

*Full Length Research Paper*

## Spatial econometric analysis of the main agricultural commodities produced in Central-West Region, Brazil

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The aim of this paper is to present novel variables in the Brazilian Central-West Region to evaluate the spatial dependence of the Gross Domestic Product of agriculture and livestock (GDPagri) and the Gross Value of Production (GVP) on the main agricultural and livestock commodities in order to identify clusters of high and low spatial correlations. Data on the municipalities of Mato Grosso do Sul State (MS) between 2000 and 2010 is used. Initially, a spatial exploratory data analysis is performed to verify the hypothesis of global spatial randomness of the evolution of GDPagri and GVP, with Moran's I statistic as the instrumental measurement. In addition, econometric and spatial models were utilized. The results of the three spatial models used indicated that the SAR model (Spatial Auto Regressive) is most appropriate for the evaluation of GDPagri in MS. Despite beef cattle having presented the greatest GVP, the culture of sugar cane allowed for a greater increase in GDPagri.

**Key words:** Agribusiness, gross domestic product, spatial econometrics, Brazil.

### INTRODUCTION

The ideas of commodity systems have been constantly changing over the decades; however, we can say that knowledge of supply chain management in business and studies of commodities have become important influences in economic development (Jackson et al., 2006). Brazilian agribusiness represents more than 20%

of the national Gross Domestic Product (GDP), yielding more than R\$ 1.0994 trillion in 2012. The amount involving exports accounted for approximately R\$ 252 billion (Fraga and Silva Neto, 2017).

Agriculture, through poverty reduction and food supply strategies, has been instrumental for economic

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development in past years in many countries. However, it is essential that the theory of studies from agricultural research results in practices, technologies and applicable knowledge to be more effective, leading eventually to global changes in socio-economic, political and institutional contexts (Thornton et al., 2017).

In past decades, the Central-West Region of Brazil performed remarkably, emerging as the new agricultural and livestock power in the country. Silva et al. (2017) citing data from the Brazilian Institute of Geography and Statistics - IBGE, verified that the key for the increased development was the agricultural expansion based on land incorporation, exemplified by the 1995/6 to 2006 panel data, which indicates that the crops presented growth of 20% in the total area occupied, while planted pasture areas grew approximately 2% over the same period. The main regional representative was the Center-West, in which the crop areas grew +64%, followed by the North (+37%) and Northeast (+29%) regions of Brazil (Silva et al., 2017).

Considering Brazil's importance to worldwide food production, the occurrence of inter-regional movements of this nature may represent a change in the regional economic growth pattern, whose impact affects not only the productive structure of the country but also the social structure (Diao et al., 2010; Penna et al., 2012; Rada, 2013). In this context, as part of the Center-West – the region that most contributes to the Brazilian agribusiness – the State of Mato Grosso do Sul ('MS') there was a great economic and social transformation. According to IBGE (2015), in the past decade, the MS was fairly representative as driver and developer of agribusiness in the country, as in this period, the state occupied the 18th position in relation to the total GDP and the 11th position among the agricultural GDP (IBGE, 2015).

Thus, to address the importance of economic activity for measuring the wealth value for one or more commodities produced in a particular region, it is necessary to cover its production system and the value aggregator that this chain comprises in order to assess their economic and social growth. For this, two economic indicators can be used as agricultural activity measures produced in space and time: the Gross Value of Production (GVP) and the agricultural GDP (GDPagri).

The GVP shows the evolution of the performance of crops and livestock throughout the year and corresponds to the gross income within the establishment based on the agricultural crops and livestock production and the prices received by producers "inside the gate", that is, excluding freight, taxes, and other costs (MAPA, 2015). The GDPagri is calculated starting with the input-output matrices, summing the value added by the segment of each sector of the economy. The GDP the economic sector represented is obtained from the difference between the GVP and intermediary consumption in the period considered.

The economy is regarded then as a large set of

productive chains that sequentially involve several segments, each producing inputs for the next segment. There is a high correlation between GDPagri and GVP because the agriculture and livestock GDP is the GVP agriculture less the value of purchased inputs of the upstream segment, that is, GVP less stocks, if any exist (Barros et al., 2011; Mahmood and Munir, 2017; Rehman et al., 2017). Thus, if GDPagri and GVP grow, the holders of labor, capital and land, as well as business owners, can share a higher real income among themselves.

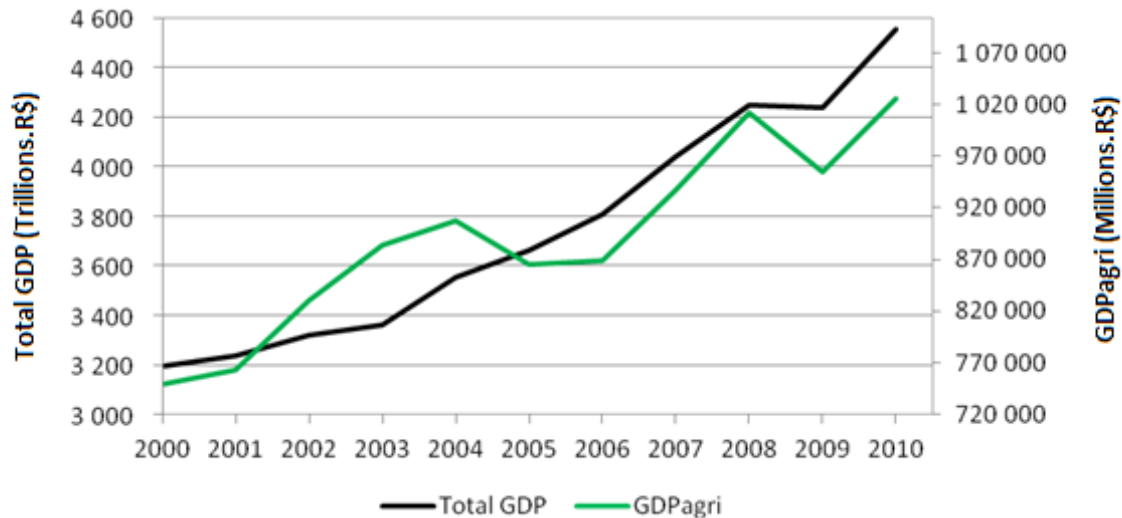
It is important to note that within the agricultural productive dynamics, the producer will choose the agribusiness that will make more sense, taking into account its internal production structure, external logistics structure, and the cost-benefit factors to optimize profit. Therefore, the consolidation of a certain agricultural business determines the spatial pattern of production in their respective regions. This pattern also arises from the creation and use of technological and logistical packages that provide high-income area with higher productivity growth rates than those in other regions. In addition, political incentives to encourage local production can create production standards.

In this sense, Gomes et al. (2013) stated that the municipalities that have good management skills, concentration of fertile land and adequate infrastructure tend to better organize their production locally, regionally, nationally and even globally and make provisions for the promotion of a common development model that articulates the social, environmental and economic dimensions.

