Analysis of the competitiveness of small, medium, and large sugarcane producers: A study among suppliers in the state of São Paulo, Brazil.

Recebimento dos originais: 20/04/2023
Aceitação para publicação: 02/12/2023

Fernando Rodrigues de Amorim
PhD in Agricultural Engineering from the State University of Campinas (UNICAMP)
São Paulo State University (UNESP)
Domingos da Costa Lopes, 780, Jardim Itaipu. Tupã/SP, Brazil
CEP: 17602-660
E-mail: **fernando.amorim@unesp.br**

Camila Carla Guimarães
PhD in Biotechnology from the University of Ribeirão Preto (UNAERP)
Franco da Rocha College of Technology (FATEC)
Rod. Pref. Luiz Salomão Chamma, 240 – Franco da Rocha/SP, Brazil
CEP: 07857-050
E-mail: **camila.guimaraes@fatec.sp.gov.br**

Timóteo Ramos Queiroz
PhD in Production Engineering from the Federal University of São Carlos (UFSCar)
São Paulo State University (UNESP)
Domingos da Costa Lopes, 780, Jardim Itaipu. Tupã/SP, Brazil
CEP: 17602-660
E-mail: **timoteo.queiroz@unesp.br**

Mário Otávio Batalha
PhD in Industrial Systems Engineering from Institut National Polytechnique de Lorraine (INPL - França)
São Carlos Federal University (UFSCar)
Rodovia Washington Luis, km 235, Monjolinho, São Carlos/SP, Brazil
CEP: 17602-660
E-mail: **dmob@ufscar.br**

Abstract

Over the past few years, the Brazilian sugar-energy sector has sought strategies to remain highly competitive in the production of sugar and ethanol from sugarcane. Some studies reveal that the competitiveness of the sugar and alcohol industry is conditioned by the productivity of the sugarcane raw material, which in turn seem to be linked to the production scale. The different realities of sugarcane suppliers make it difficult to analyze and, consequently, to adopt measures that increase the competitiveness of the sector. In this sense, the objective of this study was to carry out a descriptive analysis of sugarcane suppliers stratified according to the production area, as well as to evaluate their competitiveness, considering the variables productivity (PROD), total recovered sugar (TRS), average sugarcane cuts (ASC) and average total cost (ATC). For this, 55 sugarcane suppliers were selected to answer a survey, previously validated by specialists. These suppliers were stratified according to their respective production areas; the groups of small, medium, and large suppliers were examined through descriptive analysis and evaluated using the competitiveness index (CI) which investigated the variables (separately and jointly): PROD, TRS, ASC, and ATC, with equal weights. The results show that there is great variability within the different groups. Large suppliers stood out in the CI referring to PROD, while most small suppliers had the lowest CI in the variables PROD, ART, and ATC. When the variables were analyzed together, no group was able to reach the proposed high competitiveness index.

Keywords: Productivity. Production costs. Sugar energy.

1. Introduction

Research related to the theme of costs and competitiveness plays an extremely important role in the sugarcane agricultural sector. It significantly contributes to resource optimization and sustainability promotion (SEEBALUCK et al., 2008), stimulates innovation (ANTAS, LEGEY, MAZZONE, 2013; CHEN, CHU, 2013), influences public policies, and mitigates financial risks (OLUKUNLE, 2016). These studies play an essential role in ensuring the prosperity of the sugarcane industry in a challenging economic and environmental scenario.

Brazil stands out as one of the most competitive countries in obtaining ethanol, sugar, and energy from sugarcane as raw material (SALLES-FILHO et al. 2017; PAZ, GARNICA, CURBELO, 2019). During the 2022/2023 harvest, the crushing of 598.3 million tons of sugarcane in the country produced 26,596 billion liters of ethanol and 36.3 million tons of sugar (CONAB, 2022); numbers that characterize Brazil as the largest sugar producer in the world (UNICA, 2022) and the 2nd largest in ethanol production (VIDAL, 2022). This confirms the great relevance of the sugar and alcohol industry in the Brazilian economic scenario.

In terms of production area, approximately 8,307.3 thousand hectares of the country territory were destined to the cultivation of sugarcane in the last year. The largest producer – the state of São Paulo – has the domain of 4,147.6 thousand hectares and productivity estimated at 74 ton/ha, slightly above the national average, which is around 72 ton/ha (CONAB, 2022).

To reach this level of production that is found today, sugarcane cultivation and management practices have undergone significant changes in relation to the need for labor in the field as well as the increase in mechanization and modernization of agriculture (ORLANDI et al. al., 2011, SILVA, GILLIO, CASTRO, 2019; LANÇONI et al., 2020), not to mention changes related to the reality of the economic market (CORTEZ, 2018). These changes encouraged studies in different contexts that make up the sugar-energy production chain, with emphasis on those who analyze the competitiveness of the agricultural and industrial sectors (RAMÃO, SCHNEIDER, SHIKIDA, 2007; ALVES, WANDER, 2010; FAGUNDES, COSTA, 2012; PERRESSIM, BATALHA, 2017; PAVANI, BATALHA, 2021).

Some of these studies in recent years have shown evidence that the low remuneration of the sector is affecting investment in new technologies (ZAMBIANCO, REBELLATO, 2019; DE AMORIM et al., 2020; SALLES-FILHO et al., 2017). Torquato, Jesus, and Zorzo (2015), for example, report that smaller-scale sugarcane suppliers are having difficulties investing in modern agricultural machinery, while Salles-Filho et al.; (2017) state that the technological contribution directly affects the competitiveness of the industry.

Small sugarcane suppliers still need to deal with agricultural production costs, which also vary according to property size (DEMATTÊ et al.; 2014). In this sense, De Amorim et al. (2020) state that sugarcane mills are more competitive than raw material suppliers, as they work with a larger production scale. Furthermore, the variation between the sizes of rural properties has a direct correlation with the technological package used and, consequently, with the level of competitiveness of suppliers (NEVES and CONEJERO, 2010; TORQUATO, JESUS, ZORZO, 2015; DE AMORIM et al., 2020).

