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Urban sustainability: advances and challenges in the Baixo Amazonas Integration Region, Pará, Brazil

Sustentabilidade urbana: avanços e desafios na Região de Integração Baixo Amazonas, Pará, Brasil

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ABSTRACT: This paper analyzes urban sustainability panorama of the Integration Region (RI) Baixo Amazonas for the years 2000 and 2010 and reports advances and challenges toward sustainability. RI is defined as a unit of analysis composed of 13 municipalities located in the northern half of the state of Pará, Brazil. The region was chosen because it brings together large mining projects along with intense agricultural activity, a situation that justifies the importance of measuring the level of municipal sustainability. To this end, the Urban Sustainability Index System (SISU) was applied, characterized by three thematic indicators, in order to obtain a three-dimensional panorama, namely: the Municipal Human Development Index (IDHM); the Political-Institutional Capacity Index (ICP); and, the Environmental Quality Index (IQA). It was found in the time sample made available by official agencies, that only the IDHM showed advances in all municipalities studied. As for the ICP, only Santarém and Monte Alegre showed no increases, while Juruti stood out for more increases in the improvement in fiscal autonomy and municipal public management. As for the IQA, four municipalities (Belterra, Juruti, Santarém and Terra Santa) expressed advances in the studied period, while the other municipalities had their indices reduced. In general, the study points out that the main challenges faced by these municipalities towards sustainability are related to low basic sanitation coverage, especially regarding the adequacy of facilities, increases in energy consumption due to domestic pressure, significant use of the vehicle fleet, and also reduction rates of vegetation cover, deforestation and forest degradation across IR.

Keywords: sustainability indicators; regional development; Amazon; Lower Amazon; sustainable development.

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RESUMO: Este artigo analisa o panorama da sustentabilidade urbana da Região de Integração (RI) Baixo Amazonas para os anos 2000 e 2010 e relataos respectivos avanços e desafios em direção à sustentabilidade. RI é definida como uma unidade de análise composta por 13 municípios situados na metade setentrional do estado do Pará, Brasil. A região foi escolhida por reunir grandes empreendimentos minerários juntamente com intensa atividade agropecuária, situação que justifica a importância de mensurar o nível de sustentabilidade municipal. Para tal, aplicou-se o Sistema de Índices de Sustentabilidade Urbana (SISU), caracterizado por três indicadores temáticos, a fim de se obter um panorama tridimensional, a saber: o Índice de Desenvolvimento Humano Municipal (IDHM); o Índice de Capacidade Político-Institucional (ICP); e, o Índice de Qualidade Ambiental (IQA). Apurou-se na amostra temporal disponibilizada pelos órgãos oficiais, que apenas o IDHM apresentou avanços em todos os municípios estudados. Quanto ao ICP, somente Santarém e Monte Alegre não apresentaram incrementos, enquanto Juruti destacou-se por mais acréscimos na melhoria na autonomia fiscal e gestão pública municipal. Quanto ao IQA, quatro municípios (Belterra, Juruti, Santarém e Terra Santa) expressaram avanços no período pesquisado, enquanto os demais municípios tiveram seus índices reduzidos. Em geral, o estudo aponta que os principais desafios encontrados para estes municípios rumo à sustentabilidade relacionam-se à baixa cobertura de saneamento básico, notadamente quanto à adequação das instalações, aumentos do consumo de energia pela pressão doméstica, uso expressivo da frota de veículos, taxas de redução da cobertura vegetal, desmatamento e degradação florestal em toda a RI.

Palavras-chave: indicadores de sustentabilidade; desenvolvimento regional; Amazônia; Baixo Amazonas; desenvolvimento sustentável.

1. Introduction

The urbanization process that took place in the Amazon from the 20th century on was subordinated to the policies of integration of this region to the rest of the country, leading to transformations in the regional reality that were decisive for the configuration of the territory, such as the intense migratory flows, the installation of large projects by the Federal Government, the strengthening and stimulus to the emergence of cities on the banks of highways and at the confluences of rivers, among other factors (Trindade-Júnior, 2015). Thus, the urban space was organized in different ways through different demographic, social, political, economic and cultural arrangements reflected in the structures of the cities (Nascimento, 2016).

