Productive agglomerations in the sugarcane sector in the formal labor market: an analysis by Brazilian micro-regions (2019 to 2021)

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Abstract
This paper analyzed the potential for generating formal employment in sugarcane cultivation in the micro-regions of the states of Minas Gerais, São Paulo, Paraná, Mato Grosso do Sul and Goiás (2019 to 2021). The Normalized Concentration Index (NCI) was estimated using the Locational Quotient, the Hirschman-Herfindahl index and the Relative Share index. The construct to verify patterns of concentration or spatial dispersion in the sector was developed using information on formal employment obtained from RAIS. The data shows that in 2019, of the 156 micro-regions surveyed, 38 showed minimal densification, representing 84.58% of the jobs in the sugarcane sector. Of this total, 34 micro-regions were characterized as being specialized (NCI>1). In 2020, 38 micro-regions indicated minimum densification, representing 83.94% of the jobs allocated to the sector, and of these, 34 had an NCI above one, being considered specialized in the employment of labor for sugarcane cultivation. Similarly to previous years, 38 micro-regions showed minimal densification in 2021, which represented 84% of the jobs allocated to the sector, and 34 of these micro-regions were considered specialized, with an NCI above one. The micro-regions with the most specialized agglomeration in the employment of formal labor in the sugarcane sector are in São Paulo state.
Keywords: Productive agglomerations. Sugarcane. Formal work. Brazilian micro-regions.

Aglomerações Produtivas do setor canavieiro no mercado de trabalho formal: uma análise por microrregiões brasileiras (2019 a 2021)

Resumo

O artigo analisou o potencial da geração de emprego formal no cultivo de cana-de-açúcar nas microrregiões dos estados de Minas Gerais, São Paulo, Paraná, Mato Grosso do Sul e Goiás (2019 a 2021). O Índice de Concentração Normalizado (ICN) foi estimado a partir do Quociente Locacional, do índice Hirschman-Herfindahl e do índice de Participação Relativa. O constructo para verificar padrões de concentração ou dispersão espacial no setor foi elaborado por meio de informações sobre vínculo formal obtidas junto a RAIS. Os dados mostram que em 2019, das 156 microrregiões pesquisadas, 38 apresentaram adensamento mínimo, representando 84,58% dos vínculos no setor canavieiro. Desse total, 34 microrregiões foram caracterizadas como sendo especializadas (ICN>1). Em 2020, 38 microrregiões indicaram adensamento mínimo, representando 83,94% dos vínculos alocados no setor, e dessas, 34 apresentaram índice acima de um, sendo consideradas especializadas no emprego de mão de obra para o cultivo de cana-de-açúcar. De forma análoga aos anos anteriores, 38 microrregiões apresentaram adensamento mínimo em 2021, o que representou 84% dos vínculos alocados no setor, sendo que dessas microrregiões 34 foram consideradas especializadas, com índice acima de uma unidade. As microrregiões com maior aglomeração especializada no emprego de mão de obra formal do setor canavieiro se encontram no Estado de São Paulo.

Palavras-chave: Aglomerações produtivas. Cana-de-açúcar. Trabalho formal. Microrregiões brasileiras.

Clusters Productivos del sector de la caña de azúcar en el mercado laboral formal: un análisis por microrregiones brasileñas (2019 a 2021)

Resumen

El artículo analizó el potencial de generación de empleo formal en el cultivo de caña de azúcar en las microrregiones de los estados de Minas Gerais, São Paulo, Paraná, Mato Grosso do Sul y Goiás (2019 a 2021). El Índice de Concentración Normalizado (ICN) se estimó utilizando el Cociente de Localización, el índice de Hirschman-Herfindahl y el índice de Participación Relativa. El constructo para verificar los patrones de concentración o dispersión espacial del sector se elaboró a partir de la información sobre empleo formal obtenida del RAIS. Los datos muestran que en 2019, de las 156 microrregiones relevadas, 38 presentaron una densificación mínima, representando el 84,58% de los empleos del sector cañero. De este total, 34 microrregiones fueron caracterizadas como especializadas (ICN>1). En 2020, 38 microrregiones presentaron densificación mínima, representando el 83,94% de los empleos destinados al sector, y de ellas, 34 presentaron índice superior a uno, siendo consideradas especializadas en el empleo de mano de obra para el cultivo de caña. Al igual que en años anteriores, 38 microrregiones presentaron densificación mínima en 2021, lo que representó el 84% de los empleos asignados al sector, y de éstas, 34 microrregiones se consideraron especializadas, con un índice superior a uno. Las microrregiones con mayor aglomeración especializada en el empleo de mano de obra formal en el sector de caña de azúcar se encuentran en el estado de São Paulo.

Palabras clave: Clusters productivos. Caña de azúcar. Trabajo oficial. Microrregiones brasileñas.

1 Introduction

With the incentives for expanding international trade and the opening of markets in the 1990s, Brazil achieved a prominent position, especially in agribusiness products such as grains (soybeans and corn), meats (chicken and pork), fruits, as well

as in an old and well-known crop, sugarcane, in the forms of sugar and ethanol. Brought by the Portuguese in the 16th century, this crop was used to demonstrate land ownership and occupation. For this purpose, it was cultivated in various regions of the national territory, and over time, planting began to be focused in specific areas due to favorable soil and climatic conditions (TSCHÁ et al., 2010).

According to Miranda (2008), in the establishment of sugarcane in Brazil, the labor force used was that of slaves, which gave the Northeast region of Brazil prominence in productivity and advancement in an expanding global market, making sugarcane the first major export product of Brazilian agribusiness. Over time, the workforce became salaried, and cultivation techniques were modernized, aiming for higher productivity, reduced environmental and social impact in the production process of its derivatives, balancing economic gains and ensuring the safety of employees in their work execution.

Considering the above, we ask: Did the formal Brazilian labor market influence productive agglomerations in the sugarcane sector in the micro-regions of the states of Minas Gerais, São Paulo, Paraná, Mato Grosso do Sul, and Goiás? The main aim is to assess the potential of sugarcane cultivation in generating formal employment, using data from the Annual Social Information Report (RAIS), from 2019 to 2021, in micro-regions from the five states with the highest sugarcane production in Brazil.

The specific aims are to identify and analyze the micro-regions with the highest indices of specialized activity in generating formal employment in the five main sugarcane-producing states. They are named Minas Gerais, São Paulo, Paraná, Mato Grosso do Sul, and Goiás. For this purpose, the Normalized Concentration Indexes (NCI) were calculated, seeking patterns of concentration or spatial dispersion through information obtained from the Annual Social Information Report (RAIS) from 2019 to 2021.

The temporal scope of this research spans the period from the "pre" and "post" phases of the pandemic caused by the health crisis of Coronavirus Disease 2019 (Covid-19). This phase was marked by damages caused to the socioeconomic organization of the global supply chain, food insecurity, and changes in the labor market. According to Costa (2020), one of the pandemic consequences was the increase in unemployment and, therefore, the rise in informalization of work, including outsourced and subcontracted employees, part-time workers, and the sub-proletariat.

