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ABSTRACT

The fundamental principles of sustainable development and sustainability aim to mitigate the negative impacts of progress that neglects social well-being and environmental preservation. These concepts emerge from recognizing the inherent weaknesses in the current development model and the growing perception of the need to adopt a more balanced and equitable approach to promoting progress. Understanding the meanings of sustainable development and sustainability is important, as they are tied to a paradigm shift and a new global perspective that considers not only economic and political factors but also ecological aspects to achieve true development. This study aims to analyze the sustainability situation of the municipalities in the Maranhense Amazon by calculating a Municipal Sustainable Development Index. For this analysis, adaptations were made to existing proposals in the literature, with the index calculated based on the normalization and weighting of variables of interest organized into different dimensions. The findings revealed that the average Sustainable Development Index for the municipalities in the Maranhense Amazon was 0.481, with 89% of the municipalities classified in an alert situation. The proposed classification enhances the understanding of inequalities among the analyzed municipalities and can serve as a basis for developing public policies and actions aimed at improving conditions and promoting sustainability in the region.

Keywords: Sustainable Development Index, Maranhense Amazon, Regional Development.

RESUMO

Os princípios fundamentais do desenvolvimento sustentável visam mitigar os impactos negativos resultantes de um desenvolvimento que negligencia tanto o bem-estar social quanto a preservação ambiental. Esse conceito surge do reconhecimento das fragilidades inerentes ao modelo de desenvolvimento atual e da crescente percepção da necessidade de adotar uma abordagem mais equilibrada e justa para promover o desenvolvimento. É importante compreender os significados de desenvolvimento sustentável, pois ele está ligado a uma mudança de paradigma e a uma nova perspectiva global que considera não apenas fatores econômicos e políticos, mas também os aspectos ecológicos para alcançar o desenvolvimento. Sendo assim, o objetivo deste trabalho é apresentar a distribuição espacial da situação de sustentabilidade dos municípios da Amazônia Maranhense a partir do cálculo de um Índice Municipal de Desenvolvimento Sustentável. Para o desenvolvimento deste trabalho foram realizadas adaptações a propostas apresentadas na literatura, cujos índices são calculados a partir de normalização e ponderação de variáveis de interesse organizadas em diferentes dimensões. Como resultados, o Índice Médio de Desenvolvimento Sustentável para os municípios da Amazônia maranhense foi de 0,481, sendo 89% dos municípios classificados em situação de alerta. A classificação proposta contribui para compreensão das desigualdades entre os municípios analisados e pode servir de subsídio para a elaboração de políticas públicas e ações voltadas à melhoria das condições e promoção da sustentabilidade na região.

Palavras-chave: Índice de Desenvolvimento Sustentável, Amazônia Maranhense, Desenvolvimento Regional.

INTRODUCTION

The advancement of capitalist production relations, particularly through processes of industrialization and financialization, combined with Brazil's vast territory and the challenges in accessing certain regions, has resulted in uneven development across the country. Consequently, persistent socio-environmental issues continue to affect various areas. As noted by Amorim, Santos, and Cândido (2008), unequal and accelerated industrialization has contributed to environmental degradation and the emergence of local environmental problems that not only have global implications but also significantly affect human life, culminating in the environmental crisis observed in recent decades. According to Martins and Cândido (2012), this situation stems from the development model adopted throughout the twentieth century, centered on the expansion of production and consumption, which has led to new social, economic, environmental, and political-institutional challenges.

The concepts of sustainable development and sustainability aim fundamentally to mitigate the negative consequences of a development paradigm detached from social well-being and environmental preservation. These concepts arise from the recognition of the limitations of the current model and

the urgent need for a more balanced and equitable vision of progress. In this context, understanding the terms “sustainable development” and “sustainability” is important, as they are closely linked to a paradigm shift and a global perspective that incorporates economic, political, and ecological dimensions into development strategies.

Sustainable development is associated with a transformative process in which the management of limited resources is harmonized with the promotion of economic growth, addressing the needs of the present without compromising the ability of future generations to meet their own (CMMA, 1987). This concept has evolved from a relatively long historical process of critically reassessing the relationship between civil society and the natural environment. Given its continuous and complex nature, numerous definitions and approaches to sustainability currently exist, as illustrated by the diversity of interpretations in the literature (Bellen, 2005, p. 23).

Achieving truly sustainable and equitable development requires that sustainability criteria be fulfilled across all relevant dimensions (Ferreira et al., 2015, p. 207). However, in practice, economic considerations often prevail over social, environmental, and cultural concerns. As a result, sustainability demands coordinated and proactive engagement from federal, state, and municipal governments (Souza et al., n.d., p. 1). Sustainable development must be envisioned through a broad and adaptive lens, sensitive to local contexts and capable of moving beyond the conventional “sustainability tripod” and the traditional dichotomy between growth and development.

