RCMOS – Multidisciplinary Scientific Journal of Knowledge.
ISSN: 2675-9128. São Paulo-SP.
Year V, v.1 2025. | submission: 2025-08-28 | accepted: 2025-08-30 | publication: 2025-09-01

Spatial analysis of timber production in 2009 and 2018

Spatial analysis of wood production in the years 2009 and 2018

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SUMMARY

The planted forest sector is important to Brazil's economy, as it is one of the world's leading producers. The main products are roundwood, charcoal, and firewood.
Production exhibits spatial patterns. This study analyzed spatial aspects of wood production for firewood, logs, and charcoal in 2009 and 2018, using data from the PEVS (Brazilian Institute of Geography and Statistics) – IBGE (Brazilian Institute of Geography and Statistics). Exploratory spatial data analysis with Moran's *I* index was used . The results show production growth and positive spatial dependence for all variables. High/high agglomerations are associated with regions with well-established production chains for pulp, charcoal, and agricultural production. The research suggests that large forestry production clusters are located in major industrial hubs, meeting regional demand.

Keywords: Forest Production. Spatial autocorrelation. Moran's *I.*

ABSTRACT

The planted forest sector is important to Brazil's economy, one of the world's leading producers. The main products are roundwood, wood for charcoal, and firewood. Production shows spatial patterns. The study analyzed spatial aspects of wood production for firewood, roundwood, and charcoal in 2009 and 2018, using data from PEVS – IBGE. Exploratory spatial data analysis was used with Moran's *I* index. Results show production growth and positive spatial dependence for all variables. High/high clusters are related to regions with well-established production chains for pulp, charcoal, and agricultural production. Research suggests that large productive clusters of forestry are in major industrial hubs, meeting regional demand.

Keywords: Forest Production. Spatial autocorrelation. Moran's I.

1. INTRODUCTION

Brazil is considered one of the largest producers of wood from plantations forests. The edaphoclimatic characteristics, related to soil and climate, their territorial extension and the technological development achieved in the areas of forestry and forest management made the country an important world producer.

Brazil's planted forest sector demonstrates great strength in the face of the scenario current macroeconomic scenario. The sector's GDP (Gross Domestic Product) for 2018 reached R$73.8 billion, which corresponds to 1.1% of the national GDP (IBÁ, 2018).

Forestry activity comprises a varied set of products and segments, which are characterize everything from the production to the transformation of wood into cellulose, paper, wood

sawn timber, charcoal, firewood and wood panels mainly, in addition to non-wood products loggers. Each of these activities in question has a market dynamic specific, in which the conditions for its development are associated with the regions forest producers and determined by the demand and supply of timber.

Therefore, it is necessary to formulate specific strategies for each region. producer to the detriment of the type of forest product characteristic of these locations (MOREIRA; SIMIONI; OLIVEIRA, 2017). Thus, the use of spatial data analysis becomes an essential tool in understanding the factors involved in the production of wood for the producing regions, being able to provide analyses that aim to find certain spatial patterns that can help in developing strategies for production forestry.

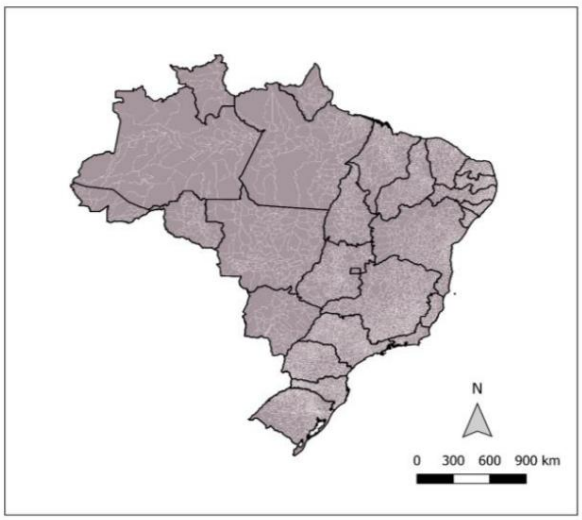
In this context, the present study aims to understand, through exploratory analysis of spatial data, the way in which timber production from forest plantations in the Brazil is affected by the spatial component in relation to municipalities, producers or not, neighbors among themselves. The years 2009 were compared, characterized by the negative impact of global crisis of 2008, with the most recent period until the publication of this study, 2018, with the purpose of comparing the spatial patterns observed in the production of roundwood, firewood and charcoal in Brazilian municipalities.

For this analysis, concepts of spatial statistics were used for area data, where the indices used to measure the effect of spatial dependence were global Moran's *I* and its local result, important in the construction of maps capable of highlighting how spatial agglomerations appear.

2. MATERIAL AND METHOD

2.1 STUDY AREA

The area of study of the work involves practically all municipalities in Brazil (FIGURE 1), excluding only some islands located on the Brazilian coast, such as the archipelago of Fenando de Noronha and Ilha Bela, in order to avoid any kind of bias that could harm the analyses.