Thus, analyzing the economic indicators for the producing regions may capture a spatial effect for the results. Therefore, it is natural to assume that the economic and social processes meet the First Geographic Law – "All things are similar, but closer things are more related than distant things" (Tobler, 1970) – that is, the role of physical proximity to the emergence of spatial interaction phenomena must be discarded. Thus, it is very important to detect the spatial interactions in the GDPagri and the GVP agricultural commodities by the observed dependence of the regions on various streams, such as income, information, people, possessions and services.

Considering the aforementioned factors, this article aims to evaluate the spatial dependence of the GDPagri and GVP evolution on the following commodities: beef cattle, cotton, maize, soybean and sugar cane between the years 2000 and 2010 in Mato Grosso do Sul State municipalities. The objective is to detect and infer a spatial pattern of such indicators, that is, locating clusters subject to their spatial interactions.

Therefore, this study followed a classical framework of economic analysis contemplating two steps: in the first step the global and local spatial randomness were tested with the *Moran's Index* statistic as the instrumental measurement, and in the second step econometric



**Figure 1.** Brazilian gross domestic product (GDP) and agriculture and livestock GDP (GDPagri) from 2000 to 2010.

Deflated values corrected to actual values by the general price index (IGP) from the Getúlio Vargas Foundation (FGV). Data: IBGE (2015) and CEPEA (2015).

models were applied to explain the spillover effects.

### Agribusiness behavior from 2000 to 2010 in Brazil

Between the years 2000 and 2010, Brazil experienced a period of great economic development, in which the Brazilian GDP grew year by year. According to the Brazilian Institute of Geography and Statistics – IBGE (2015), in 2000, Brazilian agribusiness accounted for 5.60% of its GDP; however, this percentage decreased in 2010 to 5.30%, losing part of the economic contribution to the commerce and services sectors, common in developing countries, due to the strong internal urbanization in that period.

Thus, GDP growth rates in agribusiness in Brazil, published by the Center for Advanced Studies in Applied Economics – CEPEA (2015) and based on IBGE data, showed an average GDPagri growth of 3.02% per annum during the years 2000 to 2010, practically accompanying the average growth of total GDP in this period, which was 3.70% per year (Figure 1).

In this context, it is important to highlight the period 2001 to 2004, in which the growth of GDPagri was more aggressive than the total GDP, which corresponded to an increase of approximately 4.30% per annum, while the total GDP growth year was 2.30%. Thus, at the beginning of that decade, it was found that much of Brazil's economic growth resulted from agribusiness growth.

In contrast to the urban phenomena, in which the visibility of economic and social outcomes for the populations affected by the growth is more easily perceived by analysts, the agricultural development is

characterized by presenting results that are both diffused in time and less obvious in view, that is, the territorially dispersed character of this economic activity. Thus, changes in the structure and performance of the primary sector and the effects on income generation, employment, and improved living conditions are not easily quantifiable, and comprehensive analysis is not even clearly perceived by the economic agents, including local governments (Bonelli, 2001; Dethier and Effenberger, 2012).

Among the various factors that may influence the development of agricultural production in a particular location, and consequently the increase of GDP, some constitute the most important: the increased area produced, the increase in credit to sectors of agricultural production chain, the increase in average crop yields, the increase in exports and domestic consumption (Valdés and Foster, 2010).

In this sense, Corrêa and Figueiredo (2006) observed that at the beginning of 2000, agricultural modernization in Brazil was associated with the rapid growth in the intensity of land use and work capital ratio. The results were reflected in the production and development gains in the agribusiness production chain during that period.

In addition, it was found that during the study period, there was a large increase in the use of biotechnology in the national territory, mainly of derived products and in the use of genetic engineering. The development of transgenic varieties resistant to pests and pathogens and tolerant to herbicides has been accredited as one reason for the reduction of crop losses, causing a decrease in production costs as well as in environmental conservation, making producers and consumers able to

obtain food at lower cost, which is considered the current challenge in preserving the environment and food safety (Gomes and Borém, 2013).

Another interesting study related to the development of the national agribusiness was that of Melo et al. (2015), who noted that the increase in credit in the country from 1995 to 2009 had an impact on Brazilian agriculture, promoting agricultural production, which is also based on input for livestock production. Nevertheless, the authors noted that the livestock credit line led to a significant drop in real GDP of the agricultural sector. Possibly, according to the authors, the wrong design of loan contracts for cattle producers caused such a distortion.

However, the adoption of genetic improvement programs for the cattle herd, the use of more productive pastures, and the use of integrated production contributed significantly to the main qualitatively and quantitatively advanced systems for the livestock sector in recent years (Lopes et al., 2012; Da Silva et al., 2014). As for exports, the agribusiness sector experienced a gradual and moderate growth among the total Brazilian exports from 2000 to 2010. Freitas (2014) studying the Brazilian trade balance of agricultural products, noted that there was a structural surplus in Brazilian agricultural trade; however, this signaled that some groups oscillated between surplus and deficit and could represent possible opportunities to produce better results for the country, citing cotton as an example.

### **In Mato Grosso do Sul State (MS)**

Mato Grosso do Sul State is one of the 27 federative units of Brazil, located in the Center-West Region. The state is divided into 4 mesoregions ("Pantanal Region", "North-Central Region", "Eastern Region" and "South-Western Region") and 77 municipalities as of 2010 (Figure 2). Over the years, the main agricultural commodities from MS showed an increase profile but it was from 2000 the State's contribution was more effective, particularly noteworthy the period 2000 to 2010, with a strong growth in sugar cane production (Figure 3). To understand the interactions among the indicators as well as evaluate its implications in certain period, the cross-section analysis has been heavily used in statistics and econometrics.

According to Fagundes et al. (2014), as of 2003, agriculture no longer served as the main economic activity of Mato Grosso do Sul State; however, it still contributed to contemporary development and economic growth of the region. Technological innovations have resulted in qualitative and productive increases in agriculture. This complementary economic growth occurred because agriculture had a positive correlation between growth and the growth of other sectors of the economy by generating wellbeing, employment, income and product (Souza et al., 2011; Christiaensen et al.,

2011).

Thus, MS gained prominence in the Brazilian agricultural scene, as their national participation in the production value of temporary crops jumped from 3.29% in 2000 to 4.24% in 2010 (IBGE, 2015). Regarding livestock, MS showed a decrease in their participation in the national GVP of livestock from 7.02% to 5.96% between 2000 and 2010. In this context, there was a decline in the cattle herd in the period 2003 to 2007 in the state (Figure 4). This reduction was the result of changes in the productive chain of livestock, which includes reproduction, fattening, slaughtering and meat processing in the state itself (Dos Santos et al., 2010).