According to the National Research Council (1999), for development to be considered sustainable, it is important to clarify what should be developed, what should be sustained, the nature of the relationship between the two, and the timeframe over which these efforts should be evaluated—while respecting the ecological limits of natural systems. Macedo et al. (2016, p. 326) emphasize that sustainability involves a transformative search for new forms of productive organization, prioritizing the carrying capacity of ecosystems and the development of methodologies to assess and quantify sustainability in support of public and private decision-making.

Sustainability indices are valuable analytical tools that support decision-making processes by providing quantitative representations of natural, economic, and social systems based on scientific methods (Siche et al., 2007, p. 139). According to Silva et al. (2018, pp. 150–152), these indices

offer important information for guiding targeted development and designing effective public policies. The construction of such indices begins with the selection of appropriate indicators, applying suitable methodological approaches and considering the specific characteristics and needs of each locality.

Indicators, in turn, are selected variables that reflect the conditions of a given system—either independently or in combination. They often serve as a pre-processing mechanism for raw data (Mitchell, 1996; Siche et al., 2007), enabling the description, synthesis, or estimation of states, conditions, or responses of phenomena that may not be directly observable. Thus, it is essential to establish a coherent framework for the selection and development of sustainability indicators that can classify regions according to their levels of sustainable development and support informed decision-making. Such a framework should reflect the priorities of its users—experts, civil society actors, and governmental authorities—who are responsible for both designing and applying these indicators in the monitoring of sustainability progress (Arcoverde et al., n.d.).

Barbosa and Cândido (2009, p. 3) observe that the initiative to create sustainability indices emerged from the United Nations Conference on Environment and Development (Rio-92). The initial objective was to establish development standards that integrated environmental, economic, social, ethical, and cultural dimensions. This objective required the definition of indicators capable of measuring, monitoring, and evaluating these dimensions. With the introduction of the UN's 2030 Agenda, sustainability has been addressed through a renewed perspective, centered on the Sustainable Development Goals (SDGs) and their associated targets. These goals, set to guide global action from 2015 to 2030, focus on five critical areas for the well-being of people and the planet. According to the United Nations (2020), the SDGs are integrated, indivisible, and promote a balance between the economic, social, and environmental dimensions of development.

One way to assess the extent to which the SDGs have been incorporated into public administration at the municipal level is through the construction of sustainability indices (SIs). These indices form a system of indicators capable of measuring the sustainability level of a municipality, while also serving as an informational foundation for the formulation and implementation of public policies aimed at development. As such, they contribute to strengthening local sustainable development processes.

This study aims to construct a sustainability index for the municipalities of the Maranhense Amazon, considering the SDGs established in the 2030 Agenda and selecting commonly used variables in SI development that represent the various dimensions of sustainability indicators.

STUDY AREA

The state of Maranhão comprises 217 municipalities, is located in Brazil's Northeast region, and spans approximately 331,936.95 km², making it the eighth-largest Brazilian state by land area. According to data from the Brazilian Institute of Geography and Statistics (IBGE, 2022), Maranhão has an estimated population of 6,775,152, ranking as the fourth most populous state in the Northeast.

As highlighted by Pochmann et al. (2003) in the Atlas of Social Exclusion in Brazil, the Northeast region exhibited a rural poverty rate of 53.7%. Within this context, Maranhão was identified as one of the states with the highest levels of social exclusion, with all of its municipalities classified as experiencing poverty. According to the United Nations Development Programme (UNDP, 2013), six of the 100 Brazilian municipalities with the lowest Municipal Human Development Index (MHDI)—a localized adaptation of the Human Development Index—are located in Maranhão: Fernando Falcão, Marajá do Sena, Jenipapo dos Vieiras, Satubinha, Água Doce do Maranhão, and Lagoa Grande do Maranhão. As of 2024, Maranhão continues to hold the lowest MHDI in the country, at 0.676.