It becomes evident, therefore, the need to rethink strategies to reduce production costs and increase productivity in stratified supplier groups, according to their production scale, since there are characteristics in different production systems that can result in reduction costs and greater economic profitability (AMORIM, PATINO, SANTOS, 2022).

Although the aforementioned issues are of great relevance for maintaining the competitiveness of the Brazilian sugar-energy sector, there are no stratified comparative research that evaluates and compares the competitiveness between sugarcane suppliers according to their production scale, considering agronomic and financial variables. Therefore, this subject needs further research and a significant sampling. In this context, the objective of the present work was to carry out a descriptive analysis of sugarcane suppliers, stratified according to the production area, as well as to evaluate their competitiveness considering the variables productivity (PROD), total recovered sugar (TRS), average sugarcane cuts (ASC), and average total cost (ATC).

2. Literature Review

2.1. The sugar-energy sector in Brazil

The sugar-energy industry, made up of the agricultural and industrial sectors, gained notoriety from the Brazilian National Alcohol Program (PROÁLCOOL), which was the first renewable energy program in the world and constitutes an important milestone for the social and economic development of Brazil (CORTEZ, 2018). The program began in the face of a crisis scenario, in which oil prices were experiencing large fluctuations and the country urgently needed to reduce its dependence on imports of this fossil fuel (SANT' ANNA, et al. 2016). Federal government incentives, such as tax exemptions for the production of ethanol and cars powered by ethanol, were essential for the rapid growth of ethanol production and for the expansion of the sugar-energy sector during the years between 1975 and 1985 (CENTENARO, 2011; SHIKIDA, 1998).

After this period of rapid growth, there was a slowdown in the sector as a result of the low price of oil in the international market, as well as the drop in sales of automobiles powered by ethanol, and the high price of sugar. The program entered a crisis, and the process of state deregulation of the sector was initiated (CORTEZ, 2018). Without government subsidies and with the new free market policy – where sugar and ethanol prices started to be defined according to supply and demand fluctuations (GRANCO et al., 2017; SANT'ANNA, et al., 2016) – sugarcane prices started to depend on the quality and percentage share in its final products. Consequently, the sector needed to adopt more competitive strategies to stay in the market (CENTENARO, 2011).

Faced with this reality, the scenario of crisis and rearrangement in the segment has been recurrent in recent years. The introduction of flexible-fuel vehicles in the market, the mechanization of the harvest (DE AMORIM et al., 2020), and the growing concern with sustainability (CERVI et al., 2020; HERNANDES et al., 2020) leveraged a new growth in the sector, which reflected in a significant increase in the area used for sugarcane plantation as well as in the number of sugar mills in the years between 2003 and 2008.

In 2009, however, a new crisis spread in the sector, due to significant productivity losses and lack of government incentives (CORTEZ, 2018). The recovery took place and, since 2012, the sugar-alcohol industry is responsible for approximately 10% of the agribusiness GDP in Brazil, which in 2017 corresponded to approximately R$150 billion. In the years between 2012 and 2018, the sugar-energy sector was responsible for 5% of the Brazilian trade balance (UNICA, 2019).

With the adoption of new technologies (MANUEL et al. 2018; DE AMORIM et al., 2020; AMORIM, PATINO, SANTOS, 2022; ZAMBIANCO, REBELLATO, 2019; SALLES-FILHO et al., 2017), new studies emerged, seeking to improve raw materials – such as the research carried out in the Campinas Agronomy Institute (IAC, 2023) and in the Sugarcane Technology Center (CTC, 2023) – also concerning productivity issues (DE AMORIM et al., 2020; AMORIM, PATINO, SANTOS, 2022), and the sustainability of the sector (CERVI et. al. 2020; HERNANDES et al., 2020), all of which contribute to the reinvention of the sugar-alcohol industry over the last few years (CORTEZ, 2018).

2.2. Competitiveness in the sugar-energy sector

The economic expansions and retractions of the sugar-energy sector have forced industries to establish a competitive strategy in order to obtain profitability and sustainability in the face of all the variables that compete against it in the economic sector in which it operates (UNICA, 2019).

The Brazilian sugar-alcohol industry is one of the most competitive in the world, mainly due to the climate and soil conditions of the region that are favorable for planting sugarcane, but also due to the mastery of technologies that involve the agricultural and industrial systems for transforming the raw material into sugar, ethanol, and energy (SHIKIDA, AZEVEDO, VIAN, 2011; SHIKIDA, 2013; SALLES-FILHO et al. 2017; PAZ, GARNICA, CURBELO, 2019). Additionally, the sugar-energy sector has currently been seeking to produce by-products from sugarcane bagasse (ethanol and electricity) as a competitive strategy to remain in the market (CERVI et al.; 2020; HERNANDES et al. 2020).

These facts combined with the low cost of production, the availability of land (CERVI et al., 2020), and the adoption of new technologies in the cultivation of sugarcane expanded the production of this raw material in the field, favoring the growth of many suppliers. However, the challenges were also increasing for many rural producers (NEVES, CONEJERO, 2010; TORQUATO, JESUS, ZORZO, 2015; DE AMORIM et al., 2020).

Zambianco and Rebellato (2019), Bernardo et al. (2019), as well as Silva and Marques (2017), for instance, report that the sector has been losing productivity efficiency in recent years. The difficulties of transition to mechanized planting and harvesting are cited as one of the main factors that contribute to this reality (DE AMORIM et al., 2020).

The competitiveness of the sugar-energy industry in Brazil is mainly conditioned by production scale (DE AMORIM et al., 2020; NEVES, CONEJERO, 2010) and productivity (MOREIRA, BONIZIO 2012; SILVA, MARQUES, 2017). The price of the raw material is determined in a standardized way by councils of agroindustry representatives and suppliers (ROSSI, FERNANDES, 2020). All this considered, it becomes important to recognize the challenges and reality of each producer, in a way that it will be possible for them to continue competing in the market.