It is noteworthy that in 2000, MS was the Brazilian state with the largest number of cattle; additionally, even though in 2010 it lost its position to other states, such as Mato Grosso and Minas Gerais (1st and 2nd place, respectively), MS continued to have national relevance in the livestock industry, occupying the third position in domestic cattle, with 22,354,077 animals (IBGE, 2015).

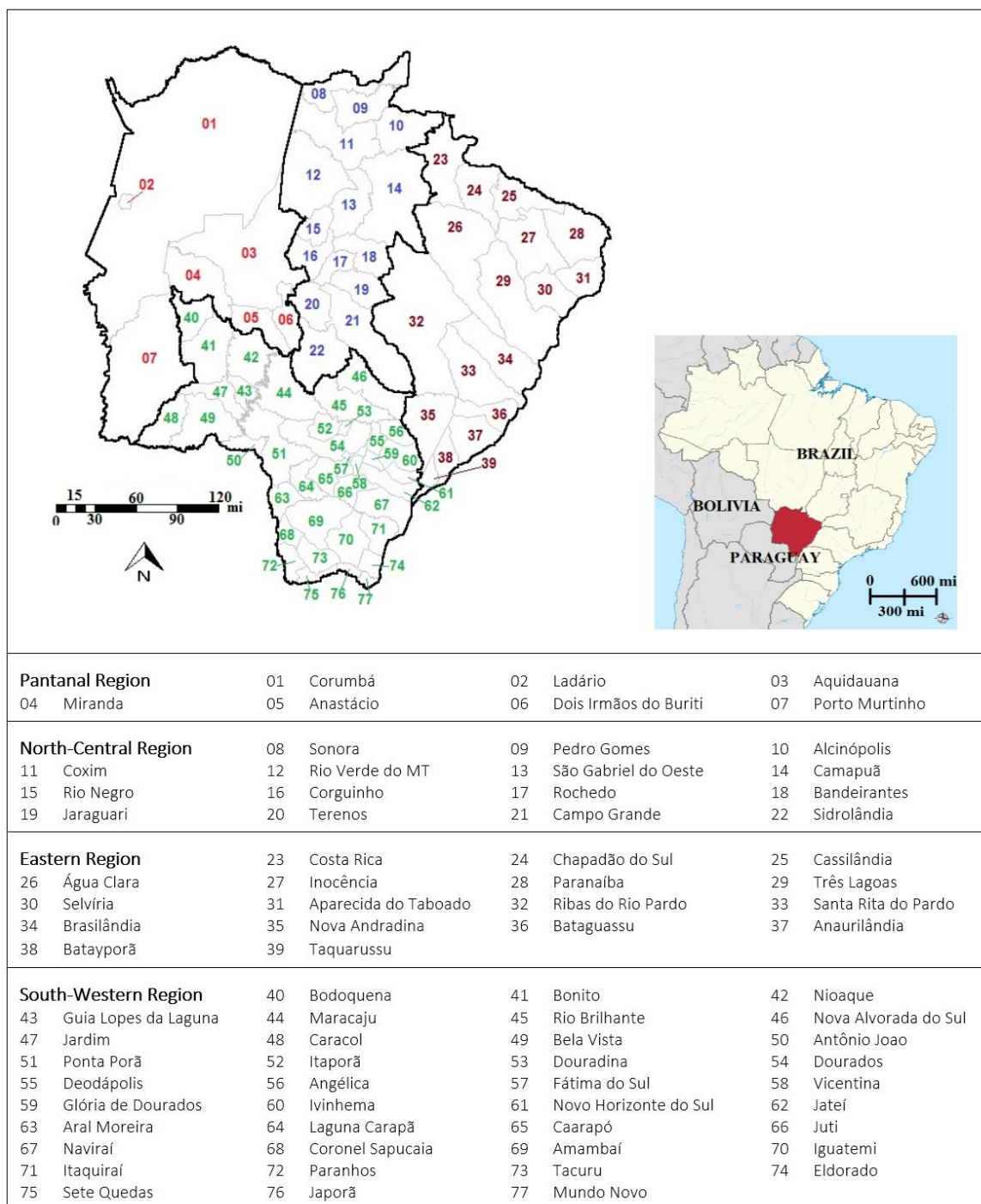
Regarding the soybean planted area, it could be observed in Figure 4 that between 2005 and 2007, there was a decrease in acreage of this crop and an increase of the planted maize area. In this period, due to the high cost of soybean production, producers chose to produce maize in the summer harvest with a temporary crop rotation, as traditionally the maize is planted in winter (PAM-IBGE, 2008).

Additionally, in Figure 4, it was found that after 2005, there was an increase in the acreage of sugar cane from approximately 136,000 ha to 400,000 ha in 2010. Thus, the new areas of sugar cane began to replace pastureland and soy, resulting in a reduction in the number of cattle and the soybean acreage between 2005 and 2010.

The cotton sector hardly changed in the planted areas between 2000 and 2010 (Figure 4), as this commodity production structure is different from other crops, mainly because of the use of more expensive machinery, the requirement for longer periods between sowing and harvesting, and the closed production chain, with traditional production by either settlements or large farms in the state (PAM-IBGE, 2010).

With respect to production gain, MS showed a growth in the sugar cane production of approximately 500% in the period 2000 to 2010 (Figure 5), thus moving from the 9th position to the 5th position in the national ranking (IBGE, 2015), surpassing traditional crop states. This increase was justified by the expansion of harvested area, mainly by producers seeking fertile and cheaper land compared to those in traditional states for this crop, especially lands with good weather conditions and high quality of soil, such some municipalities in MS (PAM-IBGE, 2010).

In addition, in Figure 5, it is possible to see that there was a significant increase in maize production in MS between the years 2000 and 2010 (approximately 250%)

