



Productive territorial specialization and the economic vulnerability of small productive cities in the sugarcane-energy agribusiness in Brazil¹

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Resumo

O presente artigo tem como objetivo analisar o processo de especialização territorial produtiva ocasionada pelo agronegócio sucroenergético e compreender como esse evento resulta em vulnerabilidade econômica dos municípios brasileiros que participam de sua produção, sobretudo aqueles que possuem pequenas cidades. Em função da lógica de uso do território pela agroindústria sucroenergética pautada no processo de exacerbada especialização produtiva, diversos municípios se revelam altamente dependentes economicamente desta atividade e se tornam vulneráveis a crises decorrentes de eventuais fechamentos de usinas. A crise do setor sucroenergético ocorrida durante a década de 2010 evidenciou os impactos econômicos provocados em vários municípios com a interrupção das operações de dezenas de usinas em recuperação judicial ou falidas. Para analisar essas situações, elaboramos o Índice de Vulnerabilidade Territorial (IVT) dos municípios produtivos do agronegócio sucroenergético, que revelou uma quantidade significativa de municípios que estão menos resilientes e mais vulneráveis à ocorrência de crise econômica provocada pelo fechamento de usinas.

Palavras-chave: Especialização territorial produtiva. Agronegócio sucroenergético. Pequenas cidades. Vulnerabilidade econômica. Índice de Vulnerabilidade Territorial.

Productive territorial specialization and economic vulnerability of the small productive cities of the sugarcane-energy agribusiness in Brazil

Abstract

This article aims to analyze the process of productive territorial specialization brought about by the sugarcane-energy agribusiness and to understand how this event has resulted in economic vulnerability in Brazilian municipalities that participate in its production, especially those with small towns. Due to the logic of territorial use by the sugarcane-energy

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agroindustry, based on a process of exacerbated productive specialization, several municipalities demonstrate a high economic dependence on this activity and have thereby become vulnerable to the crisis arising from the possible closures of sugarcane-energy plants. The crisis in the sugarcane-energy sector that occurred during the 2010s highlighted the economic impacts felt by several municipalities through the operational stoppages of dozens of sugarcane-energy plants facing judicial recovery or bankruptcy. In order to analyze these situations, we have constructed the Territorial Vulnerability Index (TVI) for the productive municipalities of the sugarcane-energy agribusiness, which has revealed a significant number of municipalities that are less resilient and more vulnerable to the occurrence of an economic crisis caused by the closure of sugarcane-energy plants.

Keywords: Territorial productive specialization. Sugarcane-energy agribusiness. Small towns. Economic vulnerability. Territorial vulnerability index.

Especialización territorial productiva y vulnerabilidad económica de pequeñas ciudades productivas de la agroindustria sucroenergética en Brasil

Resumen

Este artículo tiene como objetivo analizar el proceso de especialización territorial productiva provocado por la agroindustria sucroenergética y comprender cómo ese evento resulta en la vulnerabilidad económica de los municipios brasileños que participan de su producción, especialmente aquellos que tienen pequeñas ciudades. Debido a la lógica de uso del suelo por parte de la agroindustria sucroenergética basada en el proceso de especialización productiva exacerbada, varios municipios se revelan altamente dependientes económicamente de esta actividad y se vuelven vulnerables a crisis derivadas de posibles cierres de plantas. La crisis del sector sucroenergético ocurrida durante la década de 2010 puso en evidencia los impactos económicos causados a los municipios por la interrupción de las operaciones de decenas de usinas en recuperación judicial o en quiebra. Para analizar estas situaciones, elaboramos el Índice de Vulnerabilidad Territorial (IVT) de los municipios productivos del agronegocio sucroenergético, que reveló un número importante de municipios menos resilientes y más vulnerables a la ocurrencia de una crisis económica provocada por el cierre de centrales.

Palabras clave: Especialización territorial productiva. Agroindustria sucroenergética. Pequeñas ciudades. Vulnerabilidad económica. Índice de Vulnerabilidad Territorial.

1 Introduction

The process involving the geographic expansion of the sugarcane-energy agribusiness across the Brazilian territory, particularly during the first decade of the twenty-first century, was based on incorporating new areas for the competitive production and logistics of sugarcane and its industrial derivatives: sugar, ethanol and bioelectricity. In turn, the installation and operation of sugarcane-energy plants² substantially changed both the form and content of places through the logic of productive economic specialization, both in the countryside and in towns, especially those with a low demographic level and considered small (ENDLICH, 2009; CORRÊA, 2011; SPOSITO and SILVA, 2013). It transpires that the implementation of extensive,

² By sugarcane-energy plants we refer to units that only produce ethanol (also called distilleries), those that only produce sugar or those that produce both products, due to the fact that most of these different units have been technically modernized to serve the energy market, especially for generating bioelectricity from burning sugarcane bagasse.

continuous sugarcane monocultures around agro-industrial units leads to a corporate, “fixed” use of the territory (CASTILLO, 2013), thus implying a transformation in the rural landscape and allocating a large part of the land, of the circulation infrastructure and urban services to the operationalization of the activity.

Therefore, a large portion of the municipalities that specialize in the competitive production of the sugarcane-energy agribusiness are subject to various socio-environmental implications caused by the activity (SZMRECSANYI and GONÇALVES, 2009; THOMAZ JUNIOR, 2009; CAMELINI and CASTILLO, 2012; SANTOS and DREZZA, 2021) and to a process of exacerbated functional and economic dependence. This results in situations of *territorial vulnerability* in relation to any possible instabilities or crises felt by the agroindustry and the loss of control over the direction of local/regional development (SANTOS and CASTILLO, 2020).

During the last crisis in this sector, triggered during the 2010s, several municipalities across the country that were highly specialized and dependent on the sugarcane-energy agribusiness were hit socioeconomically by the closure of plants, thereby experiencing, among other problems, increased unemployment, a reduction in agricultural production, the closure of companies (industry and services), a reduction in the income of the population, a collapse of local trade, a considerable drop in both the gross domestic product (GDP) and the tax revenue of the town hall (SANTOS, 2022). The large number of these plants in a situation of judicial recovery or verging on bankruptcy acts as an aggravating indication of the vulnerable situation of the municipalities that participate in the production of this sector. They become surrounded by uncertainty regarding the sustainability of their economies when faced with the risks of either temporary or permanent stoppages in the agro-industrial activity on which they are extremely dependent.

