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Article

Land Concentration and Social Progress Decline in Brazilian Amazon Municipalities

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Abstract: Rural populations are directly reliant on ecosystem goods and the land structure within which they are embedded. They are hardship-impacted due to land appropriation and the absence of regulatory mechanisms that ensure sustainable development and socio-environmental conflict prevention. MATOPIBA region encompasses an ecotone area between the Cerrado and Amazon biomes, a significant Brazilian agricultural frontier, and a biodiversity conservation priority area. In this context, we observed an inverse correlation between land concentration and socio-environmental development in ten municipalities in Tocantins State, Brazil. The legal security of land is directly proportional to the Social Progress Index (SPI), which, in turn, is inversely related to land concentration. Therefore, the existence of a multifactorial relationship between SPI, land tenure security, land concentration, and land grabbing should be considered in the development of public policies for land governance and climate change in the Brazilian Amazon region.

Keywords: land tenure security; land grabbing; MATOPIBA; territorial development; rural and traditional populations

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1. Introduction

Rural communities in Brazil are marked by the contradictions of the capitalist economic development model. The concentration of land is a long-known phenomenon (Holanda, 2007; Furtado, 2007), and a striking example of this reality. This trend, rooted in the country's colonial history, continues to profoundly influence the current land structure, affecting sustainable development, land use, and the social progress of rural populations (Sant'anna, 2017).

According to França and Marques (2017), Brazil's weak performance in implementing international guidelines, such as those of the Food and Agriculture Organization of the United Nations (2012), highlights the complexity of land governance in the national context. On the other hand, market-based land reform, promoted by the World Bank Group (2014) and criticized by authors such as Sauer and Pereira Leite (2012), illustrates the tensions between a market-based economic development model and the need for more equitable and sustainable policies. The relationship between land tenure and social progress is complex and marked by historical challenges in the Brazilian context, especially regarding land concentration and the legal security of property ownership and registration.

The 1988 Constitution of the Federative Republic of Brazil (1988), in line with UN guidelines, emphasizes the need for a broader debate on access to and use of land that goes beyond economic bias. Article 5 (XXIII) of the Constitution states that land must fulfill its social function, which implies a development approach that values socio-environmental issues. However, recent governments have promoted reforms that have relaxed environmental requirements for access to land, moving away from the demands of popular movements and going against the principles of sustainable development (Sauer et al., 2020; Menezes & Barbosa, 2021). This scenario reflects a development approach focused on the commodification of land, ignoring socio-spatial and environmental complexities.

Indeed, Harvey (1973) argues that geographical space is a social construction, implying that land is more than a physical space, but a space with cultural, social, and economic meanings. Valença (2010) also sees territory as more than just a receptacle for economic processes. Several authors (Smith, 2008; Williamson, 2001; Santos, 2006; Williamson et al., 2010) argue for the need

for a holistic and integrated approach to land administration, which takes into account legal, technical, economic and social aspects, as well as a broader territorial context, recognizing its cultural, social and environmental importance. According to the general systems theory proposed by Bertalanffy and discussed by Dolci et al. (2008), effective territorial development requires an integrated understanding of the relationships among the economic, social, and environmental aspects of land governance. These approaches are corroborated by Sen (1999) who criticizes the hegemonic model of economic development, highlighting the need to consider alternatives that emphasize social well-being and freedom.

Therefore, land governance should not be reduced to a market issue, but understood in a broader context that includes culture, the environment, and social justice. It also should not be seen in isolation but as part of a broader system of territorial development. This system must integrate economic, social, and ecological approaches, recognizing the interdependence between different actors, institutions, and ecosystems. Effective land management is crucial to meeting contemporary challenges and promoting development that is truly inclusive and sustainable.

Thus, in this paper development is understood from the emergence of the last decade and a half in the panorama of development policies based on the territorial approach to rural development (Veiga, 2005). Socio-environmental development is what interests us in this research for the purposes of comparative analysis with land-use planning processes.

