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Climate changes and land use in farming regions: evidence from Buritirana district (Jalapão gateway), Tocantins state, Brazil: 2004-2018

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Abstract
The following research analyzed the interactions between climate change and land use in the Buritirana district, a farming region located at Jalapão gateway, Tocantins state, Brazil. This relatively small area gathers high-tech soybean production developed in recent years, cattle breeding, small family farming, and none associated producers. The study focused on two groups: on the one hand farmers of the agricultural settlements Sítio and Entre Rios and on the other large soybean producers. The database was obtained by the MapBioma project and the WorldClim collection. The images retrieved were processed to plot geographic illustrations and furthermore to elaborate and interpret linear regression. Such framework intended to provide more evidences about the future perspectives of agricultural production in tropical regions. The results revealed an annual increase of average temperature in the examined region, characterized by a strong expansion of soybean monoculture, between 2013 and 2018. However, based on statistical analysis, evidence of correlating soybean expansion to climate changes in the Buritirana region could not be confirmed. Nevertheless, spread of monoculture and reduction of native flora in the Jalapão region and surroundings should be considered with concern, especially for small rural familiar farmers and for wildlife as well, even after approval of the new Brazilian Forest Code in 2008.
Keywords: Climate changes. Land use and cover changes. Soybean production. Maps. Quantitative methods.

Mudanças climáticas e uso da terra em regiões agrícolas: evidências vindas do distrito de Buritirana (portal do Jalapão), Tocantins, Brasil: 2004-2018

Resumo
O artigo analisou a relação entre mudanças climáticas e o uso do solo no distrito de Buritirana, uma área agrícola localizada na região "Portal do Jalapão", Tocantins, Brasil. Essa área relativamente pequena reúne alta produção de soja com elevado nível de tecnologia,

criadores de gado, agricultores familiares e aqueles sem vínculos com a agricultura. A pesquisa concentrou em dois grupos: os pequenos produtores rurais dos assentamentos Sítio e Entre Rios, e os grandes sojicultores. O MapBioma e o WorldClim foram utilizados como fonte de dados. A partir daí, elaborou-se ilustrações geográficas, análises de tendência e uma regressão linear. Essas medidas tiveram o propósito de oferecer novas evidências sobre o futuro da produção agrícola em regiões tropicais. Os resultados demonstraram que apesar da elevação na temperatura média regional, a monocultura da soja se difundiu em Buritirana entre 2013 e 2018. Nos recentes anos, essas lavouras adentraram no Cerrado e no entorno dos assentamentos da reforma agrária, áreas onde o clima e o solo favorecem essa produção. No entanto, inexistem evidências correlacionando o avanço da soja com as mudanças climáticas. Em conclusão, o uso e cobertura do solo para os futuros agricultores familiares e para a vida selvagem é pessimista, embora o novo código florestal brasileiro esteja em vigor desde 2008.
Palavras-chave: Mudanças climáticas. Alterações no uso e cobertura. Produção de soja. Mapas. Métodos quantitativos.

Cambios climáticos y el uso de la tierra en las regiones agrícolas: evidencia del distrito de Buritirana (portal do Jalapão), Tocantins, Brasil: 2004-2018

Resumen
Este artículo analizó la relación entre cambios climáticos y el uso del suelo en el distrito de Buritirana, un area agrícola localizada en la región "Portal do Jalapão", estado de Tocantins, en Brasil. Esta area, relativamente pequeña, incorpora elevados volúmenes de producción de soja y alto nivel de tecnologia, ganadería, agricultores familiares y también aquellos sin conexión alguna con el cultivo. La investigación se concentró en dos grupos: por un lado, en los pequeños campesinos de las colonias Sítio y Entre Rios, y, por otro, en los grandes productores de soja. Los sistemas MapBioma y WorldClim fueron utilizados para la obtención de datos, elaboración de illustraciones geográficos, creación y interpretación de una regresión lineal. Estas medidas tuvieron como propósito ofrecer nuevas evidencias sobre el futuro de la producción agrícola en el trópico. Los resultados demonstraron que la temperatura média en Buritirana se elevó entre 2013 y 2018, período en que la monocultura de la soja se difundió considerablemente. Durante los últimos años, este cultivo transcendió al Cerrado y a los alrededores de las colonias de la reforma agraria. Sin embargo, con base en los datos analizados, no fueron detectadas evidencias que comprueben una correlación entre el avance de la soja y el cambio climático en esta región. De cualquier manera, el uso del suelo para el cultivo de soja en gran escala y la sustitución de selva virgen debe ser considerado con preocupación teniendo en cuenta el futuro de pequeños agricultores familiares y la flora y fauna, a pesar del reglamento del nuevo código forestal, en vigor desde 2008.
Palabras-clave: Cambio climático. Modificaciones del uso del suelo y la cobertura vegetal. Producción de soja. Mapas. Métodos cuantitativos.

1 Introduction

The ongoing climate change has been promoting the increase of global surface temperature (GST), intensification of dry and rain seasons, and the severity of wildfires in tropical regions (IPCC, 2019). These events have permanent impact on structure and composition of farming regions. Adaption of human life to drought and heatwaves is a great challenge and an overly complex task. Nowadays, the raise of rural-urban migration shows the difficulties of peasants, semi-nomadic people, and others who depend on natural resources to survive in such intense weather conditions (LI et al., 2020; YRIDOMOH et al, 2020; ZANG et al., 2020).

Further effects of instable climate on land use are correlated to reduction of average farm values in countries with high temperatures (MENDELSOHN et al., 1994) and a strong need for irrigation and adaption to heat stress conditions (DALE, 1997). These innovations may need a substantial input of capital, which is unavailable for most of the farmers (WEBB, et al., 2017). Therefore, the diversification of agricultural activities is another option of rural producers in order to survive such new environment conditions (REIDSMA; EWERT, 2008).