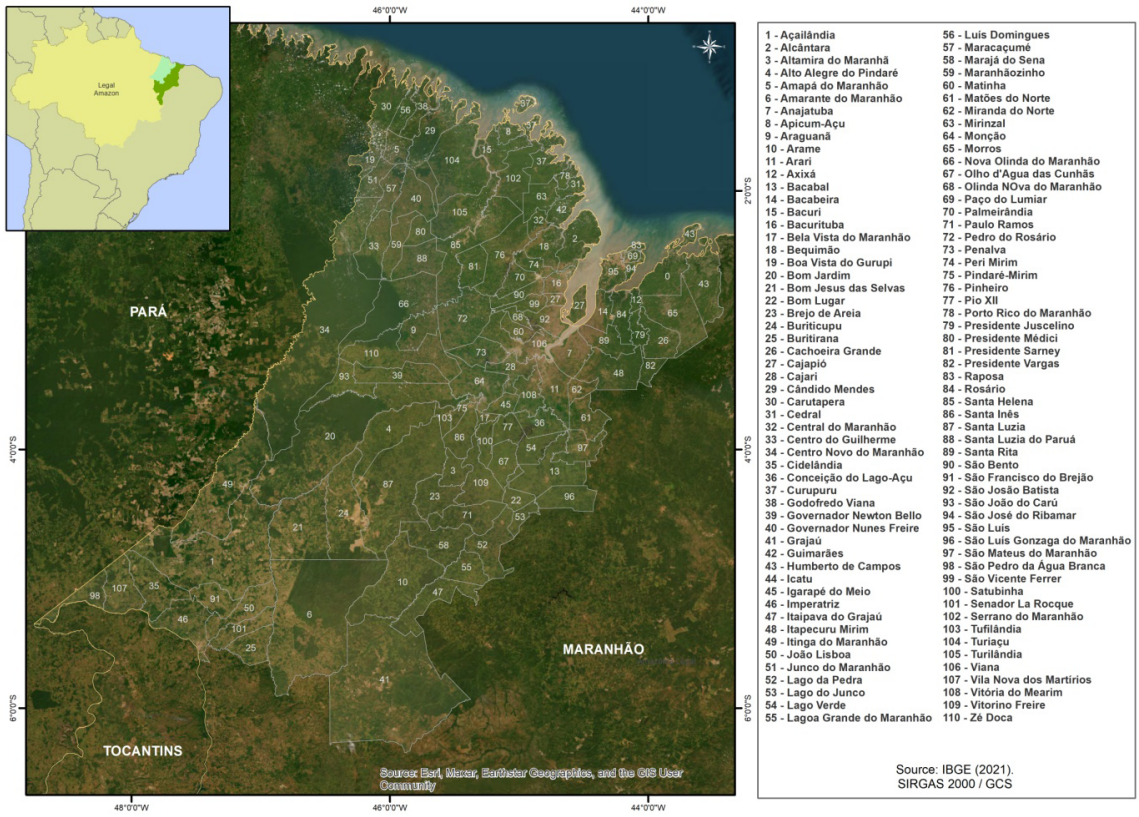
The Amazon Rainforest spans approximately 5.4 million km² and extends across eight South American countries. Its easternmost portion lies within the state of Maranhão, covering roughly 81,208.40 km², which corresponds to 24.46% of the state's territory (IBGE, 2002), encompassing 110 municipalities.

This region, which hosts an average of 570 trees per hectare and at least 100 native plant species, is also home to 109 species of fish, 124 of mammals, and 503 of birds. In addition to its biological richness, the area includes Indigenous territories such as Alto Turiaçu, Awá, Caru, and Gurupi, which were demarcated following the establishment of the Legal Amazon in 1953 (SETUR, 2022). Maranhão has historically been marked by a high concentration of wealth and land ownership, leading to significant land inequality. According to IBGE (2017), rural properties smaller than 10 hectares represent 54.39% of holdings but occupy only 1.47% of the total rural area, whereas properties larger than 1,000 hectares account for just 0.73% of holdings yet cover 43.55% of the total area. This unequal land distribution helps

explain the persistence of rural poverty and recurrent land conflicts in the state (Sousa et al., 2023).

The Maranhense Amazon covers an estimated area of 120,000 km²—approximately one-third of the state of Maranhão—and comprises 110 municipalities that collectively account for about 75% of the state's population (IBGE, 2019) (Figure 1). The region is characterized by extraordinary biodiversity (Ioris, 2020) and is considered one of the richest in species diversity and endemism (Martins & Oliveira, 2011), hosting numerous lesser-known and endangered plant and animal species. Despite its ecological importance, the region exhibits some of the highest deforestation rates in Brazil (Oliveira, 2008; Celentano, 2017). Currently, approximately 76% of the Maranhense Amazon's original forest cover has been lost (Silva Júnior et al., 2020).

Figure 1 | Municipalities of the Maranhense Amazonia



Source: Elaborated by the authors.

The Maranhense Amazon is a dynamic region with considerable natural and social potential to achieve adequate levels of socio-environmental sustainability. This is particularly relevant in the context of land-use transformations, which must be aligned with scientific understanding and social needs in order

to enable sustainable productive activities supported by socio-economic foundations that ensure the population's quality of life. Deepening the understanding of sustainability levels in the municipalities of the Maranhense Amazon, including their specific characteristics and intersections with the prevailing capitalist mode of production within a context of increasing national and global territorial integration (Santos & Silveira, 2004), is of strategic importance, particularly in light of the region's growing socio-environmental, economic, and political significance both nationally and internationally (Porto-Gonçalves, 2001, 2006; Hecht & Cockburn, 2011).

METHODOLOGICAL PROCEDURES

The municipality is the unit of analysis adopted for the development of this work. One hundred and ten (110) municipalities in Maranhão (MA) make up the Legal Amazon in the state (IBGE, 2016). The construction of the proposed sustainability index was based on adaptations of three methodological approaches: (i) the Sustainable Development Index (SDI) proposed by Sepúlveda (2005), which calculates the index by aggregating indicators using the arithmetic mean and classifies municipalities according to sustainability levels; (ii) the Sustainable Development Index for Cities (SDIC), calculated similarly but explicitly aligned with the 17 Sustainable Development Goals (SDGs) defined by the United Nations; and (iii) the grouping of indicators into thematic dimensions, as suggested by Waquil et al. (2010).