Source: The Author (2020).

FIGURE 1: Map of Brazil: territorial areas of Brazilian states and municipalities.

2.2 DATA COLLECTION

This research considered the total production of planted forests in Brazil, the purpose were timber products such as charcoal, firewood and roundwood. The data from Production of Plant Extraction and Silviculture (PEVS) used in this work were collected in the Automatic Recovery System (SIDRA) of IBGE – Brazilian Institute of Geography and Statistics.

For this study, data from 2009 and 2018 were considered. In 2009, the commercial forestry timber sector faced the worst crisis of the last decade as a result of the global economic and financial crisis that occurred in the previous year, 2008, which was reflected in the low production values for the period (ABRAF, 2011). Thus, this work considered It is important to analyze how these values are distributed in relation to the municipalities Brazilians during the crisis period, later comparing with the distribution of production wood in the most recent period in the database, 2018. Information on the quantity of firewood, roundwood are expressed in cubic meters (m^3), while for the variable coal in tons (t).

2.3 DATA ANALYSIS

An Exploratory Spatial Data Analysis (AEDE) of the variables was performed. total production of firewood, roundwood and charcoal in relation to all Brazilian municipalities.

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For this analysis, the *Python* language (PYTHON, 2019) was used with the *Pysal packages,* specific for exploratory analysis of spatial data, and *Geopandas,* used in the manipulation and spatial data visualization.

After carrying out the preliminary exploratory analysis, that is, after obtaining the general statistics on the data for each variable of interest, such as the mean, median, deviation standard, maximum, minimum and total production for the periods analyzed, a map was created thematic of equal intervals *(k* = 5, for all variables) with the purpose of observing spatially distributed production values into classes of the same amplitude. Thus, defined the spatial proximity matrix of the contiguous type in the queen form, the index was calculated global Moran's *I* , performing the pseudo-significance test with 1,000 permutations at a significance level = 5%.

The global Moran's *I* provides a global measure of linear association between values of a variable observed in a given area and the weighted average of the values of its neighbors as described in the following formula (MORAN, 1948):

$$= \frac{\ddot{y}\,\ddot{y}_{=1\,=1}\;{}^{\ddot{y}}\;(\ddot{y}\,\acute{})(\ddot{y}\,\acute{})}{{}_{0}\;\ddot{y}\,(\ddot{y}_{\ddot{y}}\,\acute{})^{\,2}}$$

Where: $0 = \ddot{y}\,\ddot{y}_{\;=1\,=1}\;{}^{\ddot{y}}$ is the normalization factor, *n* is the number of areas, *zj* is the value of the variable considered in the area, *i* and *z* the value of the variable in relation to the neighbors, *'z* the average value in the study region and *w´j* the elements of the normalized proximity matrix spatial. This statistic ranges from *-1* to 1, values close to zero indicate non-existence of spatial dependence; values close to 1 indicate that this dependence exists and is positive, that is, there is the presence of spatial *clusters ,* where neighbors have characteristics similar to each other; and values close to *-1* mean that this relationship exists, but is negative, there is dissimilarity between neighbors characterized as spatial *outliers* (DRUCK *et* al., 2004).

By obtaining a significant global statistic, that is, one that rejects the hypothesis that the data relating to regions of interest have a random distribution, were local Moran's *I* analyses were carried out according to the following formula:

$$= (\ddot{y}\,\acute{})\,\ddot{y}_{\;\ddot{y}}\;(\,-\,\acute{})^{\,2}$$

Where *Ji* represents the set of areas neighboring area i, the sum of the *j* areas belong to the *Ji..* areas .

The interpretation of this analysis is done with a scatter diagram where it is presented positive and negative spatial autocorrelation. The scatterplot is divided into quadrants, where the first constitutes a grouping in which the spatial units as well as the average of its neighbors have high values, called high/high clustering. In the second quadrant the values are low, low/low grouping. The third and fourth represent incidences that differ from those of its neighbors, characterizing high/low agglomerations and low/high respectively.

For the analysis and testing (pseudo-significance with 1,000 permutations and = 5%) of the local statistics, LISA maps were constructed, from the English *Local Indicator of Spatial Association,* with the aim of identifying patterns or *clusters* of local autocorrelation, as well as the spatial *outliers* .

3. RESULTS AND DISCUSSION

3.1 DESCRIPTIVE ANALYSIS

The table below presents the general descriptive statistics of national production of timber forest products originating from forestry according to the classification adopted by PEVS – IBGE from 2009 and 2018.

TABLE 1: General descriptive statistics of timber production from forest plantations in Brazil for the purpose of firewood (m³), logs (m³) and charcoal (t) in the years 2009 and 2018.