Thus, we seek an evaluation of the spatial distribution of micro-regions based on the labor and economic situation in local development. Additionally, this paper also aims to contribute to the articulation of public policies, intending to better understand the sugarcane sector, since the workforce can contribute to economic dynamics in a more competitive and sustainable manner.

This paper is structured into six sections, including the introduction. The second and third sections provide a brief overview of productive agglomerations and the labor market in the sugarcane sector. The fourth section outlines the methodology of this study. The fifth section presents the results and discussions. And the last section contains the final considerations.

2 Productive Agglomerations

According to Ferrera de Lima (2016, p. 16), regional development is characterized as a stage or process. To analyze the level of development of a specific region, it is necessary to evaluate a complex set of data, which includes information about population; industry, trade and services; and agribusiness, among others.

Certainly, it is necessary to emphasize that development does not occur at the same speed in all regions, given differences in income, entrepreneurial vocation, technical capacity, proximity to other centers, technology, logistics, transportation etc. It is also observed that regional development occurs in clusters or productive agglomerations, which comprise elements related to intra-agglomeration exchanges, cooperation, specialization, institutional environment supporting relationships and development (CROCCO et al., 2006). The total or partial grouping of these components, combined with the research focus, defines more precisely the Productive Agglomeration, e.g., whether they form agglomerations, localized industrial systems, industrial districts etc.

Approaches to productive agglomerations have gained importance in the context of regional analysis. In line with Silva Filho et al. (2014), productive concentration and its impacts on job creation in certain isolated areas are constantly observed in economic literature. Rodrigues et al. (2012) emphasize the importance of understanding local productive agglomerations because the form of productive organization has come to influence primarily in terms of public policy formulation.

Furthermore, Alves (2012) highlights that the most used variable in studies on productive agglomerations is the number of employees distributed by sectors. It is presumed that more specialized sectors of activity employ more labor over time. Thus, labor occupation reflects on the generation and distribution of regional income, stimulating consumption and, consequently, the region's dynamics.

Ferrera de Lima (2016) and Oliveira (2006) emphasize that the physical conditions of a particular region can be determining factors for its development such as soil fertility, climate, terrain, hydrography, ease of transportation of production. These aspects combined with labor availability justify the presence of certain crops, such as sugarcane cultivation in specific regions. On the other hand, Shikida and Staduto (2005) underline that with the increasing demand for derivative products and the expansion of production, location has become crucial for the growth and development of the activity.

According to Graef et al. (2016), the adjacent location of economic agents and the concentration of a particular economic activity constitute an efficient way to organize and distribute the productive resources of the economy.

3 Labor Market in the Sugarcane Sector

In the 1980s, Brazil became the world's largest producer of sugarcane, due to expansion areas, climatic conditions, and improved technologies (DIAS, 2021). The states selected for this study (São Paulo, Minas Gerais, Goiás, Paraná, and Mato Grosso do Sul) currently account for over 87% of the country's production.

To increase production, both formal and informal labor were used. Starting 1990s mechanization was used more intensively. According to Menezes et al. (2011),

an increase in informality can be observed with the intensification of mechanization. Younger workers (with more education) may be relocated within the sector, however, older workers with lower education levels will continue to harvest sugarcane, often with reduced wages (daily payment, without formal registration), and subjected to risks of workplace accidents. However, informal labor was not the subject of analysis in this study due to the difficulty in accessing precise data.

In line with Neves and Conejero (2007), with investment in technologies, the sector expanded its byproducts beyond sugar and ethanol, including the possibility of energy generation through bagasse burning and the use of vinasse. These are inputs that were previously discarded because they generated large volumes of environmental pollutants but are now used as fertilizers.

Table 1 presents values of total planted and harvested area, quantity produced, average yield, and the value of sugarcane production for the selected states (2019 to 2021).

Table 1 Planted area, harvested area, quantity produced, average yield, and value of sugarcane production in MG, SP, PR, MS, and GO from 2019 to 2021

Geographical Region	Year	Planted Area (thousand hectares)	Harvested Area (thousand hectares)	Quantity Produced (thousand tons)	Average Yield of Production (kg/ha)	Production Value (R$ million)
BRAZIL	2019	10,120.6	10,092.4	753,470.5	74,657	54,617.37
	2020	10,008.0	9,996.4	756,070.6	75,636	60,541.01
	2021	9,989.7	9,970.9	715,659.2	71,774	75,284.27
São Paulo	2019	5,540.5	5,515.0	425,617.1	77,174	28,813.23
	2020	5,515.8	5,512.0	431,525.6	78,288	32,516.33
	2021	5,473.2	5,462.5	405,000.6	74,142	40,638.69
Minas Gerais	2019	944.0	943.2	72,967.2	77,354	5,648.11
	2020	1,005.1	1,005.1	78,383.6	77,985	6,203.00
	2021	977.7	977.5	69,915.6	71,520	8,992.76
Goiás	2019	946.9	946.9	75,315.2	79,533	6,396.32
	2020	928.0	928.0	75,873.3	81,757	6,411.87
	2021	930.9	926.6	72,012.2	77,716	7,084.43
Mato Grosso do Sul	2019	727.7	727.7	52,245.3	71,790	4,325.72
	2020	666.4	666.4	47,896.8	71,869	5,029.65
	2021	673.3	673.3	47,287.6	70,223	5,494.62
Paraná	2019	596.9	596.9	41,642.4	69,755	2,777.96
	2020	571.8	571.8	40,294.1	70,460	3,053.52
	2021	567.4	567.4	37,506.9	66,100	3,479.53

Source: Compiled by the authors based on IBGE/PAM (2019-2021).

It is observed that the five selected states represent more than 85% of the selected variables. Only São Paulo is responsible for more than half of the entire production, planted and harvested area, justifying their selection for this analysis. Regarding labor, Souza (2010) demonstrated that in areas predominantly devoted to sugarcane cultivation, workers had little or no qualifications and were subjected to poorly paid jobs, having migrated from other crops.

Thomaz Junior (2002) reports that financial globalization forced industrial reorganization, leading to a significant change in the capital-labor relationship within the sugarcane industry in São Paulo. In this context, various labor and union

movements occur with the aim of improving and restructuring labor relations within the sugar and ethanol mills and sugarcane fields.

Over the years, improvements have been implemented in the planting and harvesting of sugarcane, with the introduction of machinery that has minimized the risks for workers when handling machetes/sickles. This has also improved the quality and productivity of sugarcane for the mills. According to Araújo and Araújo Sobrinho (2020), the use of industrial technologies and new management methods highlights the concern to reduce costs and utilize the byproducts of this crop. Menezes et al. (2011) also mention the use of mechanization to minimize environmental problems, eliminating the need to burn sugarcane before harvesting. This burning causes emissions of carbon monoxide and ozone, and damages the soil, wildlife, and surrounding population.

Verçosa and Silva (2017) found out that even with mechanization, there was no mass unemployment because this substitution was expected. Burning fields affected workers' respiratory health, making manual work unsustainable. It is observed that sugarcane cultivation still requires labor for various activities such as technicians operating machinery or drones, among others.

