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EXPANSION OF AGRICULTURAL AREAS IN BRAZIL FROM 1994 TO 2013: SOYBEANS *VERSUS* CORN *VERSUS* COTTON

Expansão de Área Agrícola no Brasil de 1994 a 2013: Soja *Versus* Milho *versus* Algodão

ABSTRACT

The objective of this article was to map disparities in the increases of agricultural areas in the Brazilian mesoregions between 1994 and 2013; particularly the levels of concentration of soybeans, corn, and cotton. The methodological approach included Cluster procedures and locational Gini coefficients. The results highlighted a frontier line identified in the central-northwest area of Brazil. As for the crops, a more concentrated expansion of the agricultural area dedicated to cotton was verified in the selected mesoregions. This expansion was less concentrated in soybeans and even less concentrated in corn.

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RESUMO

O objetivo deste artigo foi mapear as diferenças em expansão de área agrícola no âmbito das mesorregiões brasileiras no período 1994-2013, com foco nas parcelas devidas à soja, ao milho e ao algodão neste processo. Empregaram-se, como abordagem metodológica, procedimentos de análise de *clusters* e coeficientes locais. Uma fronteira de expansão agrícola foi identificada no sentido Centro-Noroeste do Brasil. Em relação às culturas avaliadas, a expansão de área agrícola nas mesorregiões selecionadas foi mais expressiva nas áreas algodão cultivadas. Essa expansão foi comparativamente menos soja concentrada e (ainda menos) milho concentrada.

Palavras Chave: Agricultura, Uso de Solo, Safras, Análise de Cluster, Brasil.

Keywords: Agriculture, Land Use, Crops, Cluster Analysis, Brazil.

1 INTRODUCTION AND OBJECTIVE

Between 1930 and 1980, Brazil transitioned from its status as a nearly monocultural producer to a country with diversified agricultural production (BRANDÃO, 2002; FREITAS, 2014a). In order to meet the country's needs with regard to food security and safety, investments and subsidies for research were directed toward Brazilian agriculture (BARROS, 2002; MARIN *et al.*, 2016), and led to a significant production increase during the last forty years.

In the first half of the 90s, domestic producers had greater exposure to international markets, which created new difficulties for Brazilian farmers. This scenario continued until 1994, especially with regard to inflation, and the sector was severely damaged because of the time lag between sowing and harvest operations. These events led to learning and solidity in the sector, which today is a main sector in the Brazilian economy. However, strategic adjustments had a variety of scattered impacts on the regions and on different crops.

On the other hand, food production remains a central concern for humanity in the twenty-first century. According to the United Nations (2015), the world population will reach 9.5 billion in 2050, and the urbanization is a notorious

process in the larger developing countries in Africa, and in China and India. Meanwhile, the major food producing countries (Russia, the United States, Argentina, Canada, and Australia) do not have any more land for economically or technically profitable farming.

For Bruinsma (2009), much of the land that already employed has some sort of constraint that cannot be easily overcome (chemical, physical, endemic diseases, or lack of infrastructure). Some of this land is covered with forests, protected areas or host settlements, for example. Moreover, agricultural systems in Africa and Southeast Asia appear to be vulnerable in terms of land productivity changes and consistent changes in water demand against the backdrop of an evolving climate (IGLESIAS, QUIROGA and DIZ, 2011).

Within this scenario, Brazil emerges as an important player for future increases in agricultural area, agricultural productivity, and food production. According to Brosig *et al.* (2012), Brazil's resources allow an excess production for exports. Brazil is already an important player in several agricultural markets, such as soybeans, sugar, and meat (beef, pork and poultry), and it is expected to maintain or even expand its share by 2023 (OECD-FAO, 2014).

In international poultry markets, for instance, Brazil has overtaken the United States as the world's largest exporter based on productivity gains, as indicated in Valdes, Hallahan and Harvey (2015). At the same time, Brazil's agricultural area is expanding into new spaces in Northeast states, increasing land prices (GASQUES, BOTELHO and BASTOS, 2014).

Therefore, the objective of this article is to map disparities in the increases of agricultural areas among the Brazilian mesoregions between 1994 and 2013; particularly the levels of concentration for soybeans, corn, and cotton. These three crops accounted for 50% of the production value of Brazilian temporary crops in the period 2010–2013 (IBGE, 2015). Soybeans and corn are also important components of animal feed for dairy and meat farming with impacts on domestic food prices and are main products among Brazilian agricultural exports (SANTO, LIMA and SOUZA, 2012; FREITAS, 2014b).

2 METHODOLOGY AND DATA

This study employed data from IBGE (2015) from 1994 to 2013 on production value, harvested area, and planted area, at the mesoregion level. The study applied two processes to measure the rates of increase in agricultural area; firstly, the percentages of mean increase in agricultural area were calculated for Brazilian mesoregions according to equations (1) and (2):

$$I_{1i} = \sum_t^T (C_{94,t}) / 19 \quad t = 1995, \dots, 2013 \quad (1)$$

where $C_{94,t}$ is the growth rate for planted area by i Mesoregion in t year compared with 1994.