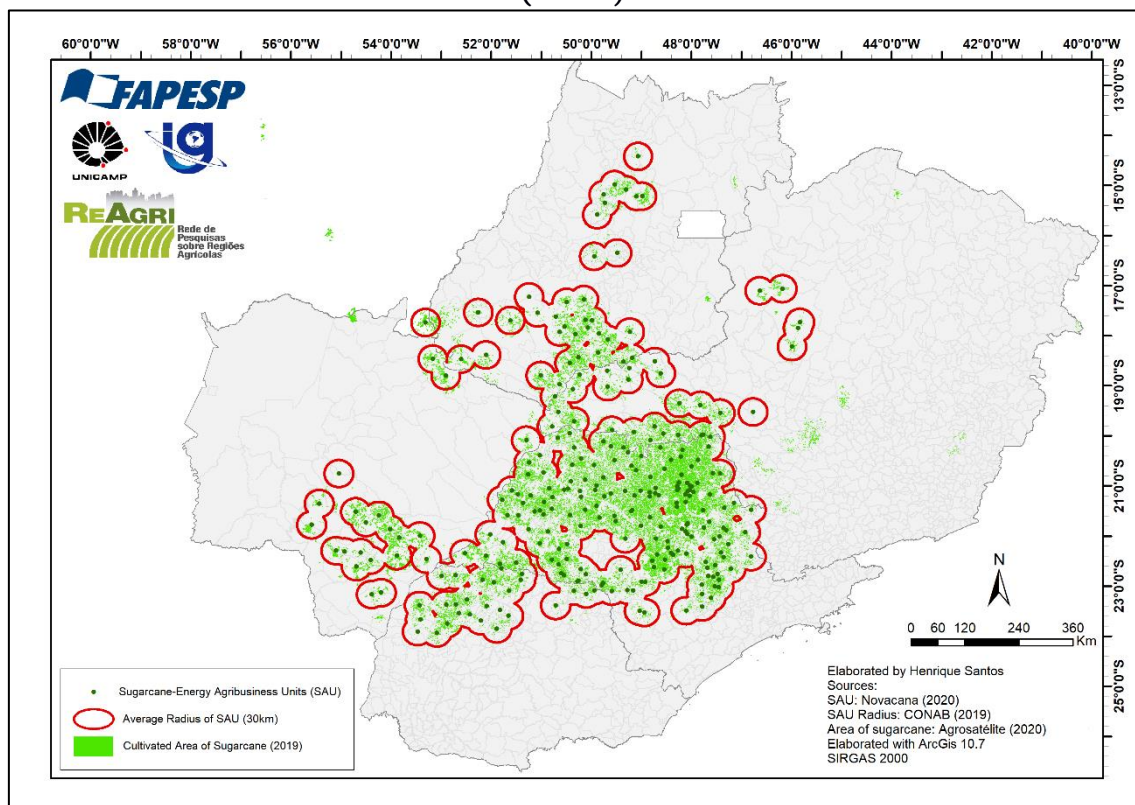
In view of this, the present article aims to analyze how the process of productive territorial specialization occurs through the sugarcane-energy agribusiness and to understand how this event results in economic vulnerability in Brazilian municipalities involved in its production, especially those, which are characterized as small towns. Our starting point is taken from the understanding that the sugarcane-energy agroindustry, throughout its operational process, uses the territory and causes a process of productive specialization of places, thereby capturing municipal economic structures. With this, we propose to develop and apply a Territorial Vulnerability Index (TVI) in order to measure and classify the productive municipalities in the sector in terms of their degree of propensity for the economic crisis caused by the possible closure or temporary shutdown of plants.

2 Productive territorial specialization and the vulnerability of the sugarcane-energy municipalities

During the expansion and crisis in the sugarcane-energy sector throughout the first two decades of the twenty-first century, significant changes occurred in the territorial dimension of this economic activity. As a result of installing new sugarcane-energy plants (greenfields) and the expansion and/or modernization of other existing, older plants (brownfields), the area and production of sugarcane doubled between 2000 and 2020, from 4.8 million hectares to just over 10 million, and from 326 million tons to 757 million (Brazilian Institute of Geography and Statistics - IBGE, 2022). This expansion occurred much more *horizontally*, occupying new lands,

especially in the Alto Paraná basin, notably in areas of the Cerrado biome, than vertically, since it was not accompanied by an increase, at the same pace, in the average production yield. New sugarcane-energy units, more modern than those of previous generations, were installed in the states of São Paulo (the largest producer, until today), Paraná, Mato Grosso do Sul, Minas Gerais and Goiás (CASTILLO, 2015; SAMPAIO, 2015). This area, given the geographical conditions of regional competitiveness for the sector and its productive representation in the global context, was called the Competitive Macroregion of Sugar and Energy Agribusiness (MCAS) of the Central-South region of Brazil (Map 1) (SANTOS, 2022).

Map 1. Central South: Competitive Macroregion of Sugarcane-Energy Agribusiness (MCAS)



Sources: Novacana (2020), CONAB (2019), Agrosatélite Geotecnologia Aplicada (2020), Rudorff et al. (2010). Own elaboration.

The sugarcane-energy sector therefore began to play a prominent role in the economy of certain regions and their respective municipalities. A geographical peculiarity of this activity (and, therefore, what differentiates it from others in agribusiness, such as the production of grains, coffee, cotton, etc.) is that the plants are typically rural industries, since they need to be located close to the cultivation of their raw material depending on certain intrinsic characteristics of the sector. According to Castillo (2013, 2015), the restriction on the storage of raw material, imposed by the perishability of sugarcane and the high logistical costs, and its economic-vegetative cycle, limited to an average of five cuts, given the drop in yield with each regrowth, are characteristics that require the formation of an extensive and continuous sugarcane monoculture in areas physically and relatively close to the

plants, within an average radius of 50 km, completely modifying the rural landscape of the municipalities, as may be observed in Figure 1.

Figure 1. Aerial view of a sugarcane-energy plant in Goiás with sugarcane plantations nearby



Source: Novacana (2018).

Installing a plant in such a manner has the potential of transforming the geographic situation of places. The productive consumption demands of the agroindustry and an increase in consumption of the growing local population, especially that of the contingent of workers attracted by the offer of jobs linked to the activity, increase the number of commercial establishments and services in the towns, and also contribute to increasing the tax collection of the town halls, which thus have more resources for new investments and for expanding the administrative staff. On the other hand, sugarcane monoculture begins to occupy a large part of the land in rural areas, thereby reducing the diversity of agricultural production, while making urban activities in several municipalities, especially those with a low demographic level³, functionalized and economically dependent on sugar-energy production dynamics.