Abreu et al. (2009) warn that little attention is given to the fate of rural workers and the social consequences that may arise from the total mechanization of sugarcane harvesting. On the social front, what is observed is the increasing adoption of equipment, replacing and displacing a large number of sugarcane cutters, and the resulting unemployment tends to increase poverty and violence. Therefore, due to technological heterogeneity, differentiated returns appear, which indirectly contribute to the concentration of wealth and power in regions (BASTOS, 2019).

Despite the conflicting social scenario regarding the modernization process of the sugarcane sector, it has been promoting positive factors such as job creation and income generation, providing taxes to municipalities and states, technology enhancing productivity, and serving as a food strategy by producing sugar and an energy strategy by generating ethanol and sugarcane bagasse (WISSMANN, SHIKIDA, 2017).

However, due to decreased competitiveness in fuel stations caused by reduced demand in the transportation sector due to social isolation during the pandemic and market fuel price interferences, there was a sharp drop in oil prices, about 65% in one month, leading to ethanol production losing ground to sugar production (NOVACANA, 2020).

The 2020/2021 harvest was also marked by dry weather between August and October, damaging the sugarcane fields, reducing productivity potential, and facilitating wildfires. Meanwhile, the 2021/2022 harvest, which began amid the pandemic, was marked by irregular rainfall since the previous harvest. The decrease in rainfall affected the main producing regions of the country, especially the states of São Paulo, Mato Grosso do Sul, and Paraná, causing delays in operations (NATIONAL SUPPLY COMPANY - CONAB, 2020/21; CONAB, 2021/22; HOFSETZ et al., 2022).

To mitigate the losses, in June 2020, the board of the National Bank for Economic and Social Development (BNDES) approved a credit program with an allocation of R$ 1.5 billion. This program aimed to provide credit for working capital linked to product storage.

To encourage job retention, the supported companies were not allowed to reduce their permanent workforce for two months. Such measures aimed to provide relief to the mills to face the period and reduce the risk of energy supply shortages during economic recovery, considering that the sector is responsible for 1 million jobs in the country's interior and generates US$ 10 billion in exports annually (BNDES, 2020).

Leite and Mazzonetto (2021) describe that, despite the negative effects of COVID-19, there was an important role played by the sugarcane sector in maintaining the country's economy, with record production and several actions that assisted federal and municipal entities in facing and preventing the pandemic. This situation was evidenced in the 3rd survey of the 2022/2023 Harvest released by CONAB, where the total sugarcane production is estimated at 598.3 million tons. Among the largest sugarcane-producing states in Brazil are São Paulo (308.15 million tons), Goiás (71.10 million tons), Minas Gerais (68.41 million tons), Mato Grosso do Sul (42.47 million tons), and Paraná (29.55 million tons) (CONAB, 2022/23).

These states represent 86.85% of national production, with the state of São Paulo alone accounting for 51.50% of total Brazilian production. In the Center-South Region, the harvest was almost complete (in December 2022, at the time of the third survey publication), estimated to reach 539.6 million tons (2022/23 harvest), which is 2.8% higher than the 2021/22 harvest. In the North-Northeast Region, due to more favorable climatic conditions, a production of 58.7 million tons is expected, which is equivalent to 9.5% higher than the harvest obtained in the 2021/22 season.

4 Methodology

To analyze the dynamic capacity of the sugarcane sector in generating formal employment, information regarding work relationships in sugarcane cultivation from 156 micro-regions with records in RAIS, a material produced by the Brazilian Ministry of Labor and Employment - MTE (MTE, 2022), was used. Information was collected nationally, and five states were grouped together, which concentrate the highest national production, according to data from the third survey of the 2022/23 Harvest, released by the National Supply Company - CONAB (CONAB, 2022/2023). These states are Minas Gerais, São Paulo, Paraná, Mato Grosso do Sul, and Goiás, from 2019 to 2021.

The information about the number of workers allocated in sugarcane cultivation and other economic activities in the study region was obtained through the National Classification of Economic Activities (CNAE 2.0 Class: 01130 - Sugarcane Cultivation and CNAE 2.0 Class: Total), provided by RAIS from 2019 to 2021, and was useful for constructing the Normalized Concentration Index (NCI).

Table 2 presents the geographical delimitation of the research. It is noted that the composition elaborated by the Brazilian Institute of Geography and Statistics (IBGE) is more comprehensive, due to 41 micro-regions not having information about formal work relationships in sugarcane cultivation, according to CNAE 2.0, made available through RAIS, 2019-2021.

Table 2. Geographical delimitation of the research: main sugarcane-producing states and micro-regions (years 2019-2021)

Federal Units	Micro-regions (IBGE)	Micro-regions (RAIS)
São Paulo	63	56
Minas Gerais	66	55
Goiás	18	15
Mato Grosso do Sul	11	10
Paraná	39	20
Total	**197**	**156**

Source: Developed by the authors based on RAIS (2019-2021) and IBGE/PAM (2019-2021).

The methodological procedure used to identify Brazilian micro-regions specialized in sugarcane activity was based on the contributions of Santana and Santana (2004), Crocco et al. (2006), Dalemolle and Santana (2008), Faria et al. (2008), Alves (2012), and Rodrigues et al. (2012). In this study, we considered the Brazilian micro-regions that have information about formal employment in the sugarcane sector in the states of Minas Gerais, São Paulo, Paraná, Mato Grosso do Sul, and Goiás, based on RAIS data from 2019 to 2021.

According to Crocco et al. (2006), for this purpose, it is interesting to develop an indicator capable of capturing four characteristics of an agglomeration: 1) the specificity of the activity or sector within a region; 2) the weight of the activity or sector in relation to the industrial/business structure of the region; 3) the importance of the activity or sector in the reference region (country, states, etc.); and, 4) the absolute scale of the local industrial/business structure.

4.1 Normalized Concentration Index (NCI)

For the construction of the NCI, we used the calculation of the Location Quotient (LQ), followed by the Hirschman-Herfindahl Index (HHI), and the Relative Share (RS) indicator. Similar to Santana and Santana (2004), the first indicator used in the study was determined by the specialization index or Location Quotient (LQ), which allows determining if a particular municipality specializes in a specific activity or sector. It is calculated based on the ratio between two economic structures. The calculation of the LQ is performed as follows:

$$LQ = \frac{E_{ij}/E_j}{E_{iA}/E_A} \qquad (1)$$

The numerator presents data related to the number of formal employment relationships allocated in the sugarcane sector by micro-regions. In this context, Eij corresponds to the employment in sector i in region j, and Ej represents the total employment in region j. In the denominator, data for all economic activities by micro-regions are represented, where EiA represents the total employment in sector i, and EA represents the total employment.

According to Rodrigues et al. (2012), most studies using this methodology consider LQ above one (LQ>1) to determine if a municipality has specialization in a specific activity or sector. Therefore, the aim was to investigate which micro-regions

exhibit a higher level of specialization and concentration through employment links in the sugarcane sector.

As expressed by Crocco et al. (2006), this indicator, although relevant, may lead to distortions as there may be asymmetries among municipalities within the region, in addition to the high representativeness of a single company in the municipality. To minimize this issue, the Herfindahl-Hirschman Concentration Index (HHI) was integrated into the calculation of the NCI using the following expression:

$$HHI = \frac{E_{ij}}{E_{iA}} - \frac{E_j}{E_A} \qquad (2)$$

This indicator seeks to capture the true significance of the weight of the activity or sector in the local productive structure. It allows comparing the weight of activity or sector i in micro-region j with the weight of the productive structure of micro-region j in the structure of the reference region. A positive value indicates that activity or sector i in micro-region j is more concentrated in the region and, therefore, has greater economic attraction power due to its specialization (SANTANA; SANTANA, 2004).

