Effect of the Substitution of Sugarcane for Food Supply Crops in Goiás

Amanda S. Diniz[1], Jeferson de C. Vieira[1], Antônio Pasqualetto[1,2] & Sergio D. de Castro[1]

[1] School of Law, Business and Communication, Pontifícia Universidade Católica de Goiás, Goiânia, Goiás, Brazil

[2] Federal Institute of Goiás [IFG], Goiânia, Goiás, Brazil

Correspondence: Jeferson de C. Vieira, School of Law, Business and Communication, Pontifícia Universidade Católica de Goiás, Goiânia, Goiás, Av. Fued José Sebba, 1184. Jardim Goiás.CEP 74805-100, Brazil. Tel: 55-62-3946-3086. E-mail: jcastrovieira@gmail.com

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Abstract

This article analyses the effect of replacing food crops with sugarcane in Goiás, according to mesoregions, between 2013 and 2020. The research intends to contribute to the discussion about the themes related to the changes that have occurred in the areas under plantation, production, and the value of sugarcane, rice, beans, corn, and soybeans. The database used is taken from IBGE's Municipal Livestock Production Survey. The results indicate that there was a rapid expansion of sugarcane production, which followed a similar direction as corn and soybeans, but with beans maintaining a very slow production rate. Sugarcane production is heavily concentrated in a single mesoregion of Goiás, which highlights a series of alerts regarding the spatial heterogeneity of this crop's production. The work concludes that there are strong indications that sugarcane is substituting rice production, but the same has not happened with beans.

Keywords: sugarcane, replacement effect, food production, agriculture in the State of Goiás, Ethanol

1. Introduction

Sugarcane is characterized as one of the main crops on the planet. It is grown in 105 countries, of which Brazil and India stand out with 59.4% of global production, according to data from the United Nations Food and Agriculture Organization - FAO (2020). These data show that after Brazil and India comes Thailand, China, Pakistan, Mexico, Colombia, Australia, Indonesia, Guatemala and the United States of America with 20% of global production. In terms of occupied area, sugarcane cultivation accounted for 20.4 million hectares in 2019, compared to 93 million for soybeans, 144.4 million hectares of corn, rice with 154.3 million hectares and wheat with 216.6 million hectares. Therefore, among the six main crops in the world, sugarcane occupied the lowest quantity of area.

In the specific case of Brazil, sugarcane production rose from 396 million tons in 2003 to 757 million in 2020, the third temporary crop in terms of area occupation, behind soybeans and corn, according to IBGE data (2020). Thus, Brazil appears as a major global player in the sugar and alcohol trade, both in domestic and foreign markets.

The creation of Proálcool (National Alcohol Program), in 1975, with the objective of stimulating the production of alcohol, aiming to meet the needs of the domestic and foreign markets at that time together with the automotive fuel policy, with the insertion of new models of *flex-fuel* vehicles in 1978, was an incentive for the expansion of sugarcane production in Brazil. According to Ramos (1999*)*, ever since the discovery of Brazil, sugar production in the country has been predominantly located in the northeast, mainly in the State of Pernanbuco, which has led sugar and mill production for a long time. With the oil crisis in 1973, the expansion of sugarcane production and its derivatives in several Federation Units was a response to international oil prices, which became exorbitant, having a contagion effect on Brazil's inflation, in addition to causing a large deficit in the Brazilian trade balance. Thus, the production of sugarcane gained space throughout Brazilian territory, competing with the production of other crops, in an intense process of replacing food crops, which have been traditionally produced in Brazil.

In the specific case of the State of Goiás, over time there has been an increasing expansion of sugarcane cultivation, with the State positioning itself in 2020 in third place in the ranking for national production. Over time, the production of sugarcane in Goiás has risen from 614 thousand tons in 1974 to 754 million tons in 2020, according to data from IBGE's Municipal Agricultural Production (2022). Therefore, the study of the expansion of sugarcane production becomes an interesting case to analyse from the point of view of the regional issue, of the occupation of land, since other crops have been forced into the background.

This article takes as its hypothesis, the process of replacing other traditional food crops, such as rice and beans, especially sugarcane crops, in addition to corn and soybeans, in the development of agriculture in Goiás, specifically between the period from 2013 to 2020. Thus, the objective was to address the area of occupation, production and value of sugarcane in the territory of Goiás, analysing the impacts and effects of its production on other genres, promoting the evaluation of the intensity of the crop replacement process.

To facilitate the reader, this article is divided into six sections, starting with an introduction. In section two, a literature review is carried out on the main references to the production of sugarcane in Goiás. In the third section, a brief assessment of Proálcool and the international market is made. The methodology utilized in this work is presented in the fourth section. In section five, the results are presented and discussed and, finally, in the sixth section, some final considerations are made.

2. Brief Evaluation of Proálcool and the International Market

With the oil shock of November 1973, in which the price of a barrel of the product quadrupled, Brazil entered a phase of economic development. The Brazilian economy was very dependent on the use of oil in its fuel matrix. At the time, Brazil imported 80% of the oil it consumed, with oil import spending rising from US$6.2 billion in 1973 to US$12.6 billion in 1974, causing a trade deficit of US$4.7 billion in 1974 (BAER, 2009). Baer (2009) states that broadly speaking, from an economic point of view, Brazil had three problems to solve from the oil shock: 1) reducing the deficit in the trade balance that had caused a worsening in the reconciling of its external accounts (balance of payments); 2) risk of internal energy shortages because it was a country very dependent on oil to supply its automobile fleet; 3) substantially reducing its economic growth by reducing oil imports. Based on these affirmations, it was concluded that the most viable and short-term alternative to the problems was to research and develop new alternative sources of energy.