Variable	Year	Number of producing municipalities	Mean	Standard Deviation	Min	Median	Max.	Total
	Firewood	2,274	18,210.57	31,842.29	1	3,265.00	767,826.00	41,410,850.00
2009	Log	2.015	53,057.77	23,729.17	1	1,250.00	4,411,647.00	106,911,408.00
	Coal	851	3,970.05	19,542.40	1	90.00	305,295.00	3,378,520.00
	Firewood	2,551	20,619.82	29,328.05	3	7,000.00	1,222,200.00	52,601,179.00
2018	Log	2,242	65,327.31	25,229.42	2	3,100.00	5,342,722.00	146,463,834.00
	Coal	903	6,709.27	22,258.13	1	320.00	443,814.00	6,058,476.00

According to Table 1, in 2009, Brazil recorded the production of 41,410,850.0 m³ of firewood, 106,911,408.0 m³ of roundwood and 3,378,520.0 t of charcoal, distributed respectively between 2,274, 2,015 and 851 producing municipalities. Thus, production average among the producing municipalities corresponded to 18,210.57 m³ of firewood, 53,057.77 m³ of log and 3,970.05 tons of charcoal. The municipalities classified as the largest producers in 2009 were Santa Cruz do Sul (RS), with a total of 767,826.0 m³ of firewood, Telêmaco Borba (PR), with 4,411,647.0 m³ of roundwood and Encruzilhada do Sul (RS), with a total of 3,378,520.0 tons of charcoal (IBGE, 2010).

In 2018, there was an increase in national production and in the number of municipalities producers of timber from forestry for all variables. They were produced a total of 52,601,179.0 m³ of firewood, distributed among 2,551 municipalities; 146,463,834.0 m³ of roundwood, 2,242 municipalities; and 6,058,476.0 t of charcoal, 903 municipalities. Thus, average production showed growth of 13.3% in firewood production, 23.12% in roundwood and 69% for charcoal compared to 2009. The municipality with The largest forestry firewood production in 2018 was Butiá (RS), with 1,222,200.0 m³, which corresponds to a growth of 59% compared to the municipality that produced the most in 2009. In in the case of roundwood, the largest production was in the municipality of Três Lagoas (MS), with 5,342,722.0 m³ produced, which represents a growth of 129% of the observed value previously. For charcoal, growth was around 145% (443,814.0 t) (IBGE, 2019).

Considering firewood production, the largest producers were the states of Rio Grande do Sul and Paraná. In the Southeast region, the states of Minas Gerais and São Paulo are the highlights. According to Cunha (2019), forestry firewood is mainly used in ovens for drying grains, in food industries, in the processing of various types of minerals and in general commercial use.

The main roundwood producing states were Paraná and São Paulo. In In 2018, the state of Paraná represented 23% of total production, slightly ahead of the state of São Paulo (22%), Mato Grosso do Sul (14%), Santa Catarina (12.3%), Bahia (11.8%) and Espírito Santo Santo (7.6%). The state of Mato Grosso do Sul deserves to be highlighted, as it presented a 57% growth in production compared to 2009. Most of the production national logs are used for cellulose and processed wood (CUNHA, 2019).

As for the production of charcoal from forestry, this showed great growth, 79.3% compared to 2009. The state of Minas Gerais is the main producer of coal with around 78% of all national production in 2018, followed by the state of Maranhão, with 8% of total. The large coal production in Minas Gerais may be associated with the strength of the sector steel industry in this state, where the main pig iron and steel producing centers are located of the country, an industry dependent on charcoal (CUNHA, 2019).