Nevertheless, land changes caused by monocultures have spread out across the tropics in the 21st century (PIENIZ, 2016; KONG et al., 2018), resulting in remarkable deforestation levels. Also, the changes of land use have been contributing to approximately 70% of total greenhouse gas emissions and 23% of anthropogenic emissions of carbon dioxide, methane, and nitrous oxide to the atmosphere (IPCC, 2019; SILVA et al., 2020). Agricultural emissions are originated by the application of fertilizers to the soil and consumption of fossil fuels by farm machinery. The intensification of land use has enhanced the emergence of "urban heat islands" around rural villages and inside cities during heatwaves or rainfall periods caused by *El Niño* and *La Niña* (IPCC, 2019).

Recent scientific studies have disclosed the conflicts occurred by climate-land interactions in agricultural regions. Ploeg (2020) affirms that the need to implement environmental policies to suppress climate change will impose restrictions on the production of family farmers who already have been coping with considerable income reduction. In addition, air pollution, heatwaves, wildfires, and pesticide contamination have intensified rural decline (ZANG et al., 2020). Consequently, capital intense large-scale farming with highly specialized production should grow in the next years. Such monocultures result in impoverished landscape with minor biodiversity and reduction of welfare in rural communities (STANCZUK-GALWIACZEK et al., 2018).

In the last two decades of the 19th century, Brazil has been exposed to a solid modification from natural land cover to soybean fields (GOODMAN et al. 1985, HILLMAN; FANIMOW, 1987, SOUSA; BUSCH, 1998, WARKEN, 2000). Currently, the country has turned into one of the most important exporters of this product and, at the same time, inner lands have become strongly dependent on global agribusiness supply chains (OLIVEIRA; RODRIGUES, 2019). Furthermore, the advance of area under cultivation has threatened tropical biomes such as the Amazon, where intense deforestation has been responsible for causing irreversible changes on local and global climate (SILVA et al., 2020). In spite of the negative impacts, expansion of Brazilian agricultural has increasingly supplied food, especially to China, speeding up world economy and growth of global population (PIENIZ, 2016). For the next years, the core challenge in Brazil will be to develop a harmonious coexistence of natural forests, traditional communities with high-tech and export-oriented monocultures (OLIVEIRA et al., 2020).

The new Brazilian Forest Code (Law No. 12.651/2012) determines a minimum percentage of natural biomes (minimum of 20% of areas in the Cerrado and 80% in the Amazon rainforest) to serve as a Legal Reserve (RL) in rural properties. This code pretends to protect biodiversity in areas of agricultural expansion (POLIZEL et al., 2021). However, according to MapBiome, between 2017 and 2018, natural forests have decreased by 1.13 million hectares whereas pasture and arable land increased by 1.29 and 1.6 million hectares, respectively. In 2019, wildfire spreads in the Amazon and *Cerrado* (Brazilian Savanna) biomes provoked a tremendous dark colored rain in the city of São Paulo. Regardless of such extreme climate conditions, the Brazilian Institute of Geography and Statistics (IBGE) expected a record grain harvest for 2020, especially related to soybeans production, which increased by 6.7% compared to 2019 (IBGE, 2019).

The main reason for soybean expansion in Brazil is based on progress in technology (SANO et al., 2019). Every year, Brazilian Agricultural Research Corporation (EMBRAPA) has managed to improve seed productivity by creating species even more adapted to aridity and reduced germination periods. Thus, states in the Brazilian heatland, such as Tocantins, characterized by concentrated precipitation during only a few months and high temperatures during the whole year, have become national agricultural strongholds (CAMPOS et al., 2019). Furthermore, the support of public finance institutions and the massive investments in infrastructure brought positives impacts in the state soybean crop development (SANTOS, 2020).

Inside Tocantins state, the Jalapão region has become a highlight due to its natural landscape and major soybean production led by municipalities such as Campos Lindos and Mateiros (OLIVEIRA; DORNER, 2015). The new physical regionalization launched by IBGE in 2017 shifted the name from Jalapão to Immediate Geographic Region (RGI) of Palmas, but the early name remains as a geographic reference in scientific studies and in the media.

The soybean fields in Palmas are concentrated at the Buritirana district, one of the gateways to access the landscape of the touristic Jalapão region. However, as tourism in Buritirana is little explored, the farming activities have become the economic basis (OLIVEIRA, 2017).