The land scenario in the state of Tocantins, located in the MATOPIBA region, is a good place to investigate how land concentration and legal security influence social progress. MATOPIBA is a region comprising the state of Tocantins and parts of Maranhão, Piauí, and Bahia, where agricultural expansion has been strong since the late 1980s, particularly in grain cultivation. The name is formed from the initials of these four states (MA + TO + PI + BA). The interaction between land tenure and social progress in Brazil is a complex and multifaceted issue. Issues related to the concentration and legal security of land tenure have historically been fraught with challenges. Governance, therefore, is not limited to administration per se, but also incorporates citizen participation in the process that concerns communities and socio-environmental sustainability (FAO & Secretaria Especial de Agricultura Familiar e do Desenvolvimento Agrário, 2017).

This article explores these dynamics, analyzing how land concentration and legal land security are reflected in the Social Progress Index (SPI) in the municipalities of Tocantins. The initial hypothesis was that municipalities with greater legal security and lower land concentration would exhibit a higher SPI, suggesting that these factors are crucial for advancing social progress. Through this lens, the study contributes to the debate on rural development, offering a critical perspective on the prevailing economic development model and its implications for land-use planning and social progress.

2. Materials and Methods

2.1. Study Area

Despite being located in the Legal Amazon, the state of Tocantins has around 90% of its original territory occupied by the Cerrado biome. This region, which includes the aforementioned MATOPIBA (Figure 1), is characterized by the expansion of agriculture and the major socio-environmental implications resulting from this scenario (Favareto et al., 2019). This expansion has consequences for the environment and the living conditions of the population, putting the concept of development and social welfare at the center of the debate.

This agricultural frontier has the characteristics of agribusiness in the capitalist mold (Santos, 2020), marked by mechanized agriculture and the incorporation of industrial equipment such as harvesters, planters, biotechnology, and genetic manipulation (Favareto et al., 2019). This technological intensification involves the use of pesticides, fertilizers, and the application of practices aimed at increasing productivity and financial profitability.

Figure 1. Location of the state of Tocantins and the MATOPIBA region in Brazilian territory.

However, the social and internal contradictions of capitalism persist, as Harvey (1973) argues. Tocantins and the Amazon region as a whole are the scene of conflicts between different actors, such as farmers, indigenous people, riverside dwellers, peasants, and quilombolas, as highlighted by the Pastoral Land Commission (Comissão Pastoral da Terra, 2022). These conflicts are directly related to the concentration of land, which perpetuates inequalities and prevents democratic access to natural resources (Pereira & Sauer, 2011).

Figure 2 shows a map illustrating the size and type of each of the main public lands in Tocantins state.

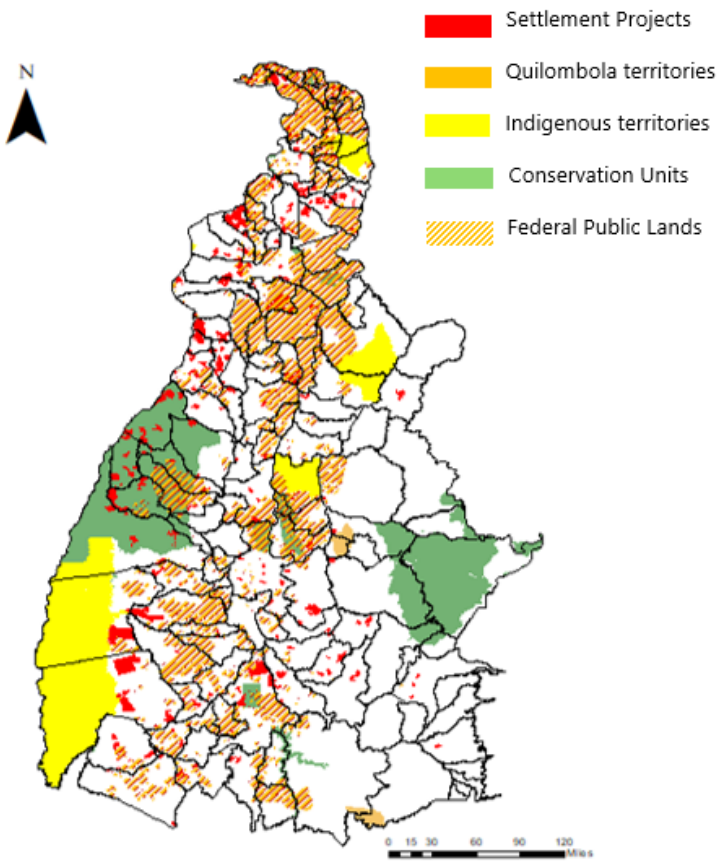

Figure 2. Tocantins' land network.