Thus, in November 1975, by Decree No. 76.593 (BRAZIL, 1975), the National Alcohol Program (Proálcool) was created by the federal government, with the objective of restructuring the sugarcane sector in Brazil to become a viable alternative to confront the high cost and dependence on imported oil. Proálcool was created in conjunction with efforts to attain genetic improvement, rationalization and give support to the sugar agribusiness. These actions were prepared and proposed by the Sugar and Alcohol Institute under the name of the National Sugarcane Improvement Program (*Planalsucar*), progressively implemented by regional coordinators and substations in several units of the Federation, including the State of Goiás.

According to a report on *Planalsucar*, prepared by RIDESA (Interuniversity Network for the Development of the Sugarcane Sector (2015), the Program was extremely viable because with teams of researchers and technicians, sugarcane production and productivity increased. There was modernization of agricultural and industrial mechanization, an introduction of biological pest control, calibration of macro and micronutrients in soils with recommendations for liming and fertilization of sugarcane, optimization of industrial processes in the manufacture of sugar and alcohol and, finally, the establishment of parameters for payment of sugarcane by sucrose content.

Thus, with the creation of Proálccol, an incentive was given for the production of alcohol, with expansion of production, new varieties of seeds, expansion and modernization of alcohol production and industrialization. In addition, from *Planalsucar*, specific lines of financing and a policy of stimulating the price parity between ethanol and sugar were established, making the production of ethanol, which until then was a less valued by-product, something of increased value.

In the context of the oil crisis in the 1970s, production goals were established and several incentives were created to expand the production and use of fuel ethanol, initially, increasing the addition of anhydrous ethanol to gasoline (Milanez; Faveret Filho; Rosa, 2008). In 1978, the first ethanol-powered vehicles emerged, in which there was an incentive to produce anhydrous alcohol to add 22% to gasoline, with the aim of reducing oil imports when the automotive industries introduced *flex-fuel* engines to the market.

In 1979, the Government and the National Association of Automotive Vehicle Manufacturers (ANFAVEA) signed a protocol in which car manufacturers were to seek new technologies for the mass production of ethanol-powered vehicles. The maximum price of ethanol was limited to 64.5% of the price of gasoline and the IPI for ethanol-powered vehicles was reduced (Queiroz, 2008). In addition to this competitive price structure, Proálcool presented several advantages in relation to the use of petroleum products, especially with regard to technological development, supply strategy, economic performance, employment level and environmental preservation.

From the point of view of external dependence on oil, Brazil has developed a technology, unique in the world, for the large-scale use of a renewable fuel independent of the international oil market. Several regions of the country, which

had not produced or produced little ethanol, developed this productive practice, offering job opportunities using national technology and as an alternative to reduce carbon gas emissions in society. In this sense, attention was drawn to studies on green economy in Higher Education Institutions in Brazil, which have been fundamental for a more accurate understanding of the expansion of sugarcane and its achievements for the environment (Dos Ramos, 2019).

Pro álcool went through three evolutionary phases: 1) moderate expansion, between 1975 and 1979; 2) accelerated expansion, between 1980 and 1985; 3) deceleration and crisis, between 1986 and 1995, due to the fall in the international oil price and the crisis in government accounts (Shikida & Bacha, 1998).

In this phase of low production, which began in 1986, a period called "oil counter-shock", crude oil prices fell from between US$30 and US $40 to between US$12 and US$20, a fact that disrupted the programs for replacing oil derivatives and efficient use of energy worldwide, according to the Inter-American Institute of Cooperation for Agriculture - IICA (2007). In addition, in the Brazilian energy policy, the effects were felt from 1988, a time that coincided with a period of scarcity of public resources to subsidize programs for stimulating alternative energy sources, resulting in a decrease in investments in domestic energy production. The incentive programmes and tax benefits for producers were not as strong as they were initially.

The 1990s were marked by privatizations in Brazil, with government priorities to stabilize the economy, in which energy policy underwent a process of deregulation of sugarcane. The government's justification was the fiscal crisis of the State, which could no longer put subsidized money into this alternative production program, which began a long period of highs and lows in the sugarcane sector. At various times the prices paid to ethanol producers were low, discouraging any increase in domestic ethanol production. On the other hand, the demand for ethanol by consumers depends a lot on the maintenance of a relatively attractive price, compared to that of gasoline. Consumers need the guarantee of ethanol supply, and can choose the cheapest and most suitable fuel for their budgets.

The sugar-energy sector invested in Brazil with high investments in the production of sugarcane. There is a volatility around harvesting and the time between harvests with ethanol production causing price fluctuations, and with plants undergoing judicial reorganization and other processes of productive restructuring. The growth of the sector depends greatly on the market and the ability to generate new efficiency and productivity gains in the production process. However, some disruption technologies have emerged coupled with changes in public policies associated with ethanol, mainly in the international and domestic spheres.

There is an intense global debate on greenhouse gas emissions in the earth's atmosphere, in which it has been concluded that it is important to aggregate the economic, environmental and social components in addressing the world's socioeconomic development. These debates have been intensifying since the RIO-92 Conference and until COP-26, held in Glasgow and COP-27, which is expected to be held in Egypt in 2022, according to United Nations Environment Reports (United Nations, 2021). Without going into the merits of the origins of these negative issues, one of the sectors that has contributed most to the alarming growth rates is energy generation based on the use of fossil fuels (Chouinard et al., 2011).

In this regard, the use of ethanol is considered strategic, as it is efficient in the results it obtains and, at the same time, environmentally viable and sustainable. It is possible to produce ethanol in a renewable way with different raw materials (corn, barley, wheat, sugarcane, etc.). In the specific case of Brazil, the production of biofuels is essential in relation to the current energy issue. Ethanol is part of this set of biofuels and is the main energy alternative, both in the economic sense and in the sense of protecting and reducing emissions of gases and the greenhouse effect in the environment (C ôrtes et al., 2019). This same line of approach was noted by Feil and Schreiber (2017).