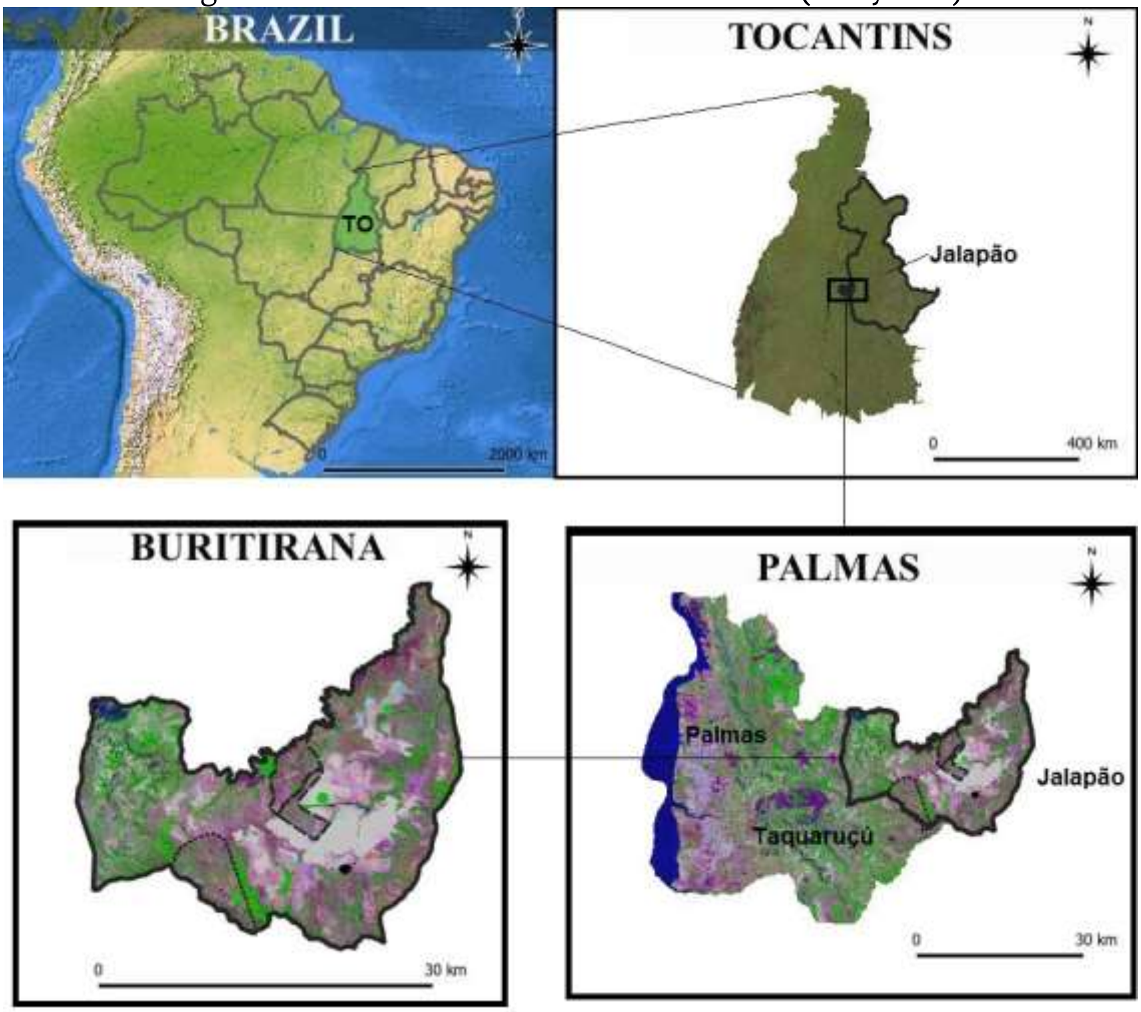
Buritirana district is particularly interesting, as it gathers at a relatively small area high-tech soybean production, developed in recent years, cattle breeding, small family farming and, as well, people not associated to any of those activities. Such a framework allows to study the consequences of climate changes on land use and land cover in farming regions by using accurate data available by Mapbiomas Project and WorldClim. Therefore, this article intends to provide more evidence about the future development of agricultural production in tropical countries such as Brazil. The focus of this research was on two groups: small farmers of agricultural settlements (PA Sítio and PA Entre Rios) and high-tech oriented soybean farmers. The next chapter describes with details study object, methods, and data collection, followed by exposure of results, conclusions, and references.

2 Research design

2.1 Study area

The state of Tocantins is localized in the North region of Brazil. Its capital, Palmas, is the newest capital city in Brazilian territory (founded in 1989). In 2001, the population of Palmas had only 150.884 inhabitants (IBGE, 2000). However, during the following years, the population increased steadily and reached 299.127 in 2019 (IBGE, estimated population). Due to migration, Palmas has become an essential urban hub at Brazilian Central-North, providing opportunities to citizens who wish to boost their income and access public services such as education and health (OLIVEIRA; PIFFER, 2015; OLIVEIRA; PIFFER, 2017). Outside the urban area, the municipality embraces two districts: Taquaruçú and Buritirana (figure 1).

Figure 1 - Localization of the Buritirana district (study area)



Source: SICAR. Elaborated by the authors (2020).

Taquaruçú village is 30 kilometers away from Palmas civic center, in the lower mountain range of Carmo. The region is characterized by diverse fauna and flora, a mix of Amazon Forest with Brazilian Savanna (*Cerrado*). During the 1990s, the state government formalized areas of environmental protection to preserve natural resources such as creeks, centenary trees, and wildlife. Tourism has explored these landscapes in the last decades, and its community has been strongly involved in such activities (MILAGRES; SOUSA, 2012).

Nonetheless, Buritirana district is entirely different from Taquaruçú. Firstly, the relatively long distance from the village to the urban core of Palmas (65 kilometers), seems to avoid a deeper relationship between both. Secondly, the number of inhabitants (less than 1,000) (IBGE – Demographic Census, 2010) is extremely low and characterized by even less density in the rural area. Since 1999, only 104 families have been living in the agricultural settlement (PA)[1] of Entre Rios and 52 in Sitio (INCRA, 2020). Thirdly, topography is molded by an extensive plain (approximately 56,500 hectars or 565 km²), favorable condition to run large-scale agriculture. Fourthly, the urban life in the village is extremely poor and lacks of economic activity (OLIVEIRA, 2017). Nevertheless, the district is known by its vast soybean fields, which can be considered as an excellent field area to understand land-climate interactions in farming regions.

2.2 *Proceeding and data collection*

The analyzed period starts in 2004, when Buritirana had a low-level production of soybean, and extends to 2018, which was considered a year of a super-harvest. Three steps were formulated to investigate climate-land interactions at the Jalapão gateway region:

1. Land cover and land use changes focusing on agricultural settlements and soybean areas (the entire Buritirana district);
2. Identification of the climate zones in Buritirana district and the variations along the years of study;
3. Correlation analysis.

The first two steps consist on visualization analysis across time. The first step used MapBioma Project as a source of geographic information of land use and land cover in Brazil. The database is a component of the Climate Observatory, an initiative commanded by Brazilian universities and public institutions. The researchers retrieve Landsat multispectral images to process and to classify land cover and land use in Brazil. Google Earth gathers these images in a matrix format (30x30m pixels) and offers an option to download such data to a municipality scale. The respective mosaics to Palmas municipality were transported to Qgis and-trimmed to match the Buritirana district area. Each mosaic contained 28 layers of information, including spectral bands, fractions, and indices. The low complex-level in the research area led to choose only five layers:

- Forest formation (color: dark green);
- Savanna formation (color: light green);
- Grassland (color: soft green);
- Pasture (color: yellow);
- Annual and perennial crop (color: magenta).

In addition, the land cover/use changes in Buritirana were summarized in graphics, enhancing the user to verify evolution of soybean field areas, deforestation and as well, to clearly display the agricultural settlements of Sítio and Entre Rios.