A third indicator called Relative Participation Index (RPI) was used to capture the importance of activity or sector i in micro-region j in the total represented by activity i in the region. This index is calculated using the following expression:

$$RPI = \frac{E_{ij}}{E_{iA}} \qquad (3)$$

According to Dalemolle and Santana (2008), this indicator should vary between zero and one; the closer it is to one, the greater the importance of the activity or sector for the region. After these procedures, Rodrigues et al. (2012) emphasize that these three indicators will provide inputs for the construction of the NCI, which basically consists of the linear combination of LQ, HHI, and RPI, obtained through the following expression:

$$NCI_{ij} = \theta_1 LQ_{ij} + \theta_2 HHI_{ij} + \theta_3 RPI_{ij} \qquad (4)$$

Where: θ_1 is the weight assigned to the Quotient Location indicator, LQ; θ_2 is the weight assigned to the modified Hirschman-Herfindahl Concentration indicator, HHI; θ_3 is the weight assigned to the sectoral Relative Participation indicator, RPI. According to Santana and Santana (2004), since the sum of the weights is equal to one, it becomes feasible that the linear combination of the standardized indicators contributes to generating the Normalized Concentration Index (NCI), in which the coefficients are the weights themselves calculated by the principal components method, according to equation 4.

The weights of the coefficient for each of the indicators were determined by the Principal Component Analysis (PCA) method. This method seeks a linear combination of variables such that the maximum variance is explained in that combination. A new linear combination of variables is sought to explain the remaining variance as much as possible, and so on. This interaction results in orthogonal factors, meaning they are not correlated with each other, according to

the Foundation Institute of Accounting, Actuarial, and Financial Research - FIPECAFI (FIPECAFI, 2017).

The most commonly used orthogonal rotation method is Varimax, which aims to minimize the risk of a variable having high loadings on different factors, allowing each variable to be easily identified with a single factor. Santana and Santana (2004) emphasize that, from the correlation matrix of the indicators, PCA reveals the proportion of the variance of the total dispersion of the data cloud generated, representing the agglomerationing attributes, explained by these three indicators.

According to Rodrigues et al. (2012), the central idea of this procedure is to reduce the dimension of a series of data by creating a new series of variables, principal components, that are uncorrelated and ordered by their highest explanatory power. This process is reduced to a problem of solving for eigenvalue-eigenvector pairs. After completing this step, specific weights are obtained for each indicator that take into account their contribution to explaining the potential for the formation of local productive agglomerations that geographic units present sectorally (CROCCO et al., 2006).

According to Faria et al. (2008), based on the overall results, the average NCI (Normalized Concentration Index) is calculated, represented by α, which is the result of the simple arithmetic mean of the NCI indicators of all spaces included in the sample. The space that presents an NCI above average (NCI > α) is considered specialized in the productive system in question.

Based on the NCI calculated for the triennium 2019-2021, in this study, we chose to define micro-regions with an NCI above one unit (NCI > 1) as specialized spaces. That is, regions where there is a concentration of formal employment, the performance of the sugarcane sector tends to be more significant in the region's economic dynamics. Micro-regions with an NCI below 1 but above α are defined as differentiated spaces or productive differentiation (α < NCI < 1).

For the calculation of the Normalized Concentration Index, data on formal employment from RAIS for the years 2019, 2020, and 2021 were used. The calculation of specialization coefficients, concentration, and participation, as well as principal components, was performed using R software, version 4.2.2, assisted by the RStudio interface.

5 Results and Discussion

In 2019, out of the 156 micro-regions with formal employment records in sugarcane cultivation across the states of Minas Gerais, São Paulo, Paraná, Mato Grosso do Sul, and Goiás, 118 (75.64%) had a Normalized Concentration Index below average (NCI < 0.78), classifying them as undifferentiated spaces. It is noted that in areas where there is no specialization and concentration, the participation of sugarcane activity indicates little relative importance in job creation, suggesting that the local wealth composition is linked to other economic sectors.

According to Scaramuzzo (2020), the sugarcane culture was affected by the pandemic due to the drop in oil prices, which consequently affected the ethanol price. The result of this decline was the loss of space for sugarcane to grains such as soybeans, corn, and even peanuts. According to Clein (2021), many sugarcane

agroindustries went bankrupt starting from the global crisis of 2008 (about 96 sugarcane production units ceased their activities between 2008 and 2015).

The determining factors considered for the closure of these units were: lack of appropriate management and adverse climatic conditions (microeconomic perspective); and reduction in credit availability and erratic fuel pricing policies at certain times (macroeconomic perspective). The micro-regions with NCI below the average together generated 11,749 jobs and produced more than 233 million tons of sugarcane; however, they did not perform sufficiently to identify a specialized agglomeration in the year 2019. Essa situação é evidenciada quando se constata que, embora 17 microrregiões tenham apresentado LQ maior que 1, o percentual dos índices de HHI e RPI apresentaram valores insignificantes (entre 1% a 2%), sendo que em alguns casos o valor do HHI chegou a ser negativo.

Table 3 presents the values for employment and sugar cane production quantity in the micro-regions that achieved an NCI above average but below 1 ($α<NCI<1$) for the year 2019. The estimated average NCI ($α$) was 0.78, with only 4 micro-regions showing an index above this average.

Table 3. Sugar cane-producing micro-regions in MG, SP, PR, MS, and GO with Normalized Concentration Index above the average and below 1 (Differentiated Spaces): 2019

Micro-region	Formal Link (Absolute Value)	Quantity Produced (thousand tons)	LQ	HHI	RPI	NCI
Ribeirão Preto (SP)	3,943	26,269,376	2.88	0.03	0.05	0.99
Presidente Prudente (SP)	1,046	21,649,314	2.09	0.01	0.01	0.95
Dracena (SP)	177	7,113,900	1.71	0.00	0.00	0.89
Bauru (SP)	1,112	11,629,064	1.60	0.01	0.01	0.88

Source: Developed by the authors from RAIS (2019-2021) and IBGE/PAM (2019-2021).

Only 4 out of the micro-regions from the states that concentrate the highest national production (2.56%) showed density in terms of jobs allocated in the sugarcane sector, which can be considered differentiated spaces. In other words, these micro-regions had an NCI above the simple arithmetic mean of all spaces in the sample but below one unit.

This performance is demonstrated both by the number of jobs and by the production concentrated in the micro-regions, with emphasis on Ribeirão Preto and Presidente Prudente, which together account for 6.55% and 7.18%, respectively, of the links and quantity produced in 2019. It is also noted that in all micro-regions, the LQ was equal to or greater than 1. Furthermore, three micro-regions in São Paulo presented a RPI equal to or greater than 1%, confirming the economic importance of the sector in local job creation. The concentration of employment in the activity is higher in Ribeirão Preto, as HHI showed a positive value of 3%.

