Champions in production, champions in development?

An analysis of socioeconomic indicators in soy production territories in Brazil

ARILSON FAVARETO[1,2], LOUISE NAKAGAWA[1], LUCAS SILVA[2], THIAGO MORELLO[2], BRUNA FERNANDES[2]

[1]Centro Brasileiro de Análise e Planejamento (CEBRAP)

[2]Universidade Federal do ABC (UFABC)

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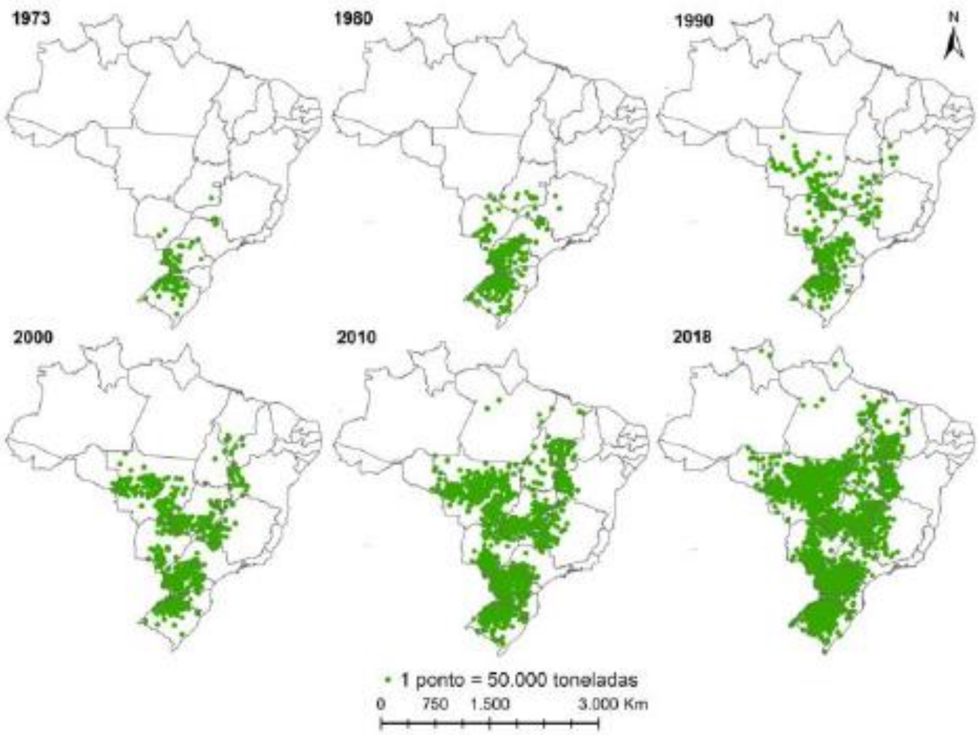
Summary

1. Introduction

For a few decades, Brazil went from being a country with a deficit in food production to one of the world's largest food exporters (Vieira et al. 2019). In this context, soy has become the main product planted and exported (Embrapa, 2021). In 30 years, the area planted in soy has grown by more than 200%, while production increased by around 500% (Embrapa, 2019). In 2019, around 36 million hectares of soy were planted (4.3% of the Brazilian territory), and the total amount exported surpassed US$ 40 billion in 2018 (Agrostat, 2018, Trase, 2019; Soterroni et al., 2019) – approximately 70% of production is exported. Around 50% of the total amount of soy is cultivated in the Cerrado, and 14% in the Legal Amazon (MapBiomas, 2021).

Up until the 1970s soy plantations were restricted to southern Brazil, where small-scale farmers are predominant. From that point on, soy planting began spreading throughout the Brazilian hinterland and advancing into tropical systems, like the Cerrado and the Amazon (Figure 1). After the 1980s, the consolidation of soy production occurred mainly in the Cerrado, in central Brazil. During the following decade it advanced towards the Amazon frontier. With soy expansion in Central Brazil and its more recent advance towards the Matopiba region (Cerrado area in the states of Maranhão, Tocantins, Piaui and Bahia), the Cerrado is the biome most affected by land use changes caused by agricultural expansion (Carneiro & Costa, 2016; PAM, 2019; Soterroni et al. 2019).

Figure 1. *Soy production (tons) from 1973 to 2018.*



Source: GEMAP (2019) based on PAM/IBGE. Prepared by Valdemar Wesz Jr in Leite (2020).

However, does that performance translate into good development indicators? The argument presented by business leaders is unequivocal: soy's overall contribution to agribusiness is positive in that it transforms regions marked by precarious and lethargic economic activity into prosperous areas with positive development indicators (Abag, 2016). Problems such as deforestation are seen as the necessary price of progress. Scientific evidence, however, shows that those effects are at best ambiguous.

On one hand, the presence of soy is associated with improvements in agricultural and ranching production (Embrapa, 2021), GDP (Vieira et al., 2019), income (VanWey et al., 2013; Weinhold et al., 2013), employment (Weinhold et al., 2013; Brandão et al., 2005) and poverty reduction (Weinhold, Killick & Reis, 2013; Sassen, 2014; Cheng et al., 2019). There is also evidence of a positive correlation between the presence of soy and the performance of social variables. Some of this evidence is measured by summarised indicators such as the Human Development Index, or by specific indicators such as educational quality (VanWey et al., 2013; Garrett & Rausch, 2016).

On the other hand, because soy cultivation leads to concentrated and land ownership and higher land prices, it tends to expand income inequality (Garrett et al., 2013; Garrett & Rausch, 2016; Weinhold et al., 2013). There is also research indicating problems related to migration, rural exodus and a possible increase in urban poverty due to the displacement of small-scale producers and workers (Domingues & Bermann, 2012; Alves, 2015; Sauer, 2018; Carvalho et al., 2019). Since expanding soy cultivation is associated with large and highly mechanized properties, the jobs produced may not be enough to absorb those who have been displaced from their traditional means of support, which may be a cause of several types of social conflicts (Weinhold, Killick & Reis, 2013; ActionAid, 2017; Sauer, 2018; Cerqueira et al., 2020; Porto-Gonçalves; Chagas, 2021). Land-grabbing and land speculation are among of the most notable aspects in those conflicts (Alves, 2009; Frederico & Buhler, 2015; Pereira & Pauli, 2016; Bassi, Castilho & Vendrame, 2017; Dulci, 2017; Pitta, Boechat & Mendonça, 2017; Stabile et al., 2020). And there is a vast literature pointing out the environmental problems related to deforestation (Sassen, 2014; Rajão et al., 2020; Reis et al., 2020; Vasconcelos et al., 2020), biodiversity erosion (Souza, Teixeira & Ostermann, 2015; Green et al., 2019; Duran et al., 2020), carbon emissions (Rekow, 2019; Escobar et al., 2020), pesticide use and its effects on human health (Bombardi, 2012; Pignati et al., 2017; Greenpeace, 2019) and an important increase in water conflicts (CPT, 2020).

Furthermore, there is a complex and interdependent dynamic involving sectors (soy and ranching) and regions (Cerrado and Amazon) (Sawyer, 2009; Silva & Oliveira, 2018; Carvalho et al., 2019; Lima et al., 2019; Marques et al., 2019; Waroux et al., 2019; Stabile et al., 2020). With the soy crop expansion, other agricultural activities such as ranching, are moved into the Amazon and cause the so-called indirect effects on the environment and local groups. Besides being ambiguous, the impact of large-scale crop systems tends to be quite heterogenous. The studies performed so far have generally been restricted to a single region or biome (Weinhold et al., 2013; Favareto et al., 2019; Lopes; Lima; Reis, 2021). Other limitations involve a temporal scope limited to one decade (Weinhold et al., 2013; Lima-de-Oliveira; Alonso, 2017) or a lack of intertemporal comparison (VanWey, 2013).

In this report we seek to circumvent some of those limits. With data covering a period of almost twenty years from 1991 to 2010, the period of soy expansion in Brazil, and covering every Brazilian municipality, we used a combination of methods and an unprecedented range of data. The result was a unique contribution towards investigating the territorial effects of soy expansion.

The main results obtained may be translated into five key messages, summarised below:

a) From the socioeconomic perspective alone, the effects of soy in the producing regions do not back up the narrative that negative impacts would be offset by positive effects on economic and social indicators. The scenario presented is heterogeneous considering the major regions of Brazil in terms of indicators such as income, poverty and infant mortality, when separately analysed. Besides that, there is a group of indicators for which the results observed are inconclusive: inequality, HDI, occupation/employment, GDP and number of years in school.
b) When the indicators are combined in the soy-producing municipalities, an intermediate situation predominates: 46% of municipalities present a better than average performance in approximately half of the indicators analysed, but worse in the other half; next comes the group of municipalities that have lower than average performance in at least two-thirds of the indicators analysed, which covers 33% of the soy-producing municipalities; and finally, only 21% of producing municipalities have above-average performance in at least two-thirds of the indicators.
c) On the subset of municipalities with higher-than-average soy production, the situation is repeated. There is a greater concentration of locations with intermediate performance; 54.6% of the municipalities now present better than average results for approximately half of the indicators analysed, but worse than average for the other half. Next comes the group of municipalities with performance below at least two-thirds of the indicators analysed, with 26.7% of the municipalities in that group; and, finally, only 18.5% of the municipalities have a higher performance in at least two-thirds of the indicators.
d) Finally, if one considers only the twenty “champion” municipalities of 2020 in Brazilian agribusiness (elected according to their value of agricultural production in 2020), almost all of them focused on soy production, the pattern is once again repeated. Only three of them have a higher-than-average performance in two-thirds or more of the indicators analysed; four municipalities are at the other extreme, with below average performance inferior in two-thirds or more of the indicators analysed. The great majority (13 municipalities) are in an intermediate situation, with a superior performance in approximately half of the indicators, lower performance inferior for the other half.

To demonstrate these ideas this report is organised into three parts, besides this introduction and a short conclusion. In the next section (2) we detail the existing literature regarding quantitative evidence on the effects of soy in Brazil. Section 3 presents the methodological aspects of this study, presenting the data and procedures employed. Section 4 sets out the results, in dialogue with the literature. The conclusion provides a summary of the results and the main issues for continuing this research.

2. What does the literature say?

2.1. The five most relevant aspects in the existing literature on soy's territorial impacts

According to the literature review, five relevant aspects may be listed. They concern the type of evidence mobilised, prioritised themes and scale of the data used by researchers:

- **Most of the studies in soy production are focused on environmental impacts, mainly on deforestation and its effects. And there is a dispute of narratives regarding the role played by soy crops.**

Most of the studies reviewed presented negative impacts regarding the environmental effects generated by the production of soy and cattle in the Brazilian Amazon and Cerrado. These impacts refer mainly to the deforestation and conversion of native vegetation (Fearnside, 2005; Angelsen, 2010; Prado, 2011; Meirelles Filho, 2014; Garcia et al., 2019; Lima et al., 2019; Rajão et al., 2020; Stabile et al., 2020; Trase, 2020; Vasconcelos et al., 2020), to land-use changes (Hunke et al., 2014; Silva and Oliveira, 2018; Vieira Filho, 2018; Soterroni et al., 2019; TNC, 2019; Waroux et al., 2019; Alencar et al., 2020; Guedes Pinto et al., 2020), to biodiversity loss, especially of endemic species (Green et a., al., 2019; Rekow, 2019; Duran et al., 2020), and to carbon emissions (Strassburg et al., 2009; Brancalion et al., 2017; Escobar et al., 2020), that further aggravate climate change. The relationship established by the authors between the advance of commodity production and the increase in the suppression of vegetation cover, which is mostly illegal (Guedes Pinto et al., 2020; Rajão et al., 2020; Reis et al., 2020; Vasconcelos et al., 2020) is remarkable. With that, at least two competing narratives emerge.

The first reinforces the need and urgency to not expand agricultural activities into native vegetation areas, but to occupy areas that has been previously deforested (pastures). And combined with that, implement an efficient policy for reducing deforestation. As mentioned earlier, the rapid expansion of commodity production is associated with increased deforestation, but not only that. This expansion results in other environmental impacts equally as serious as deforestation, such as water scarcity and river silting (Fearnside, 2005; Hunke et al., 2014; Bolson, 2018; Guidotti et al., 2020), pesticide contamination (Bombardi, 2012; Pignati et al., 2017; Rekow, 2019), the loss of pollinating insects (Priess et al., 2007) and endemic species that depend on the ecosystem to reproduce and feed (Vynne et al., 2010; WWF, 2015) and reduction of the carbon stock due to biomass loss (Salati & Nobre, 1991; Nogueira et al., 2018; Roitman et al., 2018; Silva, 2018). The studies that support this narrative question the efficiency of the policies in place and highlight the fragility of Brazilian environmental legislation, such as the Forest Code (Sparovek et al., 2012; Rajão et al., 2020; Trase, 2020) and the monitoring of areas where agricultural activities occur (Fearnside, 2005). They also point out that even market mechanisms, such as the Soy Moratorium in the Amazon, are insufficient for ensuring the non-conversion of forests to pastures (Carvalho et al., 2019; Lima et al., 2019; Waroux et al., 2019). In that regard, several studies have reinforced the need for policies that encourage and demand the reduction of deforestation linked to more efficient mechanisms of traceability and the transparency of the soy and beef value chain (Fearnside, 2005; Angelsen, 2010; TNC, 2019; Ferguson, Sekula and Szabó, 2020; Rajão et al., 2020; Reis et al., 2020).

In contrast, the second narrative seeks to address the issues of environmental impacts by suggesting improvements in agricultural activities and the use of new technologies, such as intensified livestock raising (Cerri et al., 2018; Vieira Filho, 2018), the increase in productivity with low costs (Saath & Fachinello, 2018; TNC, 2019), the use of sustainability indicators (Agol et al., 2014) and the implementation of integrated crop-livestock-forest systems (ICLF) (Balbino et al., 2012; Cerri et al., 2018). They agree, therefore, with the previous narrative regarding the importance of productive intensification in already deforested areas, but in this group of authors the emphasis is put on implementing market mechanisms, such as payments for environmental services (PES) (TFA, 2020) and certification strategies as a way to reduce deforestation and environmental illegalities (Brancalion et al., 2017; Ingram et al., 2018; Ferguson, Sekula and Szabó, 2020). In addition, they highlight the need for land regularization to reduce cases of land-grabbing and land speculation (Carvalho et al., 2019; Stabile et al., 2020), as the price of land is still an important factor that mobilizes the suppression of native vegetation. Other strategies that have been pointed out as alternatives are investments in private reserves (Negrões et al., 2011; Lima & Franco, 2013) and the promotion of technical assistance for small-scale rural producers (Brancalion et al., 2017; Stabile et al., 2020).

- **There is more attention to monetary indicators (GDP, income, exportation, productivity) among the studies focused on economic impacts generated by soy production. And the results are not homogeneous.**

When dealing with the economic impacts generated by the production of agricultural commodities, a significant part of the studies point out that despite the environmental, political and social problems, there has been a behaviour change of the sector through the development and application of new technologies and conservation practices (Buainain et al., 2014; Brancalion et al., 2017; Latawiec et al., 2017; Buainain, Garcia & Vieira Filho, 2017; 2018; Cerri et al., 2018; Saath & Fachinello, 2018; Viera Filho, 2018; TNC, 2019). This is reflected directly in international negotiations, as well as in increases in the exported volumes (Agrostat, 2018; Embrapa, 2019; Soterroni et al., 2019; Trase, 2019). This new pattern of agriculture has been strengthened in recent years and is considered to have brought development and economic growth to the producing regions (Buainain et al., 2014; Castro, Miranda &

Lima, 2015), with improvements above all in the income (Weinhold, Killick & Reis, 2013) and job creation (Roessing & Lazzarotto, 2004; Abag, 2016).

Within this context there are two more competing narratives. The first, represented by researchers who demonstrate positive economic impacts, is supported by studies that indicate a strong correlation between the increase in production and exports, and GDP growth of the producing municipality (Buainain & Garcia, 2016; Serigati & Possamai, 2016). Other studies show a positive correlation between the increase in soy production and growth in per capita income in the producing regions, with a consequent reduction in monetary poverty (Domingues & Bermann, 2012; Weinhold, Killick & Reis, 2013).

On the other hand, there is portion of the economic studies that highlight the negative impacts of the advance of commodities. Some authors emphasise that these studies are restricted to the use of monetary indicators (Cheng et al., 2019). And unlike the studies that aim to demonstrate improved incomes and poverty reduction, researchers call attention to the high concentration of financial and land resources by a small group of producers and transnational companies (Pita, Boechat & Mendonça, 2017; Favareto et al., 2019; Guedes Pinto et al., 2020; Rajão et al., 2020). This is because the indicators used by many studies only analyse flows, not stocks, e.g., they do not consider property concentration. Other studies show how the results, even considering only monetary indicators, are more heterogeneous between regions, and between municipalities in the same region (Favareto et al., 2019), or how, even where there is a reduction in poverty, there is a simultaneous increase in inequality (Weinhold et al., 2013; Favareto et al., 2019). In other words, the positive impacts of the agribusiness expansion cannot be generalized. As a result of this concentration of income, there is a migration from the most vulnerable places to other neighbouring municipalities, which gives the false impression that economic indicators have improved (Favareto et al., 2018; Sauer, 2018). This dynamic of wealth concentration has a notable impact on the regional development of producing municipalities (Heredia, Moreira & Leite, 2010), which are transformed into islands of production with a low dynamic and weakly diversified economy (Favareto et al., 2018).

- **Most of the studies in soy production on social impacts are related to agrarian conflicts and food insecurity. However, little attention is paid to other dimensions relevant to the well-being of the population in the producing regions.**

When reviewing the literature on the socioeconomic impacts resulting from the expansion of agricultural commodity production, what is observed is that most studies are linked to land conflicts and issues related to food insecurity. As was pointed out in the previous subsection, while the advance of commodities generates positive impacts in producing regions, such as economic growth, income increasing and decline of poverty, on the other hand, the activity generates a high concentration of wealth and especially of land. This has brutally interfered in the distribution of resources and led to an increase in social inequality and has also influenced the increase of land prices and land speculation

(Sauer & Leite, 2012; Dulci, 2017; Pita, Boechat & Mendonça, 2017; Sauer, 2018; Rede Social de Justiça e Direitos Humanos, 2018), resulting in land grabbing and increased of violence in rural areas (AATR, 2017; ActionAid, 2017).

These conflicts have generated migratory movements to neighbouring cities, where people were searching for lower costs of living. Authors such as Ribeiro, Silva & Corrêa (2015), Flexor & Leite (2017), Sauer (2018), Favareto et al. (2018) and Almeida & Junior (2019) claim that the expansion of monocultures has increased the land prices and land disputes. The Pastoral Land Commission (CPT in Portuguese) has noted that those small farmers are being expelled from their properties, increasing the rural exodus. Land prices in the agricultural frontier regions have increased substantially since the 2000s (Pita, Boechat & Mendonça, 2017). This has motivated land speculation, expropriation, and resistance from large farmers who do not recognize the rights of indigenous people and traditional communities. All these factors intensify the conflicts (AATR, 2017; Sauer, 2018; Rede Social de Justiça e Direitos Humanos, 2018). Furthermore, the areas previously used by those communities have now been occupied by large farmers. Very often, this occupation is illegal. This is the way those farmers have found to offset deforestation in other regions. This new type of Legal Reserve compensation, known as green land grabbing (Sauer & Borras Jr, 2016) has generated severe conflicts, especially in the Matopiba region (Favareto et al., 2018).

According to CPT (2019) in the document "Conflicts in the Countryside in Brazil", of the total of records of agrarian conflicts in 2019, 60% occurred in the Amazon region. From the total of 32 murders, 27 happened in the same biome (84.4%). The struggle for access to water is another issue that has increased, especially with the impacts of climate change. In only one year, from 2018 to 2019, the increase in conflicts over land was 77%. In ten years, from 2010 to 2019, these occurrences increased by more than 68%, going from 13.3 to 53.3 million hectares of claimed land. In the same period, conflicts over water increased by 18%, while the number of people involved grew by 71%.