As an additional control related to the effects of climatic conditions on agricultural production and also to capture short-term conditions, Indicator 1 (I_1) was measured exclusively for the period 2009–2013.

$$I_{2i} = \sum_t^T (C_{94,t}) / 5 \quad t = 2009, \dots, 2013. \quad (2)$$

Euclidean distance was also used; this is defined as a function of the X variables associated with two sample elements, and can be expressed as (3), where p are variables or characteristics of each sample element and k is the number of elements.

$$d(X_1, X_k) = \left[(X_1 - X_k)' (X_1 - X_k) \right]^{1/2} = \left[\sum_{i=1}^p (X_{1i} - X_{ik})^2 \right]^{1/2} \quad (3)$$

An additional variable entitled Lost Area (LA) was also calculated; this corresponds to the difference between planted area (PA, intended crop) and harvested area (HA, effective harvest). As discussed by Zhao, Hitzhusen, and Chern (1991), soil erosion and land degradation have been destructive worldwide. Because of reasons such as high population pressure on land and limited fossil energy supplies, land degradation is generally more serious in the developing world. Generally, planted area is represented as a function of agricultural product market prices, input prices, and technological conditions in field operations. Meanwhile, harvested area is a function of the same variables that affect planted area as well as random variables such as climatic conditions and the incidence of pest attack and diseases, for example. As a result, LA is also a random variable.

In practical terms, four key variables were used to measure the growth of agricultural area among the Brazilian mesoregions: planted area (PA), harvested area (HA), production value (PV), and LA, where:

$$LA = PA - HA \quad t = 1994, \dots, T \quad (4)$$

Two steps compose the calculations. Initially, the agglomerative hierarchical method was employed to indicate the number of groups that better fit the data. In the second round, within a year-by-year analysis, pseudo-T and pseudo-F tests¹ were run. These tests indicate the number of groups that produce the best gains of information. The calculations were done using the variables expressed in growth rates (planted area), in absolute values (planted area, lost area), or normalized values (planted area, lost area, and production value).

The next stage of the methodological approach employed the Locational Quotient (LQ) and the locational Gini coefficient (LGC). LGC has been employed by Krugman (1991) for analyzing location dynamics, and other studies have highlighted its benefits related to ease of implementation and data requirements (BERTINELLI and DECROP, 2005; VAN DEN HEUVEL, DE LANGEN and FRANSOO, 2013).

This tool had also been employed in studies extending beyond agricultural analyses, for instance, for studying regional specialization in China (LU, FLEGGB and DENG, 2011), for identifying industrial reallocations (RUAN and ZHANG, 2014) and for identifying high-tech concentrations (DEVEREUX, GRIFFITH and SIMPSON, 2004). Reveiu and Dardala (2011) also applied LQ to investigate employment statistics in Romania's counties.

¹These tests are standard for this methodology as described in Mingoti (2005) and SAS (2014a).

LQ indicates whether the relative importance of a specific mesoregion is greater for one crop than for all (permanent and temporary) crops combined. From LQ, it is possible to calculate LGC, which is useful for analyzing the spatial concentration of a crop in a specific area, and for identifying whether a crop is specialized in certain regions.

Based on Haddad's discussion of LQ (1989) and Isard (1960), LQ is defined as the following equation for soybeans:

$$LQ_{ij} = (S_{ij} / S_{i*}) / (A_{*j} / A_{**}) \quad (5)$$

where:

S_{ij} = planted area with soybeans in mesoregion j ;

S_{i*} = planted area with soybeans in all mesoregions;

A_{*j} = planted area in mesoregion j ;

A_{**} = planted area in all mesoregions.

In this context, (S_{ij} / S_{i*}) is the relative importance of mesoregion j in the planted area with soybeans and (A_{*j} / A_{**}) is the relative importance of mesoregion j in the combined planted area for all crops. LQ was also calculated in the same way for corn and cotton.

For dealing with large areas (mesoregions), the first step was to organize them by decreasing LQ for a chosen variable (planted area with soybeans, for example). Next, a localization curve was constructed for the chosen crop, and the curve point generators result as follows:

- Y coordinates were derived from the accumulated share of the chosen variable (planted area with soybeans, for example) in the mesoregions;

- X coordinates were derived from the accumulated share of the same variable (planted area) for all crops (temporary and permanent) in the mesoregions.

In both cases, the order in which data enter obeys the descending order of the LQ. In a hypothetical case of five mesoregions, the final curve would contain five points, as shown in Figure 1.

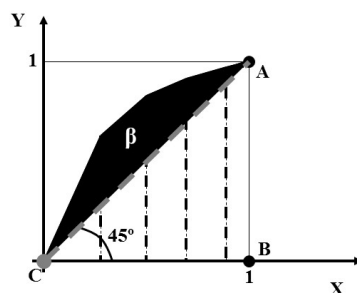


FIGURE 1 – LGC concentration area

Source: based on Krugman (1991) and Suzigan *et al.* (2003)

LGC is the ratio between the area represented by β (above) and the area of the ABC triangle, which is restricted by a 45° line. Consequently:

$$LGC = (\beta / 0.5) = 2 \cdot \beta \quad (6)$$

Then, the maximum value for LGC = 1, because the maximum value for β is 0.5. According to Suzigan *et al.* (2003), the closer the value is to 1, the more spatially concentrated the crop being analyzed is, and vice versa. In the context of a large country like Brazil, LGC will naturally tend to be relatively lower because of the dimensions of the individual mesoregions, which in many cases are larger than some European countries.