On the other hand, Table 4 shows a grouping of 34 micro-regions that had an NCI above 1, with LQ above 2, and HHI and RPI above average. This group can be considered as a specialized area in formal labor employment for sugarcane cultivation. In practice, out of the 34 considered specialized microrregions, the state of São Paulo shows 21 microrregions, representing 56.95% of jobs allocated in the activity, with a production of nearly 232 million tons in the year 2019.

Table 4. Microrregions producing sugarcane in MG, SP, PR, MS, and GO with Normalized Concentration Index above 1 (Specialized Spaces): 2019

Micro-region	Formal Link (Absolute Value)	Quantity Produced (thousand tons)	LQ	HHI	RPI	NCI
Novo Horizonte (SP)	2,290	8,520,240	30.29	0.03	0.03	10.95
Assis (SP)	7,835	17,354,502	32.17	0.10	0.10	6.17
Catanduva (SP)	4,195	9,983,164	18.67	0.05	0.06	5.49
Alto Taquari (MS)	1,252	1,394,064	11.71	0.02	0.02	5.24
Vale do Rio dos Bois (GO)	1,171	8,926,420	11.28	0.01	0.02	4.80
Auriflama (SP)	309	4,352,149	11.77	0.00	0.00	4.38
Ceres (GO)	2,143	8,147,776	12.10	0.03	0.03	4.23
São Joaquim da Barra (SP)	4,149	26,916,470	18.12	0.05	0.05	3.94
Jacarezinho (PR)	949	4,080,496	8.32	0.01	0.01	3.66
Frutal (MG)	1,287	18,606,025	7.50	0.01	0.02	3.35
Ourinhos (SP)	2,266	7,776,044	7.86	0.03	0.03	3.26
Paranavaí (PR)	1,929	9,251,702	8.22	0.02	0.03	3.25
Jales (SP)	1,900	5,590,039	14.72	0.02	0.02	3.25
Jaú (SP)	2,722	17,233,194	7.53	0.03	0.04	3.02
Ituverava (SP)	390	9,192,850	5.27	0.00	0.01	2.92
Lins (SP)	1,295	8,371,327	7.89	0.01	0.02	2.69
Ivaiporã (PR)	505	445,926	6.87	0.01	0.01	2.45
Adamantina (SP)	746	6,145,492	4.97	0.01	0.01	2.36
Batatais (SP)	644	8,036,848	6.21	0.01	0.01	2.36
Ituiutaba (MG)	320	6,101,500	2.68	0.00	0.00	2.12
Jaboticabal (SP)	2,357	22,565,280	5.49	0.03	0.03	2.10
Quirinópolis (GO)	464	13,388,197	4.65	0.00	0.01	2.00
Avaré (SP)	1,050	4,061,900	6.06	0.01	0.01	1.83
São José do Rio Preto (SP)	5,496	33,570,139	5.89	0.06	0.07	1.78
Barretos (SP)	806	10,697,142	4.79	0.01	0.01	1.78
Pirassununga (SP)	1,630	5,108,262	8.30	0.02	0.02	1.73
Dourados (MS)	2,022	23,795,587	4.06	0.02	0.03	1.65
Meia Ponte (GO)	1,261	18,481,961	3.28	0.01	0.02	1.59
Porangatu (GO)	7	583,456	0.06	0.00	0.00	1.55
Nhandeara (SP)	586	5,160,293	10.79	0.01	0.01	1.41
Birigui (SP)	720	12,270,920	3.09	0.01	0.01	1.18
Tatuí (SP)	923	2,776,570	2.93	0.01	0.01	1.18
Sudoeste de Goiás (GO)	1,465	20,670,500	2.99	0.01	0.02	1.15
São João da Boa Vista (SP)	1,077	6,982,880	2.77	0.01	0.01	1.08

Source: Developed by the authors based on RAIS (2019-2021) and IBGE/PAM (2019-2021).

The Novo Horizonte and Assis micro-regions demonstrated a high degree of specialization and concentration in the sugarcane sector, with LQ values of 30.29 and 32.17, and HHI and RPI values of 3% and 10%, respectively. Furthermore, the RPI of these micro-regions showed considerable relative importance in the activity (3% and 10%, respectively), revealing economic prominence in generating employment and income for the local economy (Table 4).

Among the 34 micro-regions with NCI above 1, in addition to São Paulo, another 6 micro-regions are located in Goiás, 3 in Paraná, 2 in Mato Grosso do Sul, and 2 in Minas Gerais. The state of Goiás ranks second in terms of the number of specialized spaces, representing 8.55% of the total employment allocated in the activity and 10.52% of the quantity produced in these spaces in 2019. The Ceres micro-region stood out among specialized spaces in Goiás for employment in sugarcane cultivation with a LQ above 12, HHI, and RPI of 3%. This denotes that, in addition to

productive concentration, the relative participation of the sugarcane sector is crucial for the composition of income and wealth in the local economy (Table 4).

Similar to 2019, in 2020 the states of Minas Gerais, São Paulo, Paraná, Mato Grosso do Sul, and Goiás had 118 micro-regions (75.64%) with a Normalized Concentration Index below average (NCI<0.78), which can be considered as undifferentiated spaces. In 2020, the estimated average NCI (α) was 0.78, the same average as in 2019.

This group, despite not having the potential for specialization in the local activity, represents 12,036 employment bonds and a production of more than 238 million tons of sugarcane in 2020. Although it presented 19 micro-regions with LQ above 1, this indicator, along with HHI and PR, was below the average of all indicators from the sample spaces. In other words, the employment of labor allocated in the sector does not exert enough economic influence to characterize it as a specialized agglomeration.

For 2020, only 4 micro-regions (2.56%) were characterized as differentiated spaces, with NCI above the average and below 1 (α<NCI<1), as observed in Table 5, all of which are located in the state of São Paulo.

Table 5. Micro-regions producing sugarcane in MG, SP, PR, MS, and GO with Normalized Concentration Index above average and below 1 (Differentiated Spaces): 2020

Micro-region	Formal Link (Absolute Value)	Quantity Produced (thousand tons)	LQ	HHI	RPI	NCI
Ribeirão Preto (SP)	3,804	26,784,256	2.82	0.03	0.05	0.99
Presidente Prudente (SP)	1,134	23,863,842	2.25	0.01	0.02	0.95
Dracena (SP)	191	6,631,950	1.81	0.00	0.00	0.89
Bauru (SP)	1,351	11,634,960	1.89	0.01	0.02	0.88

Source: Developed by the authors based on RAIS (2019-2021) and IBGE/PAM (2019-2021).

The differentiated spaces show that the micro-regions of Ribeirão Preto and Presidente Prudente in São Paulo present a better differentiation index, given that the LQ is above 2, with HHI of 3% and 1% and RPI of 5% and 2%, respectively. In these spaces, the employed workforce holds relative importance in the composition of the economic flow generated by the sugarcane sector. The remaining micro-regions depict a scenario of dependency on other economic activities in the composition of local wealth (Table 5).

In Table 6, out of a total of 156 micro-regions, 34 micro-regions had an NCI above 1, being considered as specialized spaces. The micro-regions of Novo Horizonte and Assis in São Paulo have a higher level of specialized concentration, with a LQ greater than 30, HHI and RPI of 3% and 10%, respectively. This situation is similar to that of 2019, demonstrating stability in the weight and relative importance of the sugarcane sector in generating employment and income in the local economy.