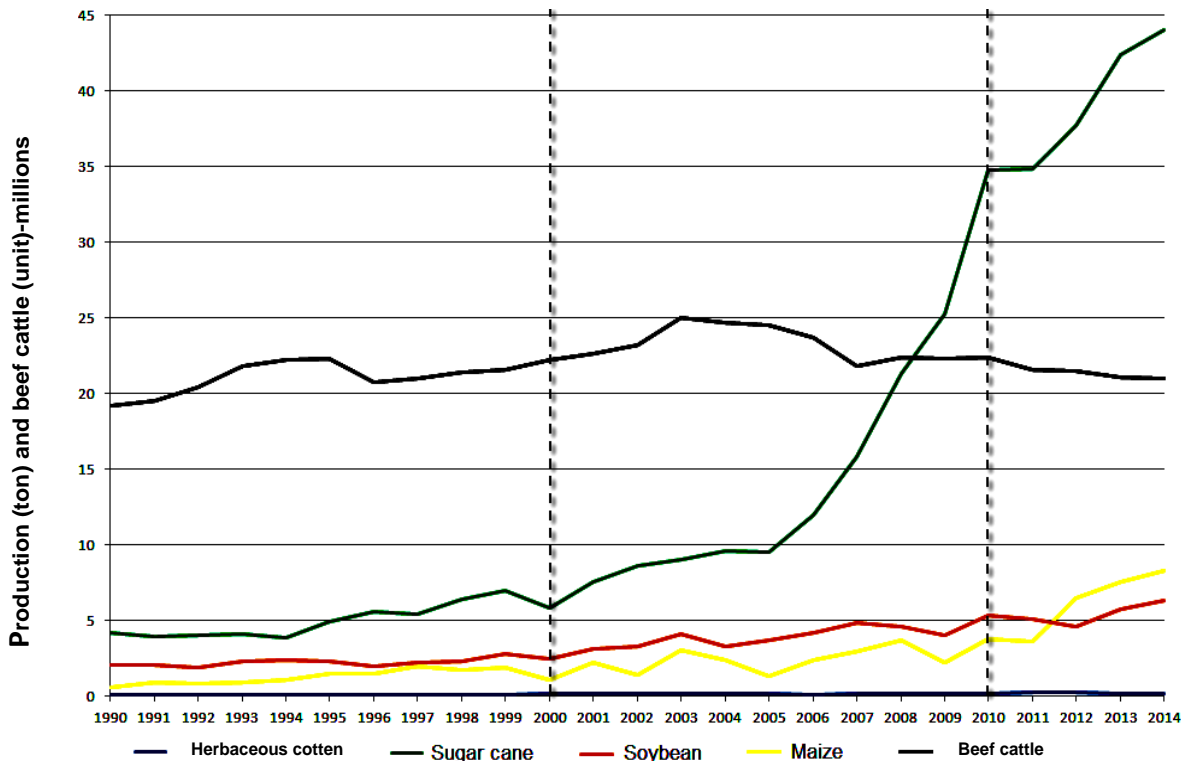


**Figure 2.** Mato Grosso do Sul State political division in municipalities and mesoregions. Data: IBGE (2015).

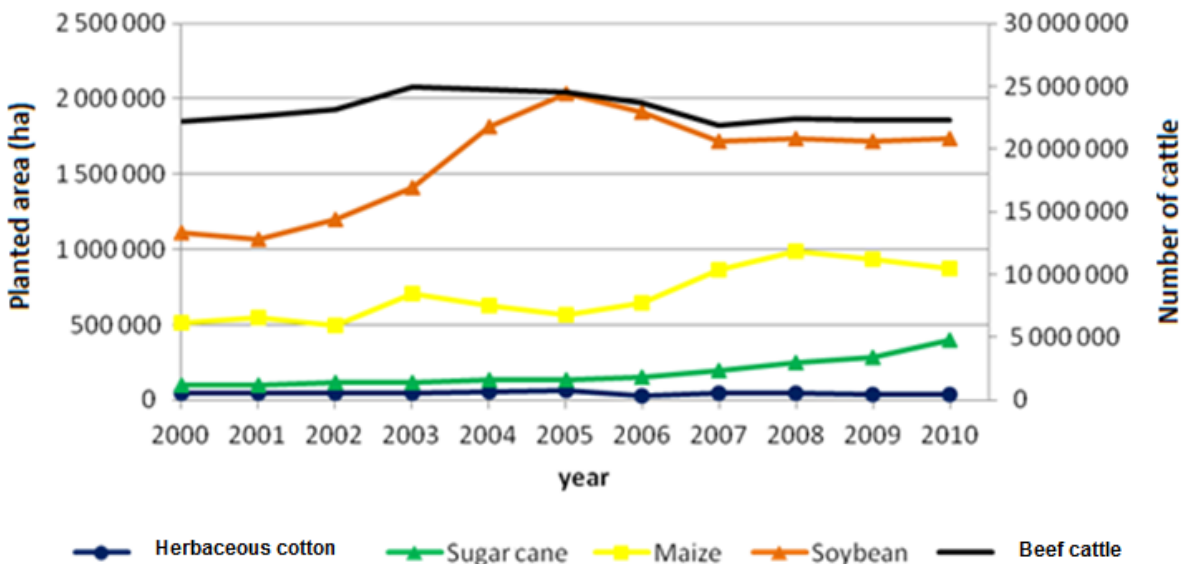
and an increase in soybeans of approximately 100%, resulting in MS ranking in the 7th and 5th positions among the Brazilian states in the national production, respectively (IBGE, 2015). Figure 6 shows the Gross Value of Production of the five agricultural commodities evaluated in the 2000 to 2010 period in MS, with the

actual values corrected by the Extended National Consumer Price Index – IPCA (IBGE, 2015), where in beef cattle exhibited the greatest GVP in the assessed period, followed by soybean.

Two factors may influence the agricultural commodity GVP: the quantity produced and the price paid to the



**Figure 3.** Production of main agricultural commodities and the effective number of beef cattle between 1994 and 2014 in Mato Grosso do Sul State. Data: IBGE.

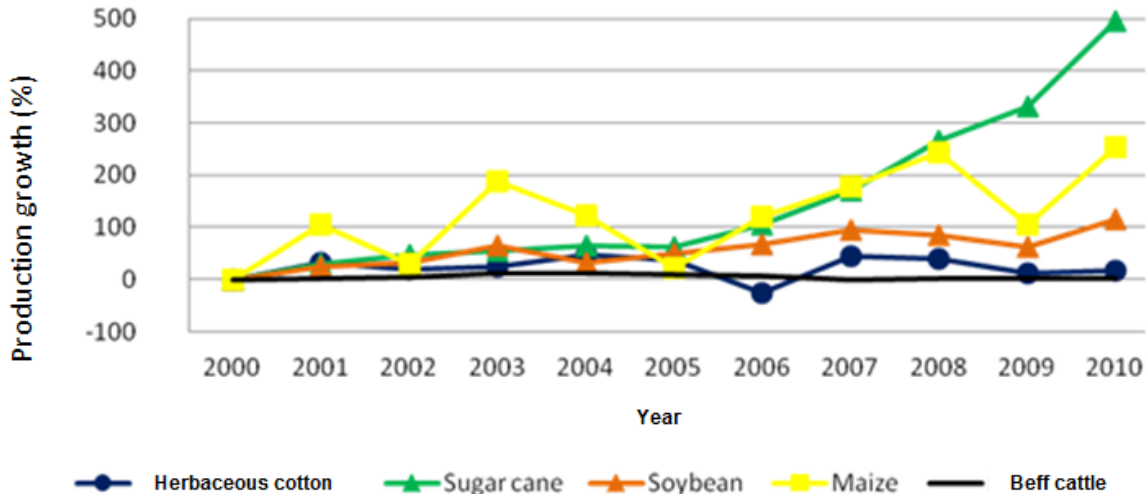


**Figure 4.** Evolution of the planted area and the number of cattle in the Mato Grosso do Sul State from 2000 to 2010. Data: IBGE (2015).

producer. In this case, it was observed that even though sugar cane always had less acreage than maize crops

(Figure 4), sugar cane experienced an increase in GVP due to the new areas opened for cultivation since 2005





**Figure 5.** Evolution of the production of cotton, sugar cane, soybean and maize (in tons) and beef cattle (number of cattle) in the Mato Grosso do Sul State in 2000 to 2010. Data: IBGE (2015).