In 2021, The United States of America led the world in ethanol generation, with 55% of world production, practically depending on corn as its raw material, (Table 1). Following quickly on that comes Brazil, with 27% of production. Therefore, 82% of global production in concentrated in only two countries. Ethanol is one of the main competitors to global oil production and is an alternative to reduce the immense dependence on imported oil, especially for Brazil.

Table 1. Global Ethanol production (Thousand gallons), 2016-2021

Region	2016	2017	2018	2019	2020	2021	Participation in world production in 2021
United States	15,413	15,936	16,091	15,778	13,941	15.000	55%

Brazil	6,870	6,760	8,080	8,790	8,080	7,500	27%
European Union	1,240	1,320	1,360	1,380	1,260	1,300	5%
China	730	850	810	1,010	930	860	3%
India	270	210	420	470	510	820	3%
Canada	450	460	460	500	430	440	2%
Thailand	330	380	390	430	390	390	1%
Argentina	240	290	290	290	210	260	1%
Rest of the World	627	664	729	682	659	740	3%
Total	26,170	26,870	28,630	29,330	26,410	27,310	100%

Source: RFA (Renewable Fuels Association) (2022).

Description: Obtained by the RFA Ranking demonstrating the participation in the world production of ethanol in the period 2016-2021.

Unlike Brazil, which uses sugarcane, the USA produces ethanol from corn and is the largest exporter of the product in the world. The production costs of ethanol from maize are double the cost production from sugarcane, and even so, the production of biofuels in the USA has been leveraging faster than in Brazil.

The European Union is the world's third largest ethanol producer, with 5% of global production, and concentrates its production using cereals such as wheat, barley and beet; however, ethanol production competes with the food industry for these raw materials. This inevitably ends up favouring Brazil with its sugarcane. It is worth mentioning that countries that are members of the European Union, and which engage in ethanol production, have an incentive with subsidies and protectionist barriers, in addition to each member country having the right to set its own ethanol goals (Bessa, 2013).

According to the ranking of the largest ethanol producers in the world, China occupies fourth place with 3% of production and its raw material is also corn, but stands out for its consumption and importation of petroleum gasoline due to its huge fleet of vehicles. It was precisely because of the quantity of vehicles, and consequently the environmental impacts caused, as there is a considerable increase in greenhouse gas emissions, that the Chinese government started to encourage the adoption of renewable energies, such as ethanol for use as fuel.

3. The Expansion of Sugarcane in Brazil

Sugarcane cultivation has been a feature in Brazil, notably in the Northeast region since the colonial period, undergoing expansion due to Pro álcool, implemented in 1975, making states such as S ão Paulo, Goi ás, Minas Gerais, Mato Grosso do Sul and Paran á, major producers, in addition to Alagoas and Pernambuco. Dias (2021) analyses the process of increasing demand for sugar and alcohol in Brazil, showing how the sugarcane production chain has become very complex with the incorporation of a modern technical base.

Brazil has demonstrated strong expansion of the sugarcane sector, driven by the production of alternative fuel at scale and the commercialization of sugar, in addition to the generation of electricity through sugarcane bagasse. In 2003, national production was 396 million tons of sugarcane, rising to 757 million in 2020, which meant a 91% growth, as can be seen in Table 2.

Table 2. Brazil: Participation of sugarcane production by the main Units of the Federation, in tons (2003 and 2020)

States	2003	Participation	2020	Participation
S ão Paulo	227,980,860	57.6%	431,525,560	57.0%
Minas Gerais	20,787,483	5.2%	78,383,655	10,4%
Goi ás	12,907,592	3.3%	76,480,368	10.1%
Mato Grosso do Sul	9,030,833	2.3%	47,896,832	6.3%
Paran á	31,925,805	8.1%	40,310,021	5.3%

Mato Grosso	14,667,046	3.7%	20,806,469	2.7%
Alagoas	27,220,770	6.9%	15,293,563	2.0%
Pernambuco	18,522,067	4.7%	14,826,596	2.0%
Para ba	6,074,074	1.5%	5,673,632	0.7%
Bahia	4,751,958	1.2%	5,449,639	0.7%
Brazil	**396,012,158**	**100.0%**	**757,116,855**	**100.0%**

Source: IBGE (2003; 2020).

Description: Data obtained by the IBGE represents the share of sugarcane production in the federation units, in tons 2003-2020.

The State of S ão Paulo, according to IBGE's 2020 data, is the main producer nationwide, followed by Minas Gerais and Goi ás. From 2003 to 2020, S ão Paulo practically does not change its relative national share in the production of sugarcane, but there is a significant increase in the production in Goi ás from 3.3% to 10.1%, Mato Grosso do Sul from 2.3% to 6.3% and Minas Gerais from 5.2% to 10.4%. Traditional states in the production of sugarcane such as Alagoas, Pernambuco, Para ba and Bahia demonstrate reduced participation in the national ranking.

> "*Considering that the expansion of the crop occurred in all producing region observed, represented by the technological expansion, infrastructure and production propensities, S ão Paulo is configured as the main producer and the state of Goi ás as the second. Results that can be evidenced and show this trend in the last crop surveys*" (ALVES, 2021, p. 307).

Regarding the competitiveness of Brazilian ethanol, Chagas and Toneto Junior (2008) state that Brazil is one of the countries that is at the most advanced stage in the search for clean energy sources. They demonstrate that the competitiveness of ethanol produced from sugarcane in Brazil is significantly higher than that of other producers, standing out in relation to US corn ethanol, both in terms of production costs and energy balance. This makes Brazil an important player in the international game of ethanol production and industrialization.