In the environmental debate, the Amazon region has witnessed successive events that affect the balance of the relationship between ecological assets and human societies. There is evidence of an increase in illegal logging and consequent deforestation, large-scale forest fires, the installation of hydroelectric plants, and the implementation and expansion of industrial and mineral activities, causing air and river pollution, with their waste and effluents (Lima, 2016).

Cities in the Amazon generally respond to what happens around them. In cities whose economy includes mining activities, deforestation and mechanized agriculture (for example), the urban-industrial logic has always been present, expressing extensive urbanization, which goes beyond the limits of the cities, with a great spatial economic process, especially favored by means of information, technical-scientific means and urban-industrial production relations (Sathler *et al.*, 2009).

However, at the end of each economic cycle, cities adapt to changes, seeking alternative ways of survival and economic strategies or incentive policies are implemented in an attempt to move and redirect the economy (Sathler *et al.*, 2009; Becker, 2013).

Thus, such urban environments were formed from divergent pioneer fronts, driven by economic cycles that are diverse and at the same time unique (in local aspects). They grew while adapting to the environment and adjacent spaces, becoming a tangle of cultural, socioeconomic and environmental aspects, configuring heterogeneous Amazonian urban spaces, where each city is unique in terms of its history and its physical urban environment.

The intense urbanization in the Amazon, whose strategy was to stimulate the country's regional development, did not aim to create complexes, but rather to provide subsidies and allocation of labor and resources necessary for the maintenance of local development projects (Becker, 2013). Without the monitoring of proportional investments in urban infrastructure, the vast majority of Amazonian cities have a poor infrastructure or none at all, their economic base is the transfer of public resources and they lack services and jobs (Oliveira, 2004; Marin, 2014).

It can be said that the development model implemented in the Amazon, based on the country's economic growth, through pioneering fronts for the exploration of natural resources or large infrastructure works in this region, produced significant environmental changes and did not positively impact socio-economic indicators, so as to enable sustainable development that is socially inclusive, environmentally sustainable and economically sustainable. For Nascimento & Vianna (2007), the concept of pluridimensional and dynamic development must be in line with cultural and biological diversity, including human, economic, social, cultural and collective rights, along with a healthy environment.

From the point of view of urbanization, this model was not accompanied by compensating investments in education, health and sanitation infrastructure, for example, resulting in socio-environmental inequalities, such as concentration of wealth and poverty, unemployment and precariousness of services (Pereira, 2016). Thus, it can be said that the complex situation associated with difficult living conditions in cities and the persistence of immense inequalities and vulnerabilities produce negative effects on the region's environmental and health situation (Viana *et al.*, 2016).

As the urbanization of the Amazon continues, the sustainability of urban areas must be a priority in scientific and policy arenas in the region. More broadly, sustainability and sustainable development has become a critical topic, and scientific advances in sustainability research are evident.

1.1. Sustainability, sustainable development and sustainability measurement tool for the Amazon

The debate on sustainable development and sustainability has different understandings and concepts. The beginning of discussions about sustainability has two origins. The first one, in the field of biology, through ecology, is based on the resilience of ecosystems, their ability to recover and reproduce from the abusive use of natural resources by man or even by natural actions (earthquakes, tsunamis, among others). In turn, the second origin is in the economy, whose term “sustainability” is linked to that of development, as an alternative to the established model, especially from the 1970s, with unsustainable high standards of production and consumption (Nascimento, 2012).

The environmental crisis marked by global warming, damage to the ozone layer, deforestation, degradation of soils and water sources, waste of energy resources and the increase in the magnitude of environmental disasters, as well as the social crisis, revealed in the growth of poverty, marginality and deterioration of people's quality of life, expresses the social dimension of ecological degradation and awakens the need for sustainable bases for the economic process (Leff, 2006).

The perception of these problems was possible thanks to the understanding of a new concept of environment, opposed to the mechanistic, simplifying, one-dimensional and fragmented rationality that led the modernization process. This new vision prioritized human development, reaffirming values and potentials of nature, social externalities, contained knowledge and the complexity of the planet (Leff, 2001).