(Figure 5).

**METHODOLOGY**

**Exploratory spatial data analysis (ESDA)**

According to Chen (2013), among the indices of spatial autocorrelation in the geographic analysis, the Moran's index is the most recommended to evaluate data from the spatial population. Thus, the *Moran's I* statistic was used to test the hypothesis of agricultural GDP in municipalities from MS presents global spatial randomness. In matrix notation, the equation is written as follows (1):

$$I = \frac{N}{\sum_i \sum_j W_{ij}} \frac{x'Wx}{x'x} \tag{1}$$

Where:

*N* is the number of elements surveyed; *W<sub>ij</sub>* are the spatial weights of the matrix elements; *i* and *j* are the spatial units; and *Wx* corresponds to the average values of the variables *x* within a spatial matrix (Lins et al., 2015).

To test the hypothesis of non-existence of spatial autocorrelation (*H<sub>0</sub>*), the following formula was used (2):

$$E(I) = \frac{-1}{N-1} \tag{2}$$

It is expected that the greater the number of *N* (approaching infinity), the Moran index will approximate to 0. In this sense, the values of *I* may vary between -1 and 1. The negative values of *I* indicate negative spatial autocorrelation, while the positive values express positive spatial autocorrelation (Lins et al., 2015). The local indicators of spatial association (LISA), proposed by Anselin (1995), was also be applied in this study. When there are significant correlations between the geographic variables, the LISA allows capturing local specificities as clusters with transition zones and spatial agglomeration zones. Depending on the spatial regime,

these spatial patterns may present spatial correlations as follows:

high-high, high-low, low-high, and low-low.

Thus, LISA uses local autocorrelation from the second-order estimate, or from the covariance analysis between different area units. While the *Moran Global Index* reports the level of spatial interdependence between all the polygons under study, the *Moran Local Index* evaluates the covariance between a given polygon and a certain neighborhood defined as a function of the distance between them. The LISA equation is described as follows (3):

$$I_i = z_i \sum_j w_{ij} z_j \tag{3}$$

Where:

*z<sub>i</sub>* and *z<sub>j</sub>* are the deviations from the average, and *w<sub>ij</sub>* is equal to the value in the neighborhood matrix for region *i* with region *j* as distance's function (Anselin, 1995).

**Econometric model**

According to LeSage (2014), when using spatial modeling it is necessary to identify the type of overflow present (local or global) and which model is most appropriate to capture this process. In spite of being global indicators, the following spatial econometrics models will be tested in this study: Spatial Autoregressive Model (SAR), Spatial Error Model (SEM) and Spatial Autocorrelation Model (SAC). These models were chosen for the following reasons:

- (1) Presenting endogenous interaction and feedback effects, thus a new equilibrium in the steady state of the studied region arises (LeSage, 2014).
- (2) The recent local models have an excessive reliance on statistical tests to find the appropriate model, and instead, the theory or specific context of empirical application should be the most important criterion for selecting a local or global spillover model (Vega and Elhorst, 2013).

Recent studies indicate that traditional spatial econometric models

**Table 1.** Variables used in the work to simulate spatial econometric modeling.

Variable	Dependent variable	Unit
GDPagri	Gross domestic product of agriculture and livestock	R\$
Variable	Explanatory variables	Unit
GVPcat2009	Gross value of beef cattle production from 2009	R\$
GVPsoy2009	Gross value of soybean production from 2009	R\$
GVPmai2009	Gross value of maize production from 2009	R\$
GVPcan2009	Gross value of sugarcane production from 2009	R\$
GVPcot2009	Gross value of herbaceous cotton production from 2009	R\$
Pop2009	Municipal population of 2009	Units

have been widely used to capture local spatial effects: SAR (Lacombe et al., 2016; Lv et al., 2016; Liu et al., 2017); SEM (Long et al., 2016; Yılmaz and Murat, 2016; Hajizadeh et al., 2016; Guimarães and Almeida, 2017) and SAC (Laryayekar and Mukhamadhyay, 2016; Song et al., 2017). The SAR (4), SEM (5) and SAC (6) models are expressed as follows (Lins et al., 2015; LeSage, 2008):

$$y = \rho W y + X\beta + \varepsilon, \text{ wherein } \varepsilon \sim N(0, \sigma^2 I_n) \quad (4)$$

$$y = X\beta + \xi, \text{ in which } \xi = \lambda W \xi + \varepsilon, \text{ wherein } \varepsilon \sim N(0, \sigma^2 I_n) \quad (5)$$

$$y = \rho W_1 y + X\beta + \xi, \text{ in which } \xi = \lambda W_2 \xi + \varepsilon, \text{ wherein } \varepsilon \sim N(0, \sigma^2 I_n) \quad (6)$$

In the SAR model, the dependent variable of a given location is spatially correlated with the dependent variable value of their peripheral neighboring regions, where in the signal and magnitude of spatial coefficient will define the type and strength of spillover effects. If it is not able to model the total spatial dependence on the data, the SEM is shown as a suitable model since part of the non-modeled dependency is estimated by the standard random error between neighboring regions, such that the errors are not spatially auto-correlated. As for the SAC model, it is a mixed model constructed with both presented types of overflow applied in a single equation (Lins et al., 2015). In order to validate the models, the spatial coefficients must always be less than 1, and should allow a dilution of the overflow as far as the distance from the analyzed shock region occurs (Lins et al., 2015).

#### Database

Data on the Gross Value of Livestock Production made available by the MAPA (2015) were used. Official data on municipal agricultural GDP (National Accounts), municipal population (Census), municipal agricultural research (PAM) and municipal livestock research (PPM) for the years 2000 to 2010 were obtained through the aggregated data system of SIDRA-IBGE (IBGE, 2015). Territorial meshes and statistical analysis were conducted through the IPEAGEO program (IPEA, 2015).

For the exploratory spatial data analysis (ESDA), the information for agricultural GDP and the gross production values of the following commodities from the period of 2000 to 2010 was used: beef cattle (GVPcat), soybean (GVPsoy), maize (GVPmai), sugar cane (GVPcan) and herbaceous cotton (GVPcot). When comparing GDPs and GVPs in a historical series, it should be observed whether the disclosed economic indicator was the real price (corrected by the depreciation of the purchasing power) or if it was applied at current (nominal) prices. Therefore, for the latter, the

deflator must be used to be able to compare it between years. Thus, these indicators were corrected to the values of the year 2010 through the Extended National Consumer Price Index (IPCA), which adjusted the official inflation rate in the period. In this period, according to the IBGE (2015), inflation from January 2000 to December 2010 was 101.18%. For the spatial econometric modeling of GDPagri of Mato Grosso do Sul State, explanatory variables were used as seen in Table 1.