INDICATOR SELECTION

The selection of indicators was guided by three main criteria: (i) data availability, (ii) reliability and relevance, and (iii) the presence of measurable quantitative information (Marchand & Le Tourneau, 2014; Jannuzzi, 2003, 2005). Most indicators were obtained from official public databases, including Atlas Brasil, the Brazilian Institute of Geography and Statistics (IBGE), and the Maranhão Institute for Socioeconomic and Cartographic Studies (IMESC), which conduct regular surveys. Due to the inability to align all variables to a single reference year, the most recent official data available for each indicator were used. Each indicator was linked to a specific SDG and grouped into one of five dimensions: demographic, social, economic, political-institutional, and environmental—based on an adaptation of the framework proposed by Waquil et al. (2006) (see Table 1).

Table 1 | Indicators used to calculate IMDS.

Dimensão	Tema	Indicador	ODS
Demography	*Population*	Urbanization rate (2010)	9;11
		Population density (2010)	9;11
		Rural population (2010)	9;11
		Life expectancy at birth (2010)	3;16
		Ageing rate (2010)	3
Social	*Equity and Social Justice*	Proportion of people vulnerable to poverty (2010)	1;11
		Theil-L labor income index (2010)	8;10
		Percentage of people in households vulnerable to poverty	1;10
		and no one has completed primary school (2010)	1;10
		Percentage of women aged 10 to 17 who have had children (2010)	10
		Percentage of mothers who are heads of household, have not completed primary school and	10
		complete and with at least one child under the age of 15 (2010)	3;10
		Percentage of people aged 15 to 24 who neither study	3;11
	Housing	Urban households with access to electric lighting (2010)	10;11
		Households suitable for living in with mains water supply (2010)	6;10;11
		% of the population living in households with bathrooms and running water (2010)	6;10
	Health	% of hospitalizations due to diseases related to inadequate environmental sanitation (2017)	3;6
		Number of UBS (2021)	3
		Number of SUS hospitalization beds (2021)	3
	Education	Functional illiteracy rate of people aged 15 (2017) or older	4;10
		Elementary school dropout rate (2014)	4;10
	Security	Homicide mortality (2021)	16
Economic	*Economic*	Average income of employed people aged 18 and over (2010)	8;10
		GDP per capita (2013)	8
	Jobs	Economically active population aged 18 and over (2010)	8
		Percentage of employed people aged 18 and over who have a job(2010)	8;10
		Percentage of employed people aged 18 and over who are employed (2010)	8;10
Political-institutional	*Management*	Transfer of State Resources to Health Programs (2020)	3
		Transfer of FUNDEB Resources (2020)	4
	Governance	Active Environmental Council (2020)	11
Environmental	*Land Use Change*	Burning and forest fires (2022)	13;15
	Sanitation	Municipalities with functioning sewage system (2017)	6;11
		% of people in urban households with garbage collection (2010)	6;11

INDEX CALCULATION

Given the heterogeneity of measurement units across indicators, it was necessary to standardize the data into dimensionless indices. This transformation involved rescaling the values of each variable to a 0–1 range. The directionality of each indicator was considered: a positive relationship (higher values indicating better performance) was assumed when increases in the variable signified improvements in the system; conversely, a negative relationship (higher values indicating worse performance) was assumed when increases indicated deterioration (Sepúlveda, 2005; Waquil et al., 2006; Martins & Cândido, 2008, 2012), using the normalization formula proposed by Waquil et al. (2006).

Positive relationship

$$I = \left(\frac{X-m}{M-m}\right)$$

Negative relationship

$$I = \left(\frac{M-X}{M-m}\right)$$

Onde:
X= observed value of each variable in each territory analyzed;
m= minimum value considered;
M = maximum value considered.