Another document that shows an overview of rural conflicts in Brazil, published by the Institute for Applied Economic Research (IPEA in Portuguese) is the "Atlas of Rural Violence" (Cerqueira et al., 2020). The authors point out that there is a positive correlation between the homicide rate and indigenous territories and land reform settlement projects, beyond the Legal Amazon. The authors conclude that the homicide rate is higher in rural municipalities where there is a greater socio-economic vulnerability for youth. Within this context, several works have highlighted the violence against rural workers, indigenous populations, and traditional communities such as quilombolas, babaçu-nut harvesters, riverine populations, communities that raise cattle on communal properties, long-established Cerrado inhabitants and other and other traditional Brazilian groups (Alves, 2015; Heck & Menezes, 2016; AATR, 2017; ActionAid, 2017; Favareto et al., 2018; Rede Social de Justiça e Direitos Humanos, 2018; CPT 2019).

Food insecurity is another critical topic brought up in the literature that refers to the production of agricultural commodities and their socio-economic impacts. For authors such as Grisa, Gazolla & Schneider (2010), Silva (2011) and Sauer & França (2012), the growing investments in the monocultures production, especially soy, have raised serious concerns regarding the increase in exposure to food insecurity and nutrition of the most vulnerable populations. According to Silva (2011), by dismantling the production of basic foods, the cultural ties are broken, and the environmental balance is altered. Therefore, family farming has increasingly lost space, importance, and incentives, which impacts not only on food security but the diversification of production and the socio-economic dynamics of the region. By promoting family farming, small-scale farmers are less exposed to market prices fluctuations (Sarris, 2013). In addition to maintaining their food autonomy (self-consumption), family farming is not only a source of monetary income but a way to reduce expenses with the acquisition of food and a way that diversifies the livelihoods of those families (Grisa, Gazolla & Schneider, 2010). Nevertheless, these studies address the issue in general terms, without mobilizing evidence on specific producing regions.

- **There is a lack of studies in soy production on socio-economic impacts covering the national/biome scale.**

Also, regarding the literature on the socio-economic impacts of commodities, what is observed is that there are many more studies with local approaches than on a national or biome scale. The findings in the studies refer primarily to the effects of the expansion of monocultures at community, municipal or, at most a regional level (Weinhold, Killick & Reis, 2013; Hunke et al., 2014; Ribeiro, Silva & Corrêa, 2015; Pignati et al., 2017; Sauer, 2018; Silva & Oliveira, 2018; Almeida & Junior, 2019). Research dealing with the Brazilian Amazon or Cerrado uses an emblematic municipality or a region of more significant importance over a given theme as its scope. As an example, we can point the soy production in the region of Sorriso, in the state of Mato Grosso (a city well known for its agricultural production), or Santarém, in Pará (which, despite its economic importance has cases of land and social conflicts), or a recent set of studies on the Matopiba region.

- **The studies on land-use change and soy production are limited to the spatial analysis of selected indicators. There is a lack of territorial studies considering the interdependencies of land use change, socio-economic effects and environmental impacts in commodities producing regions.**

In addressing the impacts generated by land-use change, most of the work is focused on spatial analysis. These studies use satellite images and sophisticated models of quantitative analysis to understand and project the advance of deforestation and land occupation (Guedes Pinto et al., 2020; Rajão et al., 2020; Vasconcelos et al., 2020), agricultural capacity (Barreto et al., 2013; Piatto & Inakake, 2016; Silva & Oliveira, 2018; TNC, 2019), the potential of carbon emissions (Strassburg et al., 2009; Escobar et al., 2020), among others. Although these studies incorporate the spatial heterogeneities of the landscape, few research analyse these impacts from a territorial perspective, supported by qualitative analyses. As mentioned in the previous subsection, a similar situation was observed in the studies of the social implications in the territory. The scope of the studies generally has a very small scale, which makes it difficult to understand the dynamics of land use on a larger scale than the local scale.

Another important finding was noted. Most studies related to the theme deal with environmental and socio-economic impacts as separate events. These analyses are made under specific and very different dimensions. In the case of socio-economic impacts, the research is based on monetary indicators such as income, production, consumption, exportation. Still, others expand the field of analysis and consider access to education and health. These indicators are commonly used to measure poverty and well-being. Similarly, environmental impacts are also analysed only from the perspective of effects on the ecosystems, biodiversity and ecosystem services. The metrics used by the researchers are restricted to the calculation of carbon emissions, habitat and species loss, loss of forest cover, soil depletion, water pollution and water capacity, etc.

However, authors like Weinhold, Killick & Reis (2013), Sassen (2014) and Cheng et al. (2019) note that there are other dimensions of poverty and well-being that must be considered, e.g., cultural differences, access to ecosystem services, gender differences and others. Thus, it is crucial to consider the interdependencies between the social, economic and environmental dimensions, and the integration between these dimensions in a more robust and broader framework analysis.

Cheng et al. (2019) point out that it is possible to mitigate poverty through environmental improvements. However, to do this one must understand how the different aspects of poverty respond to factors of environmental dynamics. Sassen (2014) also stresses the importance of biodiversity conservation as a way of mitigating poverty. For example, the forest can offer ecosystem services such as clean water, leisure and food and promote benefits for the group of individuals living on the site, improving their mental health, physical security, cultural integrity, social relationships, etc. In the study by Sassen (2014), the author finds that it is the institutional, social and political context in which individuals act that influences the results of agricultural activity, and preservation of forests. Therefore, another point requiring attention is that the expansion of agriculture and deforestation cannot be directly associated with socio-economic indicators under a single dimension such as demography or price.

3. Material and methods employed

3.1. Data employed and the aggregation of municipalities into Minimal Comparable Areas

A municipal-scale database was organised with information from several sources. For variables related to crop areas three sources were used: Municipal Agricultural Production (PAM), Agriculture and

Ranching Census and Atlas of Brazilian Pastures (prepared by the Image Processing and Geoprocessing Laboratory, LAPIG). For socioeconomic data we used the Demographic Census and other studies produced by the Brazilian Geographical and Statistical Institute (IBGE). The list of variables used, and their respective sources are indicated in Table 1, below.

Table 1. *Socioeconomic variables in the database.*

GROUP	VARIABLE	REASON FOR INCLUSION	SOURCE
Dependent: economic measure	Municipal GDP (by BRL 1,000)	Weinhold et al., 2013	IBGE
Dependent: economic measure	Average income (BRL)	Weinhold et al., 2013; VanWey et al., 2013	Demographic Census
Dependent: economic measure	Average income for 1st and 5th quintile (BRL)	Weinhold et al., 2013; VanWey et al., 2013	Demographic Census
Dependent: social measure	Gini coefficient	Garret and Rausch, 2016	Atlas of Human Development
Dependent: social measure	Theil index	Weinhold et al., 2013; Garret and Rausch, 2016	Atlas of Human Development
Dependent: social measure	Municipal HDI	Garret and Rausch, 2016	Atlas of Human Development
Dependent: social measure	Number of poor	Weinhold et al., 2013	Demographic Census
Dependent: social measure	Infant mortality (deaths per thousand births)	Makhlouf, Yousef and Vinogradov, 2017	Atlas of Human Development
Dependent: social measure	Unemployment	Favareto et al., 2019	Demographic Census
Dependent: social measure	Educational level (expected years in school)	VanWey et al., 2013	Atlas of Human Development
Main explanatory variable	Area in soy (ha)	Weinhold et al., 2013	Municipal Agricultural Production

GROUP	VARIABLE	REASON FOR INCLUSION	SOURCE
Main explanatory variable	Area in soy	Weinhold et al., 2013	MapBiomas
Control: sectoral structure	Industrial GDP (by BRL1,000)	Novais, Acca, Favareto, 2019	IBGE
Control: sectoral structure	Service sector GDP (by BRL1,000)	Novais, Acca, Favareto, 2019	IBGE
Control: sectoral structure	GDP primary sector (including agriculture) (by BRL1,000)	Novais, Acca, Favareto, 2019	IBGE
Control: infrastructure	Total road extension (km)	VanWey et al., 2013	Atlas Milton Santos
Control: infrastructure	Proportion population with access to basic sanitation	VanWey et al., 2013	UNDP (Primary: Census)
Control: infrastructure	Proportion population with access to electricity	Gómez and Silveira, 2010	Census
Control: agricultural confounders	Area in pasture (ha)	Weinhold et al., 2013	Atlas of Brazilian Pastures
Control: agricultural confounders	Area annual crops except soy (ha)	Weinhold et al., 2013	Municipal Agricultural Production
Control: agricultural confounders	Area annual crops except soy (ha)	Weinhold et al., 2013	MapBiomas
Control: agricultural confounders	Area agricultural establishments (ha)	Weinhold et al., 2013	Agriculture and Ranching Census
Control: agricultural confounders	Area permanent crops (ha)	Weinhold et al., 2013	Municipal Agricultural Production
Control: agricultural confounders	Area annual crops except soy (ha)	Weinhold et al., 2013	MapBiomas
Control: general	Area municipality (ha)	Weinhold et al., 2013	IBGE
Control: general	Rural population	Weinhold et al., 2013	Demographic Census
Control: general	Urban population	Weinhold et al., 2013	Demographic Census

Note: data obtained from satellite images and processed by the MapBiomas consortium are highlighted in dark grey.

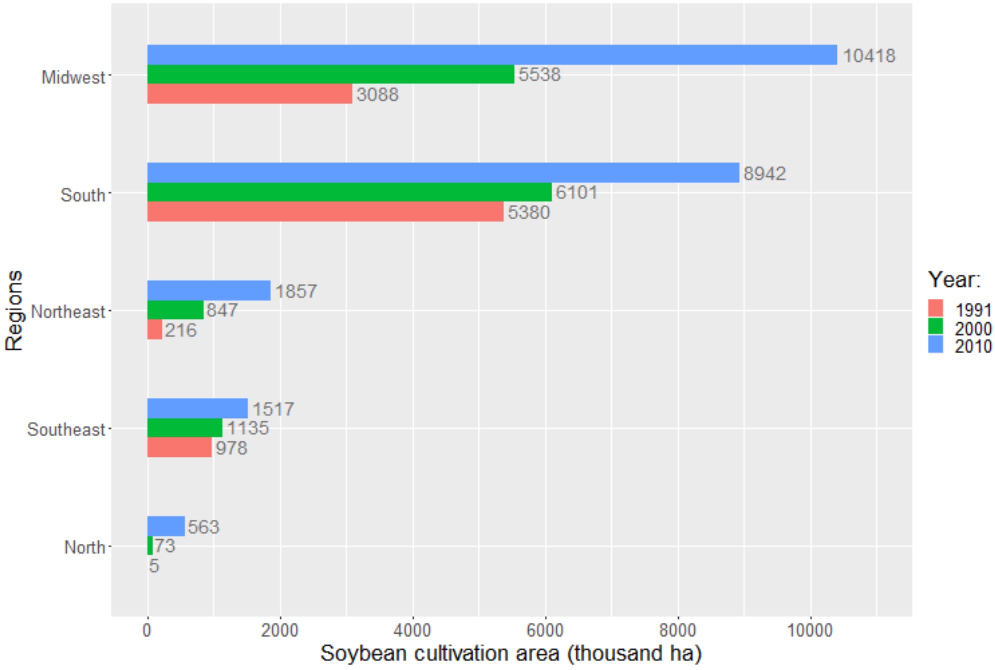
The base years for the data used cover the last three decades, the period of marked expansion of soy production in Brazil (Embrapa, 2021). The data panel follows the periodicity of the IBGE Demographic Census, the principal source of information: 1991, 2000 and 2010. However, the data for rural establishments are available only in the Agriculture and Ranching Census, available for the years 1985, 1995, 2006 and 2017. The Municipal GDP is not available for 1991, but there are data for 1985 and 1996. Therefore, as a proxy for these variables a linear interpolation was performed on the years closer to them.

Another difficulty to be solved involves the significant transformation of the municipal network for the period analysed. To compare the information, it was necessary to combine the municipalities that underwent changes into Minimum Comparable Areas (AMC). The procedures adopted are described in appendix 1. Implementation of that procedure led to the creation of 3,822 AMC, with 3,037 involving one municipality and 785 representing than one. Thus, the municipalities that involve a single AMC had the values of their variables totalled or a weighted average was produced for the resident population in each year. Hereinafter, the term "municipality" is used as equivalent to an AMC.

3.2. Use of data

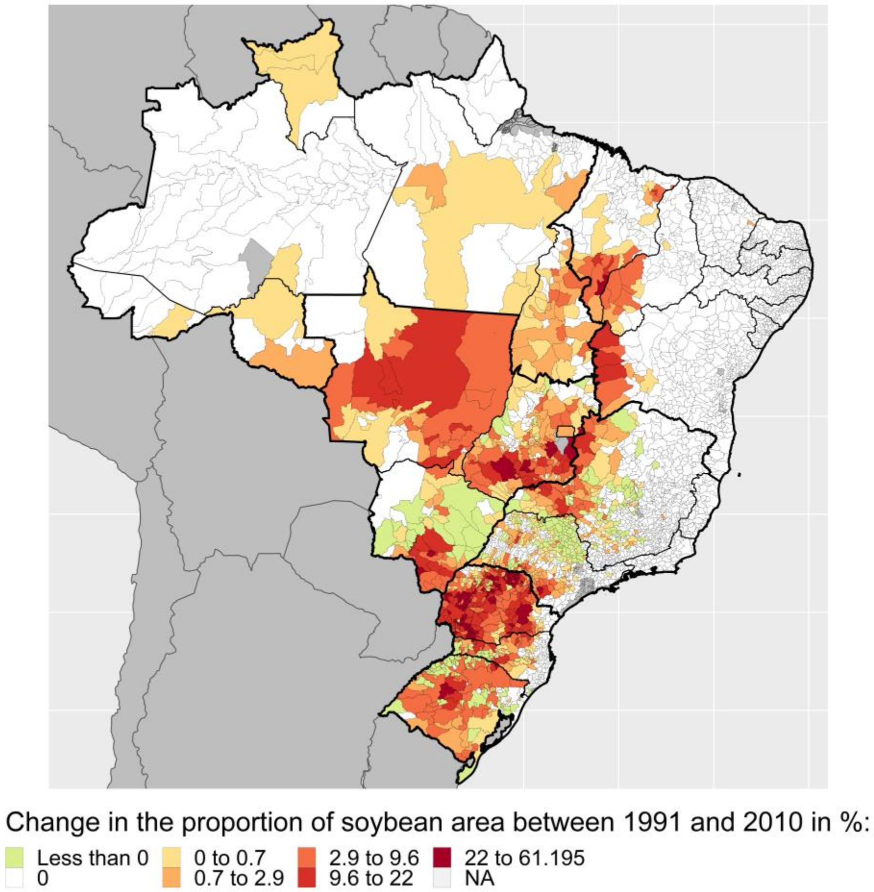
Regarding the variable to be used to attempt to understand the effect, i.e., the expansion of soy measured by the crop area, the graph in Figure 2 illustrates that during the period from 1991 to 2010 the Centre-West region overtook the South as the region with the most area allocated to soy growing, with the significant multiplication factor of 3.4 in the planted area. There was also a lower, but still significant increase in the South region, where the area in soy increased 1.7 times from 1991 to 2010. The presence of soy was not as great in other regions, although one can note soy gaining a foothold in the Northeast during this period, and in the North, especially from 2000 to 2010. As for the Southeast there was lower growth compared to the other regions. The map in Figure 3 identifies areas with an increase in the proportion of land allocated to soy. It presents the spatial distribution of the difference in the ratio between the area in soy in 1991, divided by the total area with the ratio for soy in 2010. The greatest changes are seen exactly in the South, notably in Paraná, and the Centre-West, where there is a sharp rise in southern Mato Grosso do South, a large portion of Mato Grosso and eastern and southern Goiás.

Figure 2. *Area in soy by region from 1991 to 2010 (thousand hectares).*



Source: Prepared by the authors with data from Municipal Agricultural Production (IBGE).

Figure 3. *Map showing change in proportion of Area in soy from 1991 to 2010.*



Source: Prepared by the authors with data from Municipal Agricultural Production (IBGE).

Based on the regions that showed a positive variation for the area in soy cultivation, we have sought to present the heterogeneous nature of social variables in areas where expansion has occurred, using econometrics to investigate possible relations between the variables. Table 2 shows the descriptive statistics for the variables used in the regression.

Table 2. *Descriptive statistics (Reis et al., 2005).*

Variables	N.	Average	Standard Deviation	Min.	Max.
GDP (BRL thousand)	11,465	328,400.10	3,235,053.00	-571.6	197,933,954.00
Average income (per capita)	11,466	365.2	225.1	43.7	2,043.70
Average income for 1st quintile	11,466	71.9	58.8	0	377.4
Average income for 5th quintile	11,466	1,032.20	640.4	103.6	6,735.10
Theil	11,466	0.5	0.1	0.1	3.2
Gini	11,466	0.5	0.1	0.3	0.9
Number of poor	11,466	5,338.20	11,733.10	0	269,146.00
Infant mortality (per thousand children)	11,466	33.4	19.9	8.6	120.1
Unemployment rate	11,466	0.1	0.1	0	0.6
Years in school (expected)	11,466	8.5	1.8	0.9	12.8
Area in soy crop (ha)	11,297	4,130.10	44,860.50	0	3,669,517.00
Area in annual crops (ha)	11,297	13,211.10	70,023.80	0	5,430,268.00
Area in perennial crops (ha)	11,463	136.2	1,745.00	0	78,567.30
Area in rural establishments (ha)	11,389	91,890.20	370,167.30	3.5	14,112,940.00
Area in pasture (ha)	11,463	40,883.40	147,722.00	0	5,255,485.00
GDP Agriculture and Ranching	11,465	19,009.20	46,227.60	-59,195.50	1,727,611.00
GDP Industry	11,465	89,181.40	783,230.80	-1,126.60	50,034,770.00
GDP Services	11,465	185,376.30	2,094,976.00	-20,283.00	129,378,778.00
Extent of federal highways (km)	11,466	18.8	50	0	1,714.10
Persons without electricity (%)	11,466	13.3	19	0	97
Persons with inadequate sewerage (%)	11,466	12.6	17.8	0	98.8
Total area	11,466	222,469.30	1,090,023.00	361.2	34,941,156.00
Rural population	11,466	8,504.20	16,370.50	0	621,065
Urban population	11,466	35,746.60	222,404.20	332	11,152,344

To describe the behaviour of the change in soy variable and variables of interest (income per capita, Gini coefficient, proportion of extremely poor – those families with or less than BRL 70 of income per capita per month – in relation to total population in the AMC, infant mortality, expected years in school and unemployment rate) we grouped the AMCs based on similarity in the values for expansion and presence of soy in 2010. Two variables were used to define the groupings. We first sought to capture the temporal dimension by using the temporal variation in the parcel of the area of the AMC occupied by soy from 1991 to 2010 as the basis. Next, to capture the relative size of areas under soy cultivation, we used the parcel of the area of the AMC occupied by soy in 2010.

Since the cluster analysis is purely descriptive and does not attempt to measure correlations, there was no need to include control variables. In that regard, there was no need to add interpolated variables, so that a new AMC network was created for 1991, 2000 and 2010 with 4,258 AMC.

The method employed for classifying the productive areas was *k-medoids* or *partitioning around medoids* (PAM). This algorithm, based on a number *k* of previously selected groups, partitions observations into clusters seeking to minimise the distance of one observation that represents the centre of the group (*medoid*) from the other observations. In other words, given a measure of distance between an observation with x with k *medoids*, x will be classified as belonging to the group with the shortest distance in relation to the *medoid*. In this case, the measurement for distance used was Euclidean with values normalised. As a criterion for selecting the number of groups (k), we used the silhouette average. The silhouette is a measure that seeks to compare how similar an observation is to its respective cluster, with 1 being perfect similarity and -1 perfect dissimilarity. We thus used the average of this measure for scenarios where the number of clusters is from 1 to 20 and took the *k* with the highest average as the appropriate number of clusters.

This method was applied in every region in Brazil, but we limited the analysis to the soy-producing municipalities in 2010 (AMC with crop areas higher than zero), thus avoiding an excessive number of clusters when analysing all of Brazil, which might have complicated results interpretation.