³ For the most part, the urban centers of these municipalities may be characterized as small towns or, as addressed by Milton Santos (1982), *local towns*, endowed with a certain centrality, and that have (or should have) a relatively autonomous economic and political administration, i.e., capable of meeting the urgent needs of a reduced population agglomeration, such as those related to production (agricultural and industrial) and the consumption of public and private goods and services (commerce, banks, health, education, public transport, security, sanitation, etc.). In other words, these centers have a certain concentration of residents and complexity of activities that express a social division of labor of a local (and regional, depending on the activity) scope and greatly influenced by rural/agricultural daily life, enabling them to be recognized as municipal headquarters (in the case of Brazilian legislation) (ENDLICH, 2009; FRESCA, 2010; CORRÊA, 2011; SPOSITO and SILVA, 2013; MANFIO and BENADUCE, 2021). These differ from centers of higher urban hierarchy since they find it “difficult to ensure a high level of sophisticated/diversified services, and therefore present goods that are more routine in the process of human consumption, with less scope in their maximum spatial outreach” (SPOSITO and SILVA, 2013, p. 50). Despite the great demographic variation of this geographic-functional profile of cities, in Brazil, their populations are generally less than 60 thousand (IBGE, 2020).

Given this need for the monopolistic use of the territory (CASTILLO, 2015), the sugarcane-energy agribusiness has become the main economic activity of many municipalities, predominating, for example, in the value of agricultural production, in land leasing contracts, in the use of manual labor (urban and rural), in the generation of income (profits and salaries), in the demand for urban products and services (sale of chemical and mechanical inputs, transport, maintenance of machines and equipment, hotels, restaurants, gas stations, etc.), in the movement of commerce and other services to the population (supermarkets, stores, pharmacies, banks, accounting and law firms, private schools) and, consequently, in the tax collection of town halls, involving a share of the ICMS (VAT on the Movement of Goods and Services) passed on to the municipality by the state government and the ISS (Service Tax), which is municipal in scope. As Maria Laura Silveira (2010, p. 80) argued, the productive territorial specialization caused by the installation of a large corporate enterprise “changes the conditions of the employment equation, the structure of consumption, the use of infrastructure, the composition of the public budget, the structure of public expenditure, the behavior of other companies, the image of the place, and individual and collective behavior.”⁴

Analyzing these aspects, Mirlei Pereira (2015) called some urban centers in the region of the Minas Gerais Triangle, intensely driven by the sugarcane-energy agribusiness, “sugarcane towns”. According to Pereira, it is common for these towns to have the following characteristics:

- 1) They are small urban centers, generally sparsely populated (in the case of the Minas Gerais Triangle, varying between 4 and 18 thousand inhabitants), which have one or more sugarcane-energy plants in a municipal territorial area (with plants close, or not, to the urban area);
- 2) Such centers are located in municipalities with a large predominance of sugarcane cultivation across their territorial area, when compared to all other agricultural crops (both temporary and permanent), generating monotonous landscapes that in the last decade have spread across the Minas Gerais Triangle; and
- 3) In most cases, the economy of such centers is predominantly based on agricultural activity (primary sector) or industrial activity (a secondary sector resulting in most cases exclusively or significantly from sugarcane-energy activities).

When studying the urban dynamics in the northwest of the state of Paraná, Ângela Endlich (2009) and Marcos Souza (2018) also discovered that the economy of several municipalities in the region is marked, among other activities, by the presence of the sugarcane-energy sector, which accounted heavily for the refunctionalization of these locations to become places of support for agricultural logistics and housing for agricultural workers. In the words of Endlich (2009, p. 184), in these towns, since the activity involves the use of land from several municipalities that supply raw materials and the recruitment of labor at a micro-regional level,

There is a particular prevalence of the agro-industrial sector, which is often mono-industrial, and which creates an economic situation of greater fragility in the face of the uncertainties of the world market. Agro-industrial

⁴ This and all non-English citations contained herein have been translated by the authors.

activities are significant for small towns, both for those with industrial headquarters and for neighboring municipalities.

However, this situation of significant municipal economic specialization conceals a situation of perverse territorial vulnerability. When, for various reasons, the activities of a plant are suspended, as has occurred in several cases during the crisis in the sugarcane-energy sector during the 2010s (SANTOS, 2022), the movements of a large portion of goods, population and income cease, thereby reducing consumption levels and pushing people into increased debt, seriously compromising commercial and service enterprises. The town hall, in turn, also finds itself in a difficult situation, since it stops collecting taxes generated by the production and circulation of goods and services boosted by the operation of the plant and begins to rely on a reduced budget for maintaining public services and investing in infrastructure, in addition to, eventually, dismissing outsourced employees and bearing the burden of increased social assistance costs.

From a critical perspective, we therefore consider that large sugarcane-energy plants and their adjacent sugarcane cultivation areas may be seen as geographical forms, which, according to Milton Santos (1979), through their content and function, disseminate hegemonic capital in the regions where they settle, causing major transformations in the local socioeconomic structure and various territorial implications⁵. As discussed below, the rapid economic growth offered by the expansion of the sugarcane-energy sector in these more specialized locations (which may be described as predominantly sugarcane-energy municipalities) and which, for the most part, were socioeconomically guided by family farming before the arrival of the plant, is accompanied by a concerning situation of territorial vulnerability. This is because, for Santos and Silveira (2001, p. 300), these places become *alienated specializations*, in which

[...] the economic indices obtained must, therefore, be contrasted with the fact that the coherence and, at times, the luster of local activities constitute a subordinate coherence, dependent on entities foreign to the area and whose process obeys commandments that have neither local inspiration nor concern for local destinations (except in what corresponds to their private and immediate interest), so that the growth process that occurs in the place may be defined as an alienated process, which supports such activities as being considered specializations that are not just alien, due to their origin, but alienated, by their development and destiny.

Although the installation and operation of a sugarcane-energy plant may, indeed, result in increased levels of employment and income and generate economic growth, especially in small municipalities (SHIKIDA and SOUZA, 2009; BACCHI and CALDARELLI, 2015; GILIO and MORAES, 2016; CALDARELLI and PERDIGÃO, 2018;

⁵ As Milton Santos (1979, p. 198) observed, “the forms have become ideal instruments to promote the introduction of foreign technological capital into an underdeveloped economy and to harm the process of overaccumulation, the counterpart of which is overexploitation. The economies of those countries in which this occurs become distorted, their traditions sacrificed and their populations impoverished”, since these forms “serve the dominant mode of production instead of serving the local socioeconomic formation and its specific needs. It is a sick, perverse and harmful totality” (idem, p. 202).

GUEDES, VIAN and TERCI, 2019; STACCIARINI, 2019), the way in which companies in the sector use the territory to obtain high levels of competitiveness ultimately creates bonds of dependence that may cause these places to become highly vulnerable to any unfavorable conditions arising from both the market (fluctuations in sugar and ethanol prices) and the State (public policies to control fuel prices to contain rising inflation, for example). This vulnerability is also linked to other socio-environmental implications inherent to the pattern of an intensive monoculture that expands through rural spaces close to agro-industries, as discussed by authors such as Szmrecsanyi and Gonçalves (2009), Thomaz Junior (2009), Camellini and Castillo (2012) and Santos and Drezza (2021). Thus, it is notable that, according to Camellini (2011, p. 58),

the spatial weakening [resulting] from the specialization of ethanol production which, on the one hand, confers differentiated attributes of competitiveness for this specific segment of activity while, on the other, it reduces local autonomy, since it places the municipality in a global production context, within which it becomes extremely functional and alienated. As a result of this process, it is possible to observe several manifestations that potentially compromise the quality of life, resulting from the direct or indirect interference of agents and processes completely unrelated to the local reality.