Step two used the WorldClim collection, a project of the University of East Anglia, that provides historical monthly weather data between 1960 and 2018 in

[1] Agriculture settlement is an official delimitation created by the federal government as part of the agrarian land reform politics.

GeoTiff (.tif). Among the data, average temperature (°C) displays information about the land surface temperature (LST). The LST is monitored by remote sensing technology and aircrafts, helping to understand the hydrological changes and formation of "urban heat islands" (IPCC, 2019; WU et al., 2019). However, it is only capable to detect climate anomalies over a long period (FARMER; COOK, 2012). Between 2004 and 2018 Brazil suffered El Niño (2010/2011 at a medium intensity and 2015/2016 at a high intensity) and such variations had been included in this research.

Even as the elevation of global temperatures is a major concern, precipitation (mm) assumes an essential role to affect the agricultural development as well. In this sense, Campos; Chaves (2020) affirm the existence of a relationship between reduction of precipitation and increase of deforestation in areas of Mid-West, Southwest, inner Northwest, and across the Tocantins state. Also, this negative effect causes variability of farming productivity, pressuring policymakers to seek solutions to cope with unstable rain periods (ASSAD et al., 2020).

Alike of MapBioma, the average temperature (°C) and annual precipitation (mm) WorldClim images were downloaded and transferred to Qgis. As the images are only available on a monthly basis, the freeware aggregated all of them separately for each year. However, the mosaic follows an aleatory colour pattern. Thus, the legend was created interpolating and classifying data into four quartiles: high, medium-high, medium, and low.

Based on this classification, geographic illustrations were elaborated to show heat zones and humid zones, as well as the variation of weather across time at Buritirana district. Furthermore, these data can be used to analyze trends in historical series, either average temperature (°C) or annual precipitation (mm). Among the statistics procedures, the Mann-Kendall Test (MK) is often utilized in studies about climate changes (HU et al., 2019; CAMPOS; CHAVES, 2020; WAN et al., 2020). The MK test advantages are related to flexibility of data quality requirements and distribution, and when there is no serial correlation in observations. The significance test Z and the test S are described as:

$$S = \sum_{h=1}^{n-1} \sum_{t=h+1}^{n} F(y_t - y_h) \quad (1)$$

$$F(\acute{\emptyset}) = \begin{cases} 1 \; if \; \acute{\emptyset} > 0 \\ 0 \; if \; \acute{\emptyset} = 0 \\ -1 \; if \; \acute{\emptyset} < 0 \end{cases} \quad (2)$$

$$Var(S) = \frac{[n(n-1)(2n+5) - \sum_d d(d-1)(2d+5)]}{18} \quad (3)$$

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} \; if \; S > 0 \\ 0 \; if \; S = 0 \\ \frac{S-1}{\sqrt{Var(S)}} \; if \; S < 0 \end{cases} \quad (4)$$

where y is the weather variable and $\acute{\emptyset} = y_t - y_h$ and d is the extent of any given tie. The statistical significance level p = 0.005 is used with Z = $\pm$1.96. Positive values (Z) suggest a trend to increase the average temperature (°C) or annual precipitation (mm), while the contrary indicates a decreased trend.

The Modified Mann-Kendall Test (MKK) is another option to analyze trends in historical series (HU et al., 2019). Compared with the MK test, the MMK test modified Equation (4) by using a function V(S) to replace Var(S):

$$V(S) = Var(S) \times \left(1 + \frac{2}{n(n-1)(n-2)}\right) \sum_{h=1}^{n-1} (n-h)(n-h-1)(n-h-2) R_h \quad (5)$$

$$R_h = \frac{n \sum_{c=1}^{n-h} (y_c - \bar{y})(y_{c+h} - \bar{y})}{(n-h) \sum_{c=1}^{n} (y_c - \bar{y})^2} \quad (6)$$

Finally, the non-parametric Sen´s Slope procedure is used to estimate the changes over a period in climate variables. The magnitude Q is computed using the following equation:

$$Q = \text{median} \left[\frac{(m_b - m_a)}{(b - a)}\right] \text{for all } a < b \quad (7)$$

where m_b and m_a are the values at times b and a (b > a), respectively.

The Mann-Kendall test and the Sen´s Slope procedure are available in package "trend" of the R computer program, while the Modified Mann-Kendall test is an option offered by the package "modifiedmk" of the same freeware. However, the trend indicators are insufficient to understand climate-land interactions. Therefore, a type of statistic technique is used in step 3 for modeling the relationship between land (step 1) and climate (step 2) at the Jalapão gateway. In this sense, the dependent variable is the "Annual and Perennial crop" growth rate for each year of study, and the independent variables are average temperature (°C) and annual precipitation (mm) growth rate for each year of study as well. The aim is to verify if the decision to use land cover for farming activities is related to weather conditions. The linear equation is:

$$Crop\% = \alpha + LST\%X1 + Prec\%X2 + e \quad (8)$$

where Crop% is the "Annual and Perennial crop" growth rate, LST%X1 is the average temperature (°C) growth rate, and Prec%X2 is the annual precipitation (mm) growth rate. Identical of step 1 and with the same aim, the regression analysis was separated in two zones (agricultural settlements and soybean field areas). Again, the computational program R was applied with the support by package "olsrr", to determine the estimations of linear model.