3.2 SPATIAL ANALYSIS

3.2.1 Global autocorrelation index and scatterplot

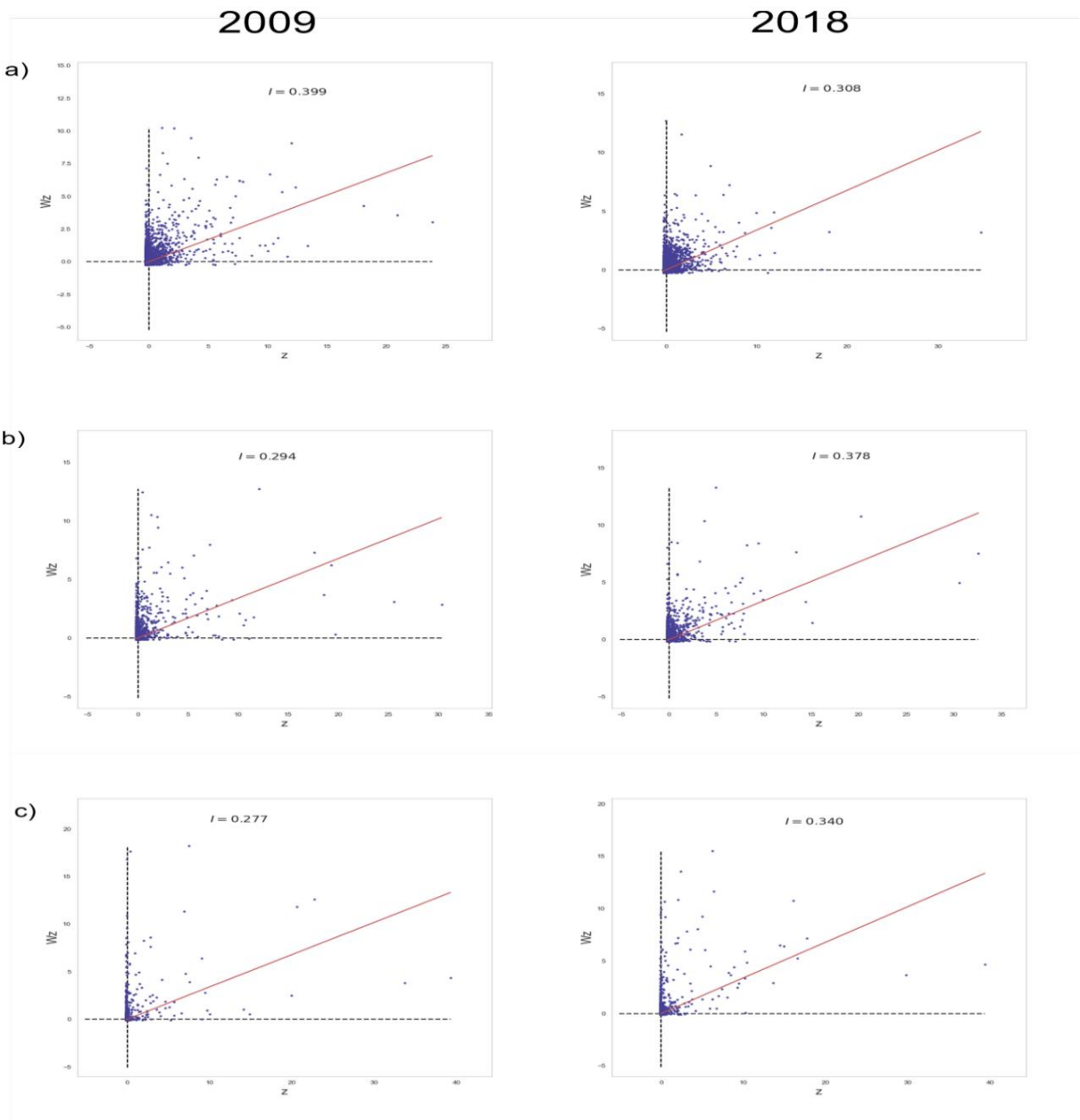
The results of the global Moran index and their respective *p* -values are presented in Table 1 below, where the occurrence of global spatial autocorrelation can be observed positive for the two periods analyzed and for all variables in question.

TABLE 2: Value of global Moran's *I* and its respective p-value for the variables of this study in the years 2009 and 2018.

Year	Variable	*I* of Moran	Value - p
2009	Firewood	0.399	0.001
	Log	0.294	0.001
	Coal	0.277	0.001
2018	Firewood	0.308	0.001
	Log	0.378	0.001
	Coal	0.340	0.001

This result is similar to that observed in the study by Perobelli *et al.* (2007) in which the global and local Moran's *I* indices show the presence of spatial dependence in agricultural productivity in Brazil and its respective *clusters.*

Moran scatterplots (FIGURE 2) show a positive slope of the curve, confirming the existence of positive spatial autocorrelation in all variables and periods analyzed.



Source: The Author (2020).

FIGURE 2: Moran scatterplots with standardized values in 2009 and 2018.
Where: a) Firewood from forestry (m³); b) Roundwood (m³); c) Charcoal (t).

Table 3 shows the number of municipalities in each quadrant in the diagram. Moran scattering.

TABLE 3: Number of municipalities in the quadrants in the Moran scatter diagram for the variables of this study in the years 2009 and 2018.

Quadrant	Firewood (m³)		Log (m³)		Charcoal (t)	
	2009	2018	2009	2018	2009	2018

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ISSN: 2675-9128. São Paulo-SP.

high/high	622	753	322	414	184	234
high/low	163	916	61	128	50	62
low/low	4,150	3,824	4,788	4,477	5.021	4,950
low/high	634	760	398	549	307	322