3 RESULTS

This section is composed of two subsections: the first describes the more representative mesoregions in terms of agricultural area growth rate, and the second describes the shares of soybeans, corn, and cotton in this process.

3.1 Selected Mesoregions

It is possible to distinguish two periods of growth in Brazil's agricultural areas between 1994 and 2013: 1994-2001 and 2002-2013.

Table 1 shows that between 1995 and 2001, planted areas were always smaller than the respective data for 1994, the mean growth rate was negative (-0.22% per year). Particularly during the period 1996-1998, there was a significant reduction compared to the 1994 base data. Afterwards, Brazilian agricultural areas recovered and expanded from 2002 to 2013, resulting in a mean growth rate of 2.91% per year during this period and a rising compound growth rate.

TABLE 1 – Brazil's planted areas and growth rates for agricultural areas, 1994-2013

Year	Planted area (hectares)	Growth rates $\frac{(t-t-1)}{(t-1)}$
1994	52,815,030	-
1995	51,853,110	-1.82%
1996	46,821,814	-9.70%
1997	48,302,405	3.16%
1998	48,509,074	0.43%
1999	50,700,694	4.52%
2000	51,819,125	2.21%
2001	51,637,167	-0.35%

Continua...

TABLE 1 – Continuation...

Year	Planted area (hectares)	Growth rates ($\frac{t-t-1}{t-1}$)
2002	54,511,629	5.57%
2003	58,460,983	7.24%
2004	63,036,966	7.83%
2005	64,319,313	2.03%
2006	62,563,908	-2.73%
2007	62,338,730	-0.36%
2008	65,527,804	5.12%
2009	65,721,594	0.30%
2010	65,374,591	-0.53%
2011	68,158,023	4.26%
2012	69,196,172	1.52%
2013	72,434,134	4.68%
Average 1995–2001		-0.22%
Standard deviation 1995–2001		4.70%
Compound growth rate 1995–2001		18%
Average 2002–2013		2.91%
Standard deviation 2002–2013		3.35%
Compound growth rate 2002–2013		46%

Source: author based on data on Municipal Agricultural Production (IBGE, 2015)

As highlighted by Awokuse and Xie (2015), the remarkable expansion of the agricultural sector in Brazil made notable contributions to the growth of the overall economy, especially in terms of Brazil becoming a top producer and exporter of beef, broiler chickens, coffee, soybeans and oilseeds, sugar, and ethanol derived from sugarcane. According to Doğan, Arslan, and Köksal (2013) the agricultural sector has changed in recent years, taking on such diverse roles as direct/indirect contributions to feeding the population, national income, employment, supplying raw materials to industry, exports, and biological diversity.

Table 2 shows the Brazilian mesoregions in which both indicators I_1 and I_2 exceeded the respective values in terms of national means; in other words, in terms of Brazilian growth rates for agricultural area compared with 1994². Forty-two mesoregions met both criteria. Geographically, these regions were located in the following regions: 11 in the north, 10 in the center-west, 9 in the south, 8 in the southeast, and 4 in the northeast. Note that half were in the North or Center-West-regions.

²The national mean for I_1 was 11.74% and for I_2 was 29.09%.

TABLE 2 – Selected mesoregions according to growth rates in planted area, 1994–2013

North Amapá – AP	Central-West Rio Grande do Sul – RS
East Tocantins – TO	Central-North Mato Grosso do Sul – MS
South Amapá – AP	Southwest Mato Grosso – MT
North Mato Grosso – MT	Northeast Rio Grande do Sul – RS
South Maranhão – MA	Minas Triangle/Upstream Paranaíba – MG
Northeast Mato Grosso – MT	Central-East Paraná – PR
South Amazonas – AM	Bauru – SP
Extreme West Bahia – BA	Southwest Amazonas – AM
Juruá Valley – AC	Marília – SP
East Goiás- GO	South Roraima – RR
Southwest Mato Grosso do Sul – MS	Downstream Amazonas – PA
Southwest Piauí – PI	Southwest Rio Grande do Sul – RS
Presidente Prudente – SP	São José do Rio Preto – SP
Southeast Mato Grosso – MT	Federal District – DF
Northwest Paraná – PR	Pioneer North Paraná – PR
South Goiás- GO	Itapetininga – SP
Central-South Mato Grosso – MT	Southeast Paraná – PR
Araçatuba – SP	Madeira-Guaporé – RO
North Roraima – RR	North Central Paraná – PR
Central Amazonas – AM	Central-West Paraná – PR
Northwest Minas Gerais – MG	Northeast Bahia – BA

Source: author based on data on Municipal Agricultural Production (IBGE, 2015)

After selecting the mesoregions, they were clustered according to the pseudo-T and pseudo-F tests described above. Table 3 presents the results that were generated using SAS software (2014b; 2014c).

For the variables measured at level (L), the tests indicate a maximum of 6 groups of different spaces, 5 or 6 groups for the planted area in growth rates (G), and a maximum of 6 representative groups for the normalized variables (NO). These values indicate 5 or 6 different spaces (areas) in terms of the growth rate for the Brazilian agricultural area.