Thus, several initiatives and events contribute to advance this discussion. Among them, the explosion of nuclear bombs (1950s), and the perception that certain problems like these could be of a global order, extrapolating the limits of territories (Nascimento, 2012); the launch of the book Silent Spring (1962) by Rachel Carson and its approach and disapproval of the use and action of chemical insecticides and pesticides (Leff, 2001; Nascimento, 2012); the "eco-development strategies" in the 1970s as a set of principles to achieve sustainable development (Leff, 2001; Leff, 2006); configuration of ecological economics and deep ecology as new theoretical fields and political action, opening interdisciplinary frontiers with the purpose of incorporating and valuing ecological conditions of development (Leff, 2001).

In addition, there are important milestones for the outlining of the concept, such as the Stockholm Conference in 1972 and the preparation of the "Club of Rome" report, which proposed the slowdown of industrial growth in developed countries and population growth in underdeveloped countries – until now – (Leff, 2006; Nascimento, 2012); and also with the formation of the World Commission on Environment and Development (CMMAD), with the elaboration of the Brundtland Report in 1987; and, among others, Rio - 92, which resulted in the creation of the Convention on Biodiversity and Climate Change, the Kyoto Protocol, the Rio Declaration and Agenda 21 (Nascimento, 2012). In 2012, 20 years after the first Earth Summit in Rio, the United Nations Conference on Sustainable Development (UNCSD) or Rio+ 20 was held. Its results included a process for the development of new SDGs (Mensah & Casadevall, 2019).

The discussion on sustainable development emerged and grew in recent decades, and was largely a critique of the current economic model, with few practical or operational guidelines. Recently, the concept of sustainable development has described, in short, an economic, ecologically sustainable and socially fair process (Fenzel & Machado, 2009). Additionally, Sustainable Development has become a field of multiple disputes, sometimes being considered as a concept, sometimes as a discourse, or even an ideology, which sometimes complement each other, sometimes oppose each other. The mastery of this multiplicity of meanings is the greatest expression of this field of forces, which conditions positions and measures of the most diverse actors, governments, businessmen, politicians, social movements and multilateral organizations.

The most accepted and known concept to define sustainable development was postulated by CMMAD in 1991, p. 9, namely: "sustainable development is one that meets the needs of the present without compromising the ability of future generations to meet their own needs". However, this concept is overlapped by two key concepts:

(i) the concept of "need", according to which the poorest people on the planet should be given priority;

(ii) the limitations that technology and social organization impose on the environment. Still in this context, it is considered that a constant transformation of the economy and society is necessary (IPEA, 2010 apud CMMAD, 1991).

Three basic goals and objectives are also considered for the conceptualization of sustainable development:

(i) the rate of consumption of renewable resources must not exceed its renewal rate;

(ii) The amount of waste produced must not exceed the capacity of waste absorption of the ecosystems;

(iii) Non-renewable resources can be used to the extent that they can be replaced by equivalent renewable resources (Fenzel& Machado, 2009).

The expression "sustainability" that has been used in the context of development is a dynamic concept and has dimensions that go beyond the environmental aspect, whose emphasis is related to the capacity of support and resilience of ecosystems, such as social, cultural, spatial, economics, politics, international politics. Finally, unlike environmental sustainability, ecological sustainability is based on reducing the volume of polluting substances, adopting clean technologies, recycling, replacement and efficient use of resources (Sachs, 2002; IPEA, 2010).

Ecological sustainability appears as a normative criterion for rebuilding the order of the economy (Leff, 2006). Thus, sound environmental decisions must consider social physical phenomena and human values, which involve diverse and conflicting values, in addition to significant scientific uncertainty (Moran, 2011). That is, we cannot perceive sustainability only with an environmental bias, given that sustainable development involves a new awareness of public policy managers, focusing on socioeconomic development with ecological balance, orienting it towards the satisfaction of basic needs and recognizing the role of cultural autonomy (IPEA, 2010).

The transition to sustainability motivates times in which the rupture of previously established rationalities provides new processes of promotion of the environmental potential, the conformation of new consciences, the formation of new actors and the mobilization of institutional changes based on new values and rationalities (Leff , 2001). Therefore, sustainable development is capable of reformulating the conditions of production, such as in rural areas, valuing indigenous peoples, peasants, rural and urban communities, which deepened in cultural identities, participate in the management of their resources (Leff, 2006) , manifesting its bases, both in rural and urban areas (Leff, 2001).

