisms, as well as there was development of the flex-fuel automotive engine and mass production of these vehicles, among other factors (SHIKIDA; RISSARDI JÚNIOR, 2017).

In addition to the advances for increasing productivity aforementioned, there was also agricultural mecanization, genetic improvement, new crop and phytosanitary control practices, introduction of transgenic variables, industrial technologies that enabled higher alcohol production per ton of sugarcane, the use of vinasse for fertigation and of the filter cake in fertilization (GOES; MARRA; SILVA, 2008).

Sugarcane yield data from the National Supply Company (CONAB, 2019) corroborate the literature. In the 2005/2006 harvests, sugarcane yield in the Center-West was 70.95 kg/ha, rising to 74.07 kg/ha in the 2017/2018 harvest (4.3% increase). Similar behavior presented the states of the region in the 2005/2006 and 2017/2018 seasons, respectively: Mato Grosso (from 65.53 to 70.97 kg/ha), Mato Grosso do Sul (70.45 to 70.48 kg/ha), and Goiás (76.80 to 77.47 kg/ha). These performances are converging to the yields presented by the Southeast, traditional producer, whose productivity evolved from 81.77 to 76.62 kg/ha in the period.

Despite the favorable conditions for the expansion of the sugarcane agroindustry in the Center-West, some obstacles remain in this sector. Shikida (2013) points out the following obstacles: i) instability in the ethanol market due to the government subsidy on the price of

gasoline and opportunity for higher profitability of sugar production; ii) inefficient road-based transport infrastructure for production flow; iii) the need to expand technological capabilities, given the high costs of learning processes; iv) large tracts of land that provide income concentration.

Sauer and Pietrafesa (2012) point out the adverse environmental impacts of monoculture, such as erosion, acceleration of the desertification process, and contamination of soil and water resources by pesticides. Yusuf and Caldarelli (2018) argue for the need for investments and innovation in the generation of second-generation (2G) ethanol and in the cogeneration of energy from bagasse and waste to sugarcane in order to increase production efficiency, reduce costs and expand production capacity.

Notwithstanding the hindrances, the prospects for the sector are promising. In sugar, falling European production, stabilizing US production, rising demand from Africa, the Middle East, East Asia, China, and India are expected to reduce world sugar stocks, raising the international price of this commodity and favoring the increase of production and exportation of the most competitive countries in production: Brazil, Colombia, Guatemala, Mexico and Thailand (GOES; MARRA; SILVA, 2008).

There are favorable conditions for the growth of Brazilian ethanol consumption, such as its low production cost (equivalent to half of that produced from corn in the US and 1/3 of that produced from beet in Europe), associated with the worldwide need for replacement of fossil fuels with renewables, increased domestic demand for flex-fuel vehicles, increased demand for ethanol due to the US Energy Bill's consumption target of 120 billion liters in 2022, the 20% share target of renewable energy in the total energy consumed by 2020 in the European Union and the expectation of potential markets such as the Japanese (GOES; MARRA; SILVA, 2008).

Finally, because Brazil is one of the largest sugarcane producers in the world, there is an excellent potential for the generation of ethanol (2G ethanol) and electricity

(cogeneration) from sugarcane bagasse and straw, without the need of increasing the area of its cultivation in the country (YUSUF; CALDARELLI, 2018).

#### 4 CONCLUSION

The expansion and accelerated diffusion of the sugarcane agroindustry in the Center-West were the results of Proálcool. It was during its second phase (of accelerated expansion, 1980-1985) that the region, then without any sugarcane tradition, began to attract investments from this agroindustry and to be part of the geographical reconfiguration of the sector.

In all subperiods analyzed, the growth rate of the harvested area, the production of sugarcane, sugar, and ethanol in the Center-West was higher than the national one, so that the participation of this region and its respective states about the country increased between 1980 and 2017, confirming the region as the frontier of expansion of this culture.

The strategy of producing a potent mix between sugar and ethanol by the sugarcane businessmen was associated with the phases that the sector has gone through since the creation of Proálcool. The accelerated expansion phases of Proálcool (1980-1985) and the resumption of ethanol production and domestic consumption (2003/2004 to 2013/2014) coincided with the highest ethanol production growth rates and the lowest sugar production growth rates. The opposite situation was observed in the phase of the deceleration and crisis of Proálcool (1986-1995) and the upsurge in deregulation of the sector (1996/1997 to 2002/2003), in which sugar became the focus. In the recent period

(2014/2015 to 2017/2018), this relationship was not maintained, which can be learned by observing similar growth rates between the two products.

The literature has pointed to several conditions for the expansion of the sugarcane agroindustry in the Center-West, such as the search for food security and sustainable energies, favorable edaphoclimatic conditions for sugarcane cultivation, and topography of lands suitable to mechanization. The leap in innovations of this agroindustry has contributed significantly to increase the sector's productivity, allowing the expansion of sugarcane cultivation to new areas. However, the expansion of this agroindustry in the region has been facing some obstacles, such as the instability in the ethanol market, inefficient transportation infrastructure for the flow of production, the need to maximize technological capabilities and reduce the adverse environmental impacts from sugarcane monoculture.

Nevertheless, there are favorable projections to the expansion and consolidation of this agroindustry in the country and the Center-West, such as the expectation of increased international demand for Brazilian sugar and ethanol, enormous potentials for 2G ethanol production and energy cogeneration.

The non-incorporation of other aspects related to the expansion of the sugarcane agroindustry in the Center-West, such as the fiscal, social, environmental, cultural, structural, and institutional impacts constitute limitations of this research. Future works that investigate these aspects are suggested, either with this methodology or another.

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