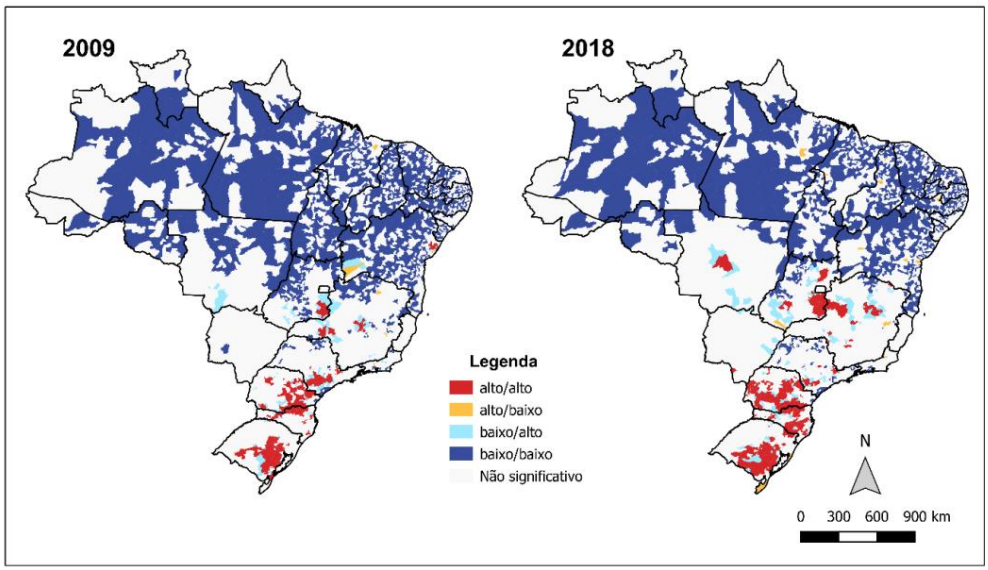
Regarding firewood production in 2018, 753 municipalities were identified in high/high quadrant, an increase of approximately 21% compared to 2009. In in relation to the high/low quadrant, a 560% increase was observed in the number of municipalities, especially in the Southeast and Central-West regions of Brazil. In the low/low quadrant, most Brazilian municipalities are located, confirming that most of the production of firewood occurs concentrated in highly productive regions. In the low/high quadrant there was also an increase in the number of municipalities, a fact that may be related with expansion of municipalities that produce in large quantities (IBGE, 2019). For the roundwood production, 414 municipalities were registered in the high/high quadrant, which corresponds to an increase of 29%. The number of municipalities present in the quadrant of the type low/low little has changed. These results may be associated with the expansion of production roundwood, since the number of municipalities belonging to the high/low quadrant practically doubled in the periods analyzed. In the case of charcoal production, the largest growth in the number of municipalities was in the high/high quadrant, with approximately 27%.

3.3 PLAIN MAPS

The results presented above do not indicate which municipalities significant, being necessary to discriminate them through local LISA indicators, capable to provide identification of spatial grouping regions and their areas corresponds.

3.3.1 Firewood (m3)

The result of the LISA map of the variable wood intended for firewood is presented in Figure 3.



Source: Author.

FIGURE 3: LISA map (= 0.05) for the variable firewood (m³) in the years 2009 and 2018.

The LISA map in 2009 shows that the south of the state of São Paulo, part of the axis north-southeast of Paraná, north of Santa Catarina, center-east and southeast of Rio Grande do South, concentrate most of the significant municipalities in relation to *clusters* of the type high/high, accounting for 74% of all national firewood production. In 2018, if a considerable increase in the number of municipalities in the high/high quadrant, mainly in Southern Brazil, where regions belonging to western Paraná, southern Santa Catarina and the extreme south of Rio Grande do Sul began to have municipalities of this type high/high. In addition, a shift in significant municipalities can also be observed of the high/high type in Minas Gerais in 2018, where a higher concentration was observed of municipalities in the western part of the state, forming a cluster with some municipalities neighbors of the eastern and southern regions of Goiás. Regions with spatial *clusters* of the type low/low belong mostly to the North and Northeast of the country, in both periods analyzed, with the exception of some low/low type municipalities present in the north of Minas Gerais and in the northern and coastal part of São Paulo and Rio de Janeiro.

Regarding *outliers,* only the municipality of Jamborandi (Bahia) presented significant high/low behavior in 2009. In 2018, in addition to this municipality, were Mata de São João (BA), Paty do Alferes (RJ), Engenheiro Caldas (MG), Bom Jesus do Galho (MG) and Urbano Santos (MA). The municipalities that presented behavior

significant of the low/high type were those where there was mainly no production of firewood and were neighbors of large producers.

When considering the municipalities with the highest production of firewood in 2009 it is observed that they make up the significant clusters of the high/high type. Santa Cruz do South, Southern Crossroads, São Jerônimo, Pântano Grande and Paverama, belonging to Rio Grande do Sul, Itaberá and Itapetininga, in São Paulo, and Paraopeba in Minas Gerais, are among the ten largest producers in the country, and are responsible for 38% of Brazilian production in period analyzed.

In 2018, the municipalities that produced the most wood for firewood were concentrated in southern portion of the country. Thus, it is possible to observe the existence of significant agglomerations of the high/high type relatively close. The municipalities of Butiá, Montenegro, Paverama, Southern Crossroads and Triunfo, in Rio Grande do Sul and Telêmanco Borba and Toledo in Paraná represent large high/high clusters, responsible for 43.6% of all production in 2018. The state of Rio Grande do Sul stands out for presenting a certain stability regarding high/high agglomerations compared to 2009. It was observed that the significant municipalities for the high/high *cluster* of firewood wood moved to the South and Central-West regions of the country. This result was also observed in the work of Simioni *et al.* (2017), who compared firewood production from forestry in the years 2000 to 2011 and identified that Paraná, Santa Catarina and Rio Grande do Sul constitute large traditional production centers in the country.