Sustainability needs a quantitative assessment to measure the level or quality of a system, and this measurement can be performed through indicators and indices.

1.2. Sustainability measurement tools in the Amazon

Parallel to the birth of the concept of sustainable development as a guide for actions and public policies, the need arose to measure the degree of sustainability on different scales (spatial and temporal, for example) and its advances and setbacks (Marchand & Tourneau, 2014). The possible forms of this measurement converge to the use of socio-environmental indicators and an index system of indicators required based on the principles of Bellagio, with many initiatives, even in the face of all the challenges, among them the incipient database and conceptual divergence (Veiga, 2009).

The Organization for Economic Cooperation and Development (OECD) defines an indicator as "a parameter or a value derived from parameters, which points to, provides information about, or describes the state of a phenomenon/environment, with a significance extending beyond that directly associated with a parameter value" (Marchand &Tourneau, 2014 *apud* OCDE, 1993, p. 6). Indicators, when made up of a single parameter or variable, are called simple indicators, the opposite is a composite indicator, when it results from different sub-indicators, parameters or variables (Marchand & Tourneau, 2014). It is also necessary to distinguish indicators from indices that result from a set of simple indicators, composite indicators or a system of indicators (a set of indicators selected because they are related to each other) (Marchand &Tourneau, 2014).

Two types of indicators can be identified: retrospective, used to describe the implementation of policies and are used to evaluate the results and effects of these policies (Tôsto & Pereira, 2011), as well as to assist in decision-making (Marchand & Tourneau, 2014); and prospective indicators, due to their speculative character, are used to plan policies, predicting future effects (Tôsto & Pereira, 2011).

In the Amazon, a region with more than 27 million inhabitants (IBGE, 2017), vast biodiversity and diversity of peoples, conflicts and low levels of development, several challenges permeate the attempt to measure sustainability, such as:

(i) the incompatibility of some economic indicators, which include several indices of the urban way of life, however incompatible with Amazonian cities and rural areas;

(ii) the unavailability of data (mainly in rural areas, protected areas and at local levels);

(iii) the difficulty of including non-quantifiable variables and elements, which are often manifested in the man-nature relationship, some models ignoring what cannot be valued and/or not considering the cultural aspect;

(iv) the difficulty in choosing the analysis elements for a highly complex region, with a minimum set of elements to be used as a way of understanding the system as a whole;

(v) the complexity of the sustainability issue; and

(vi) the need and difficulty of multiscale (local, regional and global) and multitemporal analyzes, in addition to the variation of scales between variables and the absence of comparable data for the region (Moran, 2011; Marchand &Tourneau, 2014).

Nevertheless, several initiatives have been recorded in recent years, aimed to measure sustainability in urban and rural spaces in the Amazon, such as: Martins (2014) and the Sustainability Index for the Amazon (ISA); Silva *et al.* (2015) with the Sustainability Index of Municipalities in the Amazon (ISMA); Lameira *et al.* (2015), Cardoso *et al.* (2016) and Silva & Vieira (2016) with the Sustainability Barometer in the State of Pará; Pereira & Vieira (2016) with the Urban Sustainability Index System (SISU) for the Metropolitan Region of Belém, in the State of Pará, and Ferreira & Vieira (2018) for the Metropolitan Region of Santarém, also in the State of Pará.

The Urban Sustainability Index System (SISU) is an urban sustainability measurement tool for metropolitan regions developed by Braga (2006). The SISU is composed of three thematic indexes: environmental index, political-institutional capacity index (these two first produced by the researcher based on the concept of urban sustainability adopted by her) and the municipal human development index, produced by the Brazilian Institute of Geography and Statistics (IBGE), in partnership with the João Pinheiro Foundation (FJP) and the United Nations Development Program (UNDP) (Braga, 2006).

The Municipal Human Development Index (IDHM) focuses on a methodological application of the HDI (Human Development Index) of the United Nations Development Program (UNDP). It was designed for more than five thousand Brazilian municipalities and is able to measure urban sustainability priorities related to overcoming poverty and promoting equity, through the same dimensions of the Human Development Index. For this purpose, the IDHM considers two indicators for the educational dimension: literacy rate above 15 years (weight two) and gross school attendance rate (weight one); a longevity indicator (the same as the countries' HDI); and an income indicator, through per capita municipal income (Braga, 2006 apud IBGE/FJP/PNUD, 2004).