TABLE 3 – Groups of mesoregions in Brazilian agricultural area, 1994-2013

Year	Variables at level (L)			Variables in growth rates (G)			Normalized variables (NO)		
	Pseudo-F	Pseudo-T	Mean	Pseudo-F	Pseudo-T	Mean	Pseudo-F	Pseudo-T	Mean
1994	3	2	2.5	-	-	-	3	2	2.5
1995	3	2	2.5	5	3	4.0	5	4	4.5
1996	4	3	3.5	6	4	5.0	4	3	3.5
1997	4	3	3.5	5	5	5.0	4	3	3.5
1998	3	2	2.5	3	2	2.5	5	3	4.0
1999	3	2	2.5	5	5	5.0	5	4	4.5
2000	4	5	4.5	5	4	4.5	3	2	2.5
2001	4	6	5.0	4	3	3.5	4	3	3.5
2002	4	5	4.5	4	3	3.5	5	4	4.5
2003	6	4	5.0	3	5	4.0	3	2	2.5
2004	6	4	5.0	3	2	2.5	3	5	4.0
2005	4	5	4.5	5	4	4.5	5	3	4.0
2006	3	2	2.5	5	3	4.0	3	2	2.5
2007	3	2	2.5	3	2	2.5	4	3	3.5
2008	4	3	3.5	4	2	3.0	3	2	2.5
2009	4	5	4.5	3	2	2.5	4	2	3.0
2010	4	5	4.5	4	3	3.5	5	2	3.5
2011	4	5	4.5	3	2	2.5	3	2	2.5
2012	4	3	3.5	3	2	2.5	3	2	2.5
2013	4	3	3.5	3	2	2.5	6	5	5.5

Source: author based on data on Municipal Agricultural Production (IBGE, 2015)

Assuming five groups (areas) of different rates of growth in agricultural area, Table 4 organizes the mesoregions according to their changing share in planted area between 1994 and 2013, where the last column to the right (C) is shown in descending order. In this column the value for the Extreme West Bahia, for instance, means that this area's share of Brazil's planted area in 2013 was 2.10 times its share in 1994.

Areas 1 to 4 experienced a participative increase of 11.41 percentage points (p.p.), 1.94 p.p., 7.21 p.p., and 3.57 p.p., respectively. These four areas accounted for 32.4% of Brazil's planted area in 1994 and for 56.53% of the country's planted area in 2013. Accordingly, they amounted a participative increase of 24 p.p. over twenty years.

Identifying the mesoregions with similar growth in planted area from 1994 to 2013 allowed creating a map showing the dynamics of Brazil's agricultural areas based on the previously selected areas 1 to 4, which is displayed in Figure 2.

Brazil's center-northwestern axis presented a significant expansion of planted area. In recent decades, a substantial portion of the Brazilian agricultural research was devoted to the plains areas and crops located in that region. As stated by Anderson, Pardey and Roseboom (1993), growth in agriculture depends on many factors, but the most important is the investment in agricultural research. In this context, it should be noted that several mesoregions in the center-west area experienced a minimum absolute increase of five hundred thousand hectares from 1994 to 2013. According to Helfand and Levine (2004), agricultural production and total factor productivity have grown faster in this region than in other areas since 1970.

This route also projects towards eastern areas of the North. A second section that includes the north and northeast Mato Grosso, southern Amazonas, and the Juruá Valley must be highlighted, along with the state of Amapá, which represents a frontier area. The growth of these areas is probably related to specific

supply chains upstream and downstream from the farms (MASTRONARDI *et al.*, 2015), which naturally calls particular attention to sustainability in terms of social, economic³ and environmental dimensions.

TABLE 4 – Share of selected mesoregions in planted area, 1994 and 2013

	% 1994 (A)	% 2013 (B)	C = [(B/A)-1]
North Amapá – AP	0.001%	0.011%	6.60
East Tocantins – TO	0.126%	0.630%	4.00
South Amapá – AP	0.006%	0.027%	3.32
North Mato Grosso – MT	3.092%	11.573%	2.74
South Maranhão – MA	0.292%	1.033%	2.54
Northeast Mato Grosso – MT	0.689%	2.305%	2.35
South Amazonas – AM	0.019%	0.057%	2.04
(Area 1)	4.23%	15.64%	
Extreme West Bahia – BA	1.211%	2.537%	1.10
Juruá Valley – AC	0.033%	0.067%	1.06
East Goiás – GO	0.571%	1.152%	1.02
(Area 2)	1.81%	3.76%	
Southwest Mato Grosso do Sul – MS	2.146%	4.134%	0.93
Southwest Piauí – PI	0.655%	1.235%	0.89
Presidente Prudente – SP	0.503%	0.898%	0.78
Southeast Mato Grosso – MT	1.834%	3.038%	0.66
Northwest Paraná – PR	0.676%	1.113%	0.65
South Goiás – GO	3.585%	5.766%	0.61
Central-South Mato Grosso – MT	0.167%	0.267%	0.60
Araçatuba – SP	0.543%	0.846%	0.56
North Roraima – RR	0.037%	0.057%	0.53
(Area 3)	10.15%	17.35%	
Central Amazonas – AM	0.106%	0.155%	0.46
Northwest Minas Gerais – MG	0.821%	1.192%	0.45
Central-West Rio Grande do Sul – RS	0.904%	1.264%	0.40
Central-North Mato Grosso do Sul – MS	0.782%	1.081%	0.38
Southwest Mato Grosso – MT	0.340%	0.459%	0.35
Northeast Rio Grande do Sul – RS	0.612%	0.791%	0.29
Minas Triangle/Upstream Paranaíba – MG	2.189%	2.828%	0.29
Central-East Paraná – PR	0.998%	1.279%	0.28
Bauru – SP	0.953%	1.213%	0.27
Southwest Amazonas – AM	0.021%	0.027%	0.27
Marília – SP	0.163%	0.205%	0.26
South Roraima – RR	0.024%	0.029%	0.23

Continua...