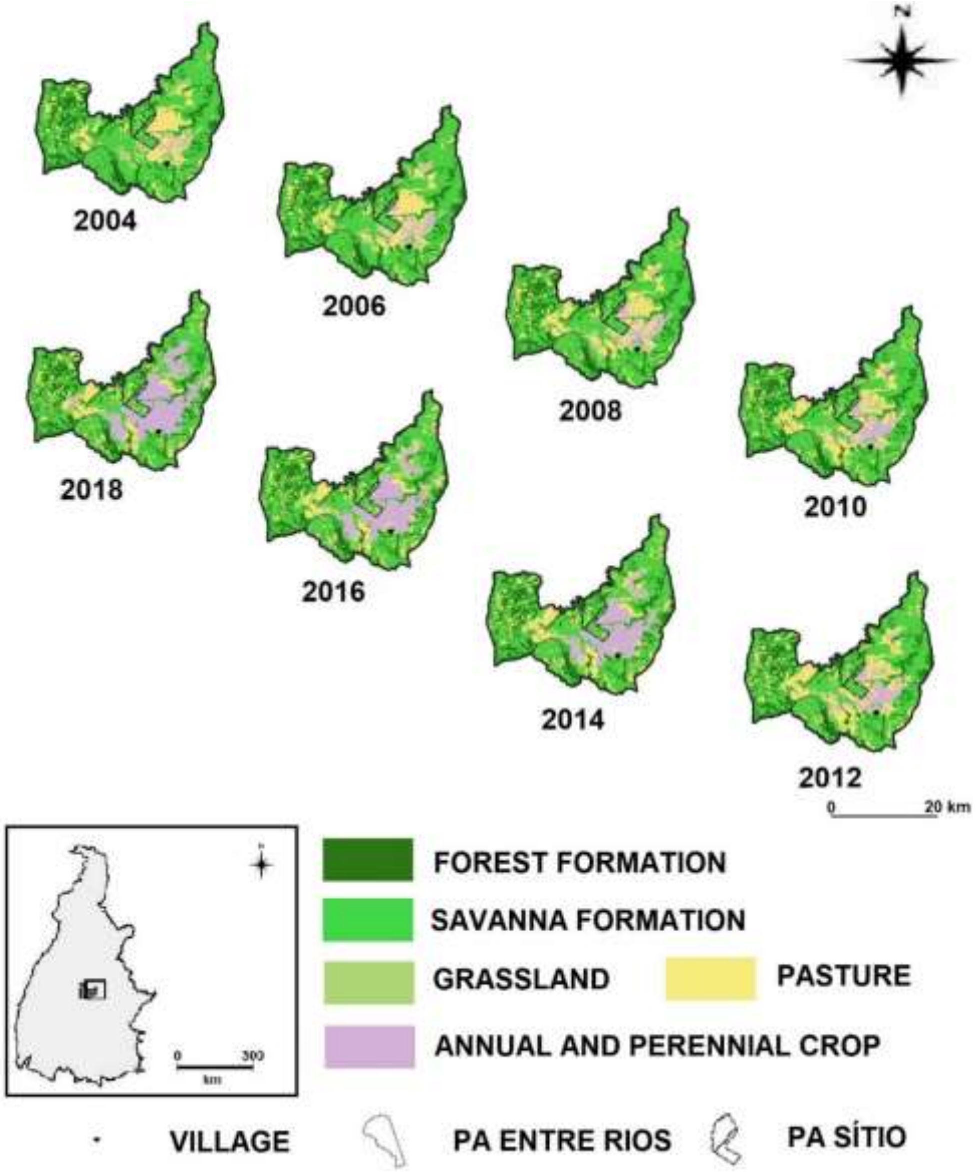
Thereby, the geographic and statistic illustrations, the trend analyses, as well as the linear regression, can provide evidence about climate-land interactions in a Brazilian farming region. Nevertheless, issues emerged during the discussions of results. A visit to Buritirana district between March and April 2020 was necessary to fulfill lacks in the methodology. The observations made during this period were utilized in the next section to explain the preliminary results.

Even taking care of all issues, the methodological processing fostered in this study has limitations in the work conclusions. The average temperature and annual precipitation historic data cover only a relative short time. The Mann-Kendall test is a non-parametric test with restrictions to evaluate the magnitude of changes. These weaknesses made the discussion of results rely strongly on visualization, comparison, and interpretation of geoprocessing images.

3 Results and discussions

The changes from natural cover to annual /perennial crop or pasture started in 2008, when agricultural land began to replace pastures in the surroundings of Buritirana village (figure 2).

Figure 2 – Distribution of land cover and land use at Buritirana district (2004/2018)



Source: MapBioma Project (2020). Elaborated by the authors.

As pointed out in figure 1, soybean production increased significantly between 2008 and 2012. However, there is no visual correlation between such expansion and deforestation, as forests and Cerrado (Brazilian Savanna) were under protection against human interference. The turning point happened in 2013, when land use at the Jalapão gateway began to change drastically. In 2018, indeed, the MapBioma detected annual and perennial crops at the extreme eastern edge of the district, a zone originally covered by native vegetation in the past decades.