The measurement of sugarcane productivity among the 10 largest national producers is a differential for analysing the expansion of this crop. The productivity of sugarcane in Goi ás is the highest in Brazil and this is due to climate conditions, soil and intensive use of technologies (Table 3). The same phenomenon, slightly smaller in proportions, is observed in Mato Grosso, S ão Paulo and Minas Gerais. When analysing the other states, which were traditionally historical producers of sugarcane in Brazil from colonial times, there is a significant loss of productivity, which would require investments in cultural treatments and technology.

Table 3. Brazil: Sugarcane productivity by 10 largest producers (2020)

State	Productivity (kg/ha)
Goi ás	81,569
Mato Grosso	78,497
S ão Paulo	78,288
Minas Gerais	77,985
Bahia	72,625
Mato Grosso do Sul	71,869
Paran á	70,449
Pernambuco	57,515
Alagoas	56,532
Para ba	56,478

Source: IBGE (2020).

Description: obtained by IBGE, data from the table reproduces the productivity of sugarcane by 10 largest producers in Brazil (2020).

The State of Goiás accounted for 10.1% of national production in 2020 (Table 2), ranking third for national production, but presented the highest productivity level in Brazil (Table 3). Goiás reached 81.5 tons per hectare, up 3.9% on Mato Grosso and 4.1% on São Paulo. This raises the hypothesis that Goiás has the best possibility for the expansion of sugarcane cultivation in Brazil.

Therefore, there is a competitive advantage in the production of sugarcane in the four main units of the Federation, which have stimulated economic agents to invest in the production of ethanol in recent years. A characteristic of Brazilian mills is that they produce sugar and ethanol in tandem. Ethanol to practically meet all internal demand, and sugar to meet both internal and external demand. Thus, the expansion of sugarcane production comes as a response to the high demand for biofuels and sugar, which is reflected in the increase in profitability or even in the viability of the sugar-energy sector. The high price of sugar is also attractive for the Brazilian producer, as Brazil is one of the largest sugar exporters in the world, according to the FAO (2020).

The production of ethanol brings advantages to Brazil, both in terms of preserving the environment and in terms of the low cost of production. In addition, it is possible to offer equipment and services. According to Vidal (2020), since 2015, the amount of mandatory blending of gasoline ethanol in Brazil has been 27%. In addition, the country is prominent in the world for having a technology that is growing consistently, such as flex cars, in which they can use any combination of gasoline and hydrated ethanol.

Brazilian agriculture has been characterized from the end of 1970 by a process of modernization, with significant transformations in the economic structure that operate in society as a whole, fruits of the rapid growth of urbanization and agricultural foreign trade. Besides, together with changes in the technical base of production in rural areas and the simultaneous consolidation of a national rural credit system, which supports and enhances the realization of grain super crops over time. This modernization process brought with it a new form of Brazilian regional development, with significant environmental and socioeconomic impacts, which has become known in the economic literature as the "conservative modernization" of agriculture. In this respect, it can be stated that:

> "*The expansion of 'modern' agriculture occurs concomitantly with the constitution of the agro-industrial complex, modernizing the technical basis of the means of production, changing the forms of agricultural production and generating effects on the environment. The transformations in the countryside have occurred, however, heterogeneously, since rural development policies, inspired by the 'modernization of agriculture', are riddled with inequalities and privileges*" (Balsan, 2006, p. 125).

From a productive point of view, the most diverse forms of production and organization of agricultural production needed to adapt and reorganize to adhere to this new concept of agriculture. A true agricultural productive restructuring was set up with organic articulation between the agro-industrial complex, the research and rural extension system and the government's subsidies and tax incentives policy. There is a precision agriculture constituted by true capital integration, ranging from agricultural-industry integration, through modern systems of commercialization and storage of products, to a well-diversified line of financial products applied by financial conglomerates that make agricultural production a true financial asset, similar to the valuation of financial assets in general.

This financial function of agricultural production creates a productive axis in which agricultural markets are circled by products that are more profitable, that have more profitability, in which the differential profit margins encourage the production of some agricultural products to the detriment of others. Faced with this modernization, Brazilian society began to adhere to the specialization of agriculture, with the concentration and centralization of production of a few crops, which although always present in the family economy, are products marketed on a scale in the domestic and global grain market. Cultures considered as family-based such as rice and soybeans, sugarcane and corn have replaced beans.

Mesquita and Furtado (2018) work with the territorialisation forces for the expansion of sugarcane production and emphasize that, unlike soybeans, in which investment in agriculture precedes the arrival of agribusinesses; sugarcane has brought a wave of investment in industrial capacity that has led to the advance of agriculture. This is important because it generates a productive chain between agricultural and industrial production, forming an integrated production system.

This process of specialization of agriculture is what is known as "monoculture". Monoculture is nothing more than a technique that is based on the cultivation of only one type of crop simultaneously in the same space, which differs from polyculture, in which the field sees the cultivation of two or more types of crops in the same space / time.

Thus, it can be added that:

> "*Monoculture is a natural growth of an industrial approach to agriculture, in which labour inputs are minimized and technology-based inputs are maximized with a view to*

increasing productive efficiency" (Gliessman, 2000, p. 35).

A criticism that is made about the process of the implementation of monoculture is that it can leave the environment vulnerable and fragile, not permitting biodiversity, especially if the farmers participating in the family economy manage to accompany the increasing advances in technological innovations, in the opening of new markets and in the dissemination of technical progress.

From the point of view of regional development, the consequences for the economy and society may be worrying if low-income farmers are unable to keep up with these changes, as they may be excluded from the income production process, further concentrating agricultural income with the largest properties. A process of concentration and centralization of agricultural income, given a worsening in the living conditions of the small agricultural producer, can deteriorate social conditions in the countryside, leading a good number of people to seek work in cities and, if they are not successful, the process of creating slum areas in certain urban economic spaces.