Table 6. Microrregions producing sugarcane in MG, SP, PR, MS, and GO with Normalized Concentration Index above 1 (Specialized Spaces): 2020

Micro-region	Formal Link (Absolute Value)	Quantity Produced (thousand tons)	LQ	HHI	RPI	NCI
Novo Horizonte (SP)	2,454	10,011,120	31.64	0.03	0.03	10.97
Assis (SP)	7,946	17,912,226	32.41	0.10	0.11	6.18
Catanduva (SP)	3,393	10,250,329	14.46	0.04	0.05	5.50
Alto Taquari (MS)	1,352	1,270,574	12.79	0.02	0.02	5.24
Vale do Rio dos Bois (GO)	1,316	9,060,781	12.64	0.02	0.02	4.80
Auriflama (SP)	309	3,937,172	11.87	0.00	0.00	4.39
Ceres (GO)	1,824	8,105,689	10.53	0.02	0.02	4.23
São Joaquim da Barra (SP)	4,249	26,922,730	18.39	0.05	0.06	3.94
Jacarezinho (PR)	1,003	3,240,780	8.95	0.01	0.01	3.66
Frutal (MG)	1,454	19,539,704	8.86	0.02	0.02	3.35
Ourinhos (SP)	2,408	7,635,934	8.92	0.03	0.03	3.27
Paranavaí (PR)	2,029	8,780,176	8.71	0.02	0.03	3.25
Jales (SP)	937	5,744,410	7.65	0.01	0.01	3.25
Jaú (SP)	2,683	16,982,712	7.55	0.03	0.04	3.03
Ituverava (SP)	454	9,192,850	6.36	0.01	0.01	2.93
Lins (SP)	1,291	8,285,847	7.78	0.02	0.02	2.69
Ivaiporã (PR)	485	440,492	6.75	0.01	0.01	2.46
Adamantina (SP)	908	5,491,630	6.10	0.01	0.01	2.36
Batatais (SP)	610	8,100,848	5.95	0.01	0.01	2.36
Ituiutaba (MG)	502	6,582,160	4.53	0.01	0.01	2.12
Jaboticabal (SP)	2,192	23,373,620	5.17	0.02	0.03	2.10
Quirinópolis (GO)	452	12,438,290	4.96	0.00	0.01	2.00
Avaré (SP)	790	3,925,017	4.56	0.01	0.01	1.83
São José do Rio Preto (SP)	4,365	33,074,647	4.74	0.05	0.06	1.78
Barretos (SP)	797	10,804,381	4.73	0.01	0.01	1.78
Pirassununga (SP)	1,701	5,066,722	8.61	0.02	0.02	1.73
Dourados (MS)	2,062	21,294,221	4.11	0.02	0.03	1.65
Meia Ponte (GO)	770	19,536,704	2.13	0.01	0.01	1.59
Porangatu (GO)	466	621,008	3.69	0.00	0.01	1.56
Nhandeara (SP)	454	5,057,500	8.30	0.01	0.01	1.41
Birigui (SP)	706	12,034,160	3.10	0.01	0.01	1.18
Tatuí (SP)	947	3,480,420	2.99	0.01	0.01	1.18
Sudoeste de Goiás (GO)	2,101	20,927,462	4.26	0.02	0.03	1.16
São João da Boa Vista (SP)	1,034	6,912,978	2.65	0.01	0.01	1.08

Source: Developed by the authors based on RAIS (2019-2021) and IBGE/PAM (2019-2021) data.

Among the 34 micro-regions specialized in labor employment for sugarcane cultivation, 21 are in São Paulo, 6 in Goiás, 3 in Paraná, 2 in Minas Gerais, and 2 in Mato Grosso do Sul. The micro-regions in São Paulo represent 54.20% of the jobs allocated in the activity with a production greater than 234 million tons of sugarcane. The Goiás micro-regions with an NCI above one unit are responsible for producing more than 70 million tons. Additionally, they generate 9.24% of employment links in the activity. The specialized micro-regions in Paraná showed the worst production performance, with just over 12 million tons produced in 2020.

The micro-regions in Minas Gerais, despite being specialized in labor employment, showed low performance regarding the total number of formal jobs registered in 2020. Out of 74,960 jobs allocated in 2020, only 2.61% are employed by the micro-regions of Frutal and Ituiutaba in Minas Gerais (Table 6).

Similarly to previous years, in 2021, 118 micro-regions (75.64%) with spaces located in the states of Minas Gerais, São Paulo, Paraná, Mato Grosso do Sul, and Goiás showed a Normalized Concentration Index below average (NCI <0.78), being considered non-specialized spaces.

The estimated average NCI (α) based on all spaces in the sample was 0.78, the same value computed in previous periods. It was observed that although 20 micro-regions had a LQ greater than 1, the HHI and RPI were below average. This indicates that the weight of the activity and its relative participation show little relevance in job creation and local wealth composition.

As micro-regions that are differentiated spaces in formal labor employment for sugarcane cultivation for the states of Minas Gerais, São Paulo, Paraná, Mato Grosso do Sul, and Goiás in 2021 are listed in Table 7. The Ribeirão Preto micro-region accounts for 5.06% of the links in the sugarcane sector in the region, with more than 26 million tons produced, a representation certified by the LQ greater than 2, HHI with a weight of 3%, and RPI with a percentage of 5%.

Table 7. Micro-regions producing sugarcane in MG, SP, PR, MS, and GO with Normalized Concentration Index above average and below 1 (Specialized Spaces): 2021

Micro-region	Formal Link (Absolute Value)	Quantity Produced (thousand tons)	LQ	HHI	RPI	NCI
Ribeirão Preto (SP)	3,340	26,798,256	2.84	0.03	0.05	0.98
Presidente Prudente (SP)	1,174	25,641,574	2.77	0.01	0.02	0.94
Dracena (SP)	236	6,192,000	2.62	0.00	0.00	0.89
Bauru (SP)	1,594	10,839,064	2.56	0.01	0.02	0.87

Source: Developed by the authors based on RAIS (2019-2021) and IBGE/PAM (2019-2021).

These indicators reveal that these micro-regions are a space with differentiated density in formal job generation, with significant economic importance of the sector in the local structure. The four micro-regions in São Paulo together represent 6,344 (10%) of the jobs allocated in sugarcane cultivation, with more than 69 million (11%) tons produced. The average NCI of these micro-regions (0.92 > 0.78) was above the arithmetic mean of all spaces in the 2021 sample.

However, Faria et al. (2008) warn that the division between spaces above or below 1 in relation to the NCI is arbitrary and cannot be considered as the exact boundary between spaces with high concentration and specialization relative to the other differentiated spaces above average. However, this procedure was used to refine the nodal points that stand out in the continuous space, aiming to identify places with greater potential in generating formal employment and wealth composition through sugarcane cultivation.