2.2. Data Collection

We analyzed the relationship between the SPI score for each of the municipalities in the state of Tocantins (highlighting ten municipalities, five with the best and five with the worst performance) and the size of rural properties, following the logic of fiscal modules, to test land concentration by municipality. We also analyzed the relationship between the SPI score and the legal status of the land, characterizing it as possession or ownership.

To analyze the land situation in the municipalities, the database of the Land Collection of the National Institute for Colonization and Agrarian Reform (INCRA; https://acervofundiario.incra.gov.br/acervo/login.php) was used. Data from INCRA's Land Management System (SIGEF) and the National Rural Registration System (SNCR) were used to analyze information on private properties. This data includes Brazil's land ownership structure, such as public lands – Settlement Projects, Conservation Units, Indigenous and Quilombola Territories – as well as data on rural properties.

After collecting the data in shapefile format, the calculations and statistical analysis were carried out using the *ggplot2* package and the dplyr package. The ggplot2 is a system for creating statistical plots and is part of the Tidyverse project's suite of packages. The dplyr package is used for a variety of data analyses, including, but not limited to, biodiversity analysis (Wickham & Grolemund, 2016). It also allowed missing data to be imputed or inconsistent data to be corrected. After this step, the number of records (rows) and variables (columns) was checked and identified, identifying variable names and types.

2.3. Data Analysis and Processing

Initially, a descriptive statistical analysis was carried out on the data collected individually (mean, median, and standard deviation), using the *tidyr* and *ggplot2* packages (*R software*). In order to analyze the land situation of the municipalities based on data from INCRA's Land Collection and correlate possible relationships between the SPI, a bivariate Generalized Linear Models (GLMs) analysis was carried out relating the SPI with the governance of the registers (ratio of the area identified versus the area of the municipality) and with land concentration (size of rural properties in each municipality), as well as the relationship of the SPI with the total area registered in

the SNCR and the total area of the municipality, according to IBGE data (https://censoagro2017.ibge.gov.br/).

Scatterplots and cross-tabulations were used to examine the relationship between SPI and these variables with the *ggplot2* package. To assess the statistical significance and strength of these relationships, GLM analysis with a gamma model was applied. Gamma models are a type of generalized regression model used for positive and continuous data, such as rates, times, or quantities. They are particularly useful when data variance increases with the mean, a phenomenon known as heteroscedasticity. The log-link function is commonly used in these models to ensure positive predictions. Gamma models have broad applications in fields such as epidemiology, finance, and ecology, where dependent variables do not follow a normal distribution (McCullagh & Nelder, 1989). After this, multiple dispersion analyses were carried out (*ggplot2* package) where linear regres-sion models were adjusted using the *lm* function.

Multiple linear regression models were used to assess the relationship between the SPI and the variables in INCRA's Land Collection, including the area of public land, as well as the tables in the Agricultural Census and the National Rural Registration System (SNCR). The models were adjusted using the ordinary least squares method and assessed for the quality of the fit based on measures such as the coefficient of determination (R^2) and the residual standard error. These models were adjusted using the maximum likelihood method and assessed for quality of fit using the adjusted coefficient of determination (adjusted R^2) and the residual deviation.

The gamma distribution model was chosen because of the asymmetric and positive distribution of the data. The *gamma* models made it possible to model the variance of the data as a function of the mean, a particularly useful feature when dealing with heteroscedastic data. "Heteroscedastic" refers to the situation in which the error variance is not constant across the values of an independent variable. This contrasts with "homoscedasticity", where the error variance is constant. Models with gamma distribution are useful for addressing heteroscedasticity, as they allow the variance to be modeled as a function of the mean^1^. This step was also carried out using the *R software,* this time using the *MASS* package.