Alves (2021) shows how the expansion of sugarcane cultivation occurred in the main producing regions, pointing to technological expansion, infrastructure and production propensities. In the same vein, Barbosa et al. (2017) draw attention to the need for public policies that monitor and guide private agents in favour of sustainability, reconciling economic interests with social and environmental ones.

An interesting debate in this sense would be to analyse how small farmers associate with large farms or what are the survival spaces in precision agriculture. Small producers can integrate with big capital in a subordinate way when they are totally dependent on the supply of agricultural inputs, machinery, and equipment and financing. They are the junior partners. This occurs in a relationship between integrator (rural enterprise) and integrated (small rural owner). If this integration is not possible, small owners will depend heavily on the strategy of diversification or specialization of the production of larger properties. What is perceived in Brazilian agriculture is a choice of profitable products on the part of the large landowners. Following this line of reasoning, it is up to small farmers to produce agricultural goods that are not in competition with large producers.

4. Methodology

The study focuses on the state of Goiás and its mesoregions (Figure 1), in the period between 2013 and 2020.

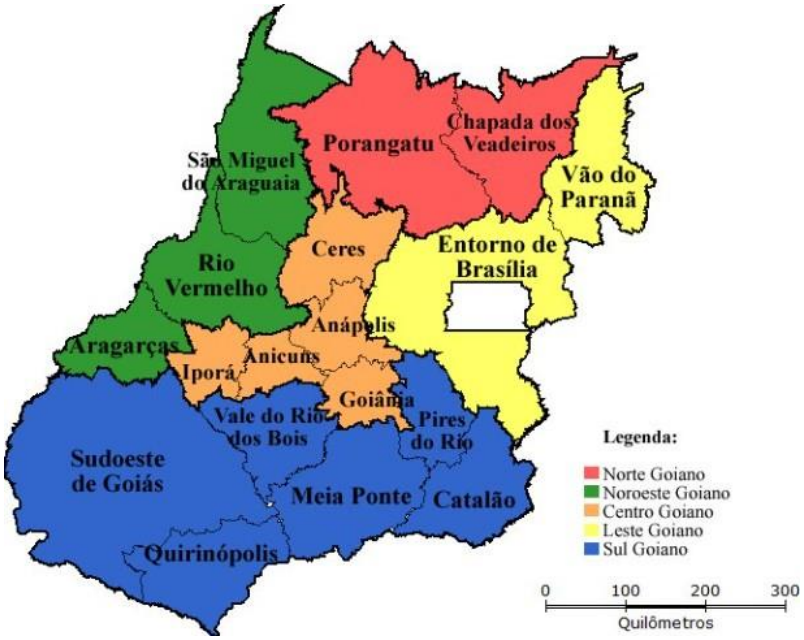

Figure 1

Source: Barroso and Paixão (2013).

Description: the figure prints the State of Goiás and its mesoregions, in the period between 2013 and 2020.

The method employed was deductive, having as references works completed on the proposed theme, consulted in Capes (Coordination for Personnel Improvement in Higher Education) journals in this area of study. The data were

extracted from the Automatic Recovery System (CIDER) of the Brazilian Institute of Geography and Statistics (IBGE).

The basic variables considered were planted area, production and value, for rice, sugarcane, beans, corn and soybeans by mesoregions in Goiás. Sugarcane productivity was used according to the Federation Units to measure the differences in productivity and data of global production of ethanol using the GFA as a source, as a way to rank the production of this product by countries.

The planted area allows the spatial and temporal development of the agricultural production of the State of Goiás according to its mesoregions. Production to characterize the crops that have grown the most, stabilize, or decreased over the proposed time period. The production value variable allows a proxy to measure the value addition of the crop under analysis.

The way to measure the variables was by the annual geometric growth rate and not by the linear growth in the period in question. With the database, the geometric rate is calculated to represent each crop by graphs. As for the tables, there will be no calculation of rates, but only of relative participation of each unit of measurement.

As for productivity per federation units, it is understood that the higher the productivity, the greater the possibility of incorporating technology. This serves as a proxy to verify how productivity can capture the use of machines and equipment and basic inputs for production in intensive production systems, such as sugarcane.

With regard to the global production of ethanol among countries, this variable is fundamental for analysing Brazil's position as a global player in the production of this product in the period between 2016 and 2021.

5. Results and Discussion

According to Figure 2, a spatial drop in the geometric growth rate in the area planted with rice by all mesoregions of Goiás in the period from 2003 to 2020 was noted, with emphasis on the South of Goiás (-23.7%), Center of Goiás (-18.3%), North of Goiás (-9%) and smaller falls in the Northwest and East of Goiás mesoregions (-2.2%). Therefore, as for rice cultivation in the soil of Goiás, there is a tendency for a significant reduction in the area planted in all mesoregions. It should also be noted that rice cultivation is widely used in areas of first soil preparation, bearing in mind its characteristic for grain production at a good soil height. This facilitates the management of new areas, with the presence of all crops and without the need for levelling.

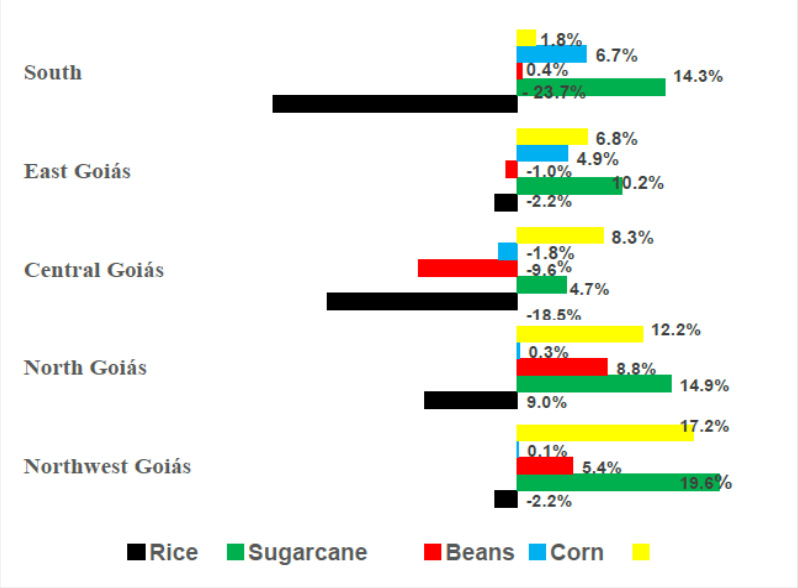

Figure 2. Goiás: Planted area of rice, sugarcane, beans, corn, soybeans, by mesoregion (Geometric growth rate 2003 - 2020)