³In the United States, for example, the connections between lower borrowing costs in land credits and increase in farmland values have been studied and there have been discussions about a possible bubble in farmland values (GLOY *et al.*, 2011).

TABLE 1 – Continuation...

	% 1994 (A)	% 2013 (B)	C = [(B/A)-1]
Downstream Amazonas – PA	0.241%	0.294%	0.22
Southwest Rio Grande do Sul – RS	1.179%	1.427%	0.21
São José do Rio Preto – SP	1.388%	1.669%	0.20
Federal District – DF	0.159%	0.189%	0.19
Pioneer North, Paraná – PR	1.308%	1.478%	0.13
Itapetininga – SP	0.674%	0.720%	0.07
Southeast Paraná – PR	0.833%	0.885%	0.06
Madeira-Guaporé – RO	0.072%	0.075%	0.04
Central-North Paraná – PR	2.446%	2.518%	0.03
(Area 4)	16.21%	19.78%	
Central-West Paraná – PR	1.607%	1.599%	-0.01
Northeast Bahia – BA	1.027%	0.874%	-0.15
(Area 5)	2.63%	2.47%	
Selected mesoregions (areas 1-5)	35.032%	58.998%	0.68
Non-selected mesoregions (area 6)	64.968%	41.002%	-0.37
Brazil	100%	100%	

Source: author based on data on Municipal Agricultural Production (IBGE, 2015)

Another core expansion area includes east Tocantins, south Maranhão, southwest Piauí, and extreme west Bahia. According to Câmara *et al.* (2015), this area may concentrate future cropland expansion in Brazil from 2020 to 2050. Furthermore, a core of intermediate-pace expansion of planted areas includes mesoregions in northern Paraná, western São Paulo, the areas surrounding the Federal District, and the center-south of Mato Grosso do Sul.

3.2 The Shares of Soybeans, Corn and Cotton in Agricultural Area Expansion.

The second stage of this study calculates LQ and LGC for soybeans, corn, and cotton. As stated by Annan *et al.* (2013), spatial patterns of yield distributions can be crucial for their implications in crop insurance.

For soybeans, LGC had little variation along the data series, as it can be seen in Table 5. The mean LGC value was 0.295. However, outlier points were present in specific years, such as from 2001 to 2003, and 2006; this is likely the result of random events associated with agricultural production, soybean prices, exchange rates (since soybeans are an international commodity) or even infrastructure restrictions of Brazil.

Especially about Brazil's infrastructure restrictions, 67% of the Brazilian soybeans are transported in highways (ALMEIDA, SELEME and NETO, 2013), with high

production losses (NAVES, 2009 *apud* ALMEIDA, SELEME and NETO, 2013). This reality demands new strategies for transporting the product if soybeans area expansion continues. Furthermore, in line with Souza, Alves e Gomes (2014), infrastructure and rural extension improvements are public goods required for all Brazilian agricultural areas.

Additionally, the results for the last four years were below the mean level for the series, which can indicate reduced soybean concentration in the selected mesoregions in recent years. At the same time, the LQ of other (non-selected) mesoregions increased for the 2009-2013 period, which is consistent with the decline in LGC for soybeans. In terms of productivity, according to Bruce and Carriquiry (2010) changes in cultivated area do not result in lower soybean productivity because the crop experiences high levels of technological inputs and productive standardization.

A second aspect to highlight is the share of planted areas resulting from the selected mesoregions. For soybeans this share increased, reaching 73% of the total planted area with soybeans in Brazil in 2013, as seen in Figure 3. This result exceeded the respective level for all crops, permanent and temporary, especially between 1994 and 2006.

Some analysts (SAUER and LEITE, 2012) suggest that soybean expansion has been concentrated on Brazilian

savannas and has a main role in deforestation process. Ferreira and Coelho (2015) endorse such argument, mainly for the northern Brazilian states.

In the context of corn production, as it can be seen in Table 6, the mean value for the LGC series was 0.016. For such crop, LGC resulted in low or negative numbers from 1994 to 2006, but the data from 2007 to 2013 showed recent growth. Nevertheless, data from the entire series points out that corn area expansion was slightly concentrated in the selected mesoregions.

As an additional tool, partial LGCs were calculated for the years when a group of selected mesoregions had negative inputs for the LGC. This occurred in every year of the series, except for 2012–2013. Partial LGC corresponds to the coefficient matrix until the point where the contribution of the selected mesoregions is positive, excluding the group of mesoregions that had negative contributions⁴ to the LGC for corn.