3.3.2 Roundwood (m3)

The results of the LISA maps for roundwood are presented in Figure 4.

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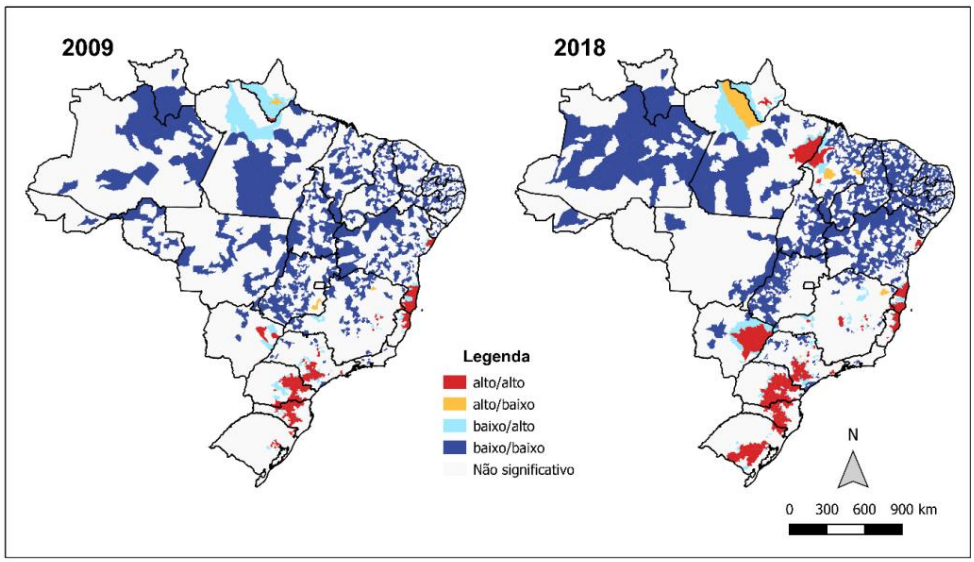


Source: The Author (2020).

FIGURE 4: LISA map (= 0.05) for the roundwood variable (m³) highlighting the region of greatest importance in the value of national production in relation to the high/high clusters in 2018.

According to Figure 4, in 2009, the main significant regions of the type alto/alto are located in the south of the states of Bahia and São Paulo, in the north of the state of Espirito Santo, on the north-south axis of eastern Paraná and also in the central region of Santa Catarina. Some other significant municipalities for the high/high type presented themselves in a isolated in eastern Mato Grosso do Sul, in northeastern Bahia and in the Rio Doce region in Minas Gerais General.

In 2018, the availability of high/high type municipalities remained relatively close to the previous period in relation to the states of Espírito Santo, Bahia, São Paulo, Paraná and Santa Catarina, but now we also notice large clusters belonging to the region south-central part of the state of Rio Grande do Sul, east of Mato Grosso do Sul, in the northeastern portion of state of Pará and western Maranhão. Isolated municipalities of the high/high isolated type can be observed in the south of Amapá and Maranhão.

Of the low/low municipalities, the majority belong to the Central-West, North and and Northeast Brazil for both periods analyzed. Most of these municipalities, besides being close to each other, they did not produce any quantity of wood. In this context, it is worth noting that the local statistics in 2018 were significant for the type standard low/low, a fact that is consistent with the history of roundwood production from

forestry in these regions, where production has had a low value or never occurred, with the exception of the state of Mato Grosso do Sul (large national producer).

As for significant spatial *outliers* of the high/low type, in 2009 only the municipalities of Porto Grande (south of Amapá), Ipameri (south of Goiás), Riacho dos Machados (north of Minas) and Caieiras (metropolitan region of São Paulo) presented this behavior. In 2018, the municipalities of Almeirim (lower Amazon), Grajaú (center Maranhão), Parnarama (eastern Maranhão), Jequitinhonha (Jequitinhonha region in Minas Gerais) Gerais), Bocaina (Bauru) and Cachoeira Paulista (Paraíba Valley) in São Paulo presented the significant behavior for the high/low type. As for the low/high type *outliers ,* It is known that the significant municipalities in the periods analyzed were mostly neighboring of large clusters of the high/high type, with the exception of some municipalities located in isolated manner in the northern part of the state of Pará, and southern Amapá and Minas Gerais.

Regarding clusters formed by significant municipalities of the high/high type, in 2009, two main macroregions can be observed. The first macroregion is composed by 117 producing municipalities and extends through a continuous axis, which comprises part southeast of the state of São Paulo, crosses Paraná and ends in the south of Santa Catarina, being represented basically by the municipalities of Telêmaco Borba (central-eastern Paraná), General Carneiro (southeast Paraná) and Itapetininga (Itapetininga region in São Paulo), with production equivalent to 41.4% of the total for the period. The second macroregion is composed of 24 municipalities located between the north of the state of Espírito Santo and the south of Bahia, and corresponds to 19.2% of the total roundwood production for the year 2009, being represented by the municipalities of Conceição da Barra (ES), Mucuri, Nova Viçosa and Caravels (BA).