Source: IBGE, 2022

Description: the graph presents data obtained by the IBGE and corresponds to the State of Goiás and its planted area of rice, sugar cane, beans, corn, soybeans, by mesoregion (geometric growth rate 2003 - 2020).

De Jesus Aguiar and De Souza (2014) portray the expansion of sugarcane production and its effects on the main producing states of this crop, showing how crop replacements were carried out. Neves and Mendonça (2020), on the other hand, make use of an analytical dissection, especially on the effects of the expansion of sugarcane agribusiness on food production in Goiás, highlighting the fact that livestock while having its area reduced did not suffer a reduction in herd numbers. They concluded that there was a process of confinement of cattle in Goiás, encouraged by the expansion of the sugarcane sector, mainly in the South Mesoregion of Goiás.

Regarding the area planted with beans, there is also a reduction in the area in Central Goiás (-9.6%), East Goiás (- 1%), and a significant increase in North Goiás (+8.8%) and Northeast Goiás (+5.4%). There is a tendency for cultivation in regions further north of the state of Goiás, yielding territorial space in the regions farther south of the state, those occupied by sugarcane, soybeans and corn, crops regulated by the international market.

As for the cultivation of sugarcane, it is the champion for the expansion of the area planted in all mesoregions of Goiás. Soy follows an expansion trend, which is sharper in the North and Northwest of Goiás, with 12.2 and 17.2% growth, respectively.

This evidence indicates that crops without a significant international market, such as rice and beans, limited to domestic consumption basically, suffer greater fluctuations, being subject to pressures for expansion to find new areas for sugarcane and soybeans especially, which have their products regulated by international prices and which are more profitable with the devaluation of the national currency.

Following the same logic, in Figure 3, a decrease in the spatial geometric rate of growth in rice production, by mesoregions of Goiás in the period from 2003 to 2020 was noted, as a direct consequence of the reduction of cultivation areas, with emphasis on South Goiás (-21.7%) and Central Goiás (-16.5%). In the North of Goiás, there was an increase in production (+9%), probably associated with better productivity data, considering that in Figure 2 there was a reduction in area planted in the period.

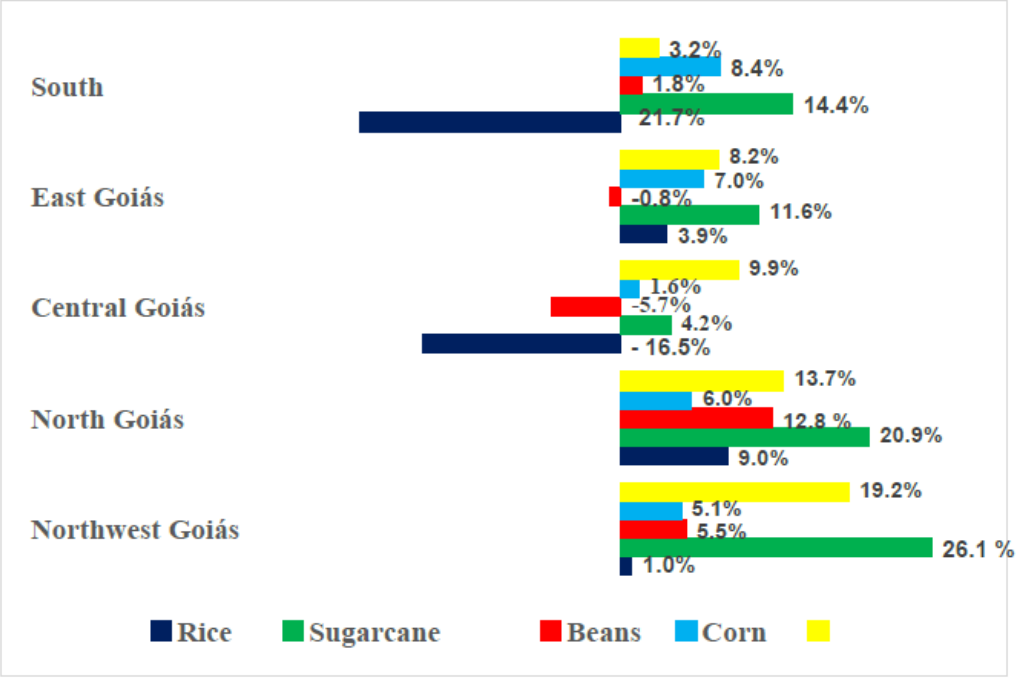

Figure 3. Goiás: Rice, Sugarcane, Beans, Corn, Soybean production growth, by mesoregion (Geometric growth rate 2003 - 2020)

Source: IBGE, 2022

Description: obtained by the IBGE, the graph reflects the Growth of Rice, Sugar Cane, Beans, Corn, Soybean production, by mesoregion (Geometric growth rate 2003 - 2020).

Regarding bean production, there is also a reduction in production in Central Goiás (-5.7%), East Goiás (-0.8%), but a significant increase in North Goiás (+12.8%) and Northwest Goiás (+5.5%). It was noted that the arrival of sugarcane, soybeans and corn are conditions that refer to the displacement of bean cultivation to regions located further north of the state of Goiás.