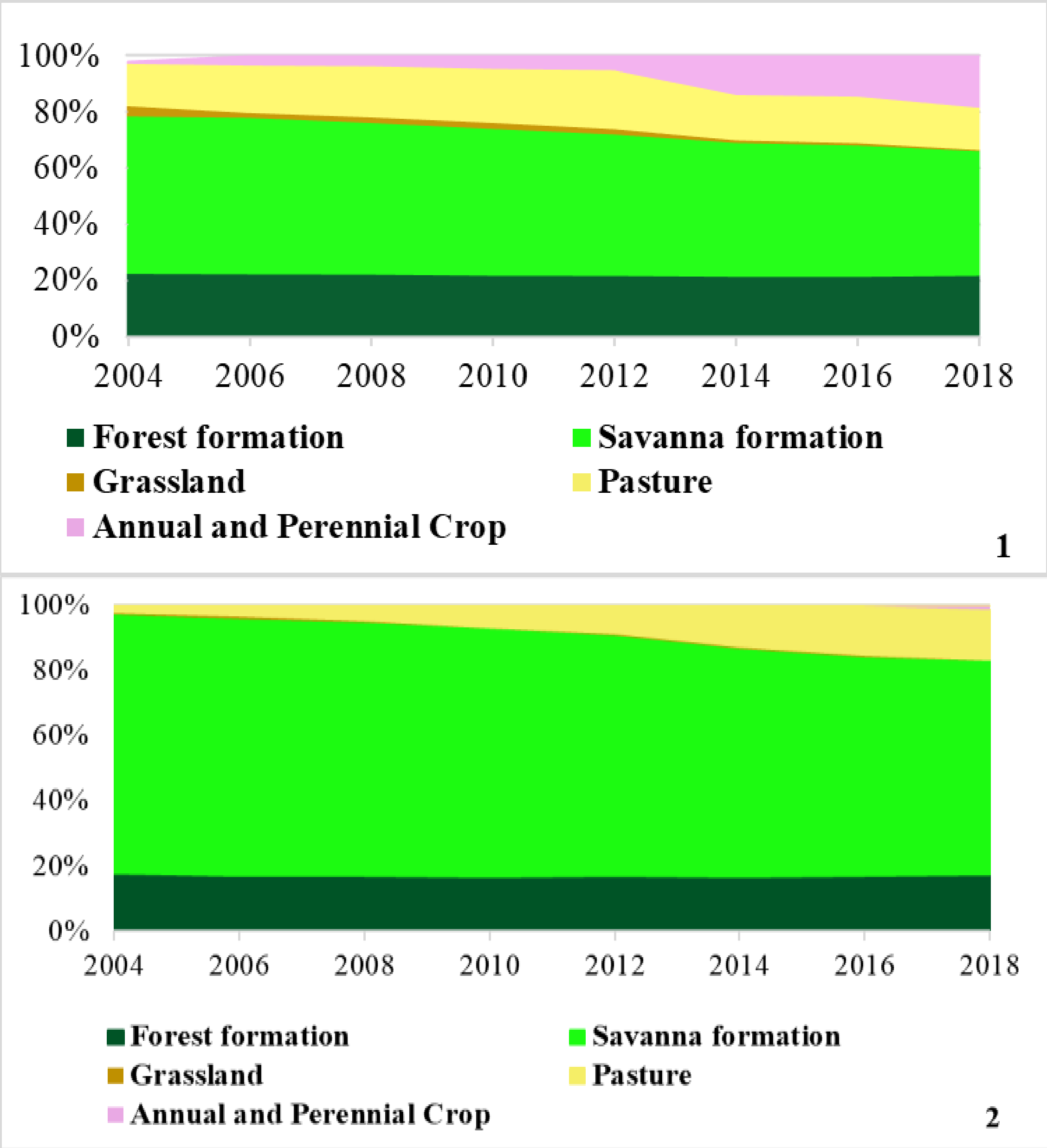
There are several reasons which could explain land changes in Buritirana and the expansion of soybean production: a relatively low price to purchase rural real estate in countryside regions (WEINHOLD et al., 2013), inner Brazilian migration movements from South to North (CAVIGLIA-HARRIS et al., 2013) and the possibility of high earnings due to favorable external prices of commodities (CHOI; KIM, 2016).

Besides, figure 2 provides evidence that the agricultural settlements (PAs) have developed humbly, even though they had been fully operating between 1999 and 2008. Apparently, these family farmers originated from North and Northeast regions had received insufficient supports such as access to rural funding and technical assistance to increase their productivity (ZELLER; SCHIESARI, 2020). In fact, these might be the reasons that explain the enormous differences in competitiveness between small family farmers and high-tech farm production.

Although natural cover has reduced significantly over the last years, native forests still represent approximately 21% of overall land cover of Buritirana and no significant loss during the analyzed period. However, grassland has diminished by 14.7%, savanna formation by 1.8% and pasture by 0.07% per annum. In contrast, annual and perennial crops increased by 22% yearly totaling in 2018 an area equal to natural forests.

From 2012 to 2014, soybean fields expanded by 61.8%, whereas agricultural settlements exploring livestock, natural grasslands and pasture, continued unchanged (figure 3).

Figure 3 – Land use and land cover composition in areas of soybean production (1) and agricultural settlements (2): 2004 – 2018