A summary of the analysis steps is shown in Table 1.

Table 1. Study analysis stages.

Stage	Action taken
Loading	Exploratory data analysis: this consisted of loading the tables into the R software, using the readr package to visualize the data;
Cleaning	Missing or inconsistent data was checked and, where necessary, dealt with;
Exploration	Explore the structure of the data, checking the number of records (rows) and variables (columns), the names of these variables and their types;
Univariate analysis	Analysis of individual variables, using tables, frequency graphs and statistical measures such as mean, median and standard deviation, with a view to understanding the distribution and variability of the data;
Bivariate analysis	Analyze the relationship between two variables using scatter plots and cross-tabulations;
Multivariate analysis	Analyze the relationships between three or more variables, using multiple scatter plots and regression models.

2.4. The Social Progress Index (SPI)

The Social Progress Index (SPI), conceived by Michael E. Porter and a team of economists, has emerged as a complementary measure to Gross Domestic Product (GDP), introduced in 2013 to assess social well-being in a more holistic way. The SPI transcends mere economic analysis, incorporating social and environmental aspects that are essential for a more comprehensive view of human development. This index is divided into three main areas – Basic Human Needs,

Foundations of Well-being and Opportunities – and twelve varied components (Figure 3) ranging from Nutrition and Basic Medical Care to Access to Higher Education (Porter et al., 2013).

Applying the SPI to specific municipalities allows for a multidimensional assessment of development which, in addition to access to goods and services, considers the importance of people's living conditions (Stiglitz et al., 2009).

The prevailing model of economic development has failed to address these critical issues, making it imperative to seek new ways of understanding and measuring development. The SPI thus offers an alternative route, prioritizing socio-environmental aspects and providing a set of valuable information that is often neglected in traditional economic analyses.

This research used the most recent version of the SPI (updated in 2021) to explore the relationship between land use planning and socio-environmental indicators, as a means of assessing social progress in the municipalities of Tocantins state. The SPI Amazon has been published since 2014 under the leadership of IMAZON on a sub-national scale (states and municipalities), and this method has been adapted for other countries in the European Union, Central America, Asia, and Africa, as well as the United States (Santos et al., 2021).

Figure 3. Structure of the Social Progress Index at the component level.
Source: SPI Amazon, 2022.

3. Results

3.1. Social Progress Index in Tocantins

The relative distribution of SPI scores in the 139 municipalities of Tocantins, analyzed in 10 (ten) frequencies, can be seen in Figure 4. This distribution can be grouped into three categories: the first group of municipalities, which represents 33% of the total, is below the average of 54.08 points; 37% is in the average range and the third group, made up of 29% of the municipalities, is above average.

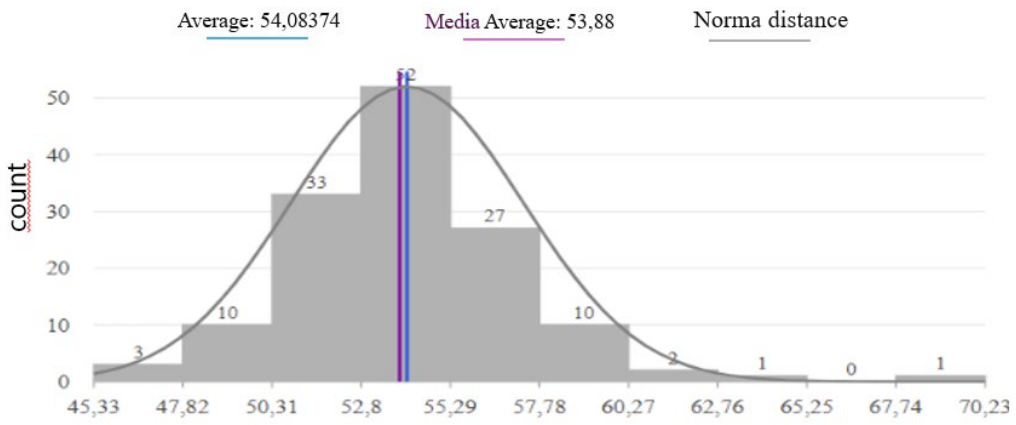

Figure 4. Distribution of SPI scores for the 139 municipalities of Tocantins.