In terms of the impacts from the recent crisis in the sugarcane-energy sector on municipalities, we have come to realize that depending on the geographical characteristics and forms of territorial use, some were more or less affected by the closure of plants, since they present different levels of *territorial economic resilience*⁶. Municipalities with a larger population, which are more economically diversified, involving a greater number of agricultural and/or urban-industrial activities, contributing to the generation of local wealth, were able to mitigate the impacts of operational closures or temporary shutdowns of a plant. Unlike municipalities that had less diversified economies, either urban or rural, and were therefore relatively specialized and dependent on the sugarcane-energy sector. In these cases, the closure of the plant activities resulted in serious disruptions in terms of employment, income and tax revenue for town halls, resulting in a local economic crisis (stagnation or decline in growth) for which recovery is slow and difficult (SANTOS, 2022). The different situations observed are related to the fact that:

Each municipality, each urban center, each local economy reacts in a particular way to fluctuations in the prices of agricultural commodities on international markets, to the decisions of large companies, to state and federal public policies (investments in infrastructure and standards), but they are all vulnerable to agents external to the place and to contingencies that they cannot control (CASTILLO et al., 2016, p. 279).

Another important aspect that generates this vulnerability is the current scenario involving the financialization and centralization of capital in the sugarcane-energy agribusiness. Although it is a fact of the competitiveness of the largest groups, the control of a large number of plants by these agents in a situation of high

⁶ Territorial (or regional) economic resilience is the ability of a territory or region, within a short period of time, to resist or respond to and recover from an economic crisis event (internal or external) (MARTIN and SUNLEY, 2015).

financial leverage reflects conditions of greater risk. As Pitta (2016) analyzed, companies in the sugarcane-energy sector (and possibly throughout agribusiness) are currently very driven by debt rollovers, in a system of fictitious reproduction of capital that assumes the continuous expansion of a future productive capacity to pay for commitments made with banks and other financial institutions and investors and the acquisition of more credits to maintain the activity. However, given market instabilities, the expectations of these groups may become frustrated and they may quickly enter a context of uncontrolled debt and operational crisis, as occurred with the sugarcane-energy sector in 2010 (SANTOS, 2022).

Over recent years, there have been several cases of large sugarcane-energy groups that have become weakened due to the enormous financial leverage and obtaining successive harvests with huge losses⁷, precisely because expenses (including debts) are almost always greater than the revenues and the value of company assets, often leading plants to file for judicial recovery, bankruptcy and, most often, their closure. As most of these groups have centralized capital and own many plants in different locations across the country, the financial difficulty and the need to continually rationalize costs through deactivating less efficient units have represented real conditions of risk and vulnerability for a wide range of municipalities.

3 The economic vulnerability of small towns specialized in sugarcane-energy agribusiness

The context of exacerbated regional and territorial productive specialization caused by the sugarcane-energy agribusiness and the risks of crisis in local activity result in geographical situations of territorial vulnerability (SANTOS and CASTILLO, 2020). Territorial vulnerability is understood here as the susceptibility of the territory (municipal, state, national) for suffering damage and losses (economic, social and/or environmental) as a result of crises (sectoral or macroeconomic, internal or external), natural disasters or socio-environmental degradation arising from some economic activity⁸.

The territorial vulnerability of the productive municipalities of the sugarcane-energy agribusiness could be characterized, for example, by the damage that the

⁷ Novacana (2/5/2018): **Eight years in the red: Umoe Bionergy had losses of 82.89 million BRL in 2017**, available at: <https://bit.ly/3xNNqbR>; Valor Econômico (8/7/2019): **Tereos has a loss and sees its debt register significant growth**, available at: <https://glo.bo/3xMe7xs>; Valor Econômico (30/7/2019): **BP and Bunge plants have already lost 7 billion BRL**, available at: <https://glo.bo/3wJVRDV>; Novacana (23/6/2020): **Atvos shows losses of 1.5 billion BRL in 2019/20**, available at: <https://bit.ly/36C7Foc>; Novacana (28/7/2020): **Biosev shows increased losses in 2019/20 to 1,55 billion BRL due to the impact of exchange rates on debt**, available at: <https://bit.ly/3kph6Z6>; Novacana (4/8/2020): **Abengoa records losses in 2019 and completes a decade of negative results**, available at: <https://bit.ly/3hOpL5L>; Novacana (9/9/2020): **Clealco triples losses in the 2019/20 harvest, reaching losses of 286.65 million BRL**, available at: <https://bit.ly/3BaVSUA>; Novacana (30/9/2020): **With a loss of R\$ 13.4 million, Della Coletta maintains a sequence of negative results**, available at: <https://bit.ly/3erjfxz>; Novacana (21/10/2020): **After five years, the Lincoln Junqueira plants return to losses in 2019/20**, available at <https://bit.ly/3eoQZxn>. Viewed in: July 2021.

⁸ Common situations of territorial vulnerability may be observed, for example, in municipalities located close to mining companies where there is a high risk of tailings dams collapsing, as well as in those subject to desertification, floods, earthquakes, drug trafficking violence, etc.

activity causes to the environment and to the social conditions in the countryside and the town as well as to the local economy. Due to the fact that most of these municipalities have a population of up to 30 thousand⁹, that is to say, they are classified within the profile of small towns (IBGE, 2020), stoppages in the main productive activity (sugarcane-energy) generates a series of medium and long-term negative effects that result in a reduction of the resident population, in the stagnation or decline of the economy (recession) or even in the loss of municipal economic autonomy, sometimes leading to a situation in which town halls have to declare a state of public calamity in order to rely on exceptional state and /or federal transfers to ensure that the administration continues to function¹⁰.

Given the different degrees of territorial vulnerability to the economic crisis caused by the closure of plants, we propose a classification of these situations for the productive municipalities in the sugar-energy agribusiness by means of the Territorial Vulnerability Index (TVI). This index tends to reveal how vulnerable the municipality is to the occurrence of an economic crisis according to its greater or lesser ability, over a short period of time, to either resist or respond and recover from the consequences caused by the closure of a sugarcane-energy plant.

The TVI is composed of three indicators and their respective variables (Table 1). Some of these variables were selected from empirical studies on territorial economic resilience, such as those conducted by Sánchez-Zamora, Cobos and Delgado (2014), Graziano and Rizzi (2016), Gonçalves (2018b) and Lapuh (2018). The weights of the variables and indicators were assigned according to the degree of importance that each has in the overall analysis of the municipal vulnerability. The justifications for using each indicator and variable, as well as their weights in the TVI series, may be found in Santos (2022).