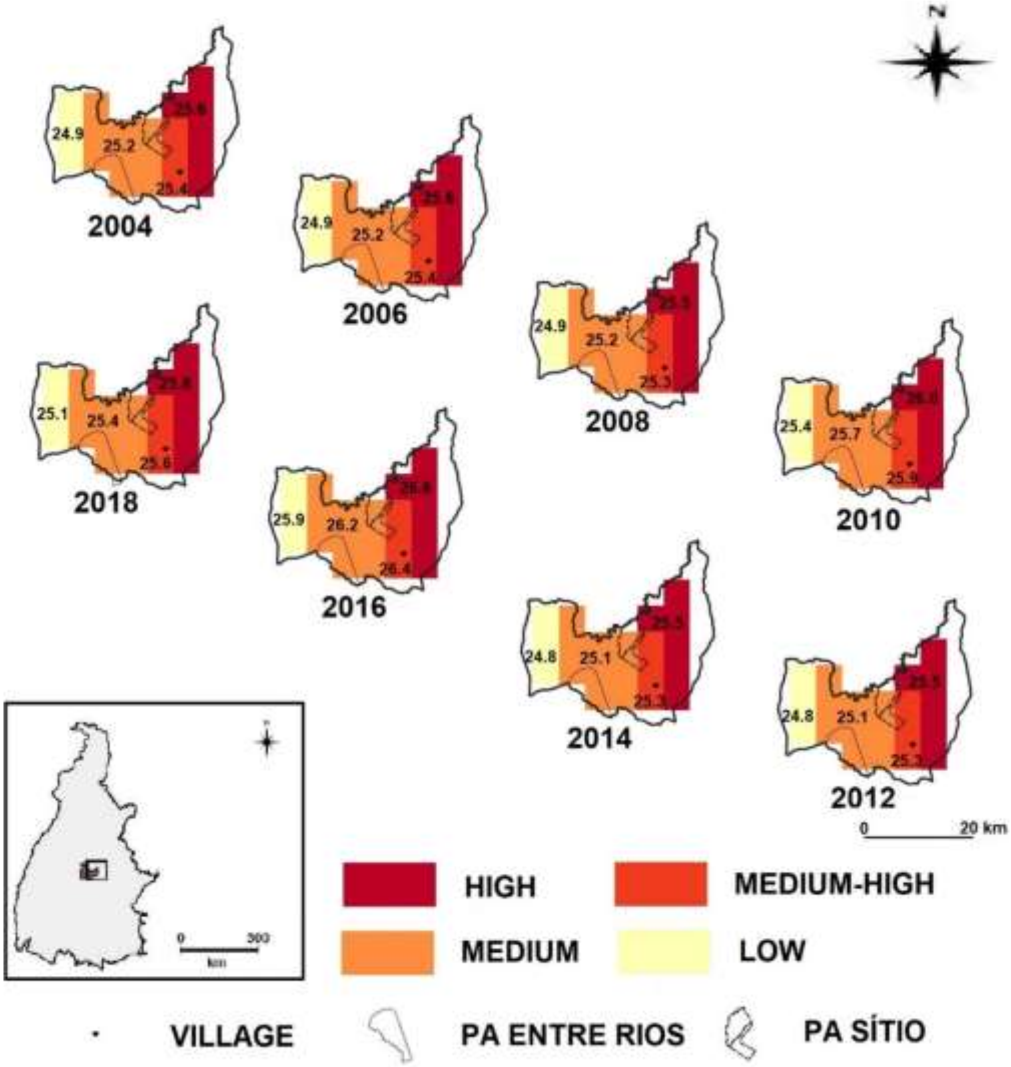


Source: MapBioma project (2020). Elaborated by the authors.

Forests and savanna still cover large areas of the agricultural settlements according to figure 3. As cattle-breeding is a traditional activity in Tocantins state, pasture has maintained its importance in PA´s land use. Even though, low budget has been limiting small family farmers to renew their pastures. Therefore, in a relatively short time, such lands tend to soil erosion and degradation (BORGHI *et al.*, 2018). Furthermore, only minor areas have been used for agriculture by these settlements, representing less than 3% of total area.

The Agricultura settlements Sítio and Entre Rios are both in a zone where average land surface temperature has been lower than in soybean fields (figure 4), contributing to preserve groundwater probably more effectively than in other areas of Buritirana district.

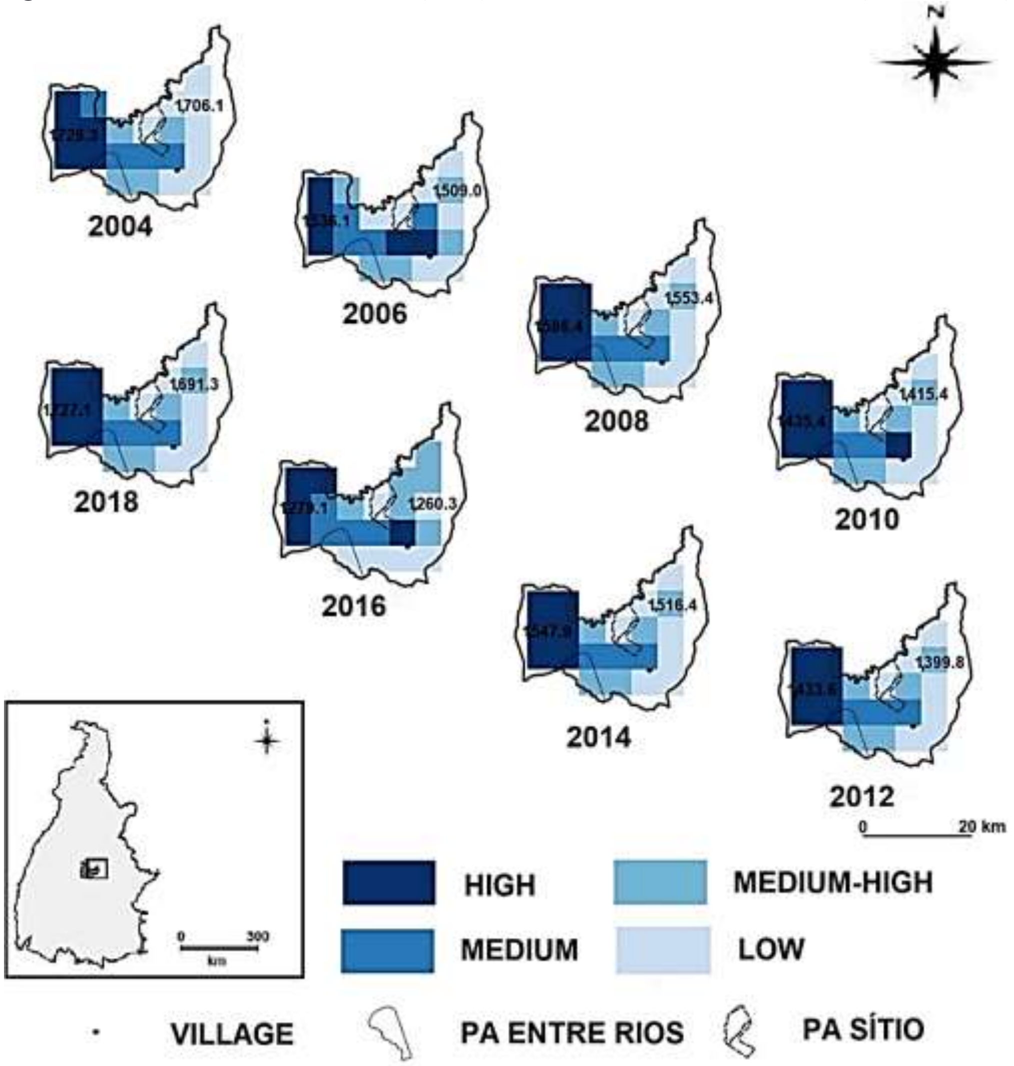
Figure 4 – Average land surface temperature (°C) zones in Buritirana district (2004-2018)



Source: WorldClim (2020). Elaborated by the authors.

Similar to the evolution of average land surface temperature, the annual precipitation zones have assumed as well heterogeneous patterns (figure 5). Areas with original cover, localized at the extreme east edge of the district, have registered higher precipitation than others. However, most likely such reduction had little impact on soybean expansion in the Jalapão gateway between 2004 and 2018.

Figure 5 – Annual precipitation (mm) zones in Buritirana district (2004-2018)



Source: WorldClim (2020). Elaborated by the authors.