The results for LQ for the non-selected mesoregions reinforce that the area expansion according to the selected

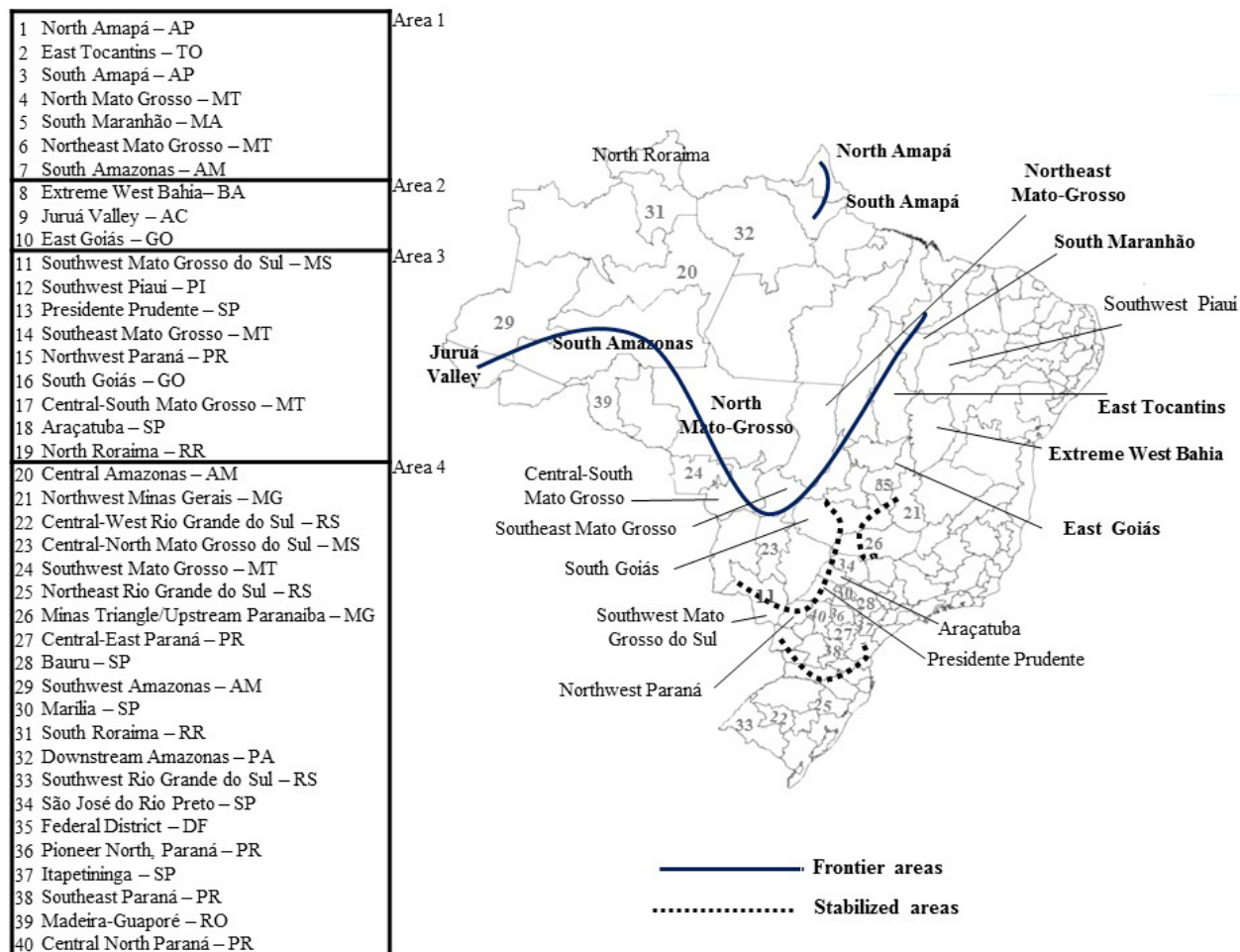


FIGURE 2 – Areas of agricultural expansion in Brazilian mesoregions, 1994-2013

Source: author based on data on Municipal Agricultural Production (IBGE, 2015)

⁴Further analyses can explore this negative contribution to understand the role that these areas play in the relatively low levels of LGC for corn. In mean terms, eight selected mesoregions had negative contributions to the LGC for corn from 1994 to 2011, which may have resulted from the specific criteria employed in selecting the mesoregions.

mesoregions was not concentrated in corn. SPAROVEK *et al.* (2016) showed that efficiency improvements are crucial for small or medium producers, which is more evident for corn⁵ producers than for soybeans or cotton farmers.

TABLE 5 – LGC for soybeans and LQ for soybeans in non-selected mesoregions, 1994-2013

Year	LGC for soybeans	LQ for soybeans in non-selected mesoregions
1994	0.301	0.651
1995	0.321	0.621
1996	0.292	0.663
1997	0.283	0.669
1998	0.296	0.640
1999	0.293	0.640
2000	0.306	0.609
2001	0.318	0.591
2002	0.320	0.537
2003	0.317	0.563
2004	0.300	0.562
2005	0.296	0.557
2006	0.317	0.546
2007	0.293	0.582
2008	0.298	0.578
2009	0.299	0.578
2010	0.279	0.599
2011	0.277	0.600
2012	0.253	0.621
2013	0.234	0.652
Average	0.295	0.603

Source: author based on data on Municipal Agricultural Production (IBGE, 2015)

Since the last two years of available data indicate a changing process, only new data can highlight this phenomenon in further studies. Simultaneously, the share for selected mesoregions in the planted area with corn resembled the pattern for all crops. In other words, corn does not differ from the general pattern of importance of selected mesoregions in terms of planted area, as illustrated in Figure 4.