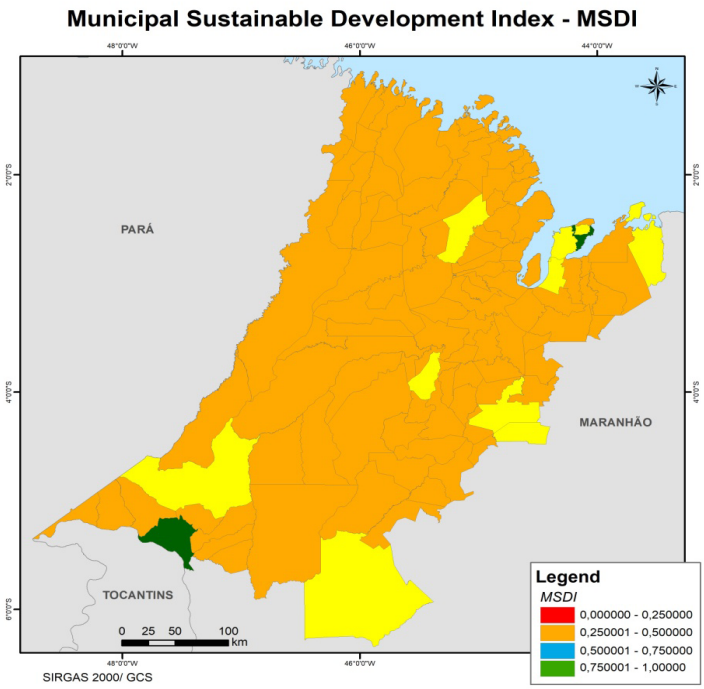
To define minimum and maximum reference values for normalization, the arithmetic mean of the five highest or five lowest values (depending on the indicator's direction) was used. Following normalization, the indicators within each dimension were aggregated using the arithmetic mean, assuming equal weighting across all variables (Sepúlveda, 2005; Scandar Neto, 2006). Subsequently, the five dimensions were combined using a weighted average to construct the overall Municipal Sustainability Index. The weights assigned were as follows: 0.25 for each of the Environmental, Social, and Economic dimensions, and 0.125 for the Demographic and Political-Institutional dimensions. The greater weight attributed to the Environmental, Social, and Economic dimensions reflects their status as the traditional "three pillars of sustainability." To interpret the final index values, a four-tier classification system was established: Critical (0.000000 – 0.250000), Alert (0.250001 – 0.500000), Acceptable (0.500001 – 0.750000), Ideal (0.750001 – 1.000000).

RESULTS AND DISCUSSION

MUNICIPAL SUSTAINABLE DEVELOPMENT INDEX

The results of the Municipal Sustainable Development Index (MSDI) for the municipalities of the Maranhense Amazon reveal that 89% (98 municipalities) fall into the alert category (Figure 2). Only 9% of the municipalities were classified as acceptable, and just 2% reached the ideal level of sustainability. None were placed in the critical category, although four municipalities had scores close to this threshold, ranging from 0.256 to 0.299. The overall average MSDI was 0.411. These findings are consistent with other national studies and indices that assess sustainability at the state and municipal levels in Brazil. For example, the Sustainable Development Index of Brazilian Cities (IDSC-BR), developed by the Instituto Cidades Sustentáveis, shows that most municipalities in Maranhão exhibit low or very low levels of sustainable development (IDSC, 2024). Similarly, the State Competitiveness Ranking (RCEB), published by the Center for Public Leadership (CLP), ranked Maranhão 23rd nationwide and second to last among northeastern states in the environmental sustainability pillar (CLP, 2024).

Figure 2 | Municipal Sustainable Development Index - Maranhense Amazônia



Source: Elaborated by the authors.

The top five municipalities in terms of MSDI performance were Imperatriz (0.795), São José de Ribamar (0.771), Paço do Lumiar (0.651), São Luís (0.650), and Grajaú (0.626). In contrast, the lowest scores were recorded in Bequimão (0.313), Central do Maranhão (0.306), Bacuri (0.305), Serrano do Maranhão (0.283), and Brejo de Areia (0.264).

Given the predominance of municipalities in the alert category, their distribution appears relatively uniform across the study area. This suggests that both inland and coastal municipalities face similar challenges across the sustainability dimensions analyzed. A more detailed and disaggregated analysis of the MSDI is therefore necessary to better understand performance within each individual dimension (Figure 3).