The statistical methodology used to elaborate the index, which was initially proposed in research published in cooperation with other researchers (SANTOS et al., 2022), was improved and based on the work of Kageyama (2004), Silva, Cândido and Martins (2009), Cutter (2011), Santos (2011) and Pereira (2021). These studies, despite having different objectives and share little similarity to ours, provided the basis for considering how to statistically treat the variables and indicators.

⁹ Of the 900 municipalities in the country with installed plants and/or a cultivated sugarcane area of over 1,000 ha, 660 (or 73% of the total) have a population of up to 30 thousand. Among the 282 municipalities with plants in operation, 167 (or 60%) have the same demographic level (SANTOS, 2022).

¹⁰ One example of this occurred in the municipality of Ibirarema (SP), with a population of just 7 thousand, when the Pau D'Alho plant, with a capacity to process 2.2 million tons of sugarcane per harvest, closed down its activities, causing several layoffs and damaging the public accounts after a drastic drop in tax collection. See Municipal Decree No. 30 of June 24, 2013, available at: <https://bit.ly/3xTr6xA>. Viewed in: July 2021.

Table 1. Indicators and variables of the Territorial Vulnerability Index (TVI) for the Productive Municipalities of the Sugarcane-Energy Agribusiness

Indicators	Variables	Data reference period	Data source	Weight of indicator
Local Sugarcane-Energy Activity Vulnerability Index (IVASL) Weight: 2.0*	Number of plants in operation in the municipality	Sep./2020	Novacana (2020)	2.5
	Number of simple plants in operation in the municipality	Sep./2020	Novacana (2020), Sapcana (2020), websites das empresas	2.0
	Number of plants operating under judicial recovery in the municipality	Sep./2020	RPA (2020), Novacana (2020)	2.0
	Total bioelectricity sold by plants in operation (GWh) in the municipality	2019	Novacana (2020)	1.0
	Number of plants operating in other municipalities within a radius of up to 50 km from the municipality's urban center	Sep./2020	Novacana (2020), Google Maps (2020)	2.5
Total				10.0
Sugarcane-Energy Productive Territorial Specialization Index (IETPS) Weight: 4.0	Sum of the grinding capacity of plants operating in the municipality	Sep.2020	Novacana (2020)	1.0
	Percentage of sugarcane in the area of temporary and permanent crops	Average 2017, 2018 and 2019	PAM/IBGE (2020a)	2.0
	Percentage of sugarcane in the agricultural area	2017	Censo Agro. (IBGE, 2017)	1.0
	Percentage of sugarcane in the area of the municipal territory	Average harvests 2017/2018, 2018/2019 and 2019/2020 (SP, MG, GO, PR, MS e MT) or 2017, 2018 and 2019 (other states)	Agrosatélite (2020) (SP, MG, GO, PR, MS e MT) IBGE (2020f) (other states)	1.0
	Percentage of sugarcane in the value of agricultural production	Average 2017, 2018 and 2019	PAM/IBGE (2020a)	1.0
	Percentage of rural establishments that grow sugar cane	2017	Censo Agro. (IBGE, 2017)	1.0
	Percentage of the sugarcane-energy sector in formal employment	Average 2017, 2018 and 2019	RAIS (2020)	2.0
	Percentage of the sugarcane-energy sector in exports	Average 2017, 2018 and 2019	ComexStat (ME, 2020)	1.0
Total				10.0
Low Urban-Industrial Dynamics Index (IBDUI) Weight: 4.0	Number of inhabitants (estimate)	2020	IBGE (2020c)	3.0
	Position of the municipality in the urban network	2018	REGIC (IBGE, 2020h)	1.0
	Distance (Km) from the urban center of the nearest regional capital or metropolis	2018	REGIC (IBGE, 2020h), Google Maps (2020)	0.5
	Number of active companies	Average 2017, 2018 and 2019	RAIS (2020)	1.0
	Total formal jobs exclusive to the sugarcane-energy sector	Average 2017, 2018 and 2019	RAIS (2020)	1.0
	Municipal Gross Domestic Product (GDP) (BRL)	Average 2016, 2017 and 2018	IBGE (2020d)	1.0
	Percentage of industry and services in GDP value added	Average 2016, 2017 and 2018	IBGE (2020d)	1.0
	Percentage of people with higher education in total formal employment	Average 2017, 2018 and 2019	RAIS (2020)	0.5
	FIRJAN Municipal Development Index (IFDM)	2016	FIRJAN (2020)	0.5
	Municipal Human Development Index (IDHM)	2010	Ipea (2015)	0.5
Total				10.0

* We assigned a lower weight to the IVASL due to the statistical distortion presented by some municipalities that had few plants within a 50 km radius or under judicial recovery and that, despite having low rates of IETPS and IBDUI (which in our view are indices that express situations of greater vulnerability), their TVI levels were raised. Own elaboration.

After collecting and organizing the data on an electronic spreadsheet, the numbers were equalized on a scale of values that varies between 0 and 1, with three decimal places¹¹. To carry out this procedure, the following two formulas were used: in the case of variables whose maximum values have the potential to generate greater vulnerability (e.g. percentage of sugarcane in the total agricultural area), formula A was used, and in the case of variables whose maximum values generate less vulnerability (e.g. number of inhabitants), formula B was used.

$$\text{(Formula A) } V = \frac{(X - X_{\min})}{(X_{\max} - X_{\min})} \quad \text{(Formula B) } V = \frac{(X - X_{\max})}{(X_{\min} - X_{\max})}$$

Where:

V – is the number that will be standardized on a scale from 0 to 1

X – is the value of the variable for the municipality

Xmin – is the minimum value of the variable verified among the municipalities in the sample

Table 2 presents the minimum and maximum values used to equalize the data and, as an example, data from the municipality of Clementina (SP).

¹¹ To arrive at the values of the sub-indices and the TVI, which have the same numerical structure, it is necessary to standardize all units of the variables in order to make the calculations viable.