3.3. Econometric model

To determine if the presence of soy in Brazilian municipalities causes socioeconomic metrics that are different from those in other municipalities, econometric models were estimated in a panel explaining each of the dependent variables listed in table 3. Two estimators were used: (i) fixed effects; and (ii) random effects. Furthermore, robust variance-covariance matrices for non-sphericity were employed. To ensure a more useful estimate, we used the Sargan-Hansen tests for overidentifying restrictions to stipulate whether the model of effects is adequate (null hypothesis) or if fixed effects (alternative hypothesis) are better (Arellano, 1993). For this we will estimate the following equation:

$$\mathrm{Development}_{ti} = \beta_0 + \beta_1 \log(\mathrm{area\ soy})_{t,i} + \mathrm{controls} + a_i + \varepsilon_{ti} \quad (1)$$

The measures for development as well as a preliminary list of control variables are found in Table 3. We also included interaction between soy planted area and the region (by multiplying the soy area by the binary variable that identifies a specific region; we also considered versions with the states, but these were not consistent, as will be explained in the next paragraph) and interaction between the region and the year to control, according to regional specificities, the relation between soy and the dependent variable. The soy area versus region permits capturing regional heterogeneity in the influence of soy area in the socioeconomic factor standing as the dependent variable.

Alternative specifications were estimated using a robustness test. Specifically, we implemented different regressions with variations in secondary elements (e.g., removing outliers by excluding observations above the top 5% percentile) by interacting (multiplying) binary variables for Brazilian states by the area in soy and/or year. That means that instead of considering terms of interaction involving major regions on the one hand, and on the other area in soy or binary values for the year, as was done in the final model, we considered terms of interaction for the states. The dependent variables with a sign for the coefficient for the area in soy with a relevant variation comparing the alternative specifications and the final specification were considered inconclusive, in other words, subject to unacceptable uncertainty and thus omitted from the results.

Table 3. *Results of estimating fixed effects with robust variance.*

Independent var.	**Income per capita (log.)**	**Average income 1st quintile (log)**	**Average income 5th quintile (log.)**	**N. Poor (log)**	**Infant mortality**
Area in soy (log.)	0.0079**	0.0280**	0.0037	-0.0361***	-0.4263***
	(0.0037)	(0.0141)	(0.0046)	(0.0073)	(0.1400)
Area in annual c. (log.)	-0.0178***	-0.0412***	-0.0163***	0.0286***	0.5867***
	(0.0029)	(0.0079)	(0.0036)	(0.0097)	(0.1319)
Area in perennial c. (log.)	-0.0059***	-0.0061**	-0.0047**	0.0015	0.2484***
	(0.0015)	(0.0028)	(0.0020)	(0.0063)	(0.0603)
Area of establishments	-0.0050	0.0346	-0.0133	-0.0721**	-0.3503
	(0.0102)	(0.0359)	(0.0116)	(0.0351)	(0.4640)
Area in pasture (log.)	0.0031	-0.0203	0.0102*	-0.0069	-0.8906***
	(0.0051)	(0.0156)	(0.0057)	(0.0127)	(0.2113)
Persons without electricity (%)	-0.0035***	0.0004	-0.0036***	-0.0012**	0.0710***
	(0.0002)	(0.0007)	(0.0003)	U(0.0006)	(0.0090)
Inadequate sewerage (%)	-0.0007***	0.0031***	-0.0006***	0.0019***	0.0008
	(0.0002)	(0.0008)	(0.0002)	(0.0003)	(0.0091)
Rural population	-0.0136***	-0.0280***	-0.0104**	0.1299***	0.0255
	(0.0049)	(0.0098)	(0.0048)	(0.0295)	(0.1848)
Urban population	-0.0274**	0.0160	-0.0108	0.3287***	1.2938***
	(0.0131)	(0.0312)	(0.0161)	(0.0409)	(0.4969)
Constant	6.1228***	5.2990***	6.7629***	2.2644***	46.1284***
	(0.1766)	(0.5309)	(0.2061)	(0.5743)	(7.3512)
Region x Soy (log.)					
Northeast	0.0004	-0.0408**	0.0088	0.0306***	0.8902***
	(0.0059)	(0.0187)	(0.0064)	(0.0102)	(0.2254)
Southeast	-0.0085**	-0.0296**	-0.0047	0.0303**	0.4519***
	(0.0041)	(0.0144)	(0.0052)	(0.0136)	(0.1464)
South	-0.0061	-0.0421***	0.0006	0.0484***	-0.3809**
	(0.0046)	(0.0151)	(0.0059)	(0.0138)	(0.1595)
Centre-West	-0.0044	-0.0262	-0.0013	0.0144	0.3619**
	(0.0049)	(0.0167)	(0.0063)	(0.0134)	(0.1596)
Controls					
GDP by sector (log.)	Yes	Yes	Yes	Yes	Yes
Extent of highways	Yes	Yes	Yes	Yes	Yes
Area of AMC * year	Yes	Yes	Yes	Yes	Yes
Observations	11257	11257	11257	11257	11257
R2 (adjusted)	0.89	0.57	0.80	0.71	0.91
F	1990	834	1040	632	1635
LL	8804	-2943	5974	-5024	-32400
Sargan-Hansen[a]	2156***	1806***	1652***	1824***	1279***

[a] Prepared using the over-identification test for regression by random effects without spatial specification.
Standard errors in parentheses (* p<0.10, ** p<0.05, *** p<0.01)

The procedures for correctly interpreting the coefficient for the area in soy need clarification, since that variable is incorporated both singly and in interaction with the Brazilian regions. Due to this interaction, and since the regional location is a categorical variable incorporated through binary variables (which assume a unitary value for specific regions and alternatively a null value), the effect on an infinitesimal increment of the area in soy is the sum of the soy coefficient with the binary variable for one of the five Brazilian regions, except for the North, which is a reference. That may be seen in the equation below, where β represents the coefficients of the subscripted variables (in the regions, this means their interaction with soy). This occurs because the binary variables for a region are exclusionary (when a region assumes a value of one, the others are necessarily zero). In this case, when all the region variables included in the regression are zero, that means that the municipality is in the North, and is therefore the reference region. From the equation, we see that the marginal effect (partial correlation) for soy is equal to the coefficient that appears, multiplied by that variable in the econometric specification increased by the coefficient of one of the four Brazilian regions other than the reference region (North). With that, the marginal effect of the reference region is strictly equivalent to the coefficient of the variable for area in soy.

$$Marginal\ effect\ of\ soy\ on\ the\ dependent\ variable = \beta_{\mathrm{Soy}} + \beta_{\mathrm{Northeast}} \times \mathrm{Northeast} + \beta_{\mathrm{Southeast}} \times \mathrm{Southeast} + \beta_{\mathrm{South}} \times \mathrm{South} + \beta_{\mathrm{Centre}} \times \mathrm{Centre} \quad (2)$$

Finally, we present the data that are part of the identification of municipalities where there is a higher or lower are proportion indicated as cultivated in soy, distinguishing those where that proportion is above the average for the respective state, and those where the area is below the average. Municipalities without the presence of soy were ignored. We next observed the performance of six specific indicators in those municipalities – income, income inequality, poverty, average number of years in school, unemployment, infant mortality. Finally, three groups were created for the municipalities with the highest presence of soy (S+), and three other groups for the municipalities with the lowest presence of soy (S-). The three groups for the S+ municipalities are respectively: S+A, with municipalities with above-average soy production and five or six positive social indicators (meaning better than the average for the respective state); S+B, for municipalities with above-average soy production and only three or four positive social indicators; S+C, with municipalities with above-average soy production and up to two positive social indicators. For the group of S-municipalities S-, the groups were defined as follows: S-D, with low share of soy and five or six positive social indicators; S-E, with lower share of soy and three or four positive social indicators; S-F, with lower share of soy and up to two positive social indicators only.

4. Results

4.1. Results of the econometric model applied to the AMC by major regions

The statistical relationship and influence of the area in soy proved inconclusive for five of the ten dependent variables: occupation and employment, HDI, GDP, inequality, education (Table 4). The statistical variables explained with conclusive results were: income per capita, average incomes for the first and fifth quintile, number of individuals in extreme poverty and infant mortality. Of those five variables, only average income for the upper quintile showed a partial null correlation for the area cultivated in soy. For the other variables, there was considerable variation in the signal and magnitude of the partial correlation among the Brazilian regions, illustrating the significant geographic heterogeneity of the influence in the area in soy.

The average income per capita is generally higher in municipalities with larger areas in soy, given the average positive relation between the variables. In other words, this backs up the idea that soy expansion increases local wealth. However, that is not what happens in municipalities in the Southeast, where an increase in soy is associated with lower per capita income. This may be explained by the higher profitability of other activities unrelated to soy in certain municipalities. Although the effect is negative in the Southeast region, its magnitude is lower than in the other regions, because with each 1 % increase in the area in soy, one expects a 0.008% increase in the average income for the North, Northeast, Centre-West and South, while in the Southeast there is a 0.001% decrease.

Looking at income for the poorest quintile (20%), there is a positive correlation between soy and that variable in the North and Centre-West regions. The opposite occurs in the rest of Brazil, meaning that where the soy production area is larger, the average income for the poorer segment is lower. Also, soy does not show a correlation with average income for wealthier residents in any region. That means that an increase in soy in a given municipality does not lead to an increase or decrease in income for wealthier inhabitants, since the coefficients estimated were not statistically different from zero.

As for the number of extremely poor individuals, the statistical analysis resulted a negative correlation between the area of soy and the social indicator for all regions except the South region. However, the negative impact was higher in the North and Centre-West regions. One must seek to understand the reason for those results by exploring the relation between the number of extremely poor persons and income for the lowest quintile. Those variables tend to be negatively related. However, that is not what occurs in the Northeast and Southeast, since in municipalities in those regions with a higher soy-producing areas, there are fewer poor people, although the income for the poorest quintile is lower. That may happen due to several factors, since while the definition of extreme poverty is fixed (BRL 70 per resident in a given household), the first quintile is defined by the poorest 20%, a classification performed at the municipal scale, meaning that the income level cut-off is geographically variable. Additionally, the social group defined by the first income quintile tends to encompass more individuals than the group of extremely poor persons, and it is thus possible to have an increase in the numbers of extremely poor persons along with a reduction in average income for the poorer 20%.

For its part, infant mortality presents a negative correlation with the soy crop in the North, South and Centre-West region. Nonetheless, in Northeast and Southeast soy is positively related with infant mortality. In the Southeast, we see that the municipalities with above-average growth in the proportion of soy from 1991 to 2010 had a reduction in infant mortality that was 2.1 units lower than in municipalities with below-average growth in soy. In the Northeast, that difference also presented the same magnitude. Furthermore, in that region, when comparing the 5% of municipalities with lower infant mortality that are below and above the average for presence of soy, we see that infant mortality, on average, is doubled for those that have more soy (9.3 to 18.2).

Table 4. *Marginal effects of the area planted in soy.*

Dependent Var.	North	Northeast	Southeast	South	Centre-West
Income per capita (log.)	0.008	0.008	-0.001	0.008	0.008
Average income 1st quartile (log)	0.028	-0.013	-0.002	-0.014	0.028
Average income 5th quartile (log.)	0.000	0.000	0.000	0.000	0.000
N. Poor (log)	-0.036	-0.006	-0.006	0.012	-0.036
Infant mortality	-0.426	0.464	0.026	-0.807	-0.064

Despite the differences in method, there are similarities between the results obtained in this study and from previous studies. The most notable is the positive association between soy and level of income. That is the case with the area in soy in the Brazilian Amazon, as found by Weinhold et al. (2013) and also by VanWey et al. (2013) in Mato Grosso. As noted earlier, that is a trend found in almost all of Brazil except for the Southeast, where there is less expansion related to soy but a significant GDP, suggesting that other activities in the region are more profitable.

Another similarity is the negative relation between the number of extremely poor persons and the area in soy. Weinhold et al. (2013) also noted the lower presence of individuals in situations of extreme poverty in the Brazilian Amazon. In this study, that affirmation is also valid for municipalities in the North region (covering most of the Brazilian Amazon) and extending to the other regions except for the South.

Although one cannot make causal statements, the evidence does not point to a rejection of the hypothesis that soy, by encouraging local economic activities, favours an increase in income for extremely poor persons. However, the average income for the first quintile makes it clear that the relation between income for poorer persons and soy is not negligible, because although the municipalities with more soy in the Northeast and Southeast tend to have a lower number of extremely poor inhabitants, there is a relative reduction of average income for those that are poorer. One should note here the hypothesis suggested by some authors (Sauer, 2019) that the poor are being exported to other areas, which could not be verified in this study.

As for income for the first quintile (higher income) it proved to have no correlation with soy in any region. And use of the income inequality variable proved inconclusive. It was thus not possible to state whether or not soy has a relation to inequality; because it affects only the income of the poorer population, one cannot stipulate whether it is moving the rich and poor farther apart.

Lima-de-Oliveira and Alonso (2017) affirm that for 2000 to 2010, the presence of soy has contradictory effects, increasing the Gini coefficient by doing a regression with the difference in values of the variables from 2000 to 2010, but without a correlation in the matched pair analysis (compare the presence of soy in municipalities with the other similar attributes).

Linking the area planted in soy with infant mortality is an exercise without parallels in the articles examined. The hypothesis that soy might, by improving income, also improve the capacity for offering public services and thus improve social indicators is not backed by the evidence in the Northeast and Southeast, but may be valid in the North, South and Centre-West. One should note that the mechanism that might provide greater wellbeing to residents in municipalities with greater presence of soy, to wit, an increase in revenue collection, was not observed by Lima-de-Oliveira and Alonso (2017); actually, that study found the exact opposite, a negative correlation between soy and the municipal budget.

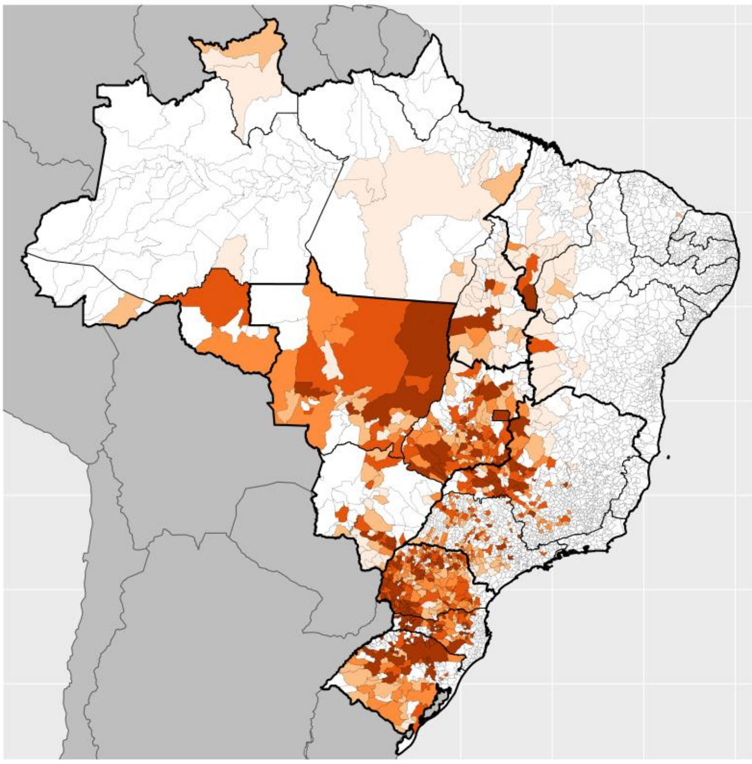
These data involve the individual performance of each variable. However, besides the inter-regional differences already pointed out, the data analysed also show a high intraregional diversity, as will be seen in the next topic.

4.2. The importance of intraregional heterogeneity

In terms of income per capita, the soy-producing regions presented a highly dispersed difference in income from 1991 to 2010 (Figure 4). In the North and Northeast, the income variation was not as significant except for municipalities in Rondônia in the North, two AMC in Maranhão and one in Bahia and Piauí, in the Northeast,. On the other hand, those two regions were the ones that presented heightened inequality measured by the Gini coefficient in the soy-producing areas (Figure 5). The other regions predominantly had a reduction of inequality.

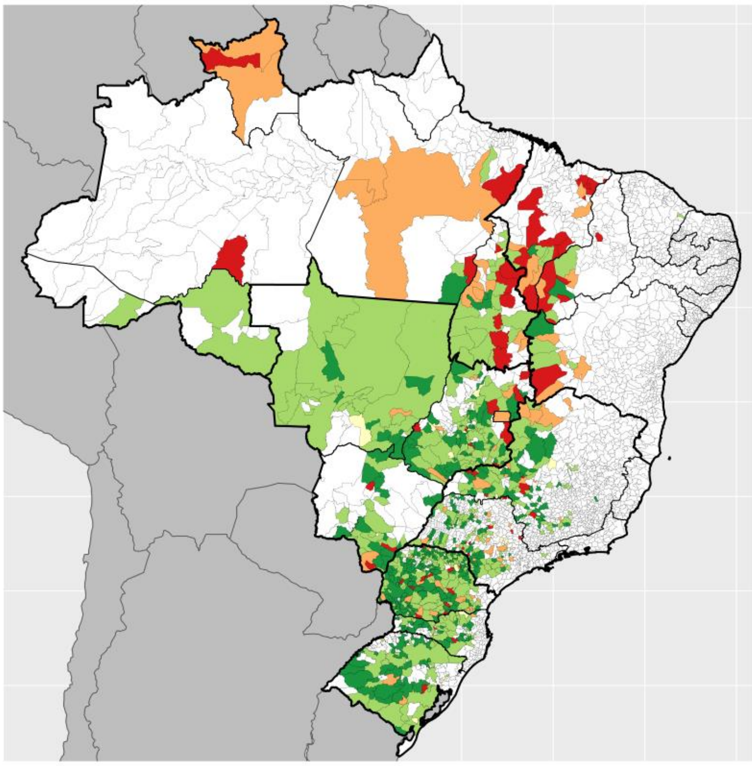
Despite the rise in inequality (Figure 6), the producing municipalities in the North and Northeast presented a significant reduction in the number of poor, a fact also found in Paraná (Figure 7). Those same areas also coincided in having lower infant mortality (Figure 8). As for the expected years in school, they showed a rise in a large portion of the producing municipalities, in the AMC of Rio Grande do Sul and western Minas Gerais (Figure 9). The unemployment rate presented considerable heterogeneity between soy-producing municipalities in a single region. Even with most municipalities having a trend towards increased unemployment, there are areas with a difference close to zero or lower (Figure 10). Piauí and Paraná stand out as states with strong heterogeneity and the Northeast AMC are more homogenous (tending to have higher unemployment).

Figure 4. *Map showing change income per capita (1991-2010) in AMC with soy expansion.*



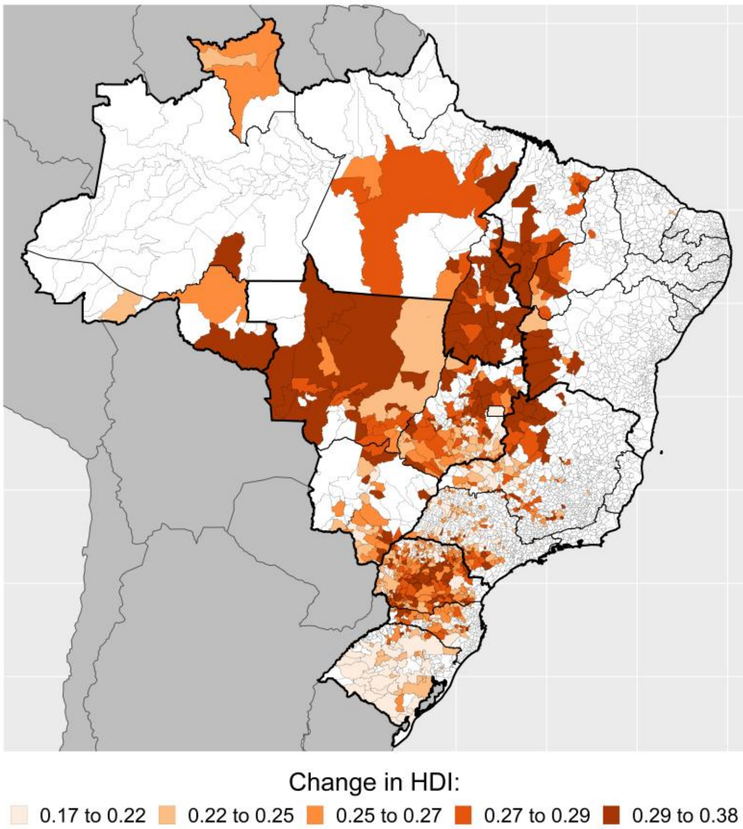
Source: Prepared by the authors with data from the Demographic Census (IBGE).