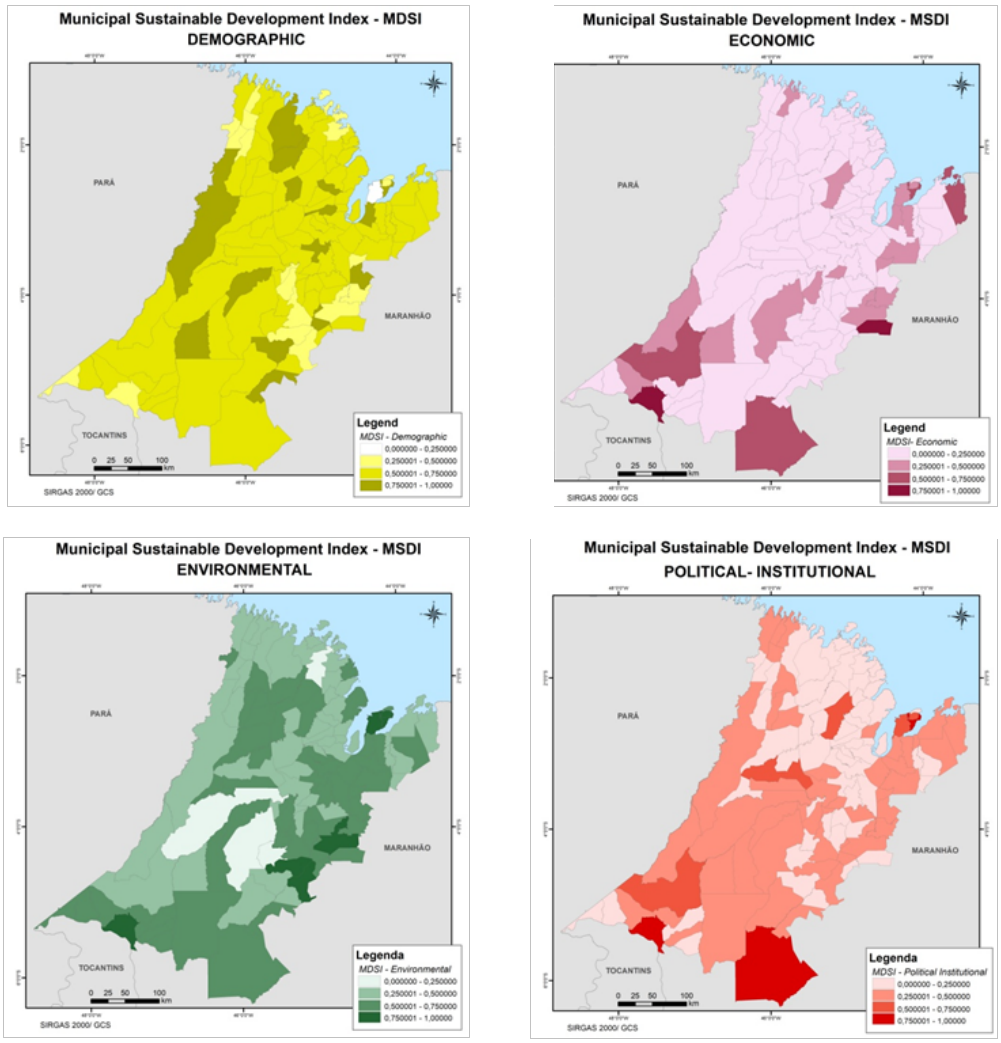
The Demographic Dimension (Figure 3), related to SDGs 3, 9, and 11 (health, infrastructure, and sustainable cities), showed that São Luís was the only municipality among the 110 analyzed to fall into the critical category. This result is attributed to its high population density (1,250 inhabitants/km² in 2010), which contrasts sharply with the 103 municipalities in the region whose population densities are below 100 inhabitants/km². Among the indicators assessed, the aging rate and urbanization rate stood out. The aging rate remains generally low across the region, ranging from 2.52 in Marajá do Sena to 9.6 in Bacurituba, indicating that the demographic transition is still at an early stage. Urbanization rates are also low: in 52% of the municipalities, less than half of the population lives in urban areas.

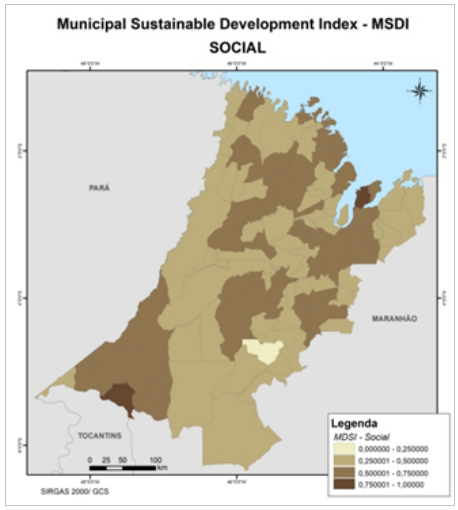
The average MSDI score for the Demographic Dimension was 0.614. The lowest scores were recorded in São Luís (0.018), Paço do Lumiar (0.299), Santa Inês (0.352), São Pedro da Água Branca (0.396), and São Mateus do Maranhão (0.413). The highest scores were found in Marajá do Sena (1.000), Bacabeira (0.855), Turiaçu (0.822), Matões do Norte (0.814), and Centro Novo do Maranhão (0.810).

The Economic Dimension (Figure 3), aligned with SDG 8 (decent work and economic growth), had the weakest performance among all dimensions analyzed. The average index value across municipalities was 0.212. Of the 110 municipalities, 88 (80%) were classified as critical, 16 (15%) as alert, four (4%) as acceptable, and only two reached the ideal level. These findings align with the State Competitiveness Ranking (RCEB), which places Maranhão 25th in the Social Sustainability pillar, which includes 16 indicators such as the Human Development Index (HDI), poverty rate, and income inequality.