⁵In this context, Santana and Contini (2011) highlighted a forecasted increasing in domestic consumption (1.7% per year) for corn in Brazil from 2010 to 2030.

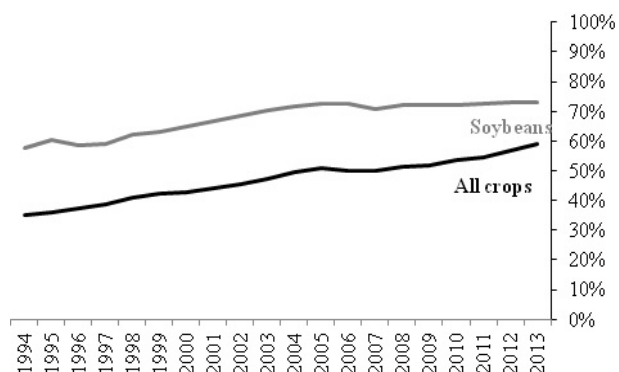


FIGURE 3 – Share of planted area in selected mesoregions, soybean and all crops, 1994–2013

Source: author based on data on Municipal Agricultural Production (IBGE, 2015)

TABLE 6 – LGC and partial LGC for corn, and LQ for corn in non-selected mesoregions, 1994–2013

Year	LGC for corn	Partial LGC for corn	LQ for corn in non-selected mesoregions
1994	-0.005	0.008	1.045
1995	-0.007	0.016	1.052
1996	0.010	0.021	1.004
1997	0.030	0.030	1.001
1998	0.000	0.023	1.060
1999	0.006	0.026	1.056
2000	0.003	0.025	1.061
2001	0.006	0.014	1.065
2002	-0.013	0.021	1.101
2003	-0.008	0.023	1.097
2004	-0.021	0.022	1.139
2005	-0.028	0.021	1.162
2006	-0.020	0.021	1.133
2007	0.028	0.039	1.043
2008	0.034	0.044	1.042
2009	0.018	0.037	1.077
2010	0.038	0.048	1.041
2011	0.037	0.050	1.056
2012	0.086	Not applicable	0.963
2013	0.124	Not applicable	0.901
Average	0.016	0.027	1.055

Source: author based on data on Municipal Agricultural Production (IBGE, 2015)

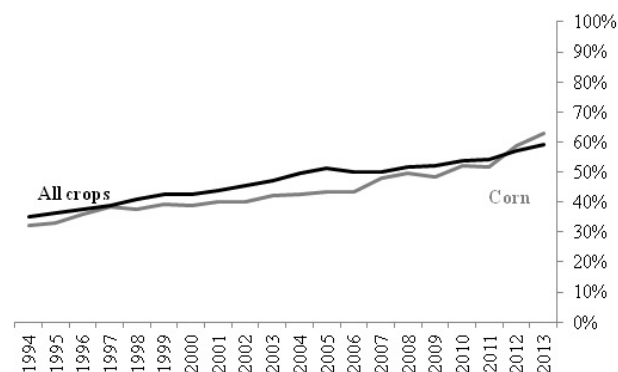


FIGURE 4—Share of planted area in selected mesoregions, corn and all crops, 1994–2013

Source: author based on data on Municipal Agricultural Production (IBGE, 2015)

Regarding the cereal, it is mandatory to report that this crop is commonly managed in association to soybeans cycle in several Brazilian regions. The real occurrence of cereal in many areas can be underrated. Only Census data can clarify this aspect since the Municipal Agricultural Production (IBGE, 2015) does not offer any farmer individual information.

For cotton, Table 7 illustrates the ascending value for LGC. This growth is specifically located in the period 2000–2010. This phenomenon is more significant in cotton than in soybeans, and greatly exceeds the value for corn. Accordingly, the LQ for the non-selected mesoregions decreased during the studied period, representing the diminishing importance of the non-selected mesoregions in the area of cotton expansion.

The selected mesoregions were also more significant in cotton expansion than in all crops expansion, as it can be seen in Figure 5. This process is clear from 1997 and stabilizes in 2007. From 2010 on, around 90% of cotton production occurred in the selected mesoregions.

According to Santo, Lima and Souza (2012) domestic uses play an important role in Brazilian cotton demand. At the same time, for some authors (LEITE and WESZ, 2010) land prices change when cattle areas are converted in cotton or soybeans cultivated areas. This way, even indirectly cotton and soybeans change the land prices in new agricultural areas.

In comparative terms, the selected mesoregions were equally representative for the expansion in corn as well as for the expansion in all crops. For soybeans, the selected mesoregions became more significant than for corn or even for all crops. Especially in recent years, three quarters of the entire planted area with soybeans was located in the selected mesoregions. Moreover, during the twenty years of the study, the share of planted area with cotton in the selected

mesoregions increased substantially, with clear difference in participative expansion *vis a vis* the all crops situation.