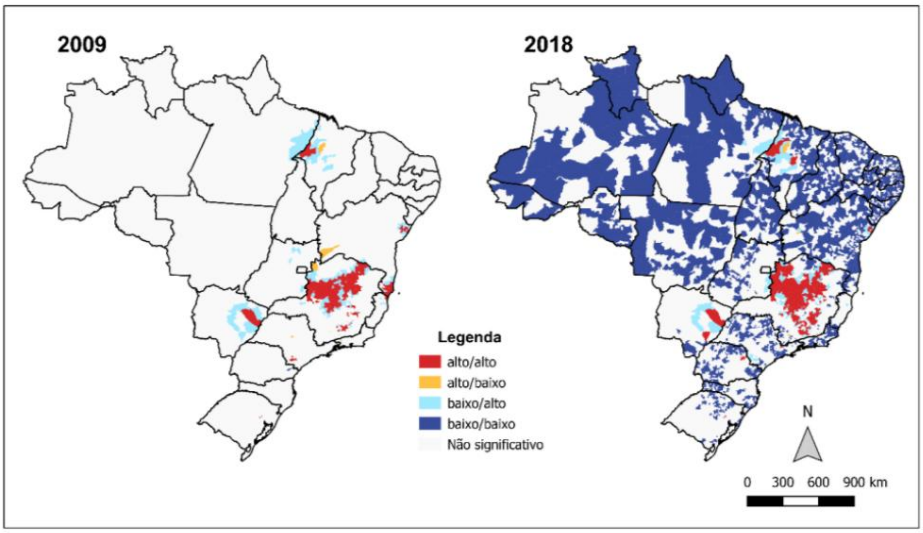
The high/high clusters for the year 2018 were more comprehensive in relation to what was observed previously. During this period, the occurrence of five macro-regions with significant agglomerations between municipalities of the high/high type, located between the states of São Paulo, Paraná and Santa Catarina; Rio Grande do Sul; Mato Grosso do Sul; Bahia and Espirito Santo; Pará and Maranhão. Although these macro-regions are of great importance when the amount of wood is taken into account produced, it is observed that only three of these clusters are fundamental for the production of round wood in the country.

The high/high cluster that belongs to the São Paulo, Paraná and Santa Catarina axis is still characterized as the most important macro-region in timber production in log. However, the municipality of Itapetininga (SP) no longer represents the region as it did in 2009, being overtaken by the municipality of Ortigueira (central-east region of Paraná). This makes that the state of Paraná is the productive center of this region, which has 146 municipalities and corresponds to approximately 38% of the total produced for the period. The second macro-region of greatest importance among the high/high clusters, in 2009, it encompasses some municipalities in the eastern region of Mato Grosso do Sul, such as Três Lagoas, Selvíria, Água Clara and Ribas do Rio Claro. This cluster has only ten municipalities, however corresponds to 12.1% of all production in 2018. The third cluster is formed by municipalities of the high/high type located between the north of Espírito Santo and the south of Bahia. This region is also an important national producer, since in 2009 local indicators LISA confirmed the existence of high/high agglomeration between nearby municipalities, with 24 producing cities and production of 10.2% of the total in 2018. The main producers and representatives of the region are the municipalities of Mucuri, Nova Viçosa and Caravela, all belonging to the south of Bahia.

Therefore, the results obtained confirm that the production of roundwood from forestry is concentrated in large production centers, where the largest industries in the sector operate. Mainly large pulp and paper companies such as Klabim in the region of the municipality of Telêmaco Borba (PR), Suzano Papel e Celulose, in microregion of Três Lagoas (MS) and Veracel Celulose, located in the south of Bahia (HORA, 2017).

3.3.3 Charcoal (t)

Finally, Figure 5 shows the LISA map for the years 2009 and 2018 of the production of wood for charcoal registered by municipality.



Source: The Author (2020).

FIGURE 5: LISA map (= 0.05) for the charcoal production variable (t) in the years 2009 and 2018.

According to Figure 5, in 2009, the regions of the States of Minas Gerais, Bahia, Sao Paulo, Maranhão, Espirito Santo, Rio Grande do Sul and Mato Grosso do Sul presented municipalities and/or agglomerations of the high/high type. The state of Minas Gerais stood out for present the largest number of significant high/high municipalities in the period, forming a large cluster in the central, northwest and northern parts of the state. Southern Bahia and northern Espírito Santo also presented a cluster of high/high municipalities. Some other municipalities important for national production presented high/high *clusters* of isolated manner, as in the case of Três Lagoas, eastern Mato Grosso do Sul, and Açailândia, in western Maranhão.