The lowest scores were observed in three municipalities: Recursolândia, Goiatins and Porto Alegre de Tocantins, with scores of 45.33. Next were Conceição do Tocantins with 47.97 and Lagoa do Tocantins with 49.14. These are the five worst-performing municipalities in the state.

On the other hand, the highest score recorded was 70.23 for the municipality of Palmas, the state capital. Next was Fátima with 63.3, Porto Nacional with 61.44, Tupiratins with 60.37 and Figueirópolis with 59.83. These are the five municipalities with the best performance in the state. Therefore, these 10 municipalities were chosen as objects of analysis for the purposes of comparing land use planning and SPI.

Figure 5 shows the spatial distribution of these ten municipalities. The three municipalities with the highest scores in the SPI Amazon, Palmas, Porto Nacional and Fátima, are in contiguous positions, so Palmas is an immediate neighbor of Porto Nacional and Porto Nacional is an immediate neighbor of Fátima, thus forming a spatial connectivity between these three geographical units.

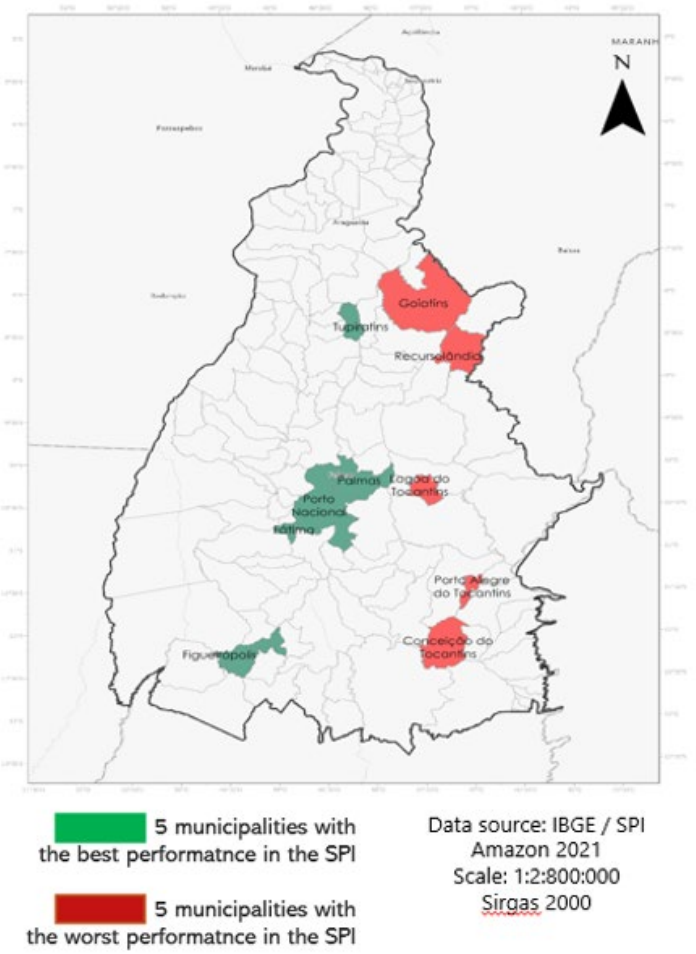

Figure 5. The five municipalities with the five best and the five worst performances in the SPI in Tocantins.

3.2. Land Concentration

The fiscal module is a concept introduced in 1979 by Law No. 6,746 (1979), which regulates the rights and obligations relating to rural properties, for the purposes of implementing agrarian reform and promoting national agricultural policy. It is a unit of area (expressed in hectares) set differently for each municipality, as it takes into account local particularities.

In relation to size, rural properties are classified as: Small Property, with an area of up to 4 fiscal modules; Medium Property, with an area of more than 4 and up to 15 fiscal modules; Large Property, with an area of more than 15 fiscal modules. The classification is defined by Law No. 8,629 (1993), amended by Law No. 13,465 (2017), and takes into account the fiscal module, which varies from 5 to 110 hectares according to the characteristics of the region. In the state of Tocantins, in the Legal Amazon, the fiscal module varies from 70 to 80 hectares.