The independent variables used in the model were related to the year 2009, as it was sought to avoid possible problems of endogeneity as well as to construct the GDPagri at the end of the studied decade. The municipal population of 2009 was also used to capture a possible population effect in the formation of agricultural GDP. Thus, after estimated the *Moran's I* and in the case of a statistical significance, the global spatial econometric models (SAC, SEM and SAR) were estimated. Therefore, through the Akaike (AIC), Schwarz (BIC), likelihood function (LIK) and significance level of spatial coefficients, it is possible to find a more appropriate model to estimate Mato Grosso do Sul State's GDPagri in the analyzed period.

## RESULTS

### Global and local spatial dependence

Under the leadership of 'Corumbá' (Table 2), a municipality in the Pantanal region, the municipalities of 'Maracaju', 'Rio Brilhante', 'Dourados', 'Sidrolândia' and 'Ponta Porã' were among the top ten with the highest agricultural GDP, located in the center-south region, as well as 'Costa Rica', 'São Gabriel do Oeste', 'Chapadão do Sul' and 'Ribas do Rio Pardo', located in the northern region of the state. The ten municipalities, among the seventy-seven municipalities of MS, held approximately 35% of the state's GDPagri in the period evaluated (Table 2).

To test the null hypothesis of spatial randomness of GDPagri and commodity GVP, the spatial autocorrelation test *Moran's Global I* was used. The positive and significant result of the statistics for the GVPs (Table 3) allowed for the conclusion that there are strong indications of positive spatial dependence for these variables; in other words, cities that had high indicators, in general, are close to each other.

However, a significant spatial correlation was not found



**Table 2.** Annual average of the agricultural GDP of the Mato Grosso do Sul State's municipalities in the period from 2000 to 2010.

Position	City	Thousand Reais (R\$)	Share (%)
1 <sup>o</sup>	Corumbá	211,148	4.47
2 <sup>o</sup>	Maracaju	200,454	4.25
3 <sup>o</sup>	Rio Brilhante	167,651	3.55
4 <sup>o</sup>	Costa Rica	166,723	3.53
5 <sup>o</sup>	Dourados	162,384	3.44
6 <sup>o</sup>	São Gabriel do Oeste	149,791	3.17
7 <sup>o</sup>	Chapadão do Sul	146,492	3.10
8 <sup>o</sup>	Ribas do Rio Pardo	145,846	3.09
9 <sup>o</sup>	Sidrolândia	141,828	3.01
10 <sup>o</sup>	Ponta Porã	139,855	2.96
-	Others (67 cities)	3,086,974	65.41
	Total (MS)	4,719,148	100

Deflated values for the year 2010 corrected by the Extended National Consumer Price Index (IPCA). Data: IBGE (2015).

**Table 3.** Value of the moran global index for the total of the economic indicators surveyed, from 2000 to 2010, in Mato Grosso do Sul State's municipalities.

Variable	Moran index	p-value
GDPagri	-0.0338	0.6640
GVPcan	0.1859	0.0220
GVPmai	0.2969	0.0000
GVPcot	0.2104	0.0200
GVPcat	0.1915	0.0080
GVPsoy	0.2899	0.0000

for agricultural GDP in the period evaluated. According to Almeida (2012), the indication of global patterns of spatial autocorrelation may not be in line with local standards, and it may often occur that global autocorrelation conceals distinct local patterns. Due to this potential problem, the *Moran's Local I* statistic was estimated with the Local Indicator of Spatial Association (LISA) in order to capture local patterns of statistically significant spatial autocorrelations (Almeida, 2012; Travnikar and Juvancic, 2015). In this way, the hypothesis of non-existence of spatial association was tested by comparing the values of each location with the values of its neighbors and conditioning them to the level of statistical significance used in the spatial autocorrelation test at a 5% probability.

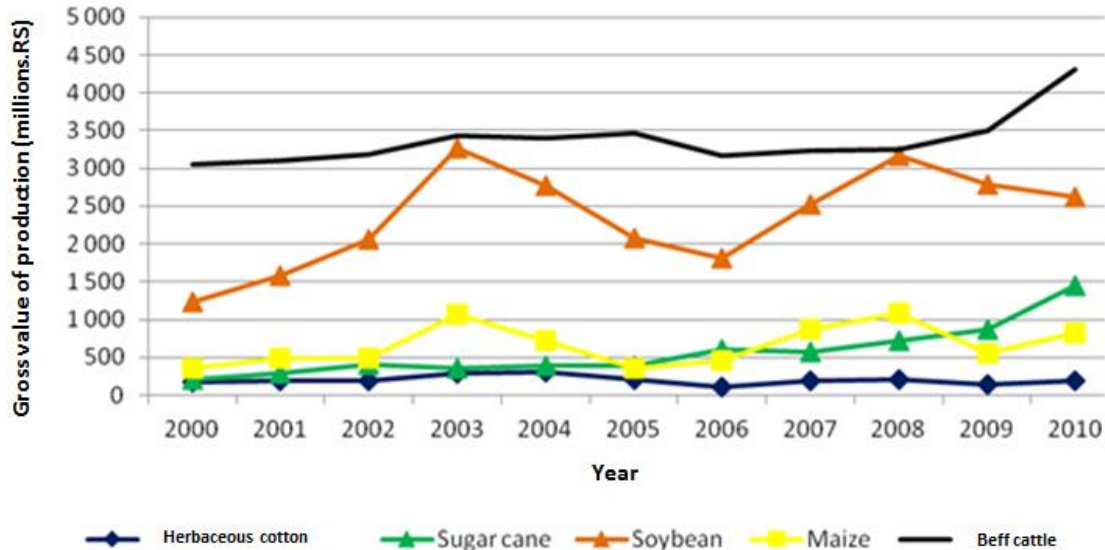
Generally, through the municipal GVP between the years 2000 and 2010, it was verified that MS has well-established characteristics regarding the spatial correlations of agricultural production; in the north of the state, there was a strong correlation between municipalities that produce beef cattle and cotton producers, while in the south of the state, the spatial

correlations were directly related to soybean, maize and sugar cane crops (Figure 7).