The lowest scores in this dimension were observed in Presidente Médici (0.015), Governador Newton Bello (0.071), Palmeirândia (0.091), Bequimão (0.095), and Governador Nunes Freire (0.100). The top-performing municipalities were Imperatriz (0.810), São Luís Gonzaga do Maranhão (0.792), Humberto de Campos (0.685), São José de Ribamar (0.606), and Grajaú (0.592). Among the most significant indicators were the percentage of workers aged 18 or older without formal employment and the average income of employed individuals. In 99% of municipalities, fewer than half of employed residents had formal contracts. Additionally, in 74% of municipalities, the average income was below the 2010 minimum wage (R$510.00). These figures point to structural limitations in education and workforce development throughout the state (Martins Filho & Melo, 2023).

Figure 3 | Dimensions of the Maranhense Amazon - MDSI.





Fonte: Elaborado pelos autores.

According to IBGE (2021), Maranhão has the lowest per capita GDP in Brazil and the highest proportion of people living in extreme poverty, accounting for 8.4% of the national total. These findings reinforce the low performance of the Economic Dimension and highlight a context marked by land concentration, economic stagnation, and precarious urbanization (Lemos, 2003). This scenario is exacerbated by migration and unplanned urban growth, contributing to housing deficits, unemployment, violence, and general deterioration in quality of life. This complex reality is clearly reflected in the MSDI and corroborated by other indicators such as the IDSC (2024), which classified 96 municipalities (87%) in the region as having “very low” and the remaining as “low” levels of development, in relation to SDG 8.

The Environmental Dimension (Figure 3) is highly complex due to the region’s location within the Amazon biome—one of the most biodiverse ecosystems on the planet. It has long suffered degradation from logging, the expansion of agricultural frontiers, and land conflicts. Moreover, several coastal municipalities face challenges related to environmental sanitation and beach water quality. In this context, deepening the analysis in relation to this dimension becomes a major challenge due to the lack of data that particularizes aspects of this dimension and that reflects the reality of most municipalities. Due to a lack of disaggregated and current data to accurately represent municipal environmental conditions, the analysis was based on three key indicators: (i) the number of wildfire and forest fire hotspots, reflecting land-use change and linked to SDGs 13 (Climate Action) and 15 (Life on Land); (ii) the presence of a functional sewage system connected to a public collection network; and

(iii) the proportion of urban households receiving solid waste collection services, both relevant to SDGs 6 (Clean Water and Sanitation) and 11 (Sustainable Cities and Communities).

Among municipalities classified as acceptable, MSDI values in this dimension showed little variation, ranging from 0.502 to 0.657. The highest scores were recorded in São Luís (0.979), Bacabal (0.948), Lago da Pedra (0.944), Imperatriz (0.937), and São José de Ribamar (0.931), while the lowest were in Santa Luzia (0.114), Brejo de Areia (0.152), Bom Jardim (0.189), Serrano do Maranhão (0.230), and Monção (0.270). In 2022, 85 municipalities registered at least 10 fire hotspots. According to the 2010 census, 29 municipalities had less than 50% of urban households served by waste collection. Furthermore, only seven municipalities had a functioning sewage network. Only seven municipalities (6%) achieved ideal scores in this dimension. In total, 4 municipalities (4%) were classified as critical, 47 (43%) as alert, and 52 (47%) as acceptable.

All municipalities are located within the Legal Amazon, underscoring the need for targeted environmental policies. Most municipalities with low environmental scores are located inland, in areas dominated by agribusiness, where deforestation and the use of fire for land clearing are common. These practices increase environmental vulnerability and contribute to soil degradation and gully formation (Medeiros et al., 2023). This fragility is also reflected in IDSC (2024) data, which ranked 34 municipalities as “very low,” 23 as “low,” and 26 as “medium” in their progress toward SDG 13. For SDG 6, the outlook is even more severe, with 85 municipalities classified as “very low.”

With regard to the political-institutional dimension, considered essential because it involves defining parameters and guidelines for the actions of public authorities and the participation of society in decisions and actions aimed at promoting urban sustainability, it should be noted that, like the demographic dimension, it received a weight of 0.125 in the final composition of the IMDS. The average score in this dimension was 0.224, with 51% of municipalities classified as critical. A major contributing factor to this poor performance is the lack of active Municipal Environmental Councils, which are essential for fostering environmental governance and participatory policymaking.

The highest scores were recorded in Imperatriz (0.840), São José de Ribamar (0.790), Paço do Lumiar (0.543), and Açailândia (0.536). The lowest were found in Porto Rico do Maranhão (0.002), Presidente Médici (0.001), Junco do Maranhão (0.001), Altamira do Maranhão (0.002), and Cedral (0.006),

indicating extreme institutional weakness.These findings are consistent with national studies and rankings. For instance, the RCEB places Maranhão 24th in the ESG (Environmental, Social, Governance) framework (CLP, 2024). The state also ranks lowest in the country for SDG 1 (No Poverty), highlighting deep-seated governance and institutional challenges in regions like the Maranhense Amazon.

The literature emphasizes the importance of active institutional structures, such as environmental councils and participatory policies, for fostering sustainable and effective governance (Viola et al., 2012; Young, 2002). In areas subject to high socio-environmental pressure, such as the Legal Amazon, strengthening local institutional capacities is critical to mitigating deforestation impacts, social inequality, and administrative fragility.