The relationship between SPI and land concentration was determined by classifying rural properties into three size classes, based on fiscal modules considered in Tocantins. The classes were defined as: (i) Small, up to 320 hectares; (ii) Medium, from 320 hectares to 1,200 hectares; (iii) Large, more than 1,200 hectares.

There was a significant relationship between SPI and land concentration ($p > 0.05$). Deviance analysis and Chi-squared (both $p < 0.05$) confirm a significant effect between property size and SPI. This rejects the null hypothesis that the SPI is the same for all municipalities, regardless of the number of small rural properties. There was a positive correlation between an increase in SPI and the number of small rural properties, as shown in Figure 6. In Figure 6 we can see that the confidence intervals include values within the expected range for the true value of the parameter estimated by the model (95%). The intercept represents the average SPI value for municipalities with zero small rural properties (52.5; 95% CI: 51.7–53.3). The slope represents the variation in the SPI for each additional unit of small rural properties (0.002; 95% CI: 0.001–0.004).

However, for medium-sized areas, the correlation was not significant. According to the model, there is no association between GSP and the total number of medium Properties ($p = 0.48$). On the other hand, there is statistically significant evidence to reject the null hypothesis that the SPI is the same for all municipalities ($p < 0.05$), regardless of the number of large rural properties. We observed that the SPI decreases as the number of large rural properties increases (Figure 7).

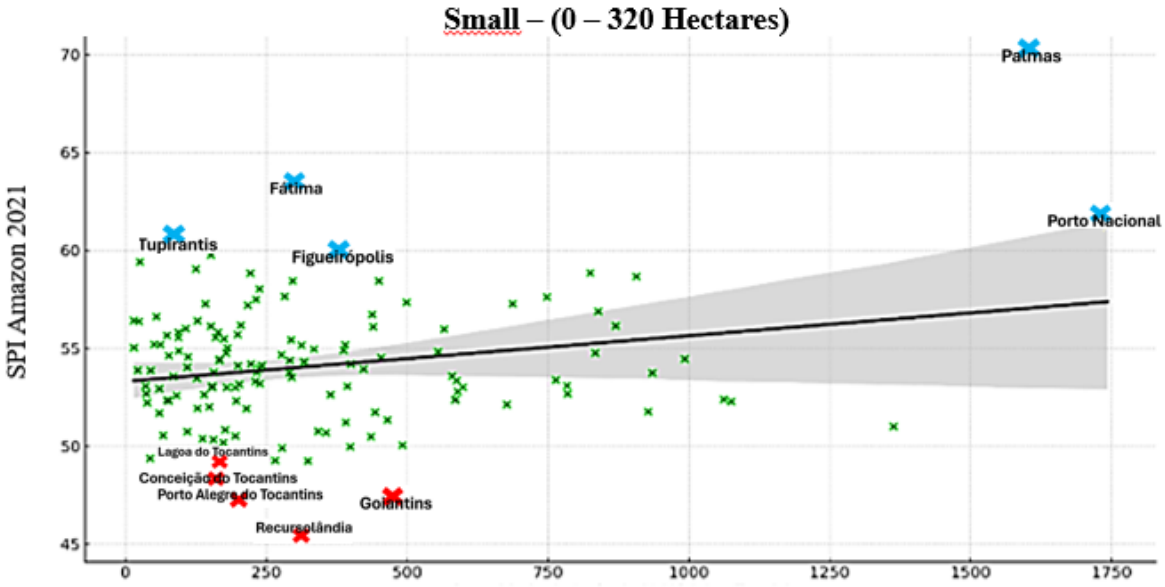

Figure 6. Linear regression between SPI and land concentration for small rural properties.