Table 2. Minimum and maximum values of the TVI variables observed in the sample and values in the municipality of Clementina (SP)

Variables	Clementina (SP)		Minimum value		Maximum value	
	Data	Index	Data	Index	Data	Index
Local Sugarcane-Energy Activity Vulnerability Index (IVASL)						
Number of plants in operation	1	1.000	0	0,000	4	0.250
Number of simple plants in operation	1	1.000	0	0.000	2	0.500
Number of plants operating under judicial recovery	1	1.000	0	0.000	2	0.500
Total bioelectricity sold by operating plants (GWh)	132.942.000	0.776	1.200	1.000	593,917.6	0.000
Number of plants operating in other municipalities within a radius of up to 50 km from the city	3	0.700	0	1.000	11	0.000
Sugarcane-Energy Productive Territorial Specialization Index (IETPS)						
Sum of grinding capacity of plants in operation (million tons/harvest)	3	0.222	0	0.000	13.5	1.000
% of sugarcane in the area of temporary and permanent crops	89.9	0.899	0	0.000	100	1.000
% of sugarcane in the agricultural area	38.5	0.385	0.0	0.000	100.0	1.000
% of sugarcane in the area of the municipal territory	43.0	0.430	0.0	0.000	80.5	0.805
% of sugarcane in the value of agricultural production	80.7	0.807	0.0	0.000	100.0	1.000
% of rural establishments that grow sugarcane	8.7	0.087	0.0	0.000	91.6	0.916
% of the sugarcane-energy sector in formal employment	74.4	0.744	0.0	0.000	84.4	0.844
% of the sugar-energy sector in exports	100.0	1.000	0.0	0.000	100.0	1.000
Urban-Industrial Dynamics Index (IBDUI)						
Number of inhabitants (estimate)	8.757	0.992	838	1.000	711.085*	0.000
Position of the municipality in the urban network	Local capital (1.0)	1.000	Local capital (1.0)	1.000	Grande metrópole nacional (0.0)	0.000
Distance (Km) from the nearest regional capital or metropolis	43	0.077	0	0.000	555	1.000
Number of active companies	139	0.996	19	1.000	21.779*	0.000
Total of formal jobs exclusive to the sugarcane-energy sector	834	0.988	166	1.000	229.579*	0.000
Municipal Gross Domestic Product (GDP) (BRL)	227.897	0.994	27.438	1.000	31,028.820*	0.000
% of industry and services in GDP added value	92.1	0.079	27.6	0.724	100.0	0.000
% people with higher education in total formal employment	10.6	0.894	2.5	0.975	68.3	0.317
FIRJAN Municipal Development Index (IFDM)	0.872	0.128	0.394	0.606	0.882	0.118
Municipal Human Development Index (IDHM)	0.725	0.275	0.505	0.495	0.815	0.185

Note: *The maximum values considered were those of Ribeirão Preto (SP), the most populous city in the sample involved in sugarcane-energy production.

Own elaboration.

Once the equalized values were obtained in the same numerical structure, the next step was to calculate the weighted average of each subindex. The calculation involved the sum of the variables multiplied by their weights, the result of which was divided by the result of the sum of the weights, as exemplified by the following formula:

$$I = \frac{(V1_{\times p1} + V2_{\times p2} + V3_{\times p3} + V4_{\times p4} + V5_{\times p5} \dots)}{(p1 + p2 + p3 + p4 + p5 \dots)}$$

Where:

I – is the value of the calculated subindex

V – is the value of the variable scaled between 0 and 1

p – is the weight attributed to the variable (as shown in Table 1)

When obtaining the values of the three sub-indices, their weighted average was taken to result in the TVI, according to the following formula:

$$TVI = \frac{(IVASL_{\times p1} + IETPS_{\times p2} + IBDUI_{\times p3})}{(p1 + p2 + p3)}$$

Where:

TVI – is the Territorial Vulnerability Index calculated for the municipality

IVASL – is the Local Sugar Energy Activity Vulnerability Index of the municipality

IETPS – is the Sugar and Energy Productive Territorial Specialization Index of the municipality

IBDUI – is the Low Urban-Industrial Dynamics Index of the municipality

p – is the weight assigned to each sub-index (as presented in Table 1)

The values of the sub-indices and the TVI vary between 0.000 and 1.000, with those closest to 1 being those that contribute most to the degree of territorial vulnerability of the municipalities.

Subsequently, we performed the TVI ranking of the Productive Municipalities of the Sugarcane-Energy Agribusiness, grouped into three classes: high, medium and low, according to the intervals presented in Table 3. From this, we created the vulnerability classification cartography of these municipalities (Maps 2 and 3) and the interpretation of the results, indicating common characteristics between the municipalities of each class according to the variables and indicators considered and the local/regional particularities¹².

¹² The list with the ranking of all municipalities and data on the variables and indicators used in the research are available in the Unicamp Research Data Repository (Redu), and may be consulted at: <https://doi.org/10.25824/redu/JI7Q1V>

Table 3. Classes and value intervals of the Territorial Vulnerability Index (TVI)

TVI Class	Value intervals	Number of Municipalities	%
High	0.550 – 0.760	209	23
Medium	0.450 – 0.549	374	42
Low	0.001 – 0.449	317	35
Total		900	100,0

Own elaboration

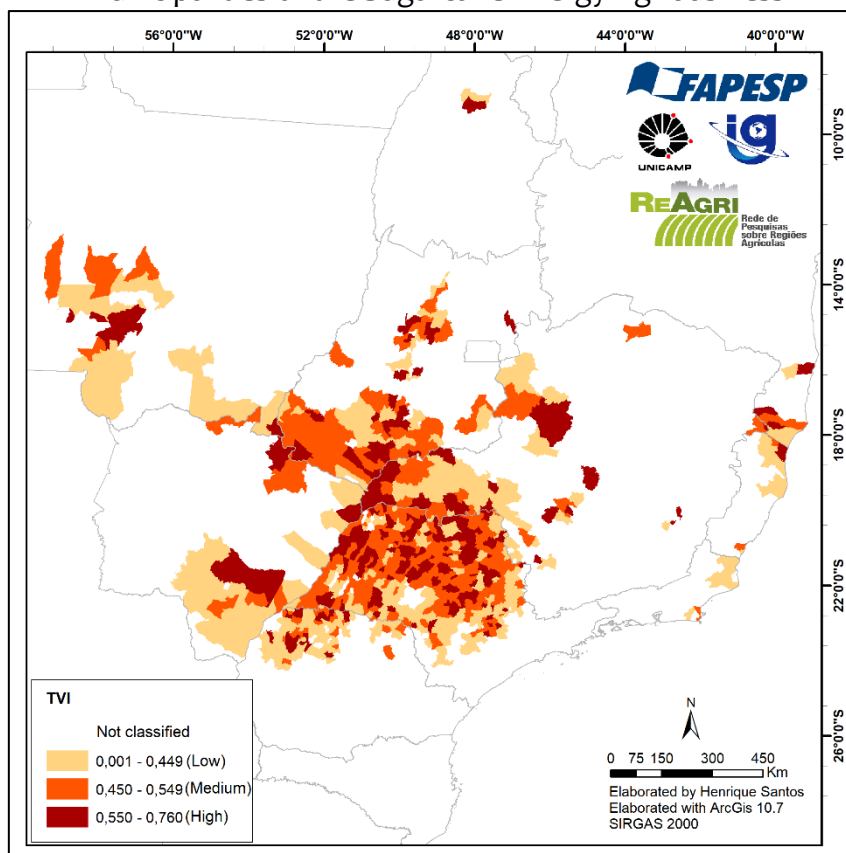
The results have demonstrated that 209 municipalities, or 23% of the total productive municipalities in the sugarcane-energy agribusiness (900) present high territorial vulnerability to the economic crisis caused by the eventual closure of sugarcane-energy plants. These are municipalities that have high IETPS and IBDUI, since they belong to highly specialized locations in the sector, with a low demographic level (up to 60 thousand inhabitants), small cities and not particularly robust economies. Furthermore, the majority have installed plants, some of which are simple (which only produce ethanol or sugar) and/or under a situation of judicial recovery, which increases territorial vulnerability. When observing Maps 2 and 3, we realize that these municipalities are distributed across all the states that are particularly outstanding in the production of sugarcane-energy agribusiness. However, the largest number of cases is concentrated in the state of São Paulo, since it also has the largest number of municipalities with high IETPS, as may be inferred from Maps 4 and 5.