Undoubtedly, sugarcane, soybeans and corn occupy traditional areas of agriculture and indirectly influence territorial changes in rice and bean crops, which go to the north and northwest mesoregions of Goiás. It should be noted that especially in the North of Goiás all crops showed an increase in production. The highlights were sugarcane (+20.9%), soybeans (+13.7%), beans (+12.8%), rice (+9%) and corn (+6%). This may be an indicator of new cultivation areas, so that it has been possible to plant several crops with less competition for the territorial spaces between them. Another aspect concerns the distance from consumer markets, focusing the production of foodstuffs to the local market.

According to Figure 4, a spatial decrease in the geometric growth rate in the value of rice production, by mesoregions of Goiás was noted in the period from 2003 to 2020, with highlights to the South of Goiás (-18.9%), Central Goiás (-13.3%).

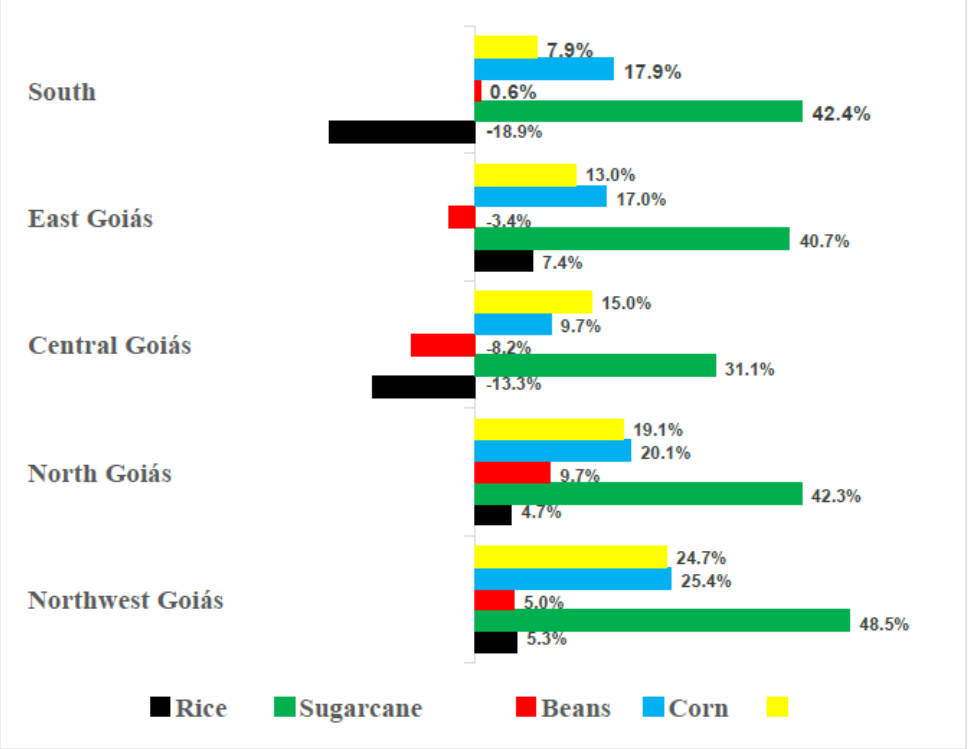

Figure 4. Goiás: Rice, Sugarcane, Beans, Corn, Soybean production growth, by mesoregion (Geometric growth rate 2003 - 2020)

Source: IBGE, 2022

Description: with data obtained by the IBGE, this graph depicts the value of production of rice, sugar cane, beans, corn, soy, by mesoregion in the State of Goiás (Geometric growth rate 2003 - 2020).

The same phenomenon is practically repeated with the value of bean production in East Goiás (-3.4%) and Central Goiás (-8.2%). In addition, the generation of values in sugarcane, corn and soybean crops is much higher than that of beans.

From a regional point of view, when analysing the expansion of production in Goiás of these selected products, the change in the process of crop substitution to the process of development of local agriculture should be taken into account. This is because crops such as soybeans and corn present price incentives, changes in the food pattern of Brazil and changes in the international market itself. As a rule, changes in agricultural production are strongly based on

stimuli of production values, profitability, which ends up not being a priority for products that are considered essential, such as rice and beans.

It would be an interesting hypothesis to verify if the production of sugarcane in Goiás, with regard to the regional sphere, in which agriculture occurs through monocultures, whether the replacement impact has a lower index than in regions where agriculture is merely family orientated, that is, where families draw their livelihood, as is the case with rice and bean production, especially in the Northwest and North Goiás.

The analysis of the mesoregional production from the data in Figure 5 allows the identification of modifications that operate in the production of sugarcane in Goiás. The production process of this crop is very spatially concentrated in practically only one food mesoregion, which is the South Goiás (82%).

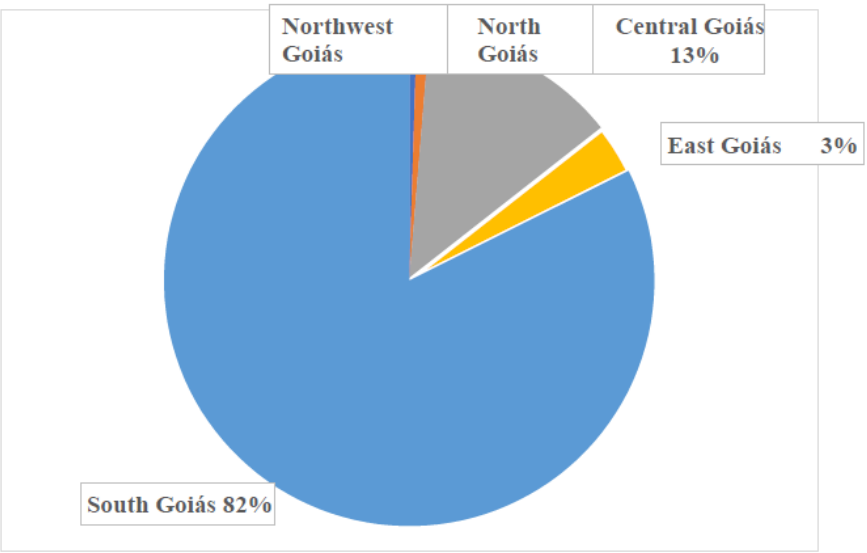

Figure 5. Goiás: Participation of Sugarcane production (%), by mesoregion (2020)

Source: IBGE, 2022

Description: Based on data provided by IBGE, the figure expresses the Sugarcane Production Share (%), by mesoregion of the State of Goiás (2020).