Table 8 presents a group of 34 micro-regions considered specialized spaces (NCI>1). The leadership in specialized concentration in the sugarcane sector in São Paulo was maintained in 2021, as observed in 2019 and 2020. Similarly to previous years, the leadership in the specialized group of 2021 was held by the Novo Horizonte micro-region, followed by the Assis micro-region. It is noted that, even in the face of Covid-19, there were no significant changes in the positioning of specialized agglomerations in the sugarcane sector in the region, indicating that the sector exhibited economic stability.

Table 8. Micro-regions producing sugarcane in MG, SP, PR, MS, and GO with Normalized Concentration Index above 1 (Specialized Spaces): 2021

Micro-region	Formal Link (Absolute Value)	Quantity Produced (thousand tons)	LQ	HHI	RPI	NCI
Novo Horizonte (SP)	2,137	8,850,580	32.35	0.03	0.03	10.92
Assis (SP)	3,710	16,340,572	18.15	0.05	0.06	6.15
Catanduva (SP)	3,142	9,172,750	16.16	0.04	0.05	5.48
Alto Taquari (MS)	1,425	1,104,299	15.45	0.02	0.02	5.22
Vale do Rio dos Bois (GO)	1,362	8,188,760	14.15	0.02	0.02	4.78
Auriflama (SP)	278	4,115,355	12.96	0.00	0.00	4.37
Ceres (GO)	1,949	8,046,899	12.45	0.03	0.03	4.22
São Joaquim da Barra (SP)	2,269	22,761,656	11.59	0.03	0.03	3.93
Jacarezinho (PR)	1,044	3,344,057	10.79	0.01	0.02	3.65
Frutal (MG)	1,465	15,802,851	9.87	0.02	0.02	3.34
Ourinhos (SP)	2,383	7,964,819	9.59	0.03	0.04	3.26
Paranavaí (PR)	1,934	8,315,104	9.55	0.03	0.03	3.24
Jales (SP)	1,006	5,513,130	9.57	0.01	0.02	3.24
Jaú (SP)	2,797	16,250,026	8.86	0.04	0.04	3.01
Ituverava (SP)	526	7,456,520	8.64	0.01	0.01	2.92
Lins (SP)	1,119	7,597,814	7.92	0.01	0.02	2.68
Ivaiporã (PR)	447	364,958	7.25	0.01	0.01	2.45
Adamantina (SP)	901	5,076,191	6.95	0.01	0.01	2.35
Batatais (SP)	622	8,100,848	6.96	0.01	0.01	2.35
Ituiutaba (MG)	631	6,512,198	6.25	0.01	0.01	2.11
Jaboticabal (SP)	2,233	22,479,350	6.15	0.03	0.03	2.09
Quirinópolis (GO)	510	12,287,816	5.89	0.01	0.01	1.99
Avaré (SP)	801	2,848,928	5.39	0.01	0.01	1.82
São José do Rio Preto (SP)	4,148	31,841,458	5.16	0.05	0.06	1.78
Barretos (SP)	753	11,331,845	5.25	0.01	0.01	1.78
Pirassununga (SP)	869	4,996,512	5.09	0.01	0.01	1.72
Dourados (MS)	2,153	19,762,442	4.81	0.03	0.03	1.64
Meia Ponte (GO)	1,544	20,189,118	4.65	0.02	0.02	1.58
Porangatu (GO)	540	692,065	4.58	0.01	0.01	1.55
Nhandeara (SP)	191	4,408,300	4.17	0.00	0.00	1.41
Birigui (SP)	689	8,359,510	3.48	0.01	0.01	1.18
Tatuí (SP)	967	3,636,047	3.46	0.01	0.01	1.17
Sudoeste de Goiás (GO)	1,511	17,447,738	3.38	0.02	0.02	1.15
São João da Boa Vista (SP)	1,079	6,669,423	3.18	0.01	0.02	1.08

Source: Developed by the authors based on RAIS (2019-2021) and IBGE/PAM (2019-2021).

Among the 34 micro-regions with a specialization index in formal labor employment in sugarcane cultivation in 2021, 21 are located in São Paulo, 6 in Goiás, 3 in Paraná, 2 in Minas Gerais, and 2 in Mato Grosso do Sul. These micro-regions represent 74.40% of the formal job positions allocated in the activity, with a production of 337 million tons of sugarcane. Of these, the micro-regions in São Paulo are responsible for 49.39% of the job positions allocated in the sector, with a production exceeding 215 million tons of sugarcane in 2021. In the second position are the micro-regions in Goiás, which together account for 11.23% of the job positions allocated and a production of over 66 million tons.

On the other hand, the micro-regions in Paraná were responsible for 5.19% of the allocated job positions, and the productivity was low compared to other micro-regions, producing just over 12 million tons. However, a LQ greater than 7 is observed,

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with HHI and RPI above 1%. Thus, despite the quantity being lower than other micro-regions, the sugarcane sector plays an economic role for the regions in Paraná.

The micro-regions in Minas Gerais, together, account for 3.17% of the employment linked to the sugarcane sector, with a production of 22 million tons. The micro-region of Frutal stands out as the area with the highest specialized concentration, with a LQ greater than 9, HHI, and RPI at 2%.

No Mato Grosso do Sul, 2 microrregiões foram consideradas espaços especializados: Alto Taquari e Dourados, representando 5,42% dos vínculos alocados, com produção acima de 20 milhões de toneladas. The Alto Taquari micro-region is a protagonist in the state, with a LQ above 15, HHI and RPI of 2%, and has been among the 4 spaces with the highest index of specialized densification in the three periods analyzed. Over the years, the sugarcane sector has been consolidating as an important segment in generating formal employment and local wealth.

Figure 1 shows the micro-regions with an NCI above one unit, whose spaces are considered specialized in formal labor employment for sugarcane cultivation.