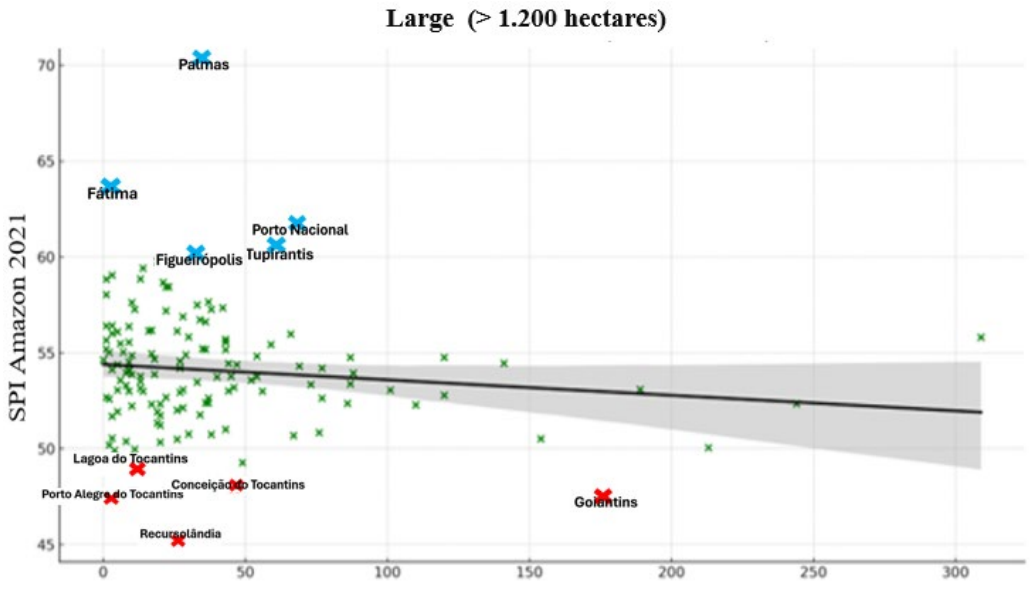

Figure 7. Linear regression between SPI and land concentration for large rural properties (> 1,200 hectares).

The confidence intervals are within the expected range for the true value of the estimated parameter (95%). The intercept represents the average GSP value for municipalities with zero large rural properties, 54.4 (54.5; 95% CI: 53.6–55.2), where the slope represents the variation in the SPI for each additional unit of large rural properties (−0.011; 95% CI: −0.019–0.004).

The correlation between the legal security of properties and the SPI score, based on the classification of legal security in terms of property status ($R^2 = 0.67$, $p < 0.005$), shows that there is a significant relationship between the number of properties and the SPI in the municipalities analyzed. The relationship between land possession and SPI was lower ($R^2 = 0.52$, $p = 0.020$). The equations, the correlation coefficient, and p-values of each regression are disposed in Table 2.

Table 2. Regression coefficient, equation, and p-values of multiple linear regressions between SPI, land concentration (small, large), legal security, and land tenure in the state of Tocantins, Brazil.

Relationship	R^2	Equation	p
SPI X land concentration for small rural properties	0.67	SPI = 52.5 + 0.002 × Number of Small Properties	< 0.005
SPI X land concentration for large rural properties	0.67	SPI = 54.5 − 0.011 × Number of Large Properties	< 0.005
SPI X legal security of properties	0.67	SPI = 53.506 + 0.001217 × Total Properties	< 0.005
SPI X land tenure	0.52	SPI = 53.506 + 0.00001207 × Total Land Tenure	< 0.05

4. Discussion

Land concentration has been central to the rural development debate, highlighting how the unequal distribution of resources impacts power, inequalities and sustainability (Robbins, 2020). Land concentration reflects the historical marginalization of indigenous populations and traditional communities, limiting their access to land and undermining their autonomy. From the perspective of environmental justice, it is observed that agricultural expansion in the Amazon accentuates imbalances by displacing indigenous peoples and overloading ecosystems (Sundberg, 2014).

Indeed, studies show that undemarcated indigenous territories are the most threatened by deforestation. Data from the Socio-Environmental Institute (Soares, 2025) indicate that only 5.89% of the original vegetation of official Indigenous Lands has been deforested, while the area outside Indigenous Lands has lost 54.4% of its vegetation.

Comparatively, in Latin America, countries such as Argentina and Paraguay present similar dynamics of land concentration, with adverse socio-environmental effects, especially for small farmers and indigenous peoples (Borras & Franco, 2013). Globally, Sub-Saharan Africa and Southeast Asia face similar challenges, with the expansion of monocultures for export often resulting in environmental degradation and loss of livelihoods (Hall et al., 2015).