Figure 5. *Map showing change in the GINI (1991-2010) in AMC with soy expansion.*



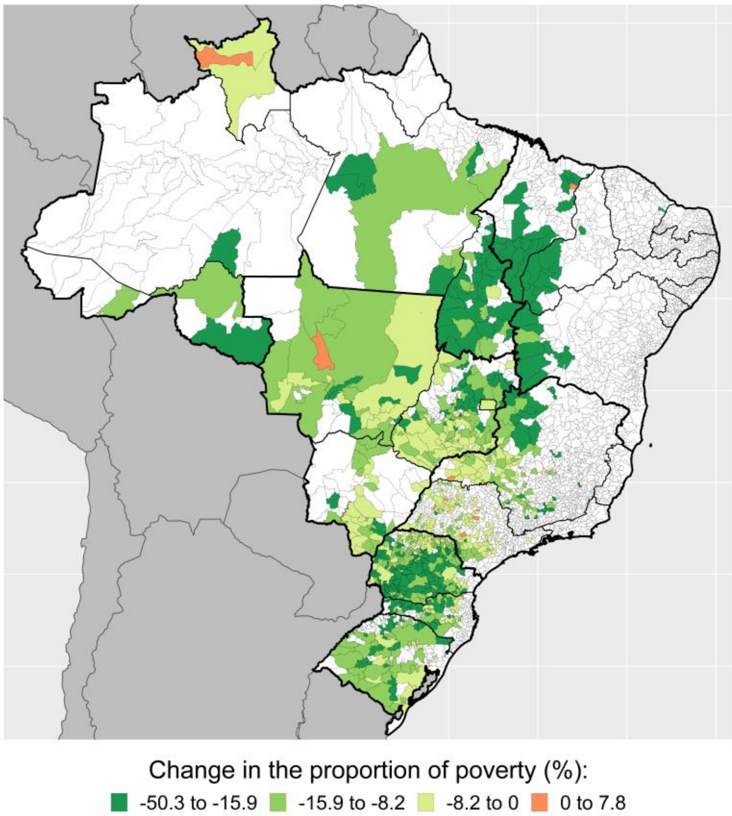
Source: Prepared by the authors with data from the Atlas of Human Development.

Figure 6. *Map showing change in the HDI (1991-2010) in AMC with soy expansion.*



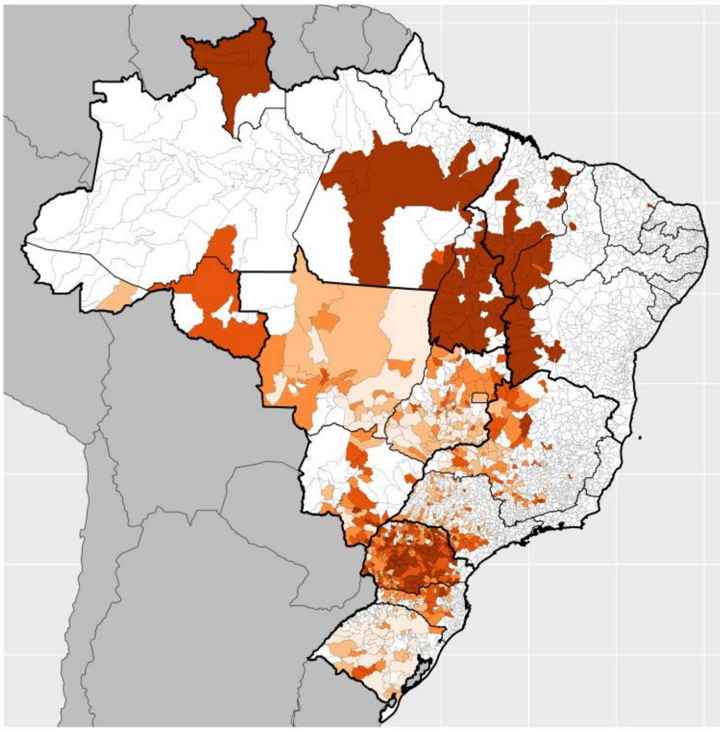
Source: Prepared by the authors with data from the Atlas of Human Development.

Figure 7. *Map showing change of the proportion in poverty (1991-2010) in AMC with soy expansion.*



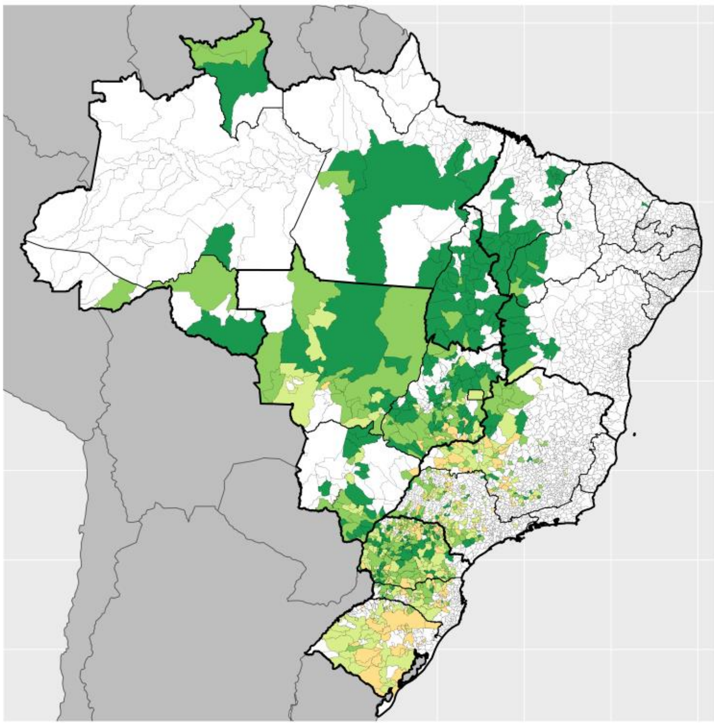
Source: Prepared by the authors with data from the Atlas of Human Development.

Figure 8. *Map showing change in infant mortality (1991-2010) in AMC with soy expansion.*



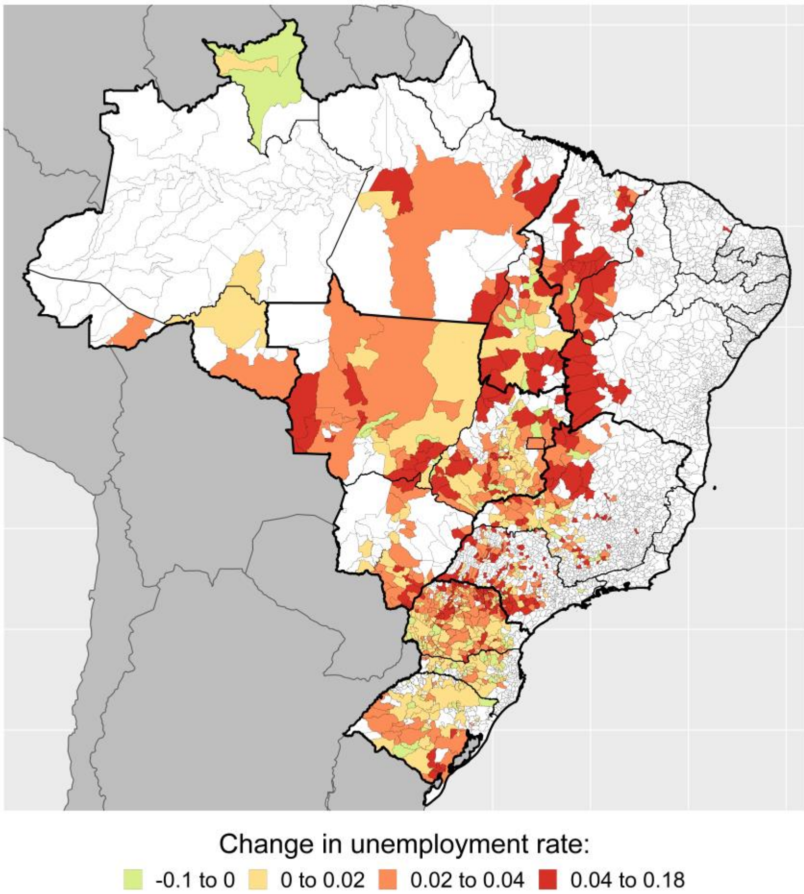
Source: Prepared by the authors with data from the Atlas of Human Development.

Figure 9. *Map showing change in expected years in school (1991-2010) in AMC with soy expansion.*



Source: Prepared by the authors with data from the Atlas of Human Development.

Figure 10. *Map showing change in unemployment rate (1991-2010) in AMC with soy expansion.*



Source: Prepared by the authors with data from the Demographic Census (IBGE).

Considering the 59 soy-producing AMC in the North region, there was a division into two groups because the highest silhouette average (0.7) occurred with that number of clusters. In Table 5 (Figure 11), we see that group A, with 14 municipalities, presented a 4% increase in the proportion of land allocated to soy, while in group B it was only 0.5%. In these municipalities with more soy, per capita income also showed a greater increase than in the other group, an increase greater than BRL 98.8, resulting in an average level of income per capita of BRL 500.9 against BRL 391.7 in group B. In turn, inequality showed a slight average drop of 0.01 unit in the Gini coefficient for the municipalities in A, with an average of 0.55 in 2010, and cases where there was an increase or decrease. The two groups are practically at the national average of 0.53 for the Gini coefficient, with B presenting an average of 0.56. In all of the A municipalities there was a reduction of the proportion in poverty. Although the reduction in the number of extremely poor persons, in group A (12%) this reduction is still lower than in B (17%). In all municipalities there was a rise in the expected years in school and a similar reduction in infant mortality similar, although the value for 2010 has one more year of study and one death less for every thousand births in group A, thus leading to an average of 18 deaths per thousand births and 9.8 years in school in 2010 for this group. Regarding the unemployment rate, there is an upward trend of 3% in both groups, leading to an average value of 7% for group A and 8% for B, both above the national rate of 6.7%. The map in Figure 10, presents the location of this clusters, with the group with the largest presence of soy located in Rondônia and Tocantins.

In contrast to the municipalities in North, the criterion employed for selecting the number of clusters led to dividing up the data into three groups in the Northeast (Table 6), with one value with a 0.64 average silhouette. While the 23 municipalities in group A (Figure 12) had an average growth of 1% in the proportion of area in soy, representing stability. As for group B, with 6 representatives, these are the AMC with the highest allocation of land dedicated to soy, with an average proportion of 18% in 2010, and 16% growth. Finally, group C represents a moderate growth of 6.49%. Although the municipalities with higher production (group B) enjoyed higher growth in per capita income (BRL 178.1) entailing an average value for income per capita of BRL 327.7, group A, with a lower value, has the second highest average increase (BRL 167.6), and achieved an average of BRL 275.4. However, considering the average values we see that both the group with moderate growth in soy (C) and with lower presence of soy have similar values. In cluster B there was also a reduction in inequality leading to an average value of 0.57. However, in some municipalities in this group there was an increase. In the other municipalities there was a general trend towards an increase in inequality. In terms of infant mortality, expected years in school and unemployment rate there was a similar trajectory among the three groups, as well as similar values in 2010. Despite the similarities, we see that infant mortality presents a level higher than the national average of 19 deaths per thousand births, given the average of 26 deaths in the clusters in the Northeast. This is also the case with unemployment, with values from 8 to 9%. Map in Figure 12 shows that the municipalities in group B are located in Bahia and Piaui.

For their part, in the Centre-West (Table 7), the region with the highest soy production, the 253 AMC with area under cultivation were divided into two groups given the value of 0.7 of silhouette average. While group A (Figure 13) represents the municipalities with the lowest ratio of cultivated area to total area (3%) and lowest expansion from 1991 to 2010 (2.2%), B represents the municipalities with the highest use of land dedicated to soy (29%) and highest growth in that proportion with an average value of 18%. It is important to note that there were municipalities in B that reduced their cultivated area. In general, the cluster with the most soy also had the highest per capita income growth with an average difference of BRL 15, resulting in an average value of BRL 691.8 in 2010. In the case of inequality, in most municipalities of the group with more soy there was a greater reduction in the Gini coefficient, with both groups below the national average for 2010. Although cluster A on average had a 3% greater reduction in the number of extremely poor, only 3% of the population of the municipalities in B were in that situation in 2010. With infant mortality, the largest reduction was also in group A. In terms of expected years in school and unemployment rate, the statistics were practically similar and had values close to or below the national average for 2010.

For the Southeast (Table 8), the observations were separated into three groups, given the value of 0.67 in the silhouette average. In contrast to the other regions, the cluster with the highest average value for the proportion of area in soy in 2010, C (19 municipalities), presents a trend towards reduction, given the negative difference of 14.5% (Figure 14). As for cluster B, with 58 AMC, it represents the cases of growth in soy because of its average of 7.7%, but with intermediate levels in land use for soy compared with C and A. In A (19 cases), there is low soy production (1% of the area in 2010) with a certain stability. In the group where soy grew, B, there was a per capita income growth similar to that of municipalities with little presence of soy, compared to the lower growth in group C, which, for its part presented the highest income in 2010. This is the same scenario for the proportion of persons in situations of extreme poverty and infant mortality. As for the unemployment rate, its increase was higher in groups with higher soy production in 2010, surpassing the national average. One may observe that areas with moderate growth in Minas Gerais and São Paulo are close to Goiás and Paraná, respectively.

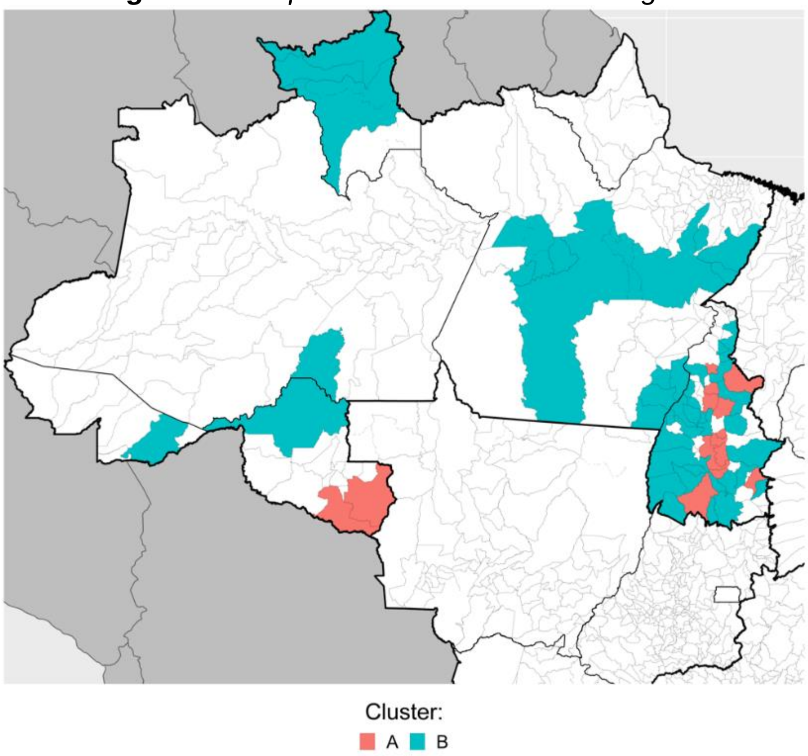
Finally, the 587 municipalities of the South region (Table 9) were divided into two groups, given the average silhouette value of 0.52. In this case, group A (Figure 15) represents municipalities with a high proportion of soy in 2010, with a 44% average use of the area, and also with high growth from 1991 to 2010 (18.1%). As for municipalities in cluster B, they had a low presence of soy with cases that had both increases and decreases of the area in soy production. Despite this drastic difference in the form in which soy is present, we see that the socioeconomic measures and the difference in level from 1991 to 2010 are generally quite close, and there is no clear difference between clusters in this regard. One may note an increase in the unemployment rate for both groups.

Comparing the classifications by region we see that the pattern of soy expansion happens in different forms in the regions. In the South, we see the highest proportion of area allocated to soy, reaching an average of 44% in one cluster in 2010, with an 18% growth from 1991 to 2010. Only in two clusters of two other regions were two-digit average growth rates observed, in the Northeast and Centre-West. Although there are no clear differences between measures of social wellbeing if one compares the clusters between regions, there are significant differences when one compares by region. This is the case with inequality, where the average Gini level for soy-producing municipalities in Northeast was greater compared to other regions (followed by the North and Centre-West), besides being the only region with municipalities where there was an average increase in inequality for some clusters. That is also valid for infant mortality, where although the producing municipalities in the Northeast presented a greater reduction compared with other municipalities, the region is still above the average for Brazil, followed by the North and Centre-West. This same pattern applies to the proportion of the population that is extremely poor. However, we see that the South region presented a reduction in the number of extremely poor persons that was higher than the Centre-West, even with a lower initial poverty rate. Additionally, Northeast municipalities also had the highest increase in the unemployment rate.