The municipalities that obtained a medium TVI, representing the majority of cases (42%), are distinguished into two profiles. The first are those with a larger population and more robust economies, but where there are plants installed on their territory and have high specialization in the field focused on the sugarcane-energy activity, generally with sugar cane occupying more than half of the area and the value of agricultural production. Particularly outstanding among these municipalities are, Jataí (GO), Presidente Prudente (SP), Cabo de Santo Agostinho (PE), Itumbiara (GO), Ituiutaba (MG), Passos (MG), Araraquara (SP), Juazeiro (BA), Araçatuba (SP), Cabo Frio (RJ), Araras (SP), Santa Rita (PB), Ourinhos (SP), Leme (SP), Jaú (SP), Catanduva (SP) and Vitória de Santo Antão (PE). In these municipalities, the closure of sugarcane-energy plants could have significant economic repercussions, since the agricultural economy is very specialized in sugarcane. However, given the greater complexity of urban activities, such municipalities are ultimately more economically resilient. The second profile of municipalities, in turn, have smaller towns, that is to say, a less complex urban-industrial structure, and with a field significantly specialized in sugarcane cultivation. Most of these municipalities have no installed plants, but those that do, for this TVI class, there is a lower degree of agricultural specialization.

The municipalities classified with a low TVI (35%) also fall into two profiles. The first is municipalities whose headquarters are medium or large towns, considered to be regional capital cities or located in metropolitan regions (IBGE, 2020). Therefore, their economic structures are more diversified and complex, i.e., they have a greater territorial resilience, such as Uberlândia (MG), Maceió (AL), Ribeirão Preto (SP), São José do Rio Preto (SP), Franca (SP), Bauru (SP), Jaboatão dos Guararapes (PE), Marília (SP), Maringá (PR), Indaiatuba (SP), Limeira (SP), São Carlos (SP), Botucatu (SP), Rio Claro (SP), Linhares (ES), Umuarama (PR), Dourados (MS), Piracicaba (SP), Uberaba

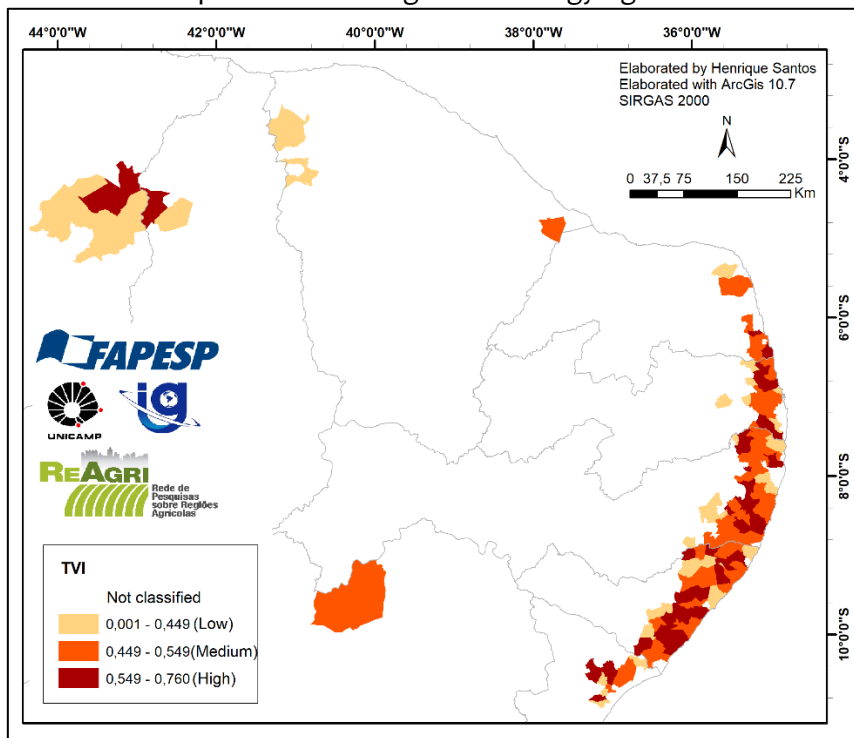
(MG), Rio Verde (GO), Barretos (SP), Santa Barbara D'Oeste (SP), Campos dos Goytacazes (RJ), among others. The second profile is made up of municipalities with lower demographic levels and less dynamic economies, but which have low IETPS and that, therefore, commonly stand out for soybean farming or other agricultural activities (coffee, corn, oranges, beef cattle farming), such as Cornélio Procópio (PR), Cáceres (MT), São Sebastião do Paraíso (MG), Unai (MG), Marialva (PR), Mandaguari (PR), Itaberaí (GO), Conchal (SP), Taquarituba (SP), Amambai (MS), Itaporã (MS), Monte Santo de Minas (MG), Alvorada do Sul (PR), Alto Araguaia (MT), among others.

Map 2. Central-South Region: Territorial Vulnerability Index (TVI) of the Productive Municipalities of the Sugarcane-Energy Agribusiness