Theoretical perspectives and global studies demonstrate that land concentration is not just a local issue but reflects trends of exclusion and injustice that cross borders, requiring policies that can promote equitable redistribution and socio-environmental resilience.

This study generated relevant information on the land structure and socio-environmental development of the municipalities in Tocantins state, as measured by the Social Progress Index (SPI). The inverse correlation identified between the concentration of land in large properties and the SPI highlights a worrying scenario: the accumulation of resources and power in a few hands seems to compromise the social well-being of the municipalities analyzed. This finding echoes the concerns raised by Sachs (2015) and Sen (1999), who argue that a more equitable distribution of resources is crucial to promoting social and environmental well-being.

On the other hand, municipalities with a more balanced land structure, especially those with a significant number of smaller properties, showed a higher SPI. This finding underscores the importance of public policies aimed at fairer land distribution, a view supported by Borras and Franco (2013), who highlighted the need for policy approaches that counter land concentration and promote social justice.

An important finding was the association between the legal security of land and the SPI score. The model suggests that municipalities with a greater number of properties tend to have a higher SPI, which was not observed in the case of land possession. This strengthens the idea that land regularization can lead to improvements in the socio-environmental indicators of municipalities.

This study broadens the understanding of the complex interaction between land structure and socio-environmental development, paving the way for future research. However, the research also identified challenges in land governance in Brazil, marked by the fragmentation of land registers and a lack of communication between the various bodies responsible for these records. This issue was highlighted by Guedes and Reydon (2012), who emphasize the need for an integrated land registration system to promote transparency and legal security in the country. Additionally, Viana

(2021) stresses the necessity of a systemic approach to sustainable territorial development, highlighting that a holistic and integrated vision is essential to address the complex problems that arise in territories with specific socio-environmental characteristics.

The association between legal land security and SPI suggests that effective land regularization policies can play a fundamental role in improving the socio-environmental indicators of municipalities, a view supported by Barbosa et al. (2006), who defend the importance of land regularization for sustainable development.

The search for comparative methods, considering indicators that are already consolidated and have a socio-environmental context, as in the case of the SPI, in parallel with the construction of methods for a broader understanding of the municipal land structure, could be a way of supporting public policies aimed at rural development.

5. Conclusions

This study sought to shed light on the complex relationships between land-use planning and socio-environmental development, using the Social Progress Index (SPI) as a reference. The implications of land concentration emerged as the most provocative findings of the research.

The results shown here indicate a significant association between the size of rural properties and the SPI in the municipalities analyzed. Municipalities with a higher concentration of land in large properties tend to have a lower SPI. At the same time, the data suggests that a more equitable distribution of land, particularly in municipalities where properties are smaller, is associated with better socio-environmental indicators. This is a crucial finding because it challenges traditional land policies under an economic development model that often neglects not only land reform in the country but also the equitable distribution of natural resources. The results obtained not only reinforce the central hypothesis of the research but also serve as an argument for the revision and reformulation of land policies towards more inclusive and sustainable development.

Although the data show a strong tendency for a relationship between the variables, the mechanisms that explain the nature of this relationship in more detail were not explored. Future research, some of which is already underway, should seek to expand the sample to other regions of the Legal Amazon to confirm the trends found for the state of Tocantins. An in-depth study of a set of cases, microregions, or municipalities, is also necessary to identify the mechanisms that lead land concentration to influence local social indicators.

CRediT Author Statement: Raimundo Fagner Frota Vasconcelos: Conceptualization, Methodology, Data curation, Investigation, and Writing-original draft; **Mário Lúcio Ávila:** Conceptualization, Methodology, Data curation, and Supervision; **Marcelo Ximenes Aguiar Bizerril:** Investigation, Supervision, Writing-original draft, and Writing-review & editing; **Tamiel Khan Baiocchi Jacobson:** Methodology, Investigation, and Writing-review & editing; **Marcelo Mateus Trevisan:** Conceptualization and Data curation.

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