Figure 1. Spatial agglomeration in sugarcane cultivation, via Normalized Concentration Index, of the geographical micro-regions: MG, SP, PR, MS, and GO (2019 to 2021)
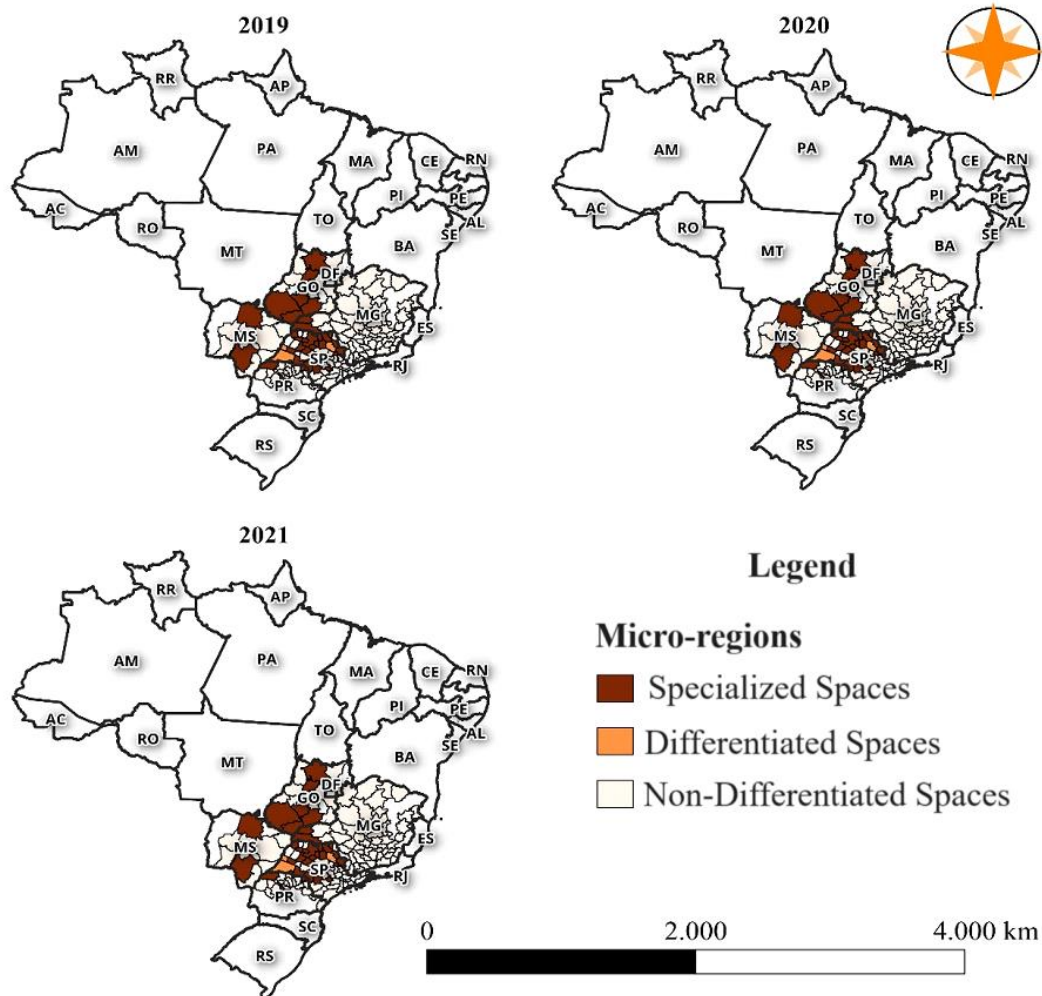
Source: Developed by the authors based on RAIS (2019-2021).

Furthermore, it is possible to identify the micro-regions that had an NCI above the global sample average but below one unit, with these spaces considered differentiated. The remaining micro-regions in the study had NCI values that were negligible, characterizing them as non-differentiated spaces.

The result of this research suggests that despite sugarcane cultivation being an important component in the composition of the Gross Domestic Product (GDP) through production and formal job generation, it lacks greater public and private investments for its expansion to be more competitive and sustainable.

Considering that the identified productive agglomeration is heavily concentrated in the micro-regions of São Paulo, there is a differential in the production structure marked by technological modernization; however, there is heterogeneity in terms of economies of scale for the other Brazilian regions.

6 Final Remarks

The present article analyzed the research question ("Did the formal labor market in Brazil influence productive agglomerations in the sugarcane sector of the micro-regions in the states of Minas Gerais, São Paulo, Paraná, Mato Grosso do Sul, and Goiás?"). With this aim, information was collected through RAIS (2019 to 2021) for the mentioned states, aiming to estimate the Normalized Concentration Index (NCI) using three indicators: Location Quotient (LQ), Hirschman-Herfindahl Index (HHI), and Relative Participation Index (RPI).

The results support that, in the year 2019, only four of the analyzed micro-regions (2.56%) showed a concentration of jobs in the sugarcane sector, considered specialized areas. These micro-regions presented a NCI above the average of all sampled areas, although with values below 1 (one).

The state of São Paulo showed a higher specialized concentration in sugarcane cultivation in 2019, where the number of jobs and production are more concentrated in the micro-regions of Ribeirão Preto and Presidente Prudente, with 6.55% and 7.18% of the employment links and produced quantity, respectively.

In terms of specialized spaces in formal labor for sugarcane cultivation, in 2019, there was a grouping of 34 micro-regions that had an NCI above 1, with a LQ above 2, HHI, and RPI above average. São Paulo leads with 21 specialized micro-regions, accounting for 56.95% of the jobs allocated in the activity and a production of almost 232 million tons, driven by the increasing degree of mechanization of operations and intensive use of inputs and improved varieties, which favored the advancement of the crop (ROCHA et al., 2010).

Regarding undifferentiated spaces, the results for 2019 and 2020 were similar: the sampled states had 118 micro-regions (75.64%) with NCI below the average (NCI<0.78). Although they do not have the potential for specialization in local activity, together they represented 12,036 employment links and a production of more than 238 million tons of sugarcane in 2020. This number of formal employment links represents 16.06% of the total recorded in the year (74,960 links). Furthermore, this value was well above the global average of recorded registrations in the sugarcane activity in 2020.

The results were also similar in both differentiated and specialized spaces, with some values of specific micro-regions varying slightly, but remaining close in

quantity. In 2021, it was found that the differentiated spaces were concentrated in the state of São Paulo, with the Ribeirão Preto micro-region accounting for 5.06% of the jobs allocated in the sugarcane sector, producing more than 26 million tons. In this state, the mechanization process was considered the main driver of evolution and expansion of the sugarcane activity, which became more pronounced with the implementation of Proálcool. However, this mechanization process has generated controversial discussions among different social groups involved in the issue of changes in employment relationships (ABREU et al., 2009).

Regarding the specialized spaces, the microrregions are distributed as follows: 21 in the state of São Paulo with 49.39% of employment links and production exceeding 215 million tons; 6 in Goiás with 11.23% of employment links and production of over 66 million tons; 3 in Paraná with 5.19% of employment links and over 12 million tons produced; 2 in Minas Gerais with 3.17% of employment links and 22 million tons; and 2 in Mato Grosso do Sul with 5.42% of employment links and production above 20 million tons. These microrregions represent 74.40% of formal employment links allocated in the activity, with a production of 337 million tons of sugarcane.

Therefore, the study identified the spaces where sugarcane cultivation is specialized and where formal labor employment is more concentrated in the activity. The result shows that sugarcane cultivation is more homogeneous in the state of São Paulo, highlighting the need for greater investments in R&D for other producing states.

The methodology used paves the way for a deeper discussion about the causes of productive agglomerationing, revealing that the indicators showed significance in the process of identifying and mapping heterogeneous spaces. This highlights the importance of this approach in the context of regional economy, as it allows for a diagnosis of regions with potential for forming local productive arrangements.

However, as highlighted by Crocco et al. (2006), the Concentration Index is not intended to identify all factors that affect the performance of a local productive agglomeration, basically capturing only some relevant aspects of an agglomeration, known as passive elements, which are nothing more than the external economies of scale associated with spatial and sectoral concentration of firms. Additionally, concentration indices have a common weakness: they are a-spatial since geographic units are considered spatially independent from each other. They are treated identically, whether they are neighboring or distant, where in many cases only the local industrial structure is considered and not its surroundings. Therefore, the spatial agglomeration as a whole may be underestimated (RODRIGUES et al., 2012).

However, despite some limitations, this type of analysis allows economic agents to develop public policies and private partnerships in a way that leverages economic dynamics, promoting local development. It is also worth noting that other studies (using different methodologies) can be conducted to investigate the formal labor market in this important economic activity in the country.

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