Table 5. *Description of clusters in the North region.*

Cluster	Average in 2010	Difference between 2010 and 1991				
		Average	Median	Minimum	Maximum	Standard D.
Proportion of Area in soy (difference in %)						
A	0.04	3.98	3.73	1.97	6.48	1.67
B	0	0.46	0.19	0	1.86	0.54
Income per capita						
A	500.9	275.41	267.5	132.82	640.86	136.2
B	391.7	176.62	180.22	-7.68	363.51	76.03
GINI						
A	0.55	-0.01	-0.01	-0.09	0.09	0.06
B	0.56	0	0	-0.18	0.14	0.07
Proportion of poor (difference in %)						
A	0.12	-19.41	-18.95	-28.07	-10.78	5.32
B	0.17	-17.14	-15.38	-41.65	7.79	9.8
Infant mortality						
A	18.2	-39	-36.77	-55.29	-23.58	9.8
B	19.49	-38.66	-38.41	-61	-14.32	9.85
Expected years in school						
A	9.79	3.17	3.19	2.08	6.01	1.05
B	8.97	3.02	3.05	1.14	5.26	1.16
Unemployment rate						
A	0.07	0.03	0.04	-0.08	0.09	0.04
B	0.08	0.03	0.03	-0.04	0.18	0.05

Figure 11. *Map of clusters in the North region.*

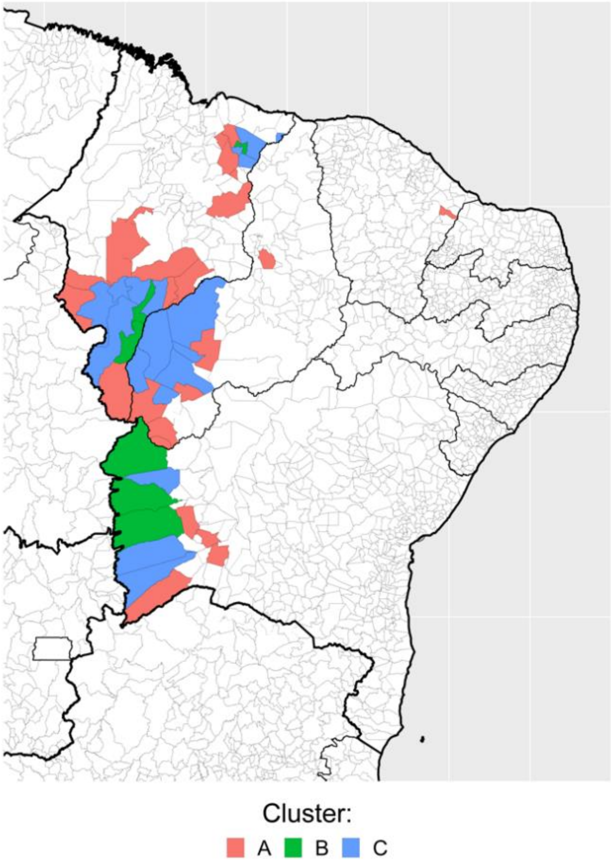


Source: Elaborated by the authors

Table 6. *Description of clusters in the Northeast region.*

Cluster	Average in 2010	Difference between 2010 and 1991				
		Average	Median	Minimum	Maximum	Standard D.
Proportion of Area in soy (difference in %)						
A	0.01	1.01	0.48	0.03	3.32	0.91
B	0.18	16.37	16.5	11.67	23.58	4.08
C	0.07	6.49	6.13	4.12	10.95	2.09
Income per capita						
A	275.38	167.63	148.05	79.66	407.45	75.11
B	327.68	178.08	151.18	94.1	364.06	101.26
C	262.73	161.89	149.75	56.29	385.65	78.4
GINI						
A	0.59	0.06	0.04	-0.04	0.2	0.07
B	0.57	-0.01	-0.02	-0.14	0.09	0.08
C	0.58	0.03	0.02	-0.12	0.23	0.09
Proportion of poor (difference in %)						
A	0.3	-27.71	-26.04	-45.55	-16.91	7.63
B	0.24	-28.62	-26.97	-49.66	-15.67	11.58
C	0.3	-30.53	-33.69	-50.26	2.08	12.54
Infant mortality						
A	26.22	-46.8	-46.44	-70.89	-30.2	11.16
B	26.03	-47.43	-44.47	-70.26	-35.24	13.1
C	26.11	-46.89	-46.38	-65.15	-22.67	10.61
Expected years in school						
A	8.71	3.12	2.81	0.85	7.55	1.43
B	9.11	3.17	2.95	2.26	4.87	0.91
C	8.73	3.27	3.27	1.6	5.35	0.95
Unemployment rate						
A	0.08	0.05	0.05	0	0.13	0.03
B	0.08	0.05	0.05	-0.02	0.09	0.04
C	0.09	0.06	0.06	0.02	0.17	0.03

Figure 12. *Map of clusters in the Northeast region.*

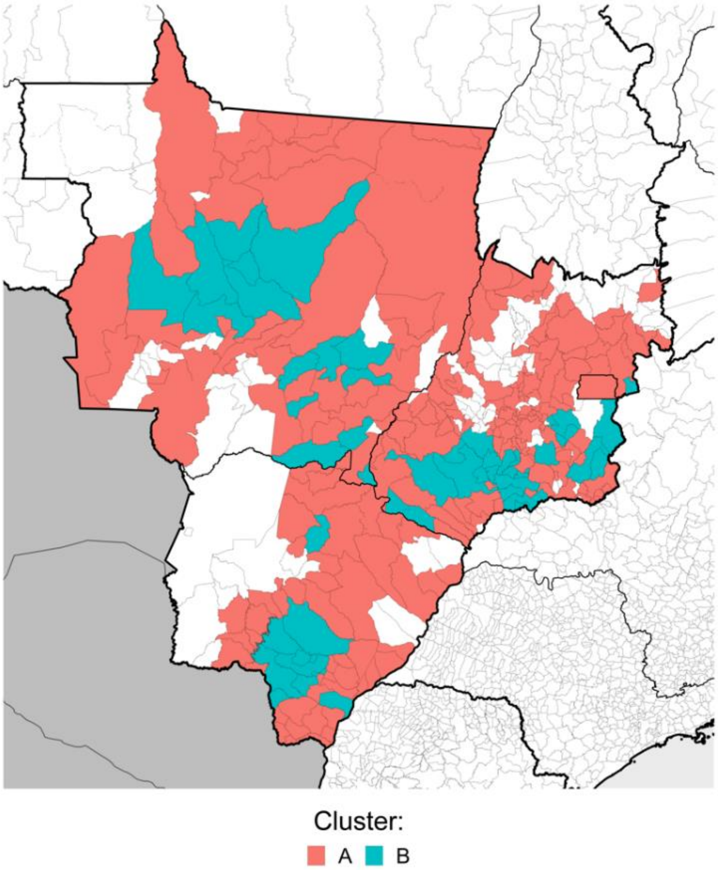


Source: Elaborated by the authors

Table 7. *Description of clusters in the Centre-West region.*

Cluster	Average in 2010	Difference between 2010 and 1991				
		Average	Median	Minimum	Maximum	Standard D.
Proportion of Area in soy (difference in %)						
A	0.03	2.23	1.38	-5.25	10.62	2.83
B	0.29	18.27	14.95	-4.64	54.33	10.43
Income per capita						
A	603.55	308.09	301.59	63.82	799.11	102.24
B	691.81	322.68	329.37	67.88	571.56	105.57
GINI						
A	0.5	-0.05	-0.04	-0.22	0.12	0.06
B	0.49	-0.07	-0.06	-0.29	0.05	0.06
Proportion of poor (difference in %)						
A	0.05	-11.72	-11.04	-34.89	8.01	6.62
B	0.03	-8.59	-8.07	-21.73	0.3	4.75
Infant mortality						
A	15.55	-16.27	-16.13	-27.22	-5.1	4.23
B	15.49	-12.98	-12.1	-27.02	-2.82	4.83
Expected years in school						
A	9.69	1.89	1.8	-1.43	5.16	1.08
B	9.55	1.41	1.36	-0.6	3.46	0.87
Unemployment rate						
A	0.06	0.02	0.03	-0.15	0.17	0.03
B	0.05	0.03	0.03	-0.09	0.08	0.03

Figure 13. *Map of clusters in the Centre-West region.*

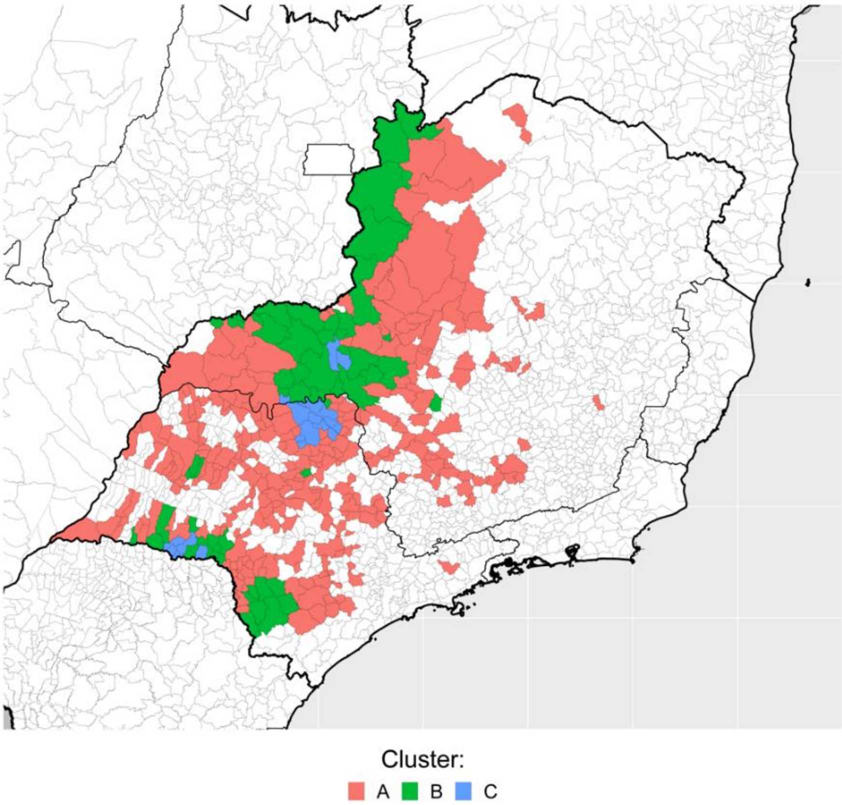


Source: Elaborated by the authors

Table 8. *Description of clusters in the Southeast region.*

Cluster	Average in 2010	Difference between 2010 and 1991				
		Average	Median	Minimum	Maximum	Standard D.
Proportion of Area in soy (difference in %)						
A	0.01	0.1	0.32	-11.79	4.11	2.08
B	0.13	7.69	5.51	-2.13	28.94	5.87
C	0.18	-14.54	-13.08	-33.99	-3.12	7.12
Income per capita						
A	691.04	298.99	300.23	68.15	777.93	93.08
B	658.57	310.22	299.34	67.19	586.18	102.61
C	744.44	289.52	270.08	110	452.44	95.29
GINI						
A	0.46	-0.06	-0.05	-0.3	0.17	0.06
B	0.47	-0.05	-0.05	-0.18	0.14	0.07
C	0.47	-0.05	-0.07	-0.16	0.12	0.07
Proportion of poor (difference in %)						
A	0.02	-7.03	-4.86	-38.77	1.98	7.17
B	0.02	-7.62	-6.69	-26.39	-0.27	5.2
C	0.01	-2.53	-1.35	-13.57	1.58	3.4
Infant mortality						
A	14.4	-14.66	-14.09	-31.72	-5.19	4.59
B	14.51	-15.47	-14.66	-25.73	-7.56	4.44
C	13.88	-13.3	-12.92	-19.77	-5.84	3.23
Expected years in school						
A	10	0.73	0.67	-2.27	5.1	0.93
B	9.75	0.66	0.54	-1.21	3.12	0.93
C	10.23	0.69	0.64	-1.4	1.91	0.78
Unemployment rate						
A	0.05	0.03	0.03	-0.05	0.14	0.02
B	0.06	0.04	0.04	-0.03	0.09	0.03
C	0.07	0.05	0.05	0	0.1	0.02

Figure 14. *Map of clusters in the Southeast region.*

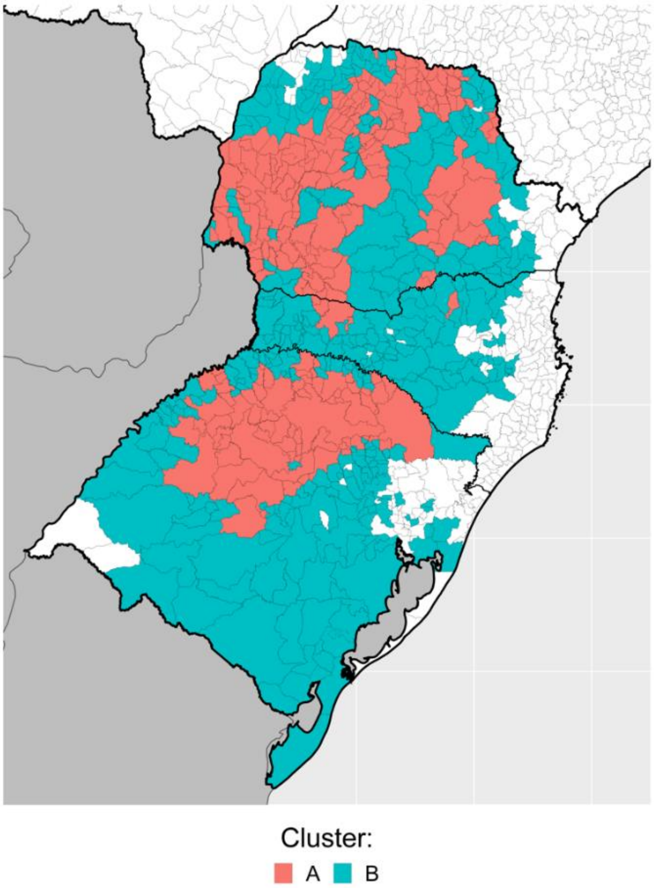


Source: Elaborated by the authors

Table 9. *Description of clusters in the South region.*

Cluster	Average in 2010	Difference between 2010 and 1991				
		Average	Median	Minimum	Maximum	Standard D.
Proportion of Area in soy (difference in %)						
A	0.44	18.14	17.54	-12.58	61.22	12.3
B	0.08	0.39	1.1	-39.66	15.36	8.19
Income per capita						
A	680.43	380.43	374.65	74.66	954.11	115.72
B	692.86	394.68	374.32	142.86	1158.68	140.24
GINI						
A	0.47	-0.08	-0.08	-0.35	0.07	0.06
B	0.46	-0.08	-0.07	-0.32	0.16	0.06
Proportion of poor (difference in %)						
A	0.03	-16.32	-15.24	-44.82	-1.03	9.06
B	0.03	-15.95	-13.93	-50.64	-1.42	9.76
Infant mortality						
A	13.48	-18.13	-18.19	-36.41	-3.3	7.27
B	13.09	-16.43	-14.67	-37.08	-3.52	7.49
Expected years in school						
A	10.61	0.9	0.83	-3.18	5.55	1.02
B	10.3	0.67	0.6	-2.37	4.46	1.03
Unemployment rate						
A	0.04	0.02	0.02	-0.04	0.09	0.02
B	0.04	0.02	0.01	-0.04	0.07	0.02

Figure 15. *Map of clusters in the South region.*

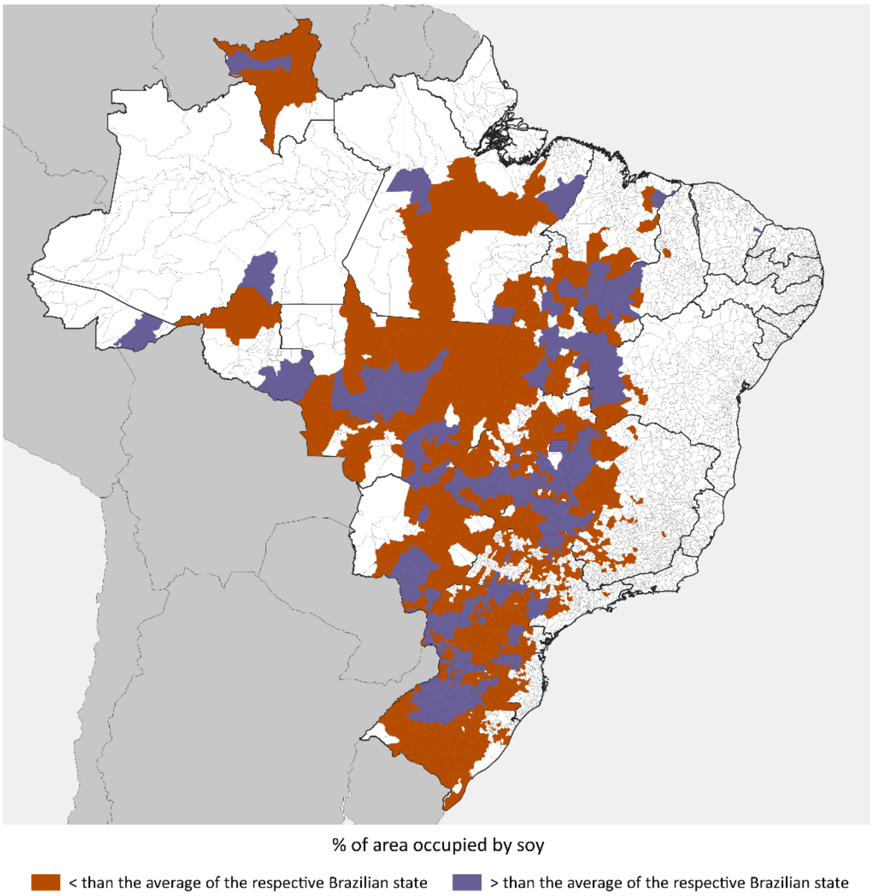


Source: Elaborated by the authors

4.3. A picture of what occurs in the municipalities with the highest soy production

The Figure 16 divides the universe of soy-producing municipalities in Brazil into two groups: that in which the area indicated for that crop is greater than the average observed in that same state; and that in which the area is below the average. And Table 10 shows the performance of those municipalities in terms of one set of socioeconomic indicators. For this purpose, we considered indicators for income, poverty, income inequality, occupation/employment, average number of years in school and infant mortality.

Figure 16. *Map of municipalities with soy production – higher or lower percentages in relation to the average for each Brazilian state.*



Source: Elaborated by the authors

The results expressed show that there is a higher concentration of municipalities in the intermediate range, both in the group of municipalities with above-average soy production and in that group of municipalities with production below the average for each Brazilian state. This means that regardless of a greater or smaller soy-producing areas, there is a predominance of municipalities where the performance in approximately half of the indicators selected is positive, while in the other half it is negative. These municipalities must always be compared with the averages for the state to which they belong, to avoid the effects of regional distortion. In second place is the group of municipalities with performance inferior to at least two-thirds of the selected indicators. Finally, there are the municipalities with performance superior to two-thirds or more of the indicators.

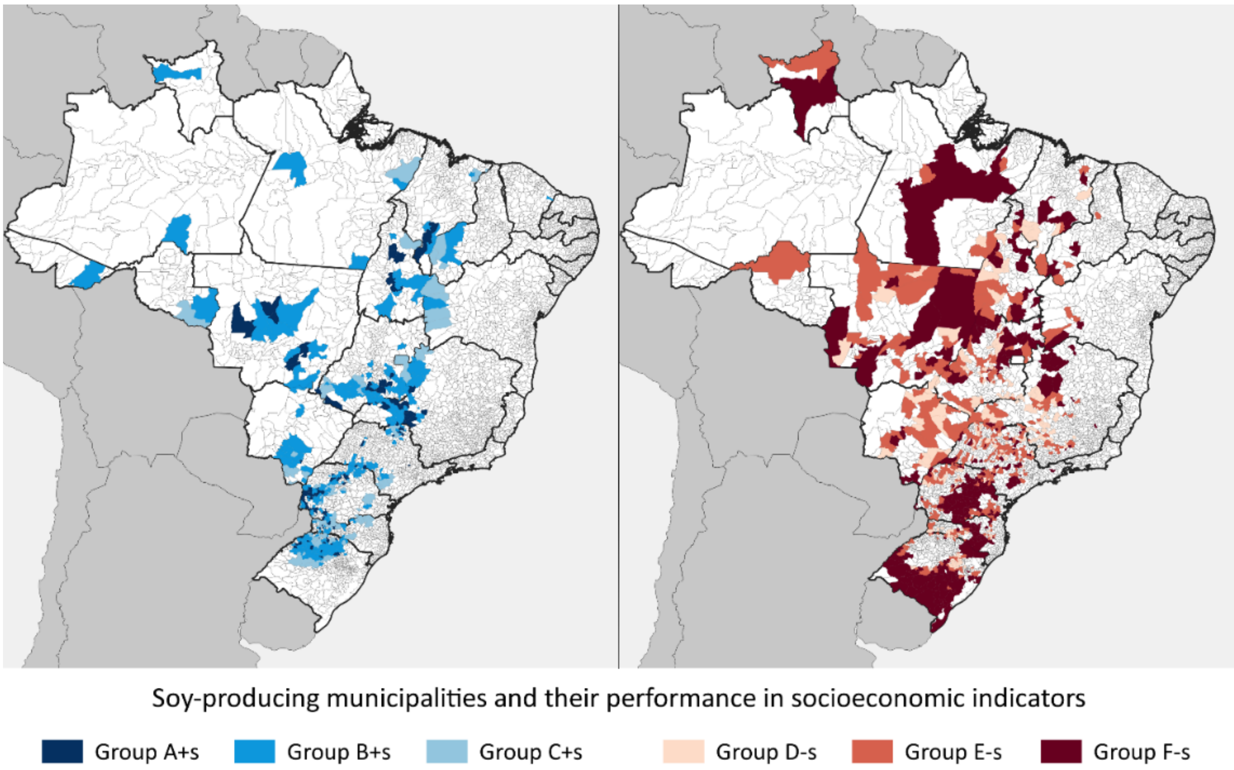
Table 10. *Soy-producing municipalities and their performance in socioeconomic indicators.*

SUMMARY BY REGION												
	% of soy production above average						% of soy production below average					
	Group A		Group B		Group C		Group D		Group E		Group F	
Region	**Nr. AMC**	**% in region**	**Nr. AMC**	**% in region**	**Nr. AMC**	**% in region**	**Nr. AMC**	**% in region**	**Nr. AMC**	**% in region**	**Nr. AMC**	**% in region**
Central-West	24	6.80%	67	18.90%	14	3.90%	64	18.00%	108	30.40%	78	22.00%
Northeast	2	2.70%	20	26.70%	13	17.30%	8	10.70%	14	18.70%	18	24.00%
North	12	7.40%	38	23.30%	10	6.10%	17	10.40%	40	24.50%	46	28.20%
Southeast	27	6.50%	57	13.80%	25	6.10%	83	20.10%	161	39.00%	60	14.50%
South	70	7.30%	216	22.50%	133	13.80%	122	12.70%	192	20.00%	228	23.70%
Brazil	**135**	**6.90%**	**398**	**20.20%**	**195**	**9.90%**	**294**	**14.90%**	**515**	**26.20%**	**430**	**21.90%**

Source: Elaborated by the authors

The maps in Figure 17 show the spatial distribution of these groups of municipalities – in blue are those with higher-than-average production, while those with below-average production are in red.