3. Material and Methods

This work is characterized as an exploratory study of a quantitative nature, as it seeks to measure the competitiveness of the sugarcane production system among different groups of sugarcane suppliers.

3.1. Sampling

This research was carried out with sugarcane suppliers located in the state of São Paulo, Brazil. The geographical cut was based on the representativeness of the state, responsible for 49.46% of all Brazilian sugarcane production in the 2022/23 harvest (CONAB, 2022).

In total, 55 sugarcane suppliers were selected, all of which are characterized by not depending on mills to carry out cultural practices on their properties. According to Orplana (2020), the total number of suppliers in the Center-South region of Brazil is around 15,000. Thus, the sampling of this work used a probabilistic approach for a finite sample and confidence interval below 10%, and lower confidence limit of 0.03%.

Among the suppliers that participated in the data collection, those selected have properties larger than 10 ha. This parameter was proposed by specialists as a minimum property size limit (considering the place where suppliers carry out the cultural practices with all machines and equipment).

The selected suppliers were stratified into small (1a), medium (1b), and large (1c) producers, according to the size of the area intended for sugarcane production, with the final classification established 10 ha $\geq$ 1a $\leq$ 31 ha; 32 ha $\geq$ 1b $\leq$ 140 ha; 141 ha $\geq$ 1c.

All participants in this study received an Informed Consent Form, which was elaborated based on resolution nº 466/2012, of the Brazilian Ministry of Health, under the guidance of the Research Ethics Committee of São Paulo State University (UNESP) nº 3,752,596, CAEE 26104619.7.0000.5402.

3.2. Choice of variables and intervals that make up the competitiveness index (CI)

The competitiveness of the sugarcane suppliers selected in this study, stratified according to the area destined for production, was evaluated using a competitiveness index (CI), as described by Wijnands, Berkum and Verhoog (2015).

The variables and intervals that made up the CI were based on secondary data from the literature and were approved by 11 specialists in the sector, through the analysis of the survey using the Delphi method. The questions sent to the specialists were based on their perception of the importance of each question, which could be interpreted as ( )4. very important, ( )3. important, ( )2. not very important and ( )1. irrelevant (WRIGHT, GIOVINAZZO, 2000).

The variables selected to compose the CI were: average total cost / ha (ATC); productivity / hectare (PROD); total recovered sugar / hectare (TRS); and the average sugarcane cuts / year (ASC) . Such variables make up the total CI proposed in this article as shown in Equation 1.

$$CI = CI_{ATC} + CI_{PROD} + CI_{TRS} + CI_{ASC} \quad \text{Equation 1}$$

Where the CI is based on the cultural practice adopted by sugarcane suppliers and analyzed through the quantification of partial indices. Each index has equal weights in its entirety, that is, the sum of the components in each index is equivalent.

The intervals of each variable that make up the CI are shown in Table 1, according to the proposed levels of competitiveness.

Table 1: Intervals that make up the different levels of the CI.

Variables	1a	2a	3a
IC_{TRS} (TRS/ha)	$100 \geq IC_{TRS} \leq 114$	$115 \geq IC_{TRS} \leq 129$	$IC_{TRS} \geq 130$
IC_{PROD} (PROD/ha)	$60 \geq IC_{PROD} \leq 74$	$75 \geq IC_{PROD} \leq 89$	$IC_{PROD} \geq 90$
IC_{ASC} (ASC/what)	$3{,}0 \geq IC_{ASC} \leq 4.4$	$4{,}5 \geq IC_{ASC} \leq 5.9$	$IC_{ASC} \geq 6.0$
IC_{ATC} (R$/ha)	$IC_{TAC} \leq 2163$	$1760 \geq IC_{TAC} \leq 2162$	$1357 \geq IC_{TAC} \leq 1759$

1α low competitiveness; 2α average competitiveness; 3α high competitiveness.
Source: Prepared by the authors (2023).

The intervals between the CIs were all standardized: 14 tons/ha for TRS; 14 ton/ha for productivity; 1.4/year for ASC, and R$ 402.00/ha for ATC. Therefore, the greater the productivity, the greater the TRS, and the greater the longevity of the cane field; the lower the production cost, the greater the competitiveness of suppliers.

3.3. Data collection

Data collection from suppliers took place through the application of a structured survey, prepared following the methodology described in item 2.2. Each interviewed sugarcane supplier answered 50 pre-established questions, with five response intervals (on a Likert scale).

3.4. Statistical analysis

The organization and tabulation of data were performed in a Microsoft Excel spreadsheet.

A comparative analysis was performed to ascertain if there were (or not) any occurrences among the variations between the variables. Fachin (2006) mentions that this type of analysis demonstrates whether the inference between the data is significant and/or similar. Gil (2008) states that if there are differences between the values that justify the deepening in treating/demonstrating these quantitative data, the investigation is evidenced through statistical analysis.

The mean values of each variable were investigated through descriptive analysis (mean, minimum, maximum, standard deviation, and coefficient of variation), using the BioEstat 5.3 (1995) software. The hypothesis of data normality was tested using the Shapiro-Wilk test, using a p-value of 5%. This test is suggested in small samples (4-30) (SHAPIRO, WILK, 1965).

4. Results and Discussion

Out of the 55 sugarcane suppliers selected and stratified according to production area, 5 were classified as small (1a); 18 as medium (1b) and 32 as large producers (1c).

Descriptive analyzes were carried out in the different groups and show the maximum, average, and minimum values of the variables considered in this study, as well as their respective measures of dispersion. These values are presented in Table 2 and are discussed below.

Table 2: Descriptive analysis of the systems of cultural practices used by sugarcane suppliers.