In Figure 7, it was also possible to verify a high spatial correlation of agricultural GDP between the municipalities of 'Nova Alvorada do Sul', 'Rio Brilhante', 'Sidrolândia', 'Maracaju' and 'Dourados'. These municipalities together accounted for approximately 16% of agricultural GDP in the MS between 2000 and 2010. It is important to note that although 'Corumbá' had the highest average annual agricultural GDP of the period (Table 2), there was no spatial correlation for this variable between this municipality and its neighbors. However, there was a strong correlation between 'Corumbá' and its proximities with respect to the beef cattle GVP, being positive in the municipalities of 'Porto Murtinho' and 'Aquidauana' (municipalities in the "Pantanal Region"); 'Rio Verde do Mato Grosso', 'Coxim', 'Camapuã' and 'Água Clara' (municipalities in the "North-Central Region"); and 'Três Lagoas', 'Brasilândia', 'Ribas do Rio Pardo' and 'Santa Rita do Pardo' (municipalities in the "Eastern Region").

This beef cattle spatial autocorrelation in MS occurred because these municipalities were established in areas of marshy plains and predominantly sandy lands, factors that limit agricultural production in this region. There were also negative correlations with 'Sonora' (an agricultural region), 'Bodoquena' (an environmental preservation region) and 'Ladário' (a marshland municipality with low numbers of cattle).

In the Northern Region, there was also a strong spatial correlation of the GVP of the cotton crop between the municipalities of 'Costa Rica', 'Chapadão do Sul' and 'Alcinópolis', which were the 1st, 2nd and 4th largest producers of herbaceous cotton in the state in the years researched. 'São Gabriel do Oeste' and 'Maracaju' (the 3rd and 5th largest cotton producers) did not have spatial correlations with their neighbors at the 5% probability



**Figure 6.** Commodity gross value of production in the Mato Grosso do Sul State from 2000 to 2010. Deflated values corrected to actual values by the Extended National Consumer Price Index (IPCA). Data: IBGE (2015) and MAPA (2015).

level.

In Mato Grosso do Sul State, cotton cultivation began in the Southern Region however, according to AMPASUL (2015), it was only in the 1990s that the cotton crop was developed in the Northern Region of the state, particularly in the municipalities of 'Chapadão do Sul', 'São Gabriel do Oeste' and 'Costa Rica', where cotton developed its new productive profile, resulting from the favorable conditions for the development of the crop and the use of varieties that were adapted to the local conditions, tolerant to diseases and had greater productive potential, together with modern cultivation techniques.

Regarding the culture of sugar cane, there was a high correlation between municipalities in "South-Western Region" (Figure 7). Among the factors already mentioned, such as the provision of fertile land with attractive prices in these places (PAM-IBGE, 2010), two other factors were determinant for sugar-alcohol development in that region: the first was the fact that sugar cane could not be produced in the Paraguay River Basin, and the crop was only released in the Paraná River Basin according to State Law no. 328 of 1982, wherein Article 1 – prohibited the installation of alcohol distilleries and sugar mills in the Pantanal area represented by the Pantaneira Plain Zone as well as in adjacent areas. Another factor is the compatible transmission lines from the Southern Region so that the industry could sell the energy produced by sugar cane bagasse (bioelectricity) to local and neighboring energy companies, according to the Sugar Cane Industry Union (UNICA, 2015).

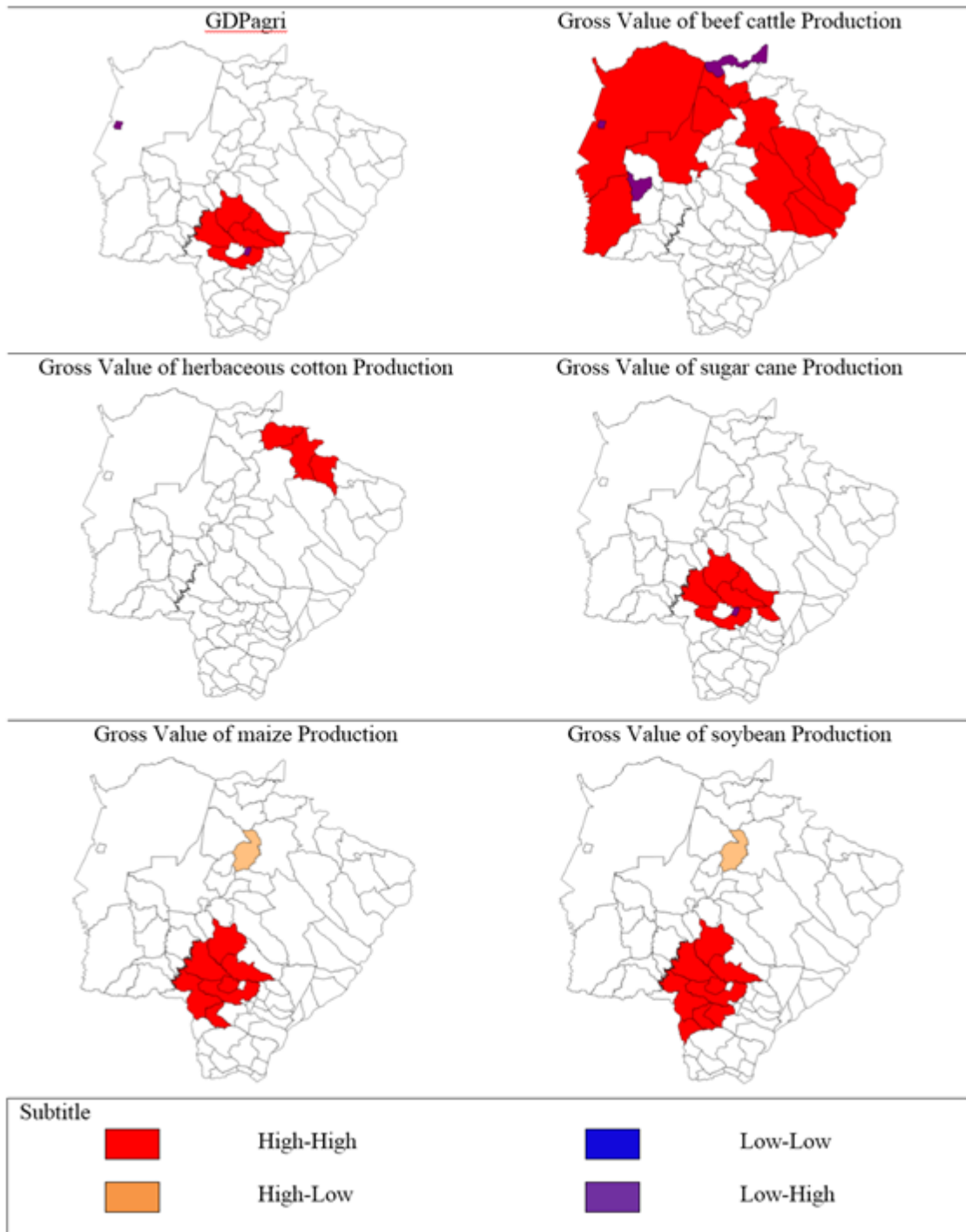
It was also verified in Figure 7 that the municipalities

that had the highest positive spatial correlations for soybean and maize were located in the Southern Region and near the border with Paraguay, confirming the conclusions of Bertholi (2006) that when studying the formation socio-spatial of MS, an increase in the migration of producers from the south of the country who sought fertile land in the state and with lower prices than their home states was found. Another factor was that at the beginning of the decade, producers had access to cheaper (and even illegal) inputs from neighboring countries, thus reducing the cost of production.