Figure 17. *Map of soy-producing municipalities and their performance in socioeconomic indicators.*



Source: Elaborated by the authors

The Table 11 presents the performance in one small set of socioeconomic indicators of the twenty "champion" municipalities in agricultural and ranching production in Brazil, of which nineteen are notable soy producers. In red are situations in which their performance is worse than the average for their state, and in blue, situations where their performance is superior. Next, map in Figure 18 shows the spatial distribution of those municipalities according to the typology.

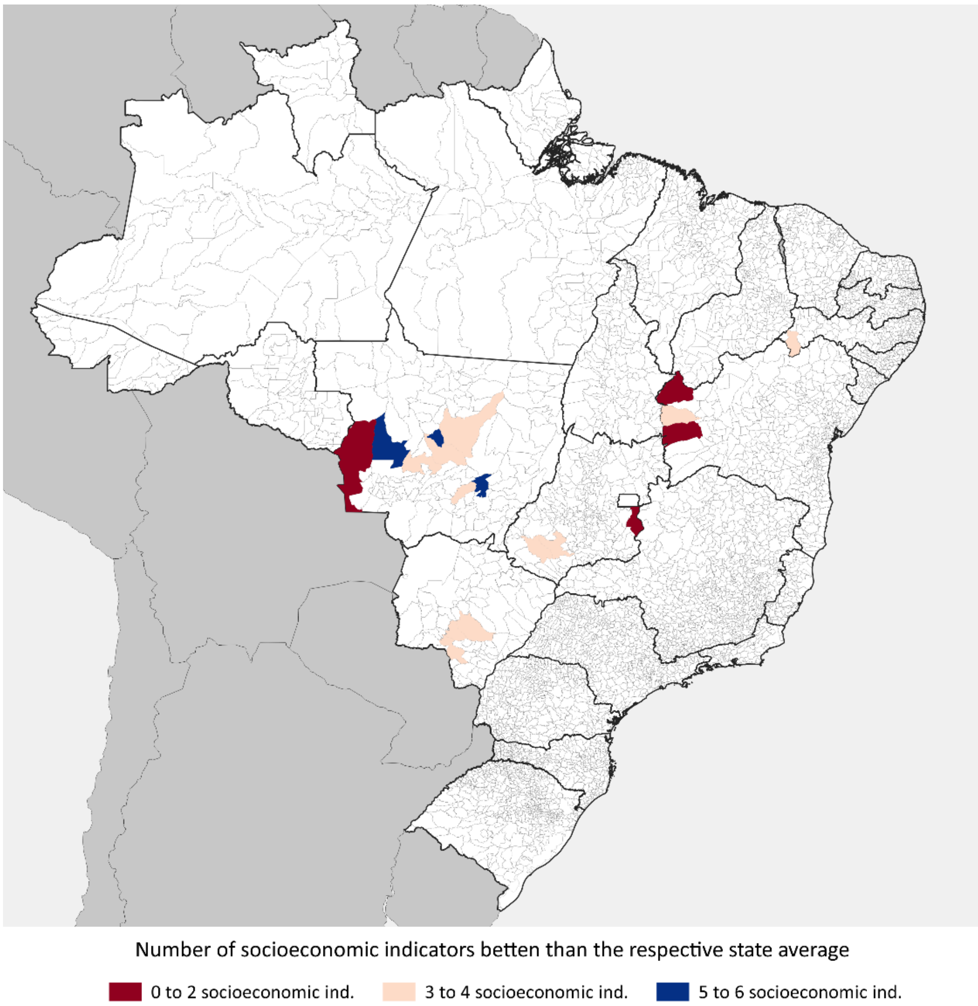
Table 11. *Municipalities with the highest agriculture production in Brazil: performance in socioeconomic indicators compared to their average of their respective states.*

State	AMC	Ranking position	Income	Gini	Poverty	Inf. Mortality	Unemploy/	Years of study	Municipalities in AMC
Bahia	Formosa do Rio Preto	1	Worse	Worse	Worse	Better	Worse	Better	Formosa do Rio Preto
Mato Grosso	Campo Novo dos Parecis, Sapezal	2 / 5	Better	Better	Better	Better	Better	Better	Campo Novo dos Parecis, Sapezal
Mato Grosso	Nova Ubirata, Sorriso	3 / 15	Better	Worse	Worse	Better	Better	Better	Feliz Natal, Nova Ubirata, Sorriso, Vera
Bahia	São Desidério	4	Better	Worse	Worse	Worse	Better	Worse	São Desidério
Mato Grosso	Diamantino	6	Better	Better	Better	Better	Worse	Better	Arenapolis, Diamantino, Santo Afonso, Nova Marilandia
Mato Grosso do South	Ponta Porã	7	Better	Worse	Worse	Worse	Better	Worse	Lagunacarapa, Ponta Porã
Mato Grosso	Campo Verde	8	Better	Worse	Better	Better	Worse	Better	Campo Verde
Bahia	Barreiras	9	Better	Worse	Worse	Better	Better	Better	Barreiras, Luis Eduardo Magalhães
Mato Grosso	Primavera do Leste	10	Better	Worse	Better	Better	Better	Better	Primavera do Leste
Mato Grosso	Campos de Julio	11	Worse	Worse	Worse	Better	Better	Worse	Campos de Julio, Comodoro, Cila Bela da Santissíma Trindade, Nova Lacerda
Mato Grosso	Nova Mutum	12	Better	Worse	Better	Better	Better	Worse	Nova Mutum, Santa Rita do Trivelato
Mato Grosso do South	Sidrolândia	13	Better	Worse	Worse	Better	Worse	Better	Nova Alvorada do South, Rio Brilhante, Sidrolandia
Goiás	Rio Verde	14	Better	Worse	Worse	Better	Better	Worse	Castelandia, Rio Verde, Santo Antonio da Barra,
Pernambuco	Petrolina (**without soy)**	16	Better	Worse	Worse	Better	Worse	Better	Dormentes, Petrolina
Mato Grosso do South	Maracaju	17	Better	Worse	Worse	Better	Better	Better	Maracaju
Goiás	Jataí	18	Better	Worse	Worse	Better	Better	Worse	Aparecida do Rio Doce, Jatai, Perolandia
Goiás	Cristalina	19	Better	Worse	Worse	Worse	Worse	Worse	Cristalina
Mato Grosso	Lucas do Rio Verde	20	Better	Better	Better	Better	Better	Better	Lucas do Rio Verde

Source: Elaborated by the authors.

The results show that in only three of them are the great majority (five to six) of socioeconomic indicators superior to the averages; all are located in the state of Mato Grosso. Four municipalities are the extreme opposite, with a minority of the indicators showing a positive performance. And the great majority of the municipalities are in an intermediate position, with three to four positive indicators among the six observed.

Figure 18. *Map of the spatial distribution of the twenty municipalities with the highest agriculture production in Brazil and their performance in socioeconomic indicators.*



Source: Elaborated by the authors

5. Conclusions

The expansion of soy growing in Brazil over the last three decades has occurred in all regions in Brazil, despite being concentrated in the Centre-West and South regions. For the purpose of contributing towards the literature about the possible socioeconomic effects on soy growing, we have compared the performance of all Brazilian municipalities from 1991 to 2010 in a single set of selected socioeconomic indicators, utilising different and complementary methods.

In summary, the results obtained did not confirm the narrative that the negative environmental effects caused by soy production would be offset by positive effects seen in economic and social indicators. What one sees is a much more heterogeneous reality between the major regions and inside the major regions in Brazil, in terms of indicators such as income, poverty and infant mortality. In addition, there is a large group of indicators for which the results observed are inconclusive: inequality, HDI, occupation/employment, GDP and number of years in school.

When one analyses the combination of these indicators in the soy-producing municipalities, an intermediate situation predominates. With whatever cut-off one uses – total of producing municipalities, municipalities with above-average production, or even the select group of the twenty champion producing municipalities, the predominant group is that of municipalities with ambivalent performance, better than average for approximately half of the indicators selected, but with a worse performance in the other half. Second place goes to the municipalities with worse-than-average indicators for at least two-thirds of the indicators. Finally, in a clear minority are the municipalities with more than two-thirds of the indicators above the average.

From the perspective of public and scientific debates on the issue, the main contribution of this study was to demonstrate that the effects of soy production are not unequivocally positive, as the dominant narrative seeks to emphasise. They are much more multifaceted and must be understood in light of their inter and intra-regional heterogeneity. From a methodological angle, our main contribution is in combining different methods and expanding the geographical, temporal and dimensional bases being analysed, and comparing them with studies already available, so as to amplify the evidence and scope of the issue.

Several issues could not be resolved in this study and the authors of this research group are already making complementary efforts to analyse them. These include: the difficulty in incorporating certain dimensions into the analysis because of the data available, such as the gender and violence dimensions, as well as an explanation of the determinants for the differentiated performance of the territories observed in the indicators. This will demand a qualitative analysis involving field work. The results will be published separately, because of the specific nature of the methods adopted for each issue.

References

AATR (2017). No rastro da grilagem. Uma publicação da Associação de Advogados de Trabalhadores Rurais do Estado da Bahia. Ano 1. Número 1.

ABAG (2016). Associação Brasileira do Agronegócio. O futuro da Soja Nacional. Available at: http://www.aprosoja.com.br/blog/soja-plus/o-futuro-da-soja-nacional-1.

ACTIONAID (2017). Impactos da expansão do agronegócio no MATOPIBA: Comunidades e meio ambiente. Rio de Janeiro.

AGOL, D., LATAWIEC, A., STRASSBURG, B. (2014). Evaluating impacts of development and conservation projects using sustainability indicators: opportunities and challenges. Environmental Impact Assessment Review, 48, p. 1-9.

AGROSTAT. (2018). Estatísticas de Comércio Exterior do Agronegócio Brasileiro. Available at: http://indicadores.agricultura.gov.br/agrostat/index.htm.

ALENCAR et al. (2020). Mapping three decades of changes in the Brazilian savanna native vegetation using Landsat data processed in the Google Earth Engine Platform. Remote Sensing. 12, 924.

ALMEIDA, J., JUNIOR, J. (2019). A luta pela terra frente à dinâmica territorial do agronegócio da soja no Maranhão: o caso da Microrregião de Chapadinha (1990-2015). Revista de Geografia e Ordenamento do Território, 16. Centro de Estudos de Geografia e Ordenamento do Território, p. 251-274.

ALVES, V.C.L. (2009). O mercado de terras nos cerrados piauienses: modernização e exclusão. AGRÁRIA, São Paulo, nos 10/11, pp. 73-98, 2009.

ALVES, V. E.L. org. (2015). Modernização e regionalização nos cerrados do Centro-Norte do Brasil. Rio de Janeiro: Consequência Ed.

ANGELSEN, A. (2010). Policies for reduced deforestation and their impact on agricultural production. PNAS. V. 107, N. 46, p. 19639-19644.

ARELLANO, M. (1993). On the testing of correlated effects with panel data. Journal of Econometrics, 59(1–2), 87–97. https://doi.org/10.1016/0304-4076(93)90040-C

BALBINO et al., (2012). Agricultura sustentável por meio da Integração Lavoura-Pecuária-Floresta (ILFP). International Plant Nutrition Institute Brasil. Informações Agronômicas. N. 138. Julho.

BARRETTO, A. G. O. P., BERNDES, G., SPAROVEK, G. & WIRSENIUS, S. (2013). Agricultural Intensification in Brazil and its Effects on Land-use Patterns: an Analysis of the 1975-2006 Period. Glob. Chang. Biol. 19, 1804–1815.

BASSI, B.; CASTILHO, A. &; VENDRAME, F. (2017). O controle de terras por estrangeiros no Brasil: Panorama geopolítico, aspectos legais e macrotendências. Análise n. 35. FES/Brasil.

BOLSON, S.H. (2018). O cerrado nas metas brasileiras do acordo de paris: a omissão do estado brasileiro com o desmatamento na cumeeira da América do Sul. Revista de Direito Ambiental e Socioambientalismo. V. 4, n. 1, p. 112- 131, Jan/Jun.

BOMBARDI, L.M. (2012). Agrotóxicos e agronegócio: arcaico e moderno se fundem no campo brasileiro. In: Merlino T, Mendonça ML, organizadores. Direitos humanos no Brasil 2012: relatório da

Rede Social de Justiça e Direitos Humanos. São Paulo: Rede Social de Justiça e Direitos Humanos; 2012. p. 75-86.

BRANCALION, P., LAMB, D., CECCON, E., BOUCHER, D., HERBOHN, J., STRASSBURG, B., EDWARDS, D. (2017). Using markets to leverage investment in forest and landscape reforestation in the tropic. Forest Policy and Economics, 85, p. 103 - 113.

BRANDÃO, A. S. P., Castro de Rezende, G., & da Costa Marques, R. W. (2005). Agricultural Growth in the Period 1999-2004, Outburst in Soybeans Area and Environmental Impacts in Brazil. Texto Para Discussão Ipea. https://doi.org/10.2139/ssrn.660442

BUAINAIN, A. M. et al. (2014). O mundo rural no Brasil do século XXI: a formação de um novo padrão agrícola e agrário. Brasília: Embrapa.

BUAINAIN, A.M.; GARCIA, J.R.; VIEIRA FILHO, J.E.R. A. (2017). Dinâmica da economia e da agropecuária no MATOPIBA. Texto para Discussão n. 2284. Brasília: IPEA.

BUAINAIN, A.M.; GARCIA, J.R.; VIEIRA FILHO, J.E.R. A. (2018). Economia agropecuária do MATOPIBA. Estudos Sociedade e Agricultura, v. 26, n. 2, p. 376-401. Julho-Setembro.

CARNEIRO FILHO, A. & COSTA, K. (2016). A Expansão da Soja no Cerrado – Caminhos para a ocupação territorial, uso do solo e produção sustentável. São Paulo: Input/Agroícone.

CARVALHO, T. S., DOMINGUES, E. P. (2016). Projeção de um cenário econômico e de desmatamento para a Amazônia Legal brasileira entre 2006 e 2030. Nova Economia, 26, 2, p. 585-621.

CARVALHO, W. D., MUSTIN, K., HILÁRIO, R. R., VASCONCELOS, I. M., EILERS, V., FEARNSIDE, P. M. (2019). Deforestation control in the Brazilian Amazon: A conservation struggle being lost as agreements and regulations are subverted and bypassed. Perspectives in Ecology and Conservation, 17, p. 122-130.

CASTRO, L.S., MIRANDA, M.H., LIMA, J.E. (2015). Indicadores sociais de desenvolvimento e a produção de soja: uma análise multivariada nos 150 maiores municípios produtores brasileiros. Revista Brasileira de Gestão e Desenvolvimento Regional. V. 11, n. 1, p. 69-87, Jan/Abr.

CERQUEIRA et al. (2020). Atlas da violência no campo no Brasil: condicionantes socioeconômicos e territoriais. IPEA, Brasília.

CERRI, C.E.P., CERRI, C.C., MAIA, S.M.F., CHERUBIN, M.R., FEIGL, B.J., LAL, R. (2018). Reducing Amazon Deforestation through agricultural intensification in the Cerrado for advancing food security and mitigating climate change. Sustainability. 10, 989.

CHENG et al. (2019). A systematic map of evidence on the contribution of forests to poverty alleviation. Environmental Evidence. 8(3).

CONAB. (2019). Companhia Nacional de Abastecimento. Safra de grãos. Available at: https://www.conab.gov.br/info-agro/safras/graos.

CPT (2019). Comissão da Pastoral da Terra. Conflitos no Campo – Brasil. Goiânia.

DOMINGUES, M. S., BERMANN, C. (2012). O arco de desflorestamento na Amazônia: da pecuária à soja. Ambiente & Sociedade, 15, 2, p. 1-22.

DULCI, L. (2017). O que professores universitários aposentados de Nova York têm a ver com a expropriação de terras de pequenos agricultores no nordeste brasileiro? Available at:

http://indebate.indisciplinar.com/2017/08/21/o-que-professores-universitarios-aposentados-de-nova-york-tem-a-ver-com-a-expropriacao-de-terras-de-pequenos-agricultores-nonordestebrasileiro/

DURÁN, A. P. et al. (2020). A practical approach to measuring the biodiversity impacts of land conversion. Methods in Ecology and Evolution. Wiley. doi: 10.1111/2041-210x.13427.

EMBRAPA. (2019). Empresa Brasileira de Pesquisa Agropecuária. Embrapa Soja. Avaliable at: https://www.embrapa.br/soja/cultivos/soja1.

ESCOBAR, N., TIZADOC, E.J., ZU ERMGASSEND, E.K.H.J., LÖFGRENF, P., BÖRNERA, J., GODARF, J. (2020). Spatially-explicit footprints of agricultural commodities: mapping carbon emissions embodied in Brazil's soy exports. Global Environmental Change. 62, 102067.

FAO (2017). Trade Policy Briefs - Voluntary sustainability standards in agriculture, fisheries and forestry trade. Rome: Italy. Available at: http://www.fao.org/economic/est.

FAVARETO, A. et al. (2012). A dimensão territorial do desenvolvimento brasileiro recente (2000-2010). Documentos de trabajo. Santiago do Chile: Rimisp.

FAVARETO, A.; NAKAGAWA, L.; PÓ, M.; SEIFER, P.; KLEEB, S. (2018). Entre chapadas e baixões do MATOPIBA: dinâmicas territoriais e impactos socioeconômicos na fronteira da expansão agropecuária no Cerrado. Greenpeace. Ed. Ilustre. 272p.

FAVARETO, A.; NAKAGAWA, L.; KLEEB, S.; SEIFER, P.; PÓ, M. (2019). Há mais pobreza e desigualdade do que bem-estar e riqueza nos municípios do MATOPIBA. Rev. NERA, Dossiê – 2019. Presidente Prudente v. 22, n. 47, pp. 348-381.

FEARNSIDE, P. (2005). Deforestation in Brazilian Amazonia: history, rates, and consequences. Conservation Biology. V. 19, N. 3, p. 680-688.

FERGUSON, B., SEKULA, J., SZABÓ, I. (2020). Technology solutions for supply chain traceability in the Brazilian Amazon: opportunities for the financial sector. Igarapé Institute. Ago.

FLEXOR, G., LEITE, S.P. (2017). Land market and land grabbing in Brazil during the commodity boom of the 2000s. Contexto Internacional. 39(2), p. 393-420.

FREDERICO, S.; BÜHLER, E. A. (2015). Capital financeiro e expansão da fronteira agrícola no Oeste da Bahia. In: ALVES, Vicente Eudes Lemos (Org.). Modernização e regionalização nos Cerrados do Centro-Norte do Brasil: Oeste da Bahia, Sul do Maranhão e do Piauí e Leste do Tocantins. Rio de Janeiro: Consequência. p.199-225.

GARCIA, J.R.; BUAINAIN, A.M. (2016). Dinâmica de Ocupação do Cerrado Nordestino pela Agricultura: 1990 e 2012. Revista de Economia e Sociologia Rural, v. 54, n. 2, p. 320-338. Abril-Junho.