Description	Unit	V.MX	V.M	V.MN	D.P	Kurtosis	Asymmetry	C.V %	P-Value
Size (1a)	Ha	30	20,2	12	8,6	-3,1	0,49	42,6	0,14
Size (1b)		140	73,8	32	28,2	0,28	0,71	38,2	0,61
Size (1c)		82,221	9,342	140	19,831	6,32	2,6	212,3	0,00
Renovation Area (1a)	Ha	11,0	5,4	1,0	3,8	-0,02	0,59	71,2	0,90
Renovation Area (1b)		36	12,7	0	9,9	0,97	1,1	77,8	0,05
Renovation Area (1c)		7,000	504,7	0	1,482	14,44	3,8	293,6	0,00
ATC (1a)	R$	2,848	2,451	2,064	61,56	-1,14	0,59	12,6	0,83
ATC (1b)		3,447	2,404	1,340	95,40	1,89	-0,46	19,9	0,06
ATC (1c)		3,219	2,263	1,307	77,10	1,1	-0,08	16,3	0,67
ASC (1a)	Year	6,4	5,2	4,4	1,1	-3,3	0,60	21,1	0,01
ASC (1b)		7,4	5,1	3,4	1,2	-0,96	0,09	24,4	0,09
ASC (1c)		7,4	5,0	3,4	1,4	1,1	0,41	13,3	0,00
PROD (1a)	Ton/ha	104,50	84,50	74,50	12,2	2,0	1,4	14,5	0,18
PROD (1b)		104,50	88,40	74,50	9,2	-0,25	0,63	10,4	0,00
PROD (1c)		104,50	89,50	64,50	11,9	-1,0	-0,48	13,3	0,00
TRS (1a)	Kg/ton/ha	144,50	134,50	124,50	7,1	2,0	0,0	5,3	0,010
TRS (1b)		154,50	135,0	114,50	10,5	-0,70	-0,12	7,8	0,10
TRS (1c)		154,50	135,7	114,50	7,9	1,02	-0,23	5,8	0,00

V.MX: maximum value; MV: mean value; V. MN: minimum value; SD: standard deviation; C.V: Coefficient of Variation; 1a = small supplier; 1b = medium supplier; 1c = large supplier; ATC: average total cost; ASC: average sugarcane cuts; PROD: productivity; TRS: total recovered sugar.
Source: Prepared by the authors (2023).

4.1. Descriptive Analysis

4.1.1. Property size

The descriptive analysis showed that there is great variability in the sizes of rural properties, especially when comparing the minimum and maximum size of properties, as well as their standard deviation.

The results of the variation coefficient showed that all supplier groups have a very high dispersion (> 30%). Regarding asymmetry, groups 1a and 1b are considered symmetrical, as they vary between -1 and <1, while group 1c has positive asymmetry.

Regarding the kurtosis, group 1a demonstrated the characteristics of the leptokurtic distribution, that is, it has values <0.263. In other words, this group has a more closed and fine-tuned distribution than the Normal distribution. Groups 1b and 1c displayed aplatykurtic distribution (>0.263), that is, a frequency curve that is more open than the Normal distribution.

Finally, the p-value of the distribution of normality demonstrated that groups 1a and 1b have variation >5%, showing that all values of these groups presented normality for the level of significance considered for this variable (SHAPIRO, WILK, 1965). However, group 1c showed no variability.

4.1.2. Cane field reform

Regarding the sugarcane field renovation area, the descriptive analysis showed that group 1c has a large variation mentioned through the maximum, minimum, average, standard deviation, coefficient of variation, and asymmetry, having obtained no significant variation. Regarding groups 1a and 1b, the values showed low variation (< 10) in the standard deviation. For the coefficient of variation, both have very high variation (> 30). With regards to asymmetry, groups 1a and 1b can be considered symmetrical, as they vary between -1 and <1. On the other hand, the p-value of the distribution of normality showed that both groups showed variation >5%.

4.1.3. Average Total Cost

Regarding the ATC, large suppliers are highlighted, since they obtained the lowest cost in terms of average and minimum value, as well as the lowest standard deviation. The minimum values of costs referring to groups 1b and 1c are similar to the study by Torres and Marques (2017), when corrected by the Consumer Price Index (IPCA) – R$1,433.55 in 2020 – that is, the value falls within the range of values used as parameters referring to this competitiveness index.

Regarding kurtosis, group 1a is characterized by aleptokurtic distribution while the other groups have aplatykurtic distribution. Finally, the asymmetry showed that group 1a has positive asymmetry while the other groups are symmetrical.

4.1.4. Average sugarcane cutting

The ASC results showed little variation in standard deviation between all groups. In general, group 1a was superior in mean value. The literature has shown similar results in the mean value of the works by De Amorim et al. (2019), Moreira and Bonizio (2012), as well as Silva and Marques (2017).

Regarding the coefficient of variation, group 1c was the highlight while groups 1a and 1b fit the same level. Regarding kurtosis, groups 1a and 1b showed the characteristics of a more refined distribution (leptokurtic), while group 1a displayed a flatter curve (platykurtic). All groups have positive asymmetry. Finally, groups 1a and 1b did not demonstrate data normality.

4.1.5. Productivity

With regards to PROD, groups 1a and 1b were similar in three aspects: maximum, average, and minimum values. Average productivity values were similar to the ones found by De Amorim et al. (2019), Moreira and Bonizio (2012), as well as Silva and Marques (2017).

Group 1b was highlighted in the smallest variation of the standard deviation and in the coefficient of variation. Group 1c, on the other hand, obtained lower values in the mean and minimum value when compared to groups 1a and 1b. Similar variation was found in the coefficient of variation.

Regarding kurtosis, groups 1b and 1c are characterized by aleptokurtic distribution while group 1a is characterized by a platykurtic distribution. Regarding asymmetry, groups 1a and 1b have positive asymmetry while 1c is symmetrical.

About the coefficient of variation, all groups are in the same range (<20%). Furthermore, all groups have data normality. On the other hand, the p-value of the distribution of normality showed that only group 1a showed variation > 5%.