Increases of average temperature and decrease of precipitation between 2010 and 2016 may be related to *El Niño*. In 2010, the average temperature was 0.5 °C higher than in 2008, and in 2016 0.9 °C higher than in 2014. Although temperatures seemed to have returned to normal levels in subsequent years, expect for 2018, when registered 0.3 °C above the range in 2014. The period between 2012 and 2018 could be considered as a warmer one, exactly when soybeans yields advanced the most on savanna formation (figures 2 and 3). In addition, precipitation reached a lower level during the data series in 2016 (below 1,300 mm), demonstrating the high impact of *El Niño* at Buritirana district.

However, annual precipitation had already dropped before the occurrence of *El Niño*. Between 2004 and 2010, annual precipitation decreased by 2.51% and between 2010 and 2016, by 1.44% per annum. 2018 was an atypical year with 1,710 mm of precipitation, a remarkable volume only outnumbered in 2004 (1,723mm). The lowest precipitation occurred in 2016 (1,270mm) during the second *El Niño* in the 2010s. The results of the Z value (trend analysis) for the Mann-Kendall Test (MK) and the Mann-Kendall Test Modified (MKK) confirmed the reduction of annual precipitation: -0.87 and -1.2 (table 1).

Table 1 – Results of trend analysis at Buritirana district (2004–2018)

Data type	Z		Sen´s Slope
	MK	MKK	
Average temperature - LST (°C)	0.39	0.5	0.01
Annual precipitation (mm)	-0.87	-1.2	-37

Elaborated by authors (2020).

In contrast, the Z values for MK and MKK are clearly below 95% of probability (<1.96). Also, by ignoring 2018 data, an atypical year of precipitation, the Z value for MKK (-2.71) reaches statistical significance. The Sen´s Slope value is -37, but no significant trend was found in annual precipitation (mm), whereas the parameter average temperature – LST (°C) is statistically significant, meaning that local warming in Buritirana could increase in the next years. These results are reliable with Campos; Chaves (2020), who also detected low significance in their database.

Finally, the last step analyzed if the expansion of land crops at the Jalapão gateway interacted with climate change. During the initial tests, the average temperature – LST (°C) was ignored by the linear regression because of its insignificant correlation with the dependent variable. As the agricultural settlement Entre Rios had annual and perennial croplands in 2018 (0.04% of overall), it was excluded from the analysis as well. Hence, the model confirmed only correlation of the annual precipitation growth rate (%) with the agriculture areas growth rate (%) at PA Sítio and soybean fields, which cover almost the whole Buritirana district (table 2).

Table 2 – Linear regression results (PA Sítio and soybean fields) at Buritirana district (2004-2018)

Area	Dependent variable	Beta	Std. Error	Std. Beta	t	Sig.	R^2
PA Sítio	Intercept	6.47	3.77		1.72	0.15	0.56
	Annual precipitation (mm)	3.75	2.51	0.56	1.5	0.2	
Soybean fields	Intercept	4.13	2.06		2.01	0.1	0.1
	Annual precipitation (mm)	-0.15	1.37	-0.05	-0.1	0.92	

Elaborated by authors (2020).

The regression coefficient (R^2) of the agricultural settlement Sítio reveals that annual precipitation (mm) is much more significant to croplands expansion (56%)

than to soybean fields expansion (10%). These results match other studies about modern agriculture, as high-tech farmers usually expand their business based on available technology (improved seeds, machinery, and chemical inputs) and funding, instead of climate factors (OLIVEIRA et al., 2020). However, the linear regression results are statistically insignificant in the annual precipitation (mm) parameter.

4 Conclusions

The study analyzed the interactions between climate changes and land use in the Buritirana district (Jalapão gateway), Tocantins state, Brazil. The research area gathered soybean farmers, livestock farmers, family farmers, and none farmers which share the same rural area. However, the study focused on only two groups: small farmers of the agricultural settlements Sítio and Entre Rios and soybean producers. The analyzed period was 2004 to 2018.

MapBioma Projects and WorldClim collection provided the database on land use and climate changes over time. Additionally, geographic illustrations were plotted to support observation. Furthermore, these data were used to verify trends (Mann-Kendall Test -MK-, Modified Mann-Kendall Test -MMK-, and Sen´s Slope) in average temperature (°C) and annual precipitation (mm). Finally, the Ordinary Least Square (OLS) method was applied to check the relation between crop growth and weather modifications. In an overview, the maps offered interesting insights about the geographic localization of crops, natural covers, temperature, and rainfall zones in Buritirana. However, statistics revealed low significance levels.

The results disclosed little deforestation between 2004 and 2012. Although, land use at Buritirana district became more intense due to soybean expansion. Even as precipitation have decreased since 2004, to monoculture farmers, at least on the short-term, such evolution seems no real obstacle for their activity, as other factors such as access to technology and funding are more decisive (OLIVEIRA et al., 2020). In contrast, small farmers of the agricultural settlements, usually cattle breeders, have been extremely dependent on stable weather conditions. Furthermore, these rural producers lack of access to modern technology and funding, compared to soybean farmers.

The observations made in the Jalapão gateway imply in several considerations about land use and land cover in farming regions. Monocultures, especially soybean production seem to be more capable to adapt to adverse climate conditions. This might have negative effects on the future of integrated systems of rural production, considered a better response to global warming. Consequently, small family farmers and wildlife may be expelled by larger farmers. Although the new Brazilian Forest Code plays and important role to protect natural resources, law enforcement seems to be limited to protect the biodiversity in the MATOPIBA region, a junction of the states Maranhão, Tocantins, Piauí, and Bahia (POLIZEL et al., 2021).

However, the methodology applied in this study was little effective to prove a correlation between different crops and climate changes, though the trend tests used suggested an increase of temperature in the future and deep impacts on agricultural production. Such changes were confirmed during personal visits made by the authors in 2020 and 2021 as new soybean fields were observed in the southern area of the district and close to ancient agricultural settlements. These viewings were highlighted by Mapbiomas in its recent publishments. Therefore, further research should focus on these new images and extend its period until 2022, when even more deforestation was registered in Brazil.

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