GARCIA, A., DE F. N. VILELA, V. M., RIZZO, R., WEST, P., GERBER, J. S., ENGSTROM, P. M., BALLESTER, M. V. (2019). Assessing land use/cover dynamics and exploring drivers in the Amazon's arc of deforestation through a hierarchical, multi-scale and multi-temporal classification approach. Remote Sensing Applications: Society and Environment, 15.

GARRETT, R. D., LAMBIN, E. F., & NAYLOR, R. L. (2013). Land institutions and supply chain configurations as determinants of soybean planted area and yields in Brazil. Land Use Policy, 31, 385–396. https://doi.org/10.1016/j.landusepol.2012.08.002

GARRETT, R. D., & RAUSCH, L. L. (2016). Green for gold: social and ecological tradeoffs influencing the sustainability of the Brazilian soy industry. Journal of Peasant Studies, 43(2), 461–493. https://doi.org/10.1080/03066150.2015.1010077

GREEN, J. M. H. et al. (2019). Linking global drivers of agricultural trade to on-the-ground impacts on biodiversity. Proceedings of the National Academy of Sciences of the United States of America. National Academy of Sciences, 116(46), pp. 23202–23208. doi: 10.1073/pnas.1905618116.

GRISA, K., GAZOLLA, M., SCHNEIDER, S. (2010). A "produção invisível" na agricultura familiar: autoconsumo, segurança alimentar e políticas públicas de desenvolvimento rural. Agroalimentaria. Vol. 16, N. 31, p. 65-79, Julio/Diciembre.

GUEDES PINTO, L.F, FARIA, V.G., SPAROVEK, G., REYDON, P.B., RAMOS, C.A., SIQUEIRA, G.P., GODAR, J., GARDNER, T., RAJÃO, R., ALENCAR, A., CARVALHO, T., CERIGNONI, F., GRANERO, I.M., COUTO, M. (2020). Quem são os poucos donos das terras agrícolas no Brasil: o mapa da desigualdade. Sustentabilidade em Debate. Imaflora, 10, abril.

GUIDOTTI, V., FERRAZ, S. F. B., PINTO, L. F. G., SPAROVEK, G., TANIWAKI, R., GARCIA, L. G., BRANCALION, P. (2020). Changes in Brazil's Forest Code can erode the potential of riparian buffers to supply watershed services. Land Use Policy. 94.

HEREDIA, B., PALMEIRA, M., LEITE, S. P. (2010). Sociedade e Economia do Agronegócio no Brasil. Revista Brasileira de Ciências Sociais, 25, 74, p. 159-176.

HUNKE, P., MUELLER, E.N., SCHRODER, B., ZEILHOFER, P. (2015) The Brazilian Cerrado: assessment of water and soil degradation in catchments under intensive agricultural use. Ecohydrology. 8(6), p.1154-1180.

INGRAM, V., VAN RIJN, F., WAARTS, Y., GILHUIS, H. (2018). The Impacts of Cocoa Sustainability Initiatives in West Africa. Sustainability. 10, 4249.

LATAWIEC, A., STRASSBURG, B., SILVA, D., ALVES-PINTO, H., FELTRAN-BARBIERI, R., CASTRO, A., IRIBARREM, A., RANGEL, M., KALIF, A., GARDNER, T., BEDUSCHI, F. (2017). Improving land management in Brazil: A perspective from producers. Agriculture, Ecosystems and Environment, 240, p. 276-286.

LEITE, S.P. (2020). Ruralidades, enfoque territorial e políticas públicas diferenciadas para o desenvolvimento rural brasileiro: uma agenda perdida? Estudos Sociedade e Agricultura. V. 28, N.1.

LENZEN, M. ET AL. (2012), International trade drives biodiversity threats in developing nations. Nature 486, 109–112.

LIMA, P.C.A., FRANCO, J.L.A. (2013). As RPPNs como estratégia para a conservação da biodiversidade: O caso da chapada dos veadeiros. Sociedade & Natureza. Uberlândia, 26 (1), p. 113-125, Jan/Abr.

LIMA, M., SILVA JUNIOR, C.A. RAUSCH, L., GIBBS, H.G., JOHANN, J.A. (2019). Demystifying sustainable soy in Brazil. Land Use Policy, 82, p. 349–352.

LOPES, G.R., LIMA, M.B., REIS, T. (2021) Maldevelopment revisited: Inclusiveness and social impacts of soy expansion over Brazil's Cerrado in MATOPIBA. World Development. 139, 105316.

MARQUES, E.Q.; MARIMON-JUNIOR, B.H.; MARIMON, B.S.; MATRICARDI, E.A.T.; MEWS, H.A.; COLLI, G.R. (2019). Redefining the Cerrado–Amazonia transition: implications for conservation. Biodiversity and Conservation. 29, p. 1501–1517.

MEIRELLES FILHO, J. C. de S. (2014). É possível superar a herança da ditadura brasileira (1964-1985) e controlar o desmatamento na Amazônia? Não, enquanto a pecuária bovina prosseguir como principal vetor de desmatamento. Boletim do Museu Paraense Emílio Goeldi. Ciências Humanas, 9, 1, p. 219-241.

NEGRÕES, N., REVILLA, E., FONSECA, C., SOARES, A.M.V.M., JÁCOMO, A.T.A., SILVEIRA, l. Private forest reserves can aid in preserving the community of medium and large-sized vertebrates in the Amazon arc of deforestation. Biodiversity Conservation. 20, p. 505–518.

NOGUEIRA, E.M., YANAI, A.M., VASCONCELOS, S.S., GRAÇA, P.M.L.A., FEARNSIDE, P. (2018). Carbon stocks and losses to deforestation in protected areas in Brazilian Amazonia. Regional Environmental Change. 18, p. 261-270.

PAM/IBGE. (2019). Produção Agrícola Municipal – Instituto Brasileiro de Geografia e Estatística. Available at: https://sidra.ibge.gov.br/pesquisa/pam/tabelas.

PEREIRA L.I.; PAULI, L. (2016). O processo de estrangeirização da terra e a expansão do agronegócio na região do MATOPIBA. Campo-Território – Revista de Geografia Agrária. Número Especial.

PIATTO, M. INAKAKE DE SOUZA, L. (2016) 10-year of Soy Moratorium in the Amazon: History, Impacts and Expansion into Cerrado Areas. Piracicaba, SP: Imaflora. Available at: http://www.imaflora.org/downloads/biblioteca/IMF-10-years-of-soy-moratorium WB.pdf

PIGNATI, W.A.; LIMA, F.A.N.S.; LARA, S.S.; CORREA, M.L.M.; BARBOSA, J.R.; LEÃO, L.H.C.; PIGNATI, M.G. (2017). Spatial distribution of pesticide use in Brazil: a strategy for Health Surveillance. Ciência & Saúde Coletiva, 22(10):3281-3293.

PITTA, BOECHAT & MENDONÇA. (2017). A produção do espaço na região do MATOPIBA: violência, transnacionais imobiliárias agrícolas e capital fictício. Estudos Internacionais, v.5 n.2 (2017), p. 155-179.

PRIESS, J.A., MIMLER, M., KLEIN, A.M., SCHWARZE, S., TSCHARNTKE, T., STEFFAN-DEWENTER, I. (2007). Linking deforestation scenarios to pollination services and economic returns in coffee agroforestry systems. Ecological Applications. 17(2), p. 407–417.

RAJÃO, R., SOARES-FILHO, B., NUNES, F., BÖRNER, J., MACHADO, L., ASSIS, D., OLIVEIRA, A., PINTO, L., RIBEIRO, V., RAUSCH, L., GIBBS, H., FIGUEIRA, D. (2020). The rotten apples of Brazil's agribusiness. Science. 369, 246.

RAYMOND, C.M., BRYAN, B.A., MACDONALD, D.H., CAST, A., STRATHEARN, S., GRANDGIRARD, A., KALIVAS, T. (2009) Mapping community values for natural capital and ecosystem services. Ecol Econ; 68: 1301–15.

REDE SOCIAL DE JUSTIÇA E DIREITOS HUMANOS (2018). Imobiliárias agrícolas transnacionais e a especulação com terras na região do MATOPIBA.

REIS, T.N.P., MEYFROIDT, P, ZU ERMGASSEN E.K.H.J., CROFT, S., LATHUILLIERE, M.J., GODAR, J. (2020). Understanding the Stickiness of Commodity Supply Chains Is Key to Improving Their Sustainability. One Earth, 3, p. 100–115.

REKOW, L. (2019). Socio-Ecological Implications of Soy in the Brazilian Cerrado. Challenges in Sustainability. 7(1), p. 7–29.

RIBEIRO, A.F.A, SILVA, R.G.C, CORRÊA, S.S. (2015). Geografia da soja em Rondônia: monopolização do território, regionalização e conflitos territoriais. Campo-Território: Revista de Geografia Agrária. v. 10, n. 20, p. 180-201, Jul.

ROESSING, A.C., LAZZAROTTO, J.J. (2004). Criação de empregos pelo Complexo Soja. Embrapa. Londrina.

ROITMAN ET AL. (2018). Optimizing biomass estimates of savanna woodland at different spatial scales in the Brazilian Cerrado: reevaluating allometric equations and environmental influences. PLOS One. 13(8), Ago.

SAATH, K. C. DE O., FACHINELLO, A. L. (2018). Crescimento da demanda mundial de alimentos e restrições do fator terra no Brasil. Revista de Economia e Sociologia Rural, 56, 2, p.195-212.

SALATI, E., NOBRE, C.A. (1991). Possible climate impacts of tropical deforestation. Climatic Change. 19: 177-196.

SARRIS, A. (2013). Food commodity price volatility and food insecurity. Bio-based and Applied Economics. 2(3), p. 213-236.

SASSEN, M. (2014). Conservation in a crowded place Forest and people on Mount Elgon Uganda. PhD thesis, Wageningen University, Wageningen, NL. 200p.

SAUER, S., FRANÇA, F.C. (2012). Código florestal, função socioambiental da terra e soberania alimentar. Caderno CRH. Salvador, v. 25, n. 65, p. 285-307, Mai/Ago.

SAUER, S., LEITE, S.P. (2012). Agrarian structure, foreign investment in land, and land prices in Brazil. The Journal of Peasant Studies, 39(3-4), 873-898.

SAUER, S., BORRAS JR, S., (2016). Land grabbing e green grabbing: uma leitura da corrida na produção acadêmica sobre a apropriação global de terras. Campo Território: revista de geografia agrária. Edição especial, p. 6-42, Jun.

SAUER, S. (2018). Soy expansion into the agricultural frontiers of the Brazilian Amazon: The agribusiness economy and its social and environmental conflicts. Land Use Policy, 79, p. 326–338

SAWYER, D. (2009). Fluxos de carbono na Amazônia e no Cerrado: um olhar socioecossistêmico. Sociedade e Estado, Brasília, v. 24, n. 1, p. 149-171.

SERIGATI, F., POSSAMAI, R. (2016). Ciclos de Kondratieff e o agronegócio brasileiro: a importância da conjuntura externa para o crescimento do setor entre 2000 e 2015. In: Agricultura, transformação produtiva e sustentabilidade. IPEA.

SILVA, J.R.S. (2011). Produção de commodities, desmatamento e insegurança alimentar na Amazônia brasileira. Revista Geográfica de América Central, vol. 2, p. 1-15 Julio/Diciembre.

SILVA, C. M. da. (2018). Entre Fênix e Ceres: A grande aceleração e a fronteira agrícola no Cerrado. Varia História, 34, 65, p. 409-444.

SILVA, G. F. N., OLIVEIRA, I. J. (2018). Reconfiguração da paisagem nas Savanas da Amazônia. Mercator (Fortaleza), 17, e17028, p. 1-20.

SOUZA, D. M., TEIXEIRA, R. F., OSTERMANN, O. P. (2015). Assessing biodiversity loss due to land use with Life Cycle Assessment: Are we there yet? Glob. Change Biol. 21, 32–47.

SOTERRONI, A. C. et al. (2018). Future environmental and agricultural impacts of Brazil’s Forest Code. Environ. Res. Lett, 13, pp. 1–12. doi: 10.1088/1748-9326/aaccbb.

SPAROVEK, G., BERNDES, G., BARRETTO, A.G.O.P., KLUG I.L.F. (2012). The revision of the Brazilian Forest Act: increased deforestation or a historic step towards balancing agricultural development and nature conservation? Environmental Science & Policy. V.16, p. 65-72.

STABILE, M. C., GUIMARÃES, A. L., SILVA, D. S., RIBEIRO, V., MACEDO, M. N., COE, M. T., PINTO, E., MOUTINHO, P., ALENCAR, A. (2020). Solving Brazil's land use puzzle: Increasing production and slowing Amazon deforestation. Land Use Policy, 91.

STRASSBURG, B., TURNER, R. K., FISHER, B., SHAEFFER, R., LOVETT, A. (2009). Reducing emissions from deforestation: The "combined incentives" mechanism and empirical simulations. Global Environmental Change, 19, p. 265-278.

TFA. Tropical Forest Alliance Latin America. (2020). Soy dialogues: payments for environmental services: a game-changer for Brazil and beyond? July.

TNC. The Nature Conservancy. (2019). Incentives for sustainable soy in the Cerrado. November.

TRASE. (2019). Transparent Supply Chains for Sustainable Economies. Available at: https://trase.earth/data?lang=en.

VANWEY, L. K., E. OSTROM, AND V. MERETSKY. 2005. Theories Underlying the Study of Human-Environment Interactions. In: Seeing the forest and the trees: human-environment interactions in forest ecosystems. Mit Press.

VANWEY, L. K., SPERA, S., DE SA, R., MAHR, D., & MUSTARD, J. F. (2013). Socioeconomic development and agricultural intensification in Mato Grosso. Philosophical Transactions of the Royal Society B: Biological Sciences, 368(1619), 1–7. https://doi.org/10.1098/rstb.2012.0168

VASCONCELOS, A. et al. (2020). Illegal deforestation and Brazilian soy exports: the case of Mato Grosso. Available at: https://www.icv.org.br/website/wp-content/uploads/2020/06/traseissuebrief4-en.pdf

VIEIRA FILHO, J.E.R. (2018). Efeito poupa-terra e ganhos de produção no setor agropecuário brasileiro. Texto para Discussão. IPEA. Brasília, Abril.

VIEIRA FILHO, J. E. R. & GASQUES, J. G. (2016). Agricultura, transformação produtiva e sustentabilidade. Brasília: Ipea.

VYNNE et al. (2010). Effectiveness of scat-detection dogs in determining species presence in a tropical savanna landscape. Conservation Biology. V. 25, N. 1, p. 154-162.

WAROUX, Y., GARRETT, R. D., GRAESSER, J., NOLTE, C., WHITE, C., LAMBIN, E. F. (2017). The Restructuring of South American Soy and Beef Production and Trade Under Changing Environmental Regulations. World Development, 121, p. 188-202.

WEINHOLD, D., KILLICK, E., REIS, E. J. (2013). Soybeans, Poverty and Inequality in the Brazilian Amazon. World Development, 52, p. 132–143.

WWF. (2015). World Wide Fund for Nature. Áreas prioritárias para conservação da biodiversidade no Cerrado e Pantanal. Dezembro.

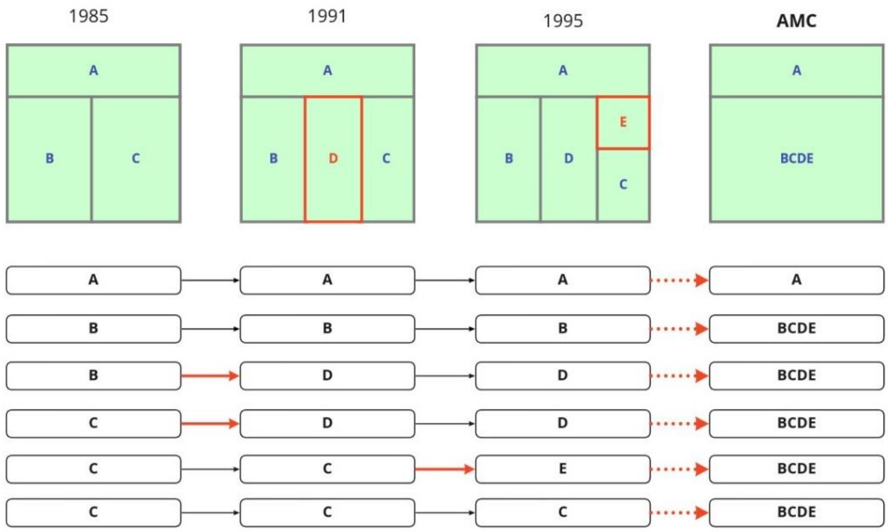
Appendix

A. Methodology for identifying Minimum Comparable Areas (AMC)

Since during the period of analysis there was a change in the Brazilian territorial structure, with the splitting up of some municipalities, those that underwent modifications from 1985 to 2017 were aggregated into AMC. During the first year of the period there were 4,092 municipalities. By 2017 it was 5,570 municipalities, meaning that 1,478 municipalities had been created. This method was also employed by Weinhold et al. (2013) to compare municipalities from 1985 to 2006. Basically, AMC is made up of municipalities that have given up territory to new ones. There are three possibilities for municipalities during that period: (i) the municipality suffered no changes; (ii) only one municipality was split to make a new municipality; and (iii), more than one municipality gave up territory for a new municipality. In all those scenarios there would be an AMC representing one municipality (if there was no change) or more than one (in the two other scenarios). We thus expect to have a lower number of AMC than municipalities in 1985, because in the cases where the third possibility occurred one must aggregate all of the municipalities split up to create the new municipality. For example, if in 1991 a new municipality Z was created in an area held by municipalities X and Y existing in 1985, all the municipalities would correspond to a single AMC. Figure A1 presents another hypothetical case.

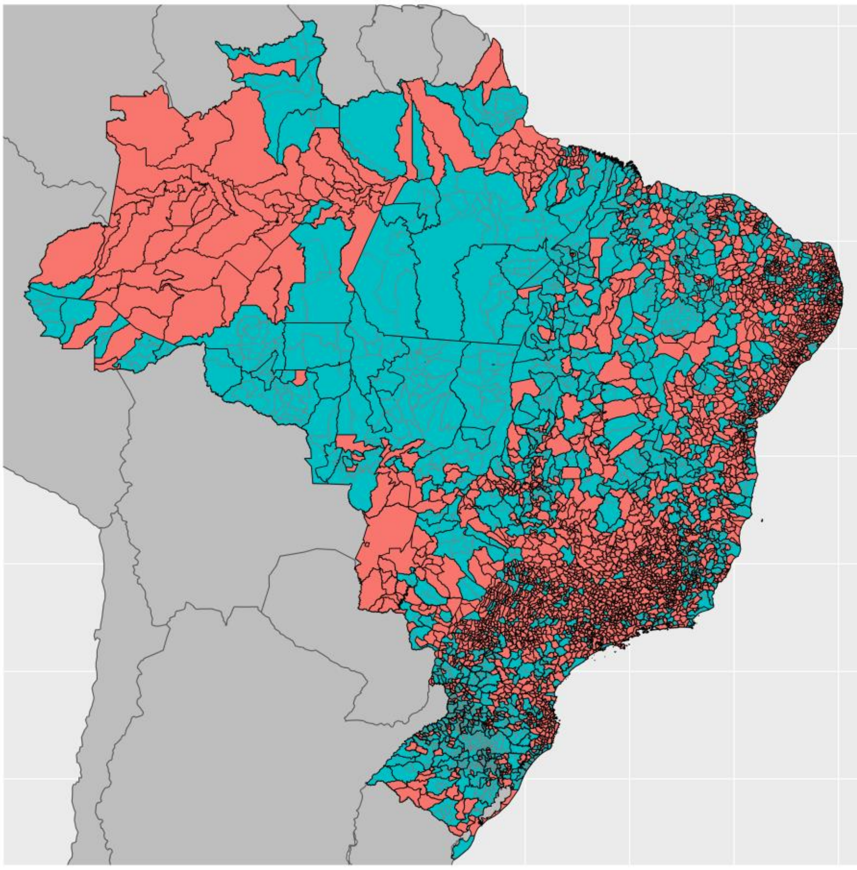
Two tables were used to build a database for the evolution of municipalities from 1985 to 2017 (Figure A2): (1) origin of the municipalities, apparently prepared by the Territorial Structure Coordination (IBGE), containing a list of municipalities that existed or exist, and from which municipality they originated; and (2), a table for population by municipality from 1872 to 2010, prepared by IBGE for the Evolution of Brazilian Territorial Division, which has a list of municipalities in each census year along with information on the origin of new municipalities.