4.1.6. Total recovered sugar

In the TRS analysis, similar mean values were found in all groups, with a lower standard deviation for group 1a. Mean TRS values were similar to the one found by De Amorim et al. (2019), Moreira and Bonizio (2012), as well as Silva and Marques (2017).

Regarding asymmetry, both can be considered symmetrical, as they vary between -1 and <1. With regard to kurtosis, groups 1a and 1c showed the characteristics of a finer distribution, while group 1c has a flatter curve. From the perspective of the coefficient of variation, all groups have low variation (<10). Finally, only group 1b showed p-value of normality distribution > 5%.

4.2. Competitive analysis

From these variables, it was possible to measure the competitiveness of the suppliers. The analysis of these parameters allows the supplier to seek to improve their profitability by reducing costs, increasing productivity, increasing the quality of the sugarcane, and increasing the longevity of their cane field. CIs from different supplier groups are presented in Table 3 and discussed below.

Table 3: Competitiveness Indexes of the variables: productivity, average total cost, average sugarcane cutting, and total recovered sugar by sugarcane suppliers.

DESCRIPTION	PROD	ASC	ATC	TRS
IC = 3				
1a	20%	40%	20%	20%
1b	33,3%	27,8%	5,5%	33,3%
1c	56,2%	28,1%	0%	28,1%
TOTAL	36,5%	31,9%	6,8%	27,1%
IC = 2				
1a	20%	40%	20%	20%
1b	33,3%	27,8%	55,5%	33,3%
1c	21,9%	21,9%	46,9%	56,2%
TOTAL	25%	30%	40,7%	36,5%
IC = 1				
1a	60%	20%	60%	60%
1b	33,3%	44,4%	44,5%	33,3%
1c	21,9%	50%	53,1%	15,7%
TOTAL	38,5%	38,1%	52,5%	36,4%

1a = small supplier; 1b = medium supplier; 1c = large supplier; PROD: productivity; ASC: average sugarcane cuts; ATC: average total cost; TRS: total recovered sugar.
TOTAL= percentage representing each group within all indexes.
Source: Prepared by the authors (2023).

4.2.1. Competitiveness analysis regarding the productivity variable

Twenty-five suppliers (45.4% of all suppliers) achieved CI=3 for the PROD variable. Group 1c had the best result in this index,

Nineteen suppliers fit the CI=2 (34.5% of all suppliers). Out of these, two suppliers are from group 1a, ten suppliers are from groups 1b, and seven suppliers from group 1c. Finally, 11 suppliers make up CI=1 (20% of the total number of suppliers). Two are from group 1a, two from group 1b, and seven from group 1c.

Together, these data indicate that most suppliers (54.5%) have an average productivity between 60 and 89 tons/ha, which is in line with the national productivity, which was 72.2 ton/ha on the last harvest.

Zambianco and Rebellato (2019) as well as Bernardo et al. (2019) state that sugarcane productivity in Brazil has been showing signs of stagnation in recent years. Although between 1992 and 2019 there was a 125.2% increase in the production of this raw material, this increase was due to the acquisition of new areas for planting this crop and not necessarily due to increased productivity (UNICA, 2020).

Data from the present study show that, among the evaluated sugarcane suppliers, most of the small suppliers (60%) are less competitive in terms of raw material productivity (CI=1), while most of the large suppliers (56.2%) achieved the highest level of competitiveness (CI=3). This result may be linked to the differences in technological input present in rural properties in these different groups of suppliers studied, as already discussed by Torquato, Jesus and Zorzo (2015), De Amorim et al. (2020), as well as Neves and Conejero (2010); smaller scale sugarcane producers have lower rates of investment in modern machinery.

4.2.2. Competitiveness analysis referring to the average cutting variable per sugarcane field

Sixteen suppliers (29.1%) fit the CI=3, when analyzing the ASC variable. Out of this total, two suppliers are in group 1a, five suppliers are in group 1b, and nine are in group 1c.

Twelve suppliers (21.8%) fit into CI=2; five from group 1a and seven from group 1c. Twenty-seven suppliers (49.1%) are at CI=1; three from group 1a, eight from group 1b, and sixteen from group 1c.

Most of the suppliers participating in the study have, on average, a sugarcane field between 3 and 5.9 years old. Similar results were found in the works by De Amorim et al. (2019), Moreira and Bonizio (2012), as well as Silva and Marques (2017). In the Center-South region of Brazil, the number of cuts varies between 5.5 and 6. High productivity in advanced cutting stages postpones the renovation of sugarcane fields. According to specialists, an economic analysis is necessary to verify the ideal cutting stage for the renovation of each sugarcane field (PUPULIN, 2020).

4.2.3. Competitiveness analysis regarding average total cost

Regarding the ATC, only two sugarcane suppliers (3.6% of the total number of suppliers) achieved CI=3, one supplier in group 1a and one supplier in group 1b.

Twenty-six suppliers achieved CI=2 (47.3% of all suppliers). Out of these, two are from group 1a, nine from group 1b, and fifteen from group 1c. Twenty-seven suppliers fit the CI=1 (49.1%), out of which two are from group 1a, eight from group 1b, and seventeen from group 1c. These results thus show that the production costs of the agricultural practices used by the suppliers can be considered a ‘bottleneck’ to be studied in greater depth in this sector.

Some authors (PAVLU, MOLIN, 2016; AMORIM et al., 2019) mentioned that the use of new technologies in sugarcane cultural practices, such as the variable rate system (VRA) collaborates in the reduction of inputs (fertilizers, pesticides, and correctives), consequently helping in the reduction of production costs. However, Demattê et al. (2014) stated that the production costs for using the VRA system as a means of applying correctives and fertilizers on their properties varied according to the size of the area, that is, the smaller the area, the higher the production cost. Therefore, increasing the production scale to use this technology can be a relevant competitive strategy in terms of production costs.