Within the "North-Central Region", the municipality of 'São Gabriel do Oeste' was highlighted in the production of soybean and maize, in which it presented a low spatial correlation with its neighbors (Figure 7). The municipalities surrounding 'São Gabriel do Oeste' presented its agricultural GDP based heavily on the production of cotton and beef cattle; in addition, a larger municipality is formed by a plateau region, characterizing an important agricultural hub producing animal feed for local swine production farms.

### Results of estimated models

Three spatial models of global scope were used: the SAR model, the SEM model and the SAC model. According to Lins et al. (2015), the most suitable model will be the one with the lowest AIC and BIC information criteria as well as a higher value for the LIK criterion. Almeida (2012) suggests that if the spatial lag coefficients are not significant, consider that these coefficients will be zero; therefore, there is no evidence that there is a spatial



**Figure 7.** Map of clusters and outliers and their spatial correlations at 5% probability level for the factors evaluated in the period of 2000 to 2010 in Mato Grosso do Sul State.

correlation, either positive or negative.

Since the AIC, BIC and LIK values showed no evident differences among them, it was not possible to choose the most suitable model using these criteria (Table 4). In this sense, was used the coefficient values to distinguish

the models. In Table 4, it was also observed that the coefficient  $\lambda$  in the SAC and SEM models were not significant at a 5% probability; therefore, it was neglected. Thus, presenting a significant  $p$ -value at the studied probability it was concluded that the spatial lag model

**Table 4.** Estimation of the spatial econometric models for GDPagri 2010 based on the gross values of production.

Variable	SAR		SEM		SAC	
	Coefficient	$\rho$ -value	Coefficient	$\rho$ -value	Coefficient	$\rho$ -value
CONSTANT	6.969.337364	0.000011	4.594.320652	0.000024	7,429.764123	0.000208
Pop2009	0.035787	0.000000	0.034947	0.000000	0.035225	0.000000
GVPcan2009	0.699196	0.000000	0.689347	0.000000	0.688395	0.000000
GVPmai2009	0.360229	0.000005	0.318835	0.000164	0.317552	0.000119
GVPcot2009	0.679186	0.000000	0.689701	0.000000	0.687465	0.000000
GVPcat2009	0.545381	0.000000	0.550645	0.000000	0.546468	0.000000
GVPsoy2009	0.322314	0.000000	0.341892	0.000000	0.343783	0.000000
$\rho$	-0.022349	0.032588	-	-	-0.02829	0.091932
$\Lambda$	-	-	0.28084	0.145077	0.309783	0.089123
LIK	-740.841.498		-740.659.113		-739.380.344	
AIC	1.499.318225		1.499.682995		1.498.760688	
BIC	1.520.412474		1.520.777244		1.522.198742	

SAR better explains the spatial dependence effect.

According to Almeida (2012), if the spatial coefficient  $\rho$  is positive, that means that there is a positive global spatial autocorrelation. In other words, a positive  $\rho$  means that a high (low) value of  $y$  in the neighboring regions increases (decreases) the value of  $y$  in the region  $i$ . If the parameter  $\rho$  is negative, it indicates that there is a negative global spatial autocorrelation. In other words, it signals that a high (low) value of  $y$  in neighboring regions decreases (increases) the value of  $y$  in region  $i$ .

Therefore, it was possible to verify that the agricultural GDP in Mato Grosso do Sul State in the analyzed period was concentrated in more structured cities, located at the South-Central Region. These municipalities (in which 'Dourados', 'Maracaju', 'Rio Brilhante' and 'Nova Alvorada do Sul') received a good part of the production of the surrounding municipalities, mainly to supply the sugar-ethanol plants and the processing industries of soybean and maize meal as well as being the main suppliers of agricultural inputs to the other municipalities through cooperatives and local trade representatives.

It was also possible to analyze that through the GVP coefficient of sugar cane, this crop contributed the most to the GDPagri. One of the reasons was that the processing of the crop is usually logistically limited to there being a distance within 35 km between the fields and the industry due to the cost of transport (UNICA, 2015). The cotton crop also contributed heavily to the GDP, probably through the state production chain that owned local cotton / producing cotton (AMPASUL, 2015).

Other commodities, such as soybean and maize, had a smaller contribution in the econometric model, as these crops were processed outside the production sites, often being sent to other Brazilian states, even to other countries, departing through the Santos Port or Paranaguá Port (APROSOJA, 2015).

The population effect was also tested to assess the

migratory flow and to verify whether this variable has some correlation to the GDPagri, and it was verified that the population direction followed the same spatial dependencies of the analyzed GVPs, tending for people to concentrate in the metropolitan area and improving the economic activity and consequently the GDP of that municipality.

## Conclusions

Although the spatial correlation calculated by the *Moran's Global I* statistic was not significant, there was local spatial dependence when the *Moran's Local I* statistic was estimated with the LISA, and it was possible to create clusters in the analyzed period. Among the three spatial econometric models tested, the SAR was the model that best explained the effect of spatial dependence. Commodity metropolization was also observed, that is, the GVP was concentrated in more structured cities, and there were positive and negative spatial autocorrelations among these municipalities. Therefore, the objective of the work was achieved once it was possible to do comparisons between the municipalities and identify their interactions.

Spatial analysis studies are very important because, in the same way that spatial correlations between municipalities can affect in a positive or negative way in regional agribusiness, the impact of these interactions will influence the national and even international agricultural scenario. In MS, if a municipality grows economically, this region could promote the growth in other municipalities and thus raise the GDPagri of the State.

Despite the fact that beef cattle had the highest GVP in the period, swampy plains areas and predominantly sandy soils are limiting factors for livestock production. In addition, the production growth of sugar cane crop

allowed for a larger increase in GDPagri, followed by the maize crop. As part of the commodities exporting region, the main impact on MS would be on beef cattle and soybean export, and even on domestic sugar cane market. In this sense, the economic growth of the MS impacts closely on the production of Brazilian agricultural commodities, and thus on the role played by Brazil in the agricultural world scene.

New proposals for studies should emerge after the discussion of this article, increasing the research of novel variables and the support for the methodology and approaches proposed in this study. Thus, by knowing the influence of agribusiness on territoriality and on local development, it will be possible to direct efforts and public policies towards improving the performance of the sector and the quality of life for the residents of a region that occupies a significant global position in the agricultural commodities production.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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