The South region of Goiás, as the largest producer of Sugarcane, has lower farming costs as a result of having its harvest fully mechanized, inserted in modern agriculture, precision, with technological standards, served by better conditions of precipitation and proximity to consumer centres.

The importance of sugarcane production for Brazilian agriculture is not new; it comes from the first plantations in the economic formation of Brazil. But sugarcane expansion occurs through a distinct procedure, in which territorialisation has greater relevance, which differs from soybean cultivation, since investment in agriculture precedes the arrival of agribusinesses, with sugarcane already investing in industrial capacity that leveraged the development of agriculture (Mesquito & Furtado, 2018, p. 83).

From an economic point of view, the sugarcane crop already has a financially sustainable nature, with better use of its products and by-products, which include diversification for the production of alcohol and/or sugar. These uses include the use of bagasse for energy generation, its use as sugarcane juice and also in animal feed, and even the use of what was previously waste, such as vinasse, in fertilizer for crops.

Neves and Mendonça (2020), on the other hand, make use of an analytical dissection, especially on the effects of the expansion of sugarcane agribusiness on food production in Goiás, highlighting the fact that livestock while having its area reduced has not suffered a reduction in herd numbers. They concluded that there was a process of confinement of cattle in Goiás, encouraged by the expansion of the sugarcane sector, mainly in the South Mesoregion of Goiás.

In the same vein, Duft (2019) points to the need to create public policies for the zoning of sugarcane production in

Southwest Goiás, which could be adopted in other regions of the State.

Finally, Da Silva Losso (2020) presents concerns about the risks of the rupture of the green economy in a post-pandemic scenario.

6. Final Considerations

From the above, it can be said that the effect of replacing sugarcane in food supply crops in Goiás, by mesoregions, between 2013 and 2020, is the result of agricultural and economic policies that have culminated in changes in the profile of agricultural production in Goiás. On the one hand, there is no doubt that there have been significant changes in the area planted, production and value of sugarcane, rice, beans, corn and soybeans. Note that while the results indicate very strong expansion in sugarcane, corn and soybean crops and a deceleration in beans, the same does not happen with rice. But, on the other hand, it is clear that there is a strong heterogeneity in the production of these crops by mesoregions in Goiás, which leads to believe that there is robust evidence of substitution of rice production by sugarcane, but the same is not happening with beans.

In this sense, the Brazilian agricultural policy of expanding sugarcane production from 1975, with the National Alcohol Program (Proálcool) and improvement of the *cerrado* soils (savannahs), expanded along with new cultivars, gained space in Brazilian territory, especially in Goiás. As a result, over time there has been an increasingly strong expansion of sugarcane, soybean and corn cultivation, with specific lines of public funding and stimuli for technological improvement. The concrete result is precision agriculture, with gains in scale and productivity that make these products competitive nationally and internationally, as is the case with soybeans and corn, specifically.

Thus, Brazilian agriculture is characterized as one of the most modern in the world, with significant transformations in the economic structure that operate in its society as a whole and causing rapid national territorialisation, which enhances the realization of grain super crops over time. This modernization process brought a new form of Brazilian regional development, with significant environmental and socioeconomic impacts, which has become known in the economic literature as the "conservative modernization" of agriculture.

Faced with this modernization, society has begun to adhere to the specialization of agriculture, with the concentration and centralization of production of a few crops, which although always present in the family economy, are products marketed on a scale in the domestic and global grain market. Soybeans, sugarcane and corn have replaced production, such as rice in family agriculture.

In view of the analyzed data, the article concludes that the hypothesis raised of replacing crops considered by the agricultural literature as traditional - rice and beans - took place in Goiás. This can be proven when considering agricultural crops by mesoregions. In addition, the trend of spatial heterogeneity in the production of grains selected by mesoregions is evident, because of the way technical progress was disseminated among economic agents. This signals high investments for the modernization of agricultural production structures for rural companies, especially large ones, but another part of these agents remained in traditional and subsistence production units.

In this sense, it is recommended that future works need to take into account the microregions established by the IBGE so that they can more accurately measure the substitution effect in agriculture in Goiás. This does not detract from the strong indications of replacement of traditional cultures in agriculture in the state of Goiás. It would also be interesting to investigate with great precision the agricultural policies to promote production, especially those aimed at traditional cultures, relating them to a public food security policy when Brazil is going through a strong process of increasing prices of food products for the low-income population.

There is also a need to deepen the relationship between large and small grain production, especially family production. In this sense, it would be interesting to carry out a deeper study on the functioning of family farming, its credit lines, technological incentives and production and distribution logistics. The comparison of statistical data from the 2017 Agricultural Census with the IBGE's Annual Municipal Surveys could enable the planning and evaluation of public policies on the agricultural sector. In this case, studies about the expansion of the agricultural frontier and the productive dynamization dictated by technological innovations could further enrich this mechanism of substitution of agricultural cultures, of transformations, resulting from the restructuring process and adjustments in the Brazilian economy and its reflexes in Goiás.

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