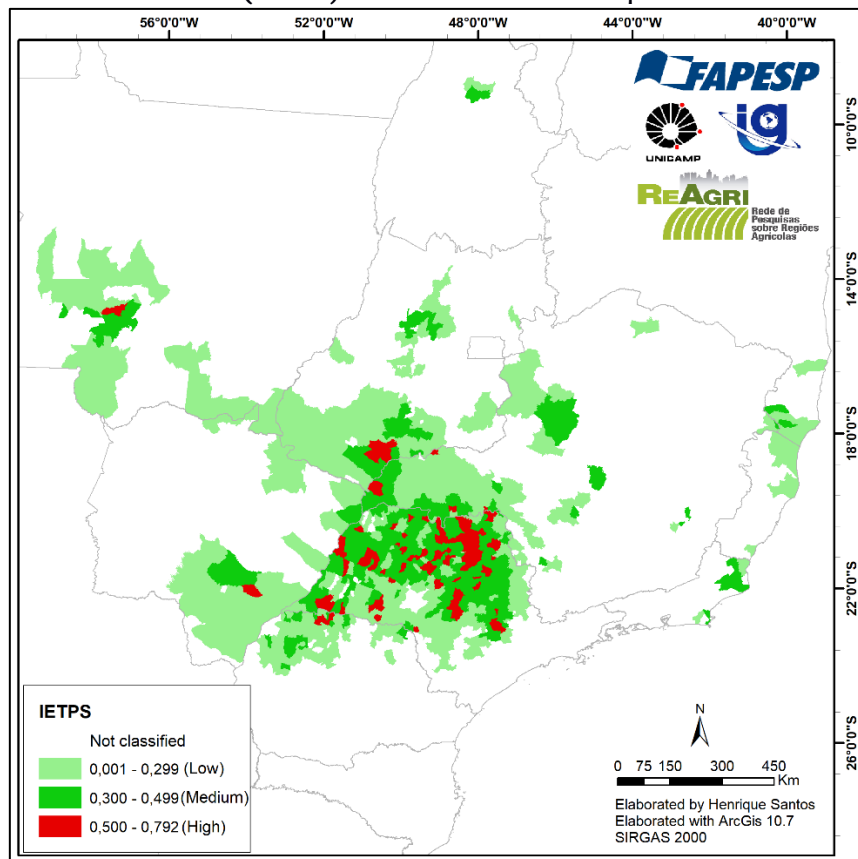
Own elaboration

Map 3. Northeastern Region: Territorial Vulnerability Index (TVI) of the Productive Municipalities of the Sugarcane-Energy Agribusiness



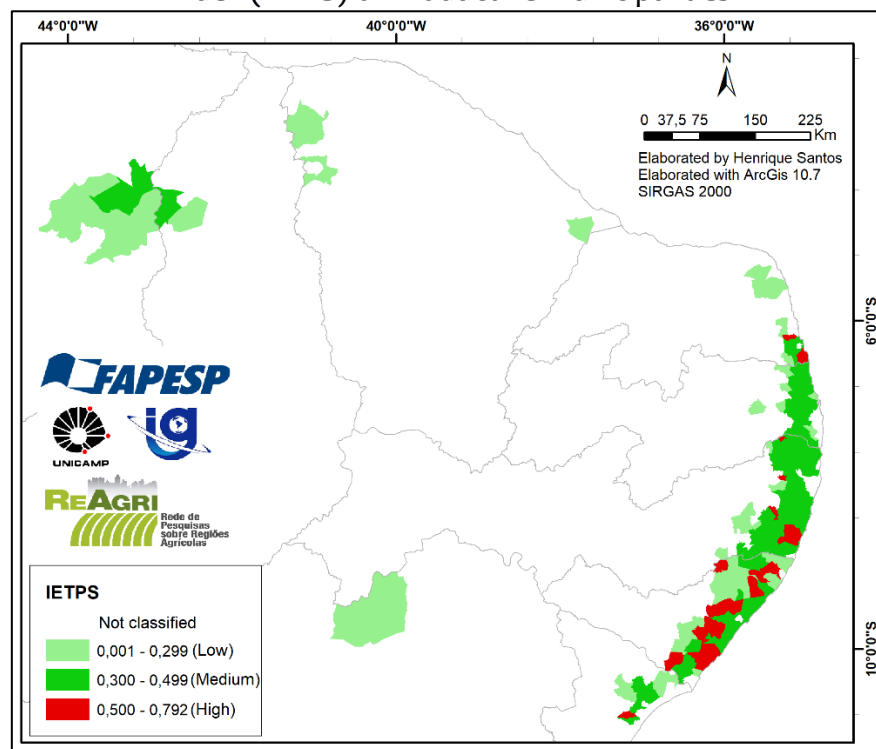
Own elaboration

Map 4. Central-South Region: Sugar-Energy Productive Territorial Specialization Index (IETPS) of Productive Municipalities



Own elaboration

Map 5. Northeastern Region: Sugar-Energy Productive Territorial Specialization Index (IETPS) of Productive Municipalities



Own elaboration

The different TVI levels reveal very different geographical situations regarding the process of regional and territorial specialization of sugarcane-energy production and its capacity to generate damage and socioeconomic losses to productive municipalities due to possible cases of plant closures.

4 Final considerations

The context of rapid geographic expansion and the subsequent economic instability, the centralization of capital and the financialization of the sugarcane-energy sector during the first two decades of the twenty-first century represented a situation of increasing territorial vulnerability in several parts of the Brazilian territory. The installation and operation of sugarcane-energy plants transformed the economy and daily life in many places, triggering an intense process of productive territorial specialization in several municipalities. Because of this, the temporary or permanent closure of the activities of plants undergoing judicial recovery or bankruptcy during the period of crisis in the sector caused situations of considerable economic instability for many of these municipalities, given their high dependence on the production and/or processing activities of sugarcane (SANTOS, 2022).

The continued economic alienation of several municipalities by the sector, especially those with a low demographic level and little urban-industrial dynamism, brings a concerning context of territorial vulnerability which, in general, is not expressed only by the risks of developing a local crisis as a result of the closure of sugar-energy plants, but also due to the various compromising effects that sugarcane monoculture causes to the environment and the well-being of local populations. Like

other activities inherent to Brazilian agribusiness, to paraphrase Elias (2021), the sugarcane-energy sector has proven to be a spatially selective, socially exclusive, economically concentrating and environmentally unsustainable production model.

In view of this particular geographic situation, an analysis of many productive municipalities in the sugarcane-energy agribusiness through the TVI has enabled us to determine that a large number present a high level of territorial vulnerability to the economic crisis caused by the closure of plants. The risks of developing an economic recession that lasts for years are high, since due to the high degree of specialization of their small economies and the frequent lack of strategic options for compensation for other activities (industries, services) and agricultural productive reconversion /agroindustrial in the short term, it is possible that the local population will suffer from a lack of jobs, reduced income, low business activity and little assistance from town halls impacted by a drop in tax collection being felt on the functioning of public services.

Considering the importance of the statistical survey on the economic situation of the municipalities involved in the production of sugarcane-energy agribusiness, we share the idea of Marandola Junior and D'Antona (2014) that the study of vulnerability provides State managers and planners with a very important resource for elaborating and executing public policies in order to better prepare places (regions, municipalities) with regard to problems arising from environmental and/or socioeconomic crises. In the case of the municipalities that we investigated, this importance is established in order to alert public authorities on the economic vulnerability underlying excessive local sugarcane-energy specialization and the risks of crisis caused by the operational stoppages at the plants. The results may indicate which municipalities need regulation and land use policies aimed at greater rural and urban productive diversification in order to reduce the levels of this vulnerability.

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