4.2.4. Competitiveness analysis regarding the total recovered sugar variable

Sixteen suppliers (29.1% of all suppliers) achieved CI=3. Out of this total, one supplier is from group 1a, six are from group 1b, and nine are from group 1c. Twenty-seven suppliers (49.1%) fit into CI=2; three in group 1a, six in group 1b and 18 in group 1c. Finally, 12 suppliers (21.8% of the total number of suppliers) fit the CI=1; one from group 1a, six from group 1b, and five from group 1c.

The results referring to the TRS CI demonstrate that most of the suppliers are producing sugarcane with TRS between 125 and 139 kg/TRS/ha. These values are similar to the average values found by De Amorim et al. (2019); Moreira and Bonizio (2012), as well as Silva and Marques (2017).

4.3. Competitiveness analysis referring to the sum of variables

In Table 4, the results of the analysis of the sum of competitiveness indexes are presented.

Table 4: Competitiveness Indexes among sugarcane suppliers stratified according to their production area.

Description	IC 3,0	IC 2,75	IC 2,50	IC 2,25	IC 2,0	IC 1,75	IC 1,50	IC 1,25
1a	0%	0%	0%	20%	20%	40%	20%	0%
1b	0%	6%	11%	11%	16%	34%	16%	6%
1c	0%	6%	9%	13%	22%	28%	16%	6%
TOTAL	0%	4%	6,6%	14,6%	19,6%	33,6%	17,6%	4%

1a = small supplier; 1b = medium supplier; 1c = big supplier.
Source: Prepared by the authors (2023).

As it can be seen (Table 4), most suppliers (70.8%) fit in the CI range of 2.0 to 1.5, out of which 80% are in group 1a, 66% are in group 1b, and 66% are in group 1c.

These data show a medium to low CI of the studied sugarcane suppliers, since no group reached CI=3, and a very low portion (4%) falls within CI=2.75.

Some of the findings of this study confirm the literature's emphasis on the competitiveness of Brazilian sugarcane suppliers in producing this raw material. Furthermore, the study demonstrates that when stratified, small-scale producers can be as competitive as their larger and medium-sized counterparts, highlighting the concept of 'lean management' within their operations.

Additionally, it is worth noting the importance of analyzing primary data from such a representative sector such as the sugarcane industry, which sheds light on how the sector behaves behind the farm gate in terms of stratified competitiveness.

5. Conclusion

Considering the productivity variable, the results of this study demonstrate that most (56.2%) of the suppliers with the largest production area (≥141ha) achieved the high level of competitiveness proposed in this work. Nevertheless, the group with the highest percentage of suppliers (50%) was classified in the low competitiveness level of the ASC.

Most of the suppliers in the group with the smallest production area (≤ 31 ha) showed a low level of competitiveness in the variables productivity (60%), total average cost (60%), and total recovered sugar (60%).

These results allow us to infer that the smaller the production scale, the lower the competitiveness of sugarcane suppliers, especially in relation to productivity and production costs. This suggests, therefore, a direct relationship with the technological package used by the suppliers. This condition may also reflect on the quality of the sugarcane, as evidenced by the TRS index. New studies in this context should be carried out to confirm this relationship.

When the variables were analyzed together, no group reached the high level of competitiveness; most suppliers fit into the intermediate CI.

Overall, the data from this work contribute to a better understanding of the reality of sugarcane producers in the state of São Paulo, Brazil, evidencing the need to rethink strategies to increase the competitiveness of the sector.

Therefore, the evidence presented in this study contributes to demonstrating that, in order to be competitive, the supplier needs to strike a balance between productivity and production costs. Furthermore, the decision to utilize a specific technological package can significantly influence their level of competitiveness.

The main limitations of this study included difficulties in obtaining data regarding expenditures on labor, inputs, and mechanization, especially for small and medium-sized sugarcane suppliers. As a suggestion for future work, the authors suggest research with exact primary data (without intervals) with a significant sample number equal to or greater than the one used in this research, using the Data Envelopment Analysis (DEA) tool.

6. References

ALVES, Nádia Christine Gomides Ferreira; WANDER, Alcido Elenor. Competitividade da produção de cana-de-açúcar no cerrado goiano. *Informações Econômicas*, São Paulo, v. 40, n. 7, p. 5-17, jul. 2010.

AMORIM, Fernando Rodrigues de; PATINO, Marco Tulio Ospina; SANTOS, David Ferreira Lopes. Soil tillage and sugarcane planting: an assessment of cost and economic viability. *Scientia Agricola*, v.79, n.1, p. 1-6, 2022.

AMORIM, Fernando Rodrigues de; OSPINA-PATINO, Marco Tulio; ABREU, Pedro Henrique Camargo de; SANTOS, David Ferreira Lopes. Avaliação econômica e de risco dos sistemas de aplicação de fertilizantes na cultura de cana-de-açúcar: taxa fixa por média e taxa variável. *Custos e Agronegócio Online*, [s. l], v. 15, n. 2, p. 140-166, 2019.

BERNARDO, Roberto; LOURENZANI, Wagner Luiz; SATOLO, Eduardo Guilherme; CALDAS, Marcellus Marques. Analysis of the agricultural productivity of the sugarcane crop in regions of new agricultural expansions of sugarcane. *Gestão & Produção*, [s. l], v. 26, n. 3, p. 1-10, 2019.

CENTENARO, Moisés. Análise da evolução da indústria sucroenergética. *Anais-Encontro Científico de Administração, Economia e Contabilidade*, v. 1, n. 1, 2011.

CTC - Centro de Tecnologia Canavieira. *Produtos*. Disponível em: https://ctc.com.br/produto. Acesso em 14 março de 2023.

CERVI, W. R.; LAMPARELLI, R. A. C.; GALLO, B. C.; BORDONAL, R. O.; SEABRA, J. E. A; JUNGINGER, M. ; HILST, F. V. D. . Mapping the environmental and techno-economic potential of biojet fuel production from biomass residues in Brazil. *Biofuels Bioproducts & Biorefining-Biofpr*, v. 15, p. 282-304, 2021.