In 2018, Minas Gerais continued to have the largest number of significant municipalities high/high, expanding to the southern and eastern portions of the state. In relation to the producing states, when compared with the previous period, there were no major changes, with the exception of the state of Espírito Santo, where no significant municipalities were registered. Regarding the composition of the high/high municipalities, some important differences are noted in relation to the year 2009, mainly in the states of Bahia, Maranhão and São Paulo. In the states of Bahia and São Paulo there is a smaller number of significant municipalities when compared to the period previously analyzed. In the case of the state of Maranhão, there is a greater number of high/high type municipalities in the western part of the state when compared to the previous period.

For the low/low spatial *cluster ,* only the municipalities of Bocaiúva do Sul, belonging to the metropolitan region of Curitiba, and Lupionópolis, in the north-central region of Paraná, were significant in 2009. In the subsequent period analyzed, the local index was significant for the vast majority of municipalities belonging to the North and Northeast regions of Brazil, as well as many other municipalities belonging to the states of Mato Grosso, Goiás, Sao Paulo, Rio de Janeiro, Paraná, Santa Catarina and Rio Grande do Sul.

As for the spatial *outliers* of wood production for charcoal, most of the municipalities that presented low/high grouping were precisely those close to municipalities or high/high clusters and did not produce any value for both periods analyzed. As for the high/low *outliers ,* only the municipalities of Bariri (Bauru, SP), São Bento do Abade (south of Minas Gerais), Buritis (northwest of Minas Gerais), Jaborandi (extreme west of Bahia), Volta Redonda (south of Rio de Janeiro), Santa Luzia and São Pedro da Água Branca (western Maranhão) for the year 2009 and none in 2018. In relation to the high/high clusters for the year 2009, two distinct regions: the first is a large region formed by municipalities in the central part, northwest and north of the state of Minas Gerais, the second, in a smaller proportion, comprises some municipalities in western Maranhão.

The high/high cluster belonging to the state of Minas Gerais has 85 municipalities and accounts for around 78% of all national production of wood for charcoal coming from forestry in 2009. The municipalities of Lassance and Rio Pardo de Minas in northern Minas Gerais; Curvelo, Três Marias and Felixlândia, located in the central region of Minas Gerais; João Pinheiro, in the Northwest, and Itamarandiba, in the Jequitinhonha region, represent this great cluster. The other region is made up of the municipalities of Açailândia, Bom Jesus das Selvas, Cidelândia and Itinga in Maranhão, all belonging to the west of the state, presenting with approximately 3.6% of the total produced for the period.

In 2018, high/high clusters remained among the states and practically between the same regions when compared to the previous period. Thus, in Minas Gerais, it is observed that the cluster formed by municipalities of the high/high type covers almost all the mesoregions of the state, is made up of 159 municipalities and corresponds to 76.6% of total production in 2018, represented by the municipalities of João Pinheiro and Vazante, in the northwest of Minas Gerais; Itamarandiba, Carbonita, Turmalina and Minas Novas, in the region of

Jequitinhonha; Três Marias, Curvelo, Pompéu and Martinho Campos, in the central region of Minas Gerais; Lassance, Buritizeiro and Olhos d'Água, in the north of Minas Gerais, and Paraopeba, in the region metropolitan area of Belo Horizonte. As for the second cluster, it is practically the same than observed in 2009, however, there is the addition of the municipality of Barra do Corda, belonging to the central Maranhão. Thus, this cluster has only five municipalities and represents about 4% of wood production for charcoal in 2018.

FINAL CONSIDERATIONS

This work aimed to analyze the production of firewood (m³), logs (m³) and charcoal plant (t) from Brazilian forestry in the years 2009 and 2018, through analysis exploratory analysis of spatial data, the identification of spatial autocorrelation and *clusters* or spatial *outliers* .

Thus, the existence of Moran's global index *I* was identified , spatial autocorrelation in relation to all variables and periods analyzed. More specifically, positive spatial autocorrelation, where the predominance of high/high and low/low regions. Which in silvicultural production reflects the fact that many of the regions that showed high production are historically established locations, with the exception of the eastern region of Mato Grosso do Sul, which in 2018 was driven by pulp and paper industry.

Another important result regarding timber production from forestry concerns the importance of the southern region of Brazil, especially the central-eastern region of the state of Paraná and the extreme south of the state of Rio Grande do Sul, centers in the production of planted forests of country, especially the production of firewood (m³) and roundwood (m³). In relation to the production of charcoal (t) from forestry, the municipalities belonging to the northeast, north and central portions of Minas Gerais presented a large cluster of the high/high type for both periods analyzed, precisely in regions where the steel industry is strong.

Therefore, this research found a significant spatial relationship between the regions of large timber production from forestry. However, it is emphasized that to enrich the results of this work it would be interesting if, in future investigations, they were carried out

more complex analyses using multivariate statistical techniques or even the use of spatial regression models.

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