Regarding this matter, Carvalho, Laureto and Pena (2015) had already detected higher productivity growth rates for cotton, corn and soybeans in the 1990's than in the 2000's, being more evident for cotton.

In a context of area expansion guided by soybeans and cotton, even if environmental impacts happen (SAUER and LEITE, 2012), some analysts (SPAROVEK *et al.*, 2016) consider possible to find out a common base of interests between farmers and conservationist groups.

Surely, those impacts are not limited to competition for agricultural endowments, as exposed by Brum, Dalfovo and Azuaga (2009). Their analysis about Sorriso County (MT) identified a distinguishable economic growth related to soybean production as an increased level of environmental damaging as a consequence of that increased activity.

TABLE 7—LGC for cotton and LQ for cotton in non-selected mesoregions, 1994–2013

Year	LGC for cotton	LQ for cotton in non-selected mesoregions
1994	0.187	0.861
1995	0.274	0.904
1996	0.329	0.595
1997	0.153	0.387
1998	0.375	0.762
1999	0.412	0.535
2000	0.369	0.723
2001	0.538	0.835
2002	0.534	0.692
2003	0.523	0.644
2004	0.543	1.174
2005	0.560	1.278
2006	0.640	0.958
2007	0.708	1.159
2008	0.729	0.177
2009	0.718	0.203
2010	0.739	0.172
2011	0.718	0.175
2012	0.707	0.179
2013	0.689	0.218
Average	0.522	0.632

Source: author based on data on Municipal Agricultural Production (IBGE, 2015)

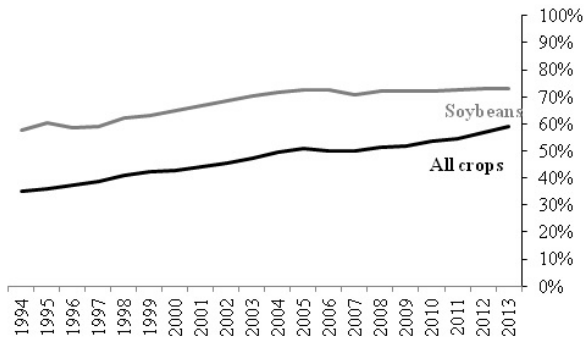


FIGURE 5 – Share of planted area in selected mesoregions, cotton and all crops, 1994–2013

Source: author based on data on Municipal Agricultural Production (IBGE, 2015)

4 CONCLUSIONS

This study investigated disparities in the growth of agricultural areas in the Brazilian mesoregions during the period 1994–2013 and focused on the shares of concentration for soybeans, corn and cotton in newly expanded areas.

The results detected forty-two mesoregions in six different areas of Brazil, according to their rates of expansion of agricultural area, which included a residual area containing the non-selected mesoregions. It was possible to recognize a concentration of mesoregions that experienced a significant growth in planted area in the central-west region of the country; this included mesoregions with an absolute increase of at least five hundred thousand hectares from 1994 to 2013. There is a clear center-northwest axis of expansion, especially towards eastern areas of the north and northern areas of the center-west.

In certain aspects, this phenomenon converges with another area of expansion comprised by east Tocantins, south Maranhão, southwest Piauí, and extreme west Bahia. Some areas with an intermediate pace of expansion in planted areas were also identified. Underlying this process, the selected mesoregions concentrated 90% of the area planted with cotton in Brazil. These values are also significant for soybeans (almost 75%) and corn (63%).

In terms of the share of growth in agricultural area per crop, the results showed the central role that is played by cotton with relation to soybeans and corn. LGC for cotton was higher than LGC for soybeans after 1998, and surpassed LGC for corn throughout the entire series. This disparity increased from 1998 to 2010 and only began to decrease in recent years. Another interesting aspect is the behavior of LGC for corn, which resembled the LGC for all crops.

Comparatively, both LGC and LQ seemed to indicate a relatively cotton concentrated expansion of agricultural areas in the selected mesoregions. This expansion is less concentrated in soybeans and even less concentrated in corn. Of course, this process can be completely different in each of the forty-two selected mesoregions, which is another point for further investigation.

This set of conclusions may support public policies related to regional aspects of agricultural expansion in Brazil, particularly for corn, soybeans, and cotton. Even though some studies, such as Câmara *et al.* (2015), have evaluated that Brazil is able to cope with environmental concerns and intense agricultural production, there is still space for debating.

Another important aspect is considering that soybean-cotton-corn expansion can diminish available area for producing other typical food products domestically consumed, such as beans, fruits, rice, wheat and edibles vegetables, roots and tuber. Kostandini, Mykerezi, and Escalante (2013) cited output choices among the factors affecting farm labor shortages. Indeed, these effects do not limit themselves to the agricultural labor markets; they also affect the final food price levels.

Other crops can also be included in future analysis, and consequent studies could include variables to identify reasons behind different growth rates, such as water availability or land and soil conditions. New studies are also welcome especially at country level and may explore the dynamics of specific mesoregions, analyze the supply of agricultural inputs in frontier mesoregions, or even measure productivity levels for other crops inside the identified areas.

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