CHEN, X.; NUÑEZ, H. M.; XU, B. Explaining the reductions in B razilian sugarcane ethanol production costs: importance of technological change. Gcb Bioenergy, v. 7, n. 3, p. 468-478, 2015.

CONAB - COMPANHIA NACIONAL DE ABASTCIMENTO. *Acompanhamento da safra brasileira de cana-de-açúcar*, Brasília, DF, v. 9, n. 3 dezembro 2022. Disponível em https://www.conab.gov.br/info-agro/safras/cana/boletim-da-safra-de-cana-de-acucar. Acesso em 30 de janeiro de 2023.

CORTEZ, Luís Augusto Barbosa (org). *Proálcool 40 anos: Universidades e empresas: 40 anos de ciência e tecnologia para o etanol brasileiro*. São Paulo: Blucher, 2018, 224 p.

DANTAS, G. A.; LEGEY, L. F. L.; MAZZONE, A. Energy from sugarcane bagasse in Brazil: An assessment of the productivity and cost of different technological routes. Renewable and Sustainable Energy Reviews, v. 21, p. 356-364, 2013.

DE AMORIM, Fernando Rodrigues de; PATINO, Marco Tulio Ospina; BARTMEYER, Petra Maria; SANTOS, David Ferreira Lopes. Productivity and Profitability of the Sugarcane Production in the State of Sao Paulo, Brazil. *Sugar Tech*, [s.l.], v. 22, n. 4, p. 596-604, 22 abr. 2020.

DEMATTÊ, José Alexandre Melo; DEMATTê, José Luiz Ioratte; ALVES, Evandro Roberto; BARBOSA, Roberto Negrão; MORELLI, Jorge Luis. Precision agriculture for sugarcane management: a strategy applied for brazilian conditions. *Acta Scientiarum. Agronomy*, [s.l.], v. 36, n. 1, p. 111, 7 jan. 2014.

FACHIN, Odila. *Fundamentos de metodologia*. 5.ed. São Paulo: Saraiva, 2006. 224 p.

FAGUNDES, Mayra Batista Bitencourt; COSTA, Caio Luca; FAGUNDES, Mayra Batista Bitencourt; COSTA, Caio Luca. Análise da competitividade da cana-de-açúcar nos estados de Mato Grosso do Sul, Minas Gerais e Paraná. *Revista de Economia e Agronegócio*, [s.l.], v. 10, n. 3, p. 441-462, 2012.

GRANCO, Gabriel et al. Exploring the policy and social factors fueling the expansion and shift of sugarcane production in the Brazilian Cerrado. *GeoJournal*, v. 82, p. 63-80, 2017.

GIL, Antônio Carlos. *Métodos e técnicas de pesquisa social*. 6. ed. São Paulo: Atlas, 2008. 248 p.

HERNANDES, T. A. D.; BORDONAL, R. O.; DUFT, D. G.; LEAL, M. R. L. V. Implications of regional agricultural land use dynamics and deforestation associated with sugarcane expansion for soil carbon stocks in Brazil. *Regional Environmental Change*, v. 22, p. 49, 2022.

IAC. Instituto Agronômico de Campinas. *Centro de Cana*. Disponível em: https://www.iac.sp.gov.br/areasdepesquisa/cana/. Acesso em 14 março de 2023

LANÇONI, Adilson Aparecido; SOARES, Wesley Martinelli; CARRER, Celso da Costa; LIMA, César Gonçalves. Efeito da Aplicação de um Sistema de Automação Agrícola em Colheita Mecanizada de Cana-de-Açúcar como Ferramenta de Gestão e Controle de Custo Operacional. *Ensaios e Ciência C Biológicas Agrárias e da Saúde*, [s.l.], v. 24, n. 2, p. 146-152, 26 ago. 2020.

MOREIRA, Mariana Guidoni; BONIZIO, Roni Cleber. Análise comparativa dos custos de cana-de-açúcar: produção independente x usina de açúcar e álcool. *Custos e Agronegócio Online*, [s. l], v. 8, n. 2, p. 84-99, 2012.

NEVES, Marcos Fava; CONEJERO, Marco Antônio. *Estratégias para a cana no Brasil: um negócio classe mundial*. São Paulo: Atlas, 2010. 310 p.

OLUKUNLE, Oni Timothy. Economic analysis of profitability and competitiveness of sugarcane enterprise in Nigeria. Journal of Development and Agricultural Economics, v. 8, n. 6, p. 160-171, 2016.

ORLANDI, Marines; OLIVEIRA, Luciana Vargas Netto; SHIKIDA, Pery Francisco Assis; BRAUN, Mirian Beatriz Schneider. O mercado de trabalho formal na agroindústria canavieira do Mato Grosso: uma análise comparativa entre 1999 e 2009. *Revista de Estudos Sociais*, [s. l], v. 13, n. 26, p. 186-203, 2011.

ORPLANA - ORGANIZAÇÃO DE ASSOCIAÇÕES DE PRODUTORES DE CANA DO BRASIL (Brasil). *Perfil Segmentado do Produtor de Cana Safra 2020/2021*. Ribeirão Preto, 2020. 175 p.

PAVANI, Daniel Augusto Borges; BATALHA, Mario Otavio. Proposta de um conjunto de indicadores de desempenho em agroindústrias: o caso de usinas sucroalcooleiras. *Revista Produção Online*, [s.l.], v. 21, n. 1, p. 28-50, 15 mar. 2021.

PAVLU, Franz Arthur; MOLIN, José Paulo. A sampling plan and spatial distribution for site-specific control of Sphenophorus levis in sugarcane. *Acta Scientiarum. Agronomy*, [s.l.], v. 38, n. 3, p. 279, 24 jun. 2016.

PAZ, José Eduardo de Matos; GARNICA, Alfredo Ismael Curbelo; CURBELO, Fabíola Dias da Silva. Redimensionamento do sistema de resfriamento da fermentação para elevação da capacidade de produção de etanol. *Holos*, [s.l.], v. 4, p. 1-19, 24 dez. 2019.