Figure A1. *Example of implementation of Minimum Comparison Areas (AMC).*



Note: The upper figures represent the hypothetical municipal network in different years. Below is an example of the structure of the database implemented for comparing the information.

Figure A2. *Map of Minimum Comparable Areas from 1985 to 2017.*



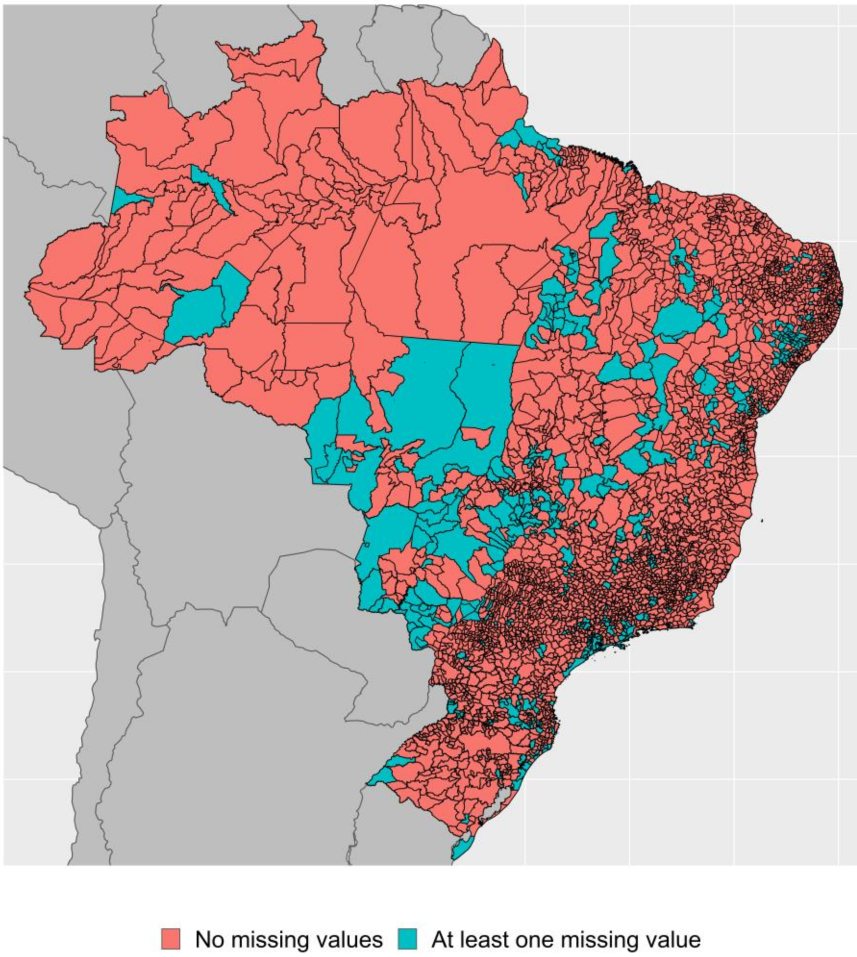
Source: Elaborated by the authors.

Note: Network of minimal comparable areas (with boundaries in black) highlighting areas representing only one municipality. The 2017 municipal network has grey boundary lines.

Considering the total data available for the three years of interest, Figure A3 shows areas with information lacking in areas of the Brazilian Centre-West, the region where soy plantations became consolidated. Thus, the absence of these municipalities from the econometric analysis might lead to results than do not represent reality, since they would not include regions with high variability in the levels of soy cultivation. By individually analysing each variable, we can verify that areas coming from the PAM (area cultivated with soy, other annual crops and perennial crops) were the main areas responsible for the non-comparable data in the Centre-West region, especially perennial crops. In that regard, a new version of those three variables extracted from another data source, MapBiomas, was added to the database.

However, the strategies for estimating these variables are quite different. Crop areas are estimated by PAM through questionnaires filled out by persons responsible in each municipality, while MapBiomas uses remote sensing techniques. There are non-observable areas where it is not possible to distinguish the type of agriculture and ranching used in a given area. This may translate into different measures for the variables. Furthermore, areas in soy were not measured by MapBiomas before 2000 and were recorded together with other annual crops.

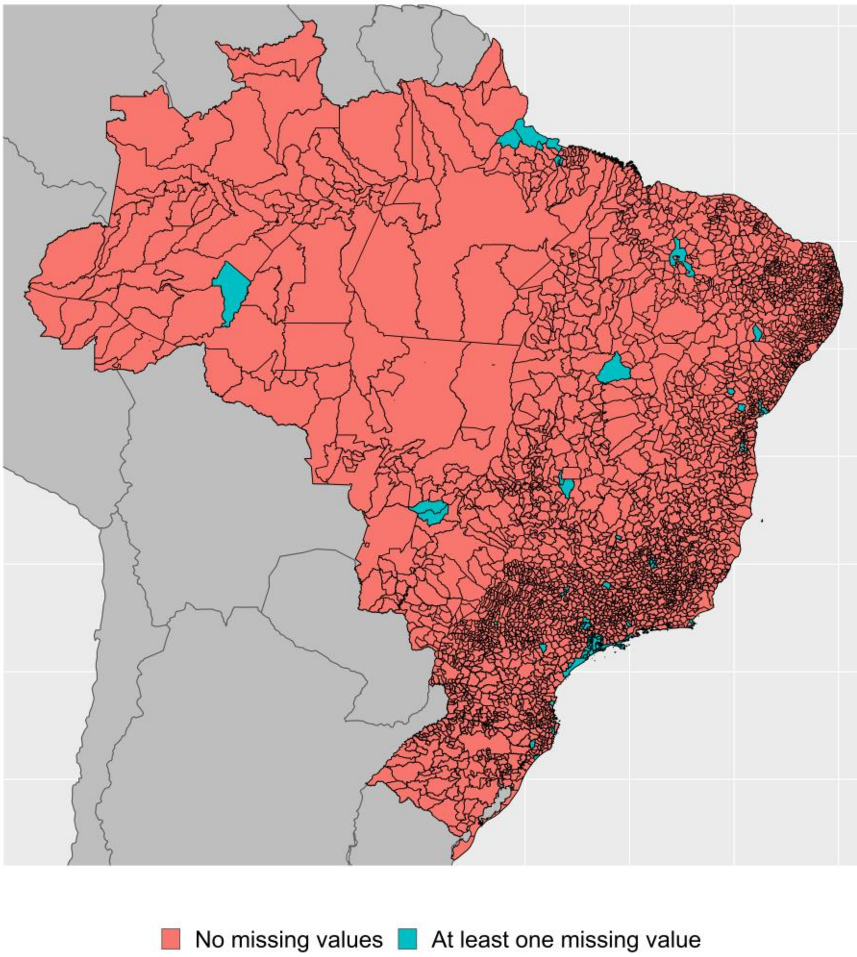
Figure A3. *Map of Minimum Comparable Areas with information lacking.*



Source: Elaborated by the authors.

To determine how similar the same variables from different sources are, Pearson correlation tests were performed for the observations in common. For the three variables in question, each had a positive relation with its respective pair with a significance lower than 1%, but with different levels of correlation. The area in soy presented the highest correlation with an index of 0.72, followed by annual crops with 0.52, and perennial crops with 0.26. In other words, although there was a strong correlation with soy, the other land allocation options presented considerable differences despite their joint variations. To address that problem, we adopted the following two-step procedure. First, we estimated two versions of the equations of interest presented in the section below, one with all the information related to the planted area in the PAM and the other only changing the source for the area in perennial crops to MapBiomas, with restrictions only for observations with data available in common for both cases. That way, we could compare the impacts of substituting the source data should the signal and significance change for both the area in soy and in perennial crops. Should there be no major changes, we can estimate another version of the equations by substituting only the area in perennial crops with MapBiomas without removing observations that are not available for PAM, thus including AMC from 1991 and from the Centre-West. The areas available for this regression version may be seen in the map in Figure A4.

Figure A4. *Minimum Comparable Areas lacking data for a complete estimate.*



Source: Elaborated by the authors.

B. Complete maps of the differences in socioeconomic variables

Figure B1. *Map showing change in income per capita from 1991 to 2010.*

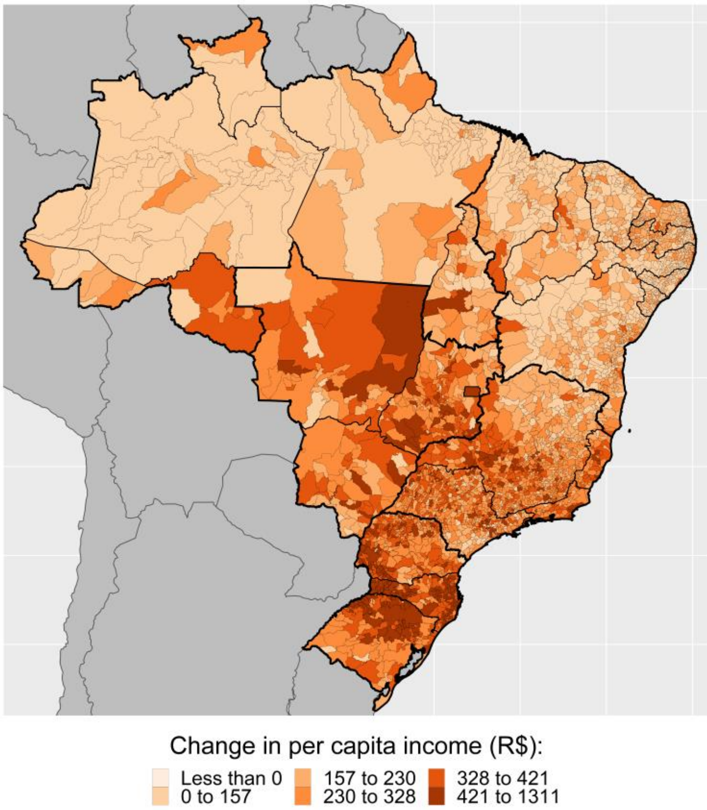
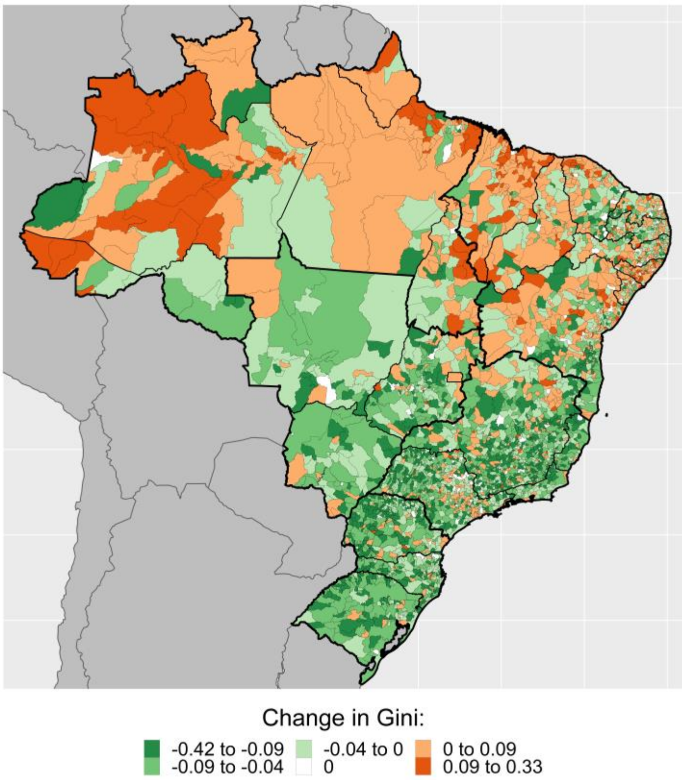


Figure B2. *Map showing change in the Gini coefficient from 1991 to 2010.*



Source: Elaborated by the authors.

Figure B3. *Map showing change of the proportion in poverty from 1991 to 2010.*

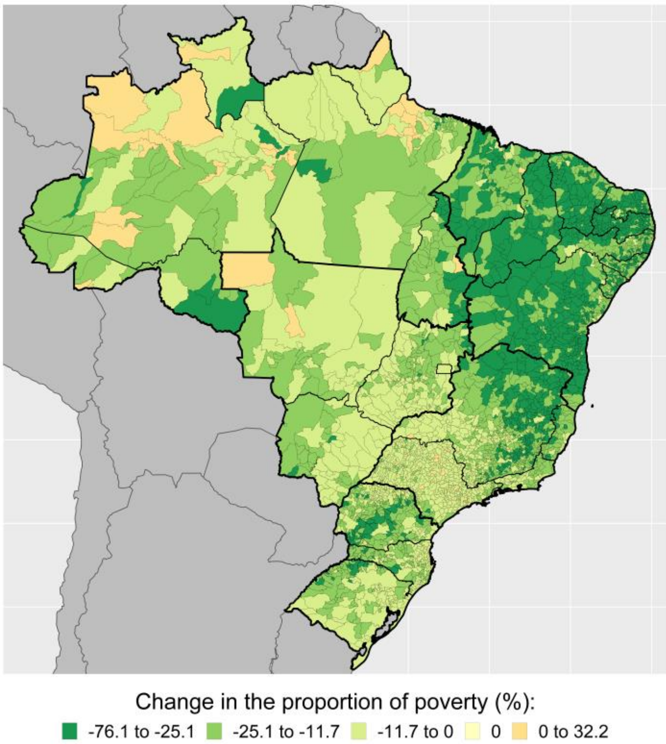
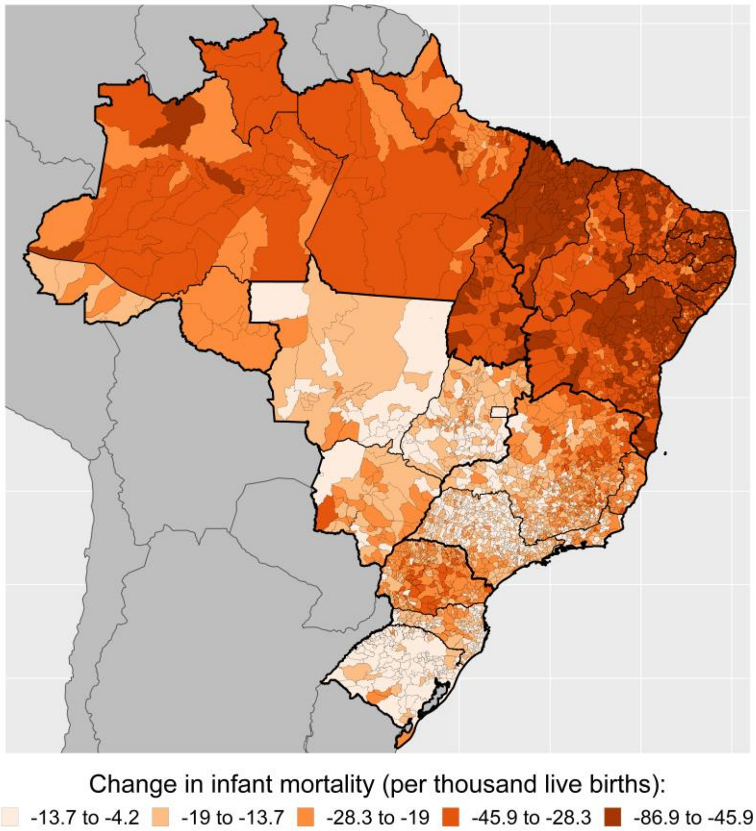


Figure B4. *Map showing change in infant mortality from 1991 to 2010.*



Source: Elaborated by the authors.

Figure B5. *Map showing change in expected years in school from 1991 to 2010.*

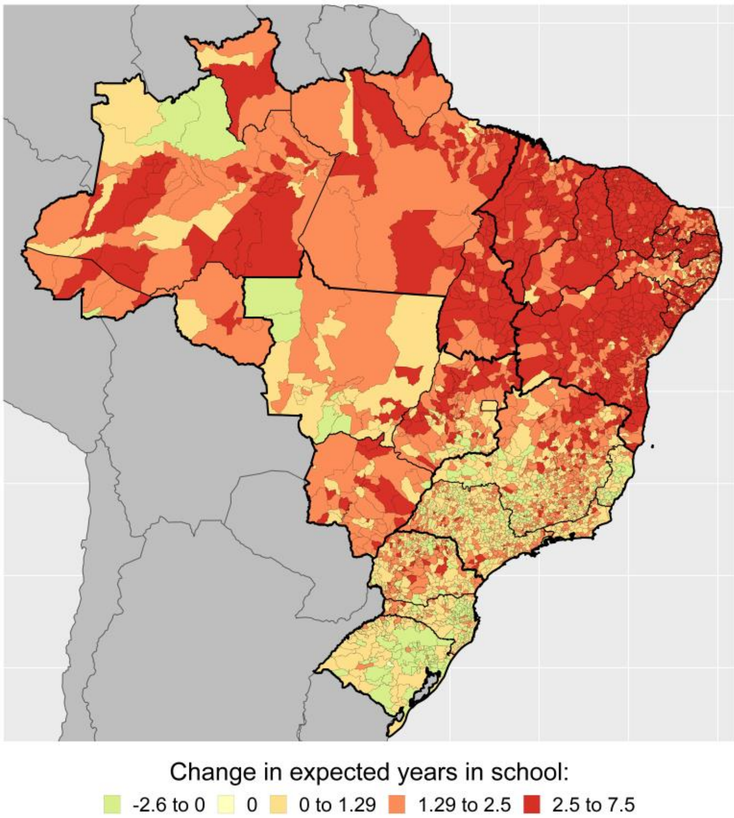
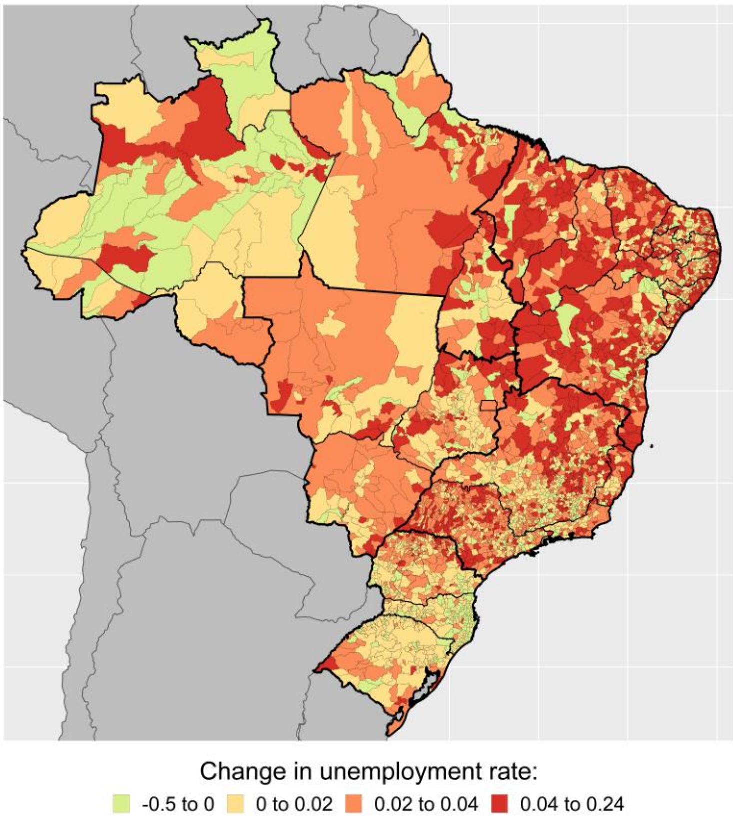


Figure B6. *Map showing change in unemployment rate from 1991 to 2010.*



Source: Elaborated by the authors.