Finally, within the Social Dimension (Figure 3) —which encompasses the largest number of indicators and thematic areas included in the calculated MSDI—only two municipalities (2%) were classified at the ideal level: São Luís (1.000) and Imperatriz (0.820). Conversely, the municipalities with the lowest scores were Marajá do Sena (0.192) and Arame (0.306).

The average MSDI score for the Social Dimension was 0.508, highlighting persistent social challenges. In 106 of the 110 municipalities analyzed, more than 50% of the population lives in vulnerable poverty conditions, revealing a structural pattern of social exclusion. This is especially concerning as multidimensional poverty compromises access to essential rights such as healthcare, education, sanitation, and food security (Alkire & Santos, 2010). Life expectancy in the region ranged from 66 to 74 years, with 107 municipalities reporting figures below the national average of 73.5 years (IBGE, 2010). This disparity reflects persistent regional inequalities and is strongly associated with the social determinants of health, including income, education, sanitation, and healthcare access (Buss & Pellegrini Filho, 2007).

With respect to healthcare infrastructure, five municipalities had no Basic Health Units (UBSs), and 21 had fewer than five units in operation, severely limiting access to primary care, particularly in remote areas. This lack of infrastructure contributes to poor outcomes such as low life expectancy and high infant mortality. Indeed, 41 municipalities reported infant mortality rates above 16 deaths per 1,000 live births—higher than the Northeast average of 15.3 and the national average of 13.3 (Ministério da Saúde, 2019). Although 11 municipalities reported zero infant deaths, these figures may be underestimated due to underreporting, particularly in areas with weak health systems and incomplete civil registration.

Concerning housing conditions, while all municipalities in the Maranhense Amazon have at least 80% of their population living in households with electricity, significant deficits in basic sanitation persist: three municipalities have less than 50% of their population with access to piped water. The lack of adequate sanitation is strongly linked to the spread of waterborne diseases and exacerbates social inequalities (Barreto et al., 2010).

CONCLUSIONS

The development and application of the Municipal Sustainable Development Index (MSDI) for the Maranhense Amazon enabled an integrated and comprehensive analysis of the environmental, social, economic, political-institutional, and demographic dimensions. The methodology adopted—based on 34 indicators—allowed for a consistent evaluation of municipal sustainability performance. Despite limitations such as the scarcity of up-to-date data and time lags in official public sources, the MSDI proved to be an effective diagnostic tool. It offers a reliable overview of territorial disparities and can play a strategic role in informing policy debates and guiding the formulation of public policies aimed at sustainable development, particularly in regions marked by historical and structural vulnerabilities.

The results revealed a concerning scenario, with most municipalities exhibiting low sustainability scores, especially in the social and political-institutional dimensions. The overall average MSDI, coupled with the predominance of municipalities in the alert category, suggests that the region faces complex structural and institutional challenges that hinder its sustainable development potential.

In the environmental dimension, although the Maranhense Amazon is located within a biome of global ecological significance, the fragility of its indicators is evident. This is reflected in low scores and the persistence of unsustainable practices associated with agribusiness expansion, such as deforestation and burning. These practices intensify environmental vulnerability and demand regionally adapted public policies that reconcile environmental conservation with the sustainable use of natural resources. The social dimension also revealed deep inequalities, characterized by high poverty vulnerability, insufficient healthcare services, low life expectancy, and poor sanitation infrastructure. These conditions not only undermine the quality of life of local populations but also limit their ability to actively engage in

development processes. The political-institutional dimension showed persistently low scores, pointing to weak environmental governance structures, including the absence of active councils and management tools to ensure public participation and policy transparency.

In this context, the MSDI stands out as a valuable tool for diagnosis and territorial planning. It contributes to the development of more effective and evidence-based public policies aligned with the Sustainable Development Goals (SDGs). By identifying the key strengths and weaknesses of each municipality, the index can support coordinated actions among various levels of government, civil society, and the private sector, thereby strengthening local resilience and adaptive capacity in the face of social, environmental, and climate-related challenges. Furthermore, this study contributes to the field of regional development by proposing a methodological framework that respects the territorial specificities of the Maranhense Amazon, integrating secondary data with analytical criteria grounded in sustainability. The MSDI can be adapted and applied in other regions with similar characteristics, expanding its utility as a tool for monitoring, evaluation, and policy decision-making in regional planning. For future improvements, it is recommended to strengthen public data systems and promote the collection of disaggregated and up-to-date information at the municipal level. Additionally, the incorporation of qualitative indicators—developed through participatory processes involving civil society and local stakeholders—could enrich the index and enhance its sensitivity to local realities.

It is hoped that the results presented here will support the design of more equitable and effective intervention strategies, capable of reducing inequalities, promoting environmental justice, and advancing a more inclusive and sustainable development model for the municipalities of the Maranhense Amazon.

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