PERRESSIM, William Sbrama; BATALHA, Mário Otávio. Desempenho dos indicadores de liquidez das maiores cooperativas agroindustriais brasileiras entre 2011 e 2015. *Revista de Gestão e Organizações Cooperativas*, [s.l.], v. 5, n. 10, p. 175, 12 fev. 2019.

PUPULIN, Cejane. *Falta de renovação dos canaviais e a produtividade*. 2020. Disponível em: https://www.canalbioenergia.com.br/falta-de-renovacao-dos-canaviais-e-a-produtividade/. Acesso em: 02 fev. 2023.

RAMÃO, Fernanda Pamplona; SCHNEIDER, Iara Elisa; SHIKIDA, Pery Francisco Assis. Padrão tecnológico no corte de cana-de-açúcar: um estudo de caso no Estado do Paraná. *Revista de Economia Agrícola*, v. 54, n. 1, p. 109-122, 2007.

SANT'ANNA, Ana Claudia; SHANOYAN, Aleksan; BERGTOLD, Jason Scott ; CALDAS, Marcellus M. ; GRANCO, Gabriel . Ethanol and sugarcane expansion in Brazil: what is fueling the ethanol industry?. *International Food and Agribusiness Management Review*, v. 19, p. 163-182, 2016.

SALLES-FILHO, Sergio Luiz Monteiro; CASTRO, Paula Felício Drummond de; BIN, Adriana; EDQUIST, Charles; FERRO, Ana Flávia Portilho; CORDER, Solange. Perspectives for the Brazilian bioethanol sector: the innovation driver. *Energy Policy*, [s.l.], v. 108, p. 70-77, set. 2017.

SEEBALUCK, V; MOHEE, R., SOBHANBABU, P. R. K., ROSILLO-CALLE, F., LEAL, M. R. L. V., JOHNSON, F. X. Bioenergy for sustainable development and global competitiveness: the case of sugar cane in Southern Africa. Thematic Report, v. 2, 2008.

SHAPIRO, S. S.; WILK, M. B. An Analysis of Variance Test for Normality (Complete Samples). *Biometrika*, [s.l.], v. 52, n. 3/4, p. 591, dez. 1965.

SHIKIDA, Pery Francisco Assis. Expansão canavieira no Centro-Oeste: limites e potencialidades. *Revista de Política Agrícola*, v. 22, n. 2, p. 122-137, 2013.

SILVA, Haroldo José Torres da; MARQUES, Pedro Valentim. Evolution of Production Costs in Brazilian Sugar-Energy Sector. *China-USA Business Review*, [s.l.], v. 16, n. 3, p. 93-107, 28 mar. 2017.

SILVA, Rodrigo Peixoto da; GILIO, Leandro; CASTRO, Nicole Rennó. Impactos da eliminação da queimada da cana sobre o setor sucroenergético: uma análise de equilíbrio geral. *Revista Econômica do Nordeste*, Fortaleza, v. 50, n. 1, p. 9-21, 2019.

SHIKIDA, Pery Francisco Assis Shikida. *A evolução diferenciada da agroindústria canavieira no Brasil de 1975 a 1995*. Cascavel: Edunioeste, 1998. 149 p.

SHIKIDA, Pery Francisco Assis; AZEVEDO, Paulo Furquim de; VIAN, Carlos Eduardo de Freitas. Desafios da agroindústria canavieira no Brasil pós-desregulamentação: uma análise das capacidades tecnológicas. *Revista de Economia e Sociologia Rural*, [s.l.], v. 49, n. 3, p. 599-628, set. 2011.

TORQUATO, Sérgio Alves; JESUS, Kátia Regina E. de; ZORZO, Catiana Regina Brumatti. Inovações no sistema de produção de cana-de-açúcar. *Informações Econômicas*: uma contribuição do Protocolo Agroambiental para a região de Piracicaba, Estado de São Paulo, São Paulo, v. 45, n. 2, p. 28-37, 2015.

UNICA - UNIÃO DA INDÚSTRIA DE CANA-DE-AÇÚCAR. *Histórico de produção e moagem*. Disponível em https://observatoriodacana.com.br/historico-de-producao-e-moagem.php?idMn=31&tipoHistorico=2. Acesso em 30 de janeiro de 2023.

UNICA - UNIÃO DA INDÚSTRIA DE CANA-DE-AÇÚCAR. *Moagem de cana-de-açúcar e produção de açúcar e etanol – safra 2018-2019*. Disponível em: http://unicadata.com.br/historico-de-producao-e-moagem.php?idMn=32&tipoHistorico=4&acao=visualizar&idTabela=2334&safra=2018%2F2019&estado=RS%2CSC%2CPR%2CSP%2CRJ%2CMG%2CES%2CMS%2CMT%2CGO%2CDF . Accesso em: 23 de novembro de 2022.

VIDAL, Maria de Fátima. Agroindústria - Etano. *Escritório Técnico de Estudos Econômicos do Nordeste - Etene*, [s. l], n. 237, p. 1-16, jul. 2022.

WIJNANDS, Jo H. M.; VAN BERKUM, Siemen; VERHOOG, David. Measuring Competitiveness of Agro-Food Industries: the swiss case. *Oecd Food, Agriculture And Fisheries Papers*, [s.l.], n. 88, p. 1-52, 1 ago. 2015.

WRIGHT, James T. C. e GIOVINAZZO, Renata Alves. DELPHI - uma ferramenta de apoio ao planejamento prospectivo. *Caderno de Pesquisas em Administração*, v.1, n.12, p. 54-65, 2000.

ZAMBIANCO, Wilson Milani e REBELATTO, Daisy Aparecida do Nascimento. Análise da eficiência econômica das regiões canavieiras do Estado de São Paulo utilizando análise envoltória de dados (DEA) e índice Malmquist. *Custos e Agronegócio Online*, v. 15, n. abr./ju 2019, p. 376-404, 2019.