The Environmental Quality Index proposed by Braga (2006) for analysis of the SISU is composed of eight indicators, half of which associate objectives of environmental safety and degradation prevention, measuring the quality of the environment at the present time both in relation to the natural environment (water resources and vegetation cover) and in relation to the built environment (sanitary services and housing quality). As for the other indicators (industrial pressure, intra-household pressure, pressure for domestic consumption and automotive pressure), they are inversely related to the environmental stress caused by human intervention in urban areas (Braga, 2006).

Finally, the Political-Institutional Capacity Index, composed of four other indicators (political-administrative autonomy, municipal public management, municipal environmental management, information and political participation), aims to assess the capacity of the political-institutional system and society in facing urban sustainability challenges, associated with strengthening citizenship and promoting society's engagement to the detriment of urban sustainability (Braga, 2006).

The SISU was first applied to analyze the urban sustainability of two important metropolitan regions in Brazil, São Paulo – SP and Belo Horizonte – MG (Braga, 2006). More recently, the system was applied in the Amazon, in the Metropolitan Region of Belém, addressing a survey in seven municipalities (Belém, Ananindeua, Marituba, Benevides, Santa Barbara do Pará, Santa Isabel do Pará and Castanhal), (Pereira & Vieira, 2016) and Metropolitan Region of Santarém, with research in three municipalities (Santarém, Mojuí dos Campos and Belterra), by Ferreira & Vieira (2018), demonstrating the application of this system of indicators for urban agglomerations in the Amazon.

Therefore, the present article sought to identify and analyze the sustainability panorama in the municipalities that make up the Baixo Amazonas Integration Region over a 10-year period, specifically 2000 and 2010, base years for the demographic census carried out by the Brazilian Institute of Geography and Statistics (IBGE), which constitutes the largest reference source of the living conditions of the population in all municipalities in the national territory. It should be stressed that this Integration Region emerged from the regionalization of the state of Pará with the purpose of planning and improving state management, and it is important in the urban-regional context to understand the status of this region in terms of sustainability.

Through the application of the Urban Sustainability Index System (SISU), a tool developed to assess the sustainability of Brazilian metropolitan areas (Braga, 2006), as a summary index of the Habitat Urban Indicators Program (UNCHS, 2004), of Sustainable Development of the United Nations (United Nations, 2001) and the Sustainable Development Indicators-Brazil 2004 (IBGE, 2004), it is possible to evaluate the sets of municipalities and combine several variables in thematic indices, which allow the perception of environmental, political-institutional and social quality. In addition, we also sought to list some factors that demonstrate trends in achieving the goals of the Sustainable Development Goals (SDGs) Agenda 2030 for the municipalities of this IR, given that the 17 SDGs prioritize, in addition to the Millennium Goals, areas such as climate change, economic inequality, innovation, sustainable consumption, peace and justice, among other priorities.

2. Methodology

2.1. Study area

The study was carried out in the Lower Amazon Integration Region, one of the 12 integration regions in which the state of Pará is subdivided, located in the Northwest Region of the state. The region is intersected by the Amazon and Tapajós rivers and by BR-163 highways (Cuiabá-Santarém Highway), PA-254 and PA-419. The total territorial area is 315.86 thousand km², 25% of the total area of the state. With regard to the economy, a Gross Domestic Product (GDP) of BRL 11 billion was recorded in 2016, the fourth highest GDP among the regions, accounting for 8% of the state's GDP (FAPESPA, 2018; 2019).

The Lower Amazon Integration Region is made up of 13 municipalities very different from each other, both in territorial, population and economic aspects (Figure 01; Table 1). It is noteworthy that the municipality of Mojuí dos Campos was only emancipated in 2010 (Gomes *et al.*, 2017) and, thus, it cannot be analyzed separately. Data on this municipality for the years 2000 and 2010 were included in the data for the municipality of Santarém, as well as in the study by Ferreira & Vieira (2018). In addition, the municipality of Faro was not included in the analyzes due to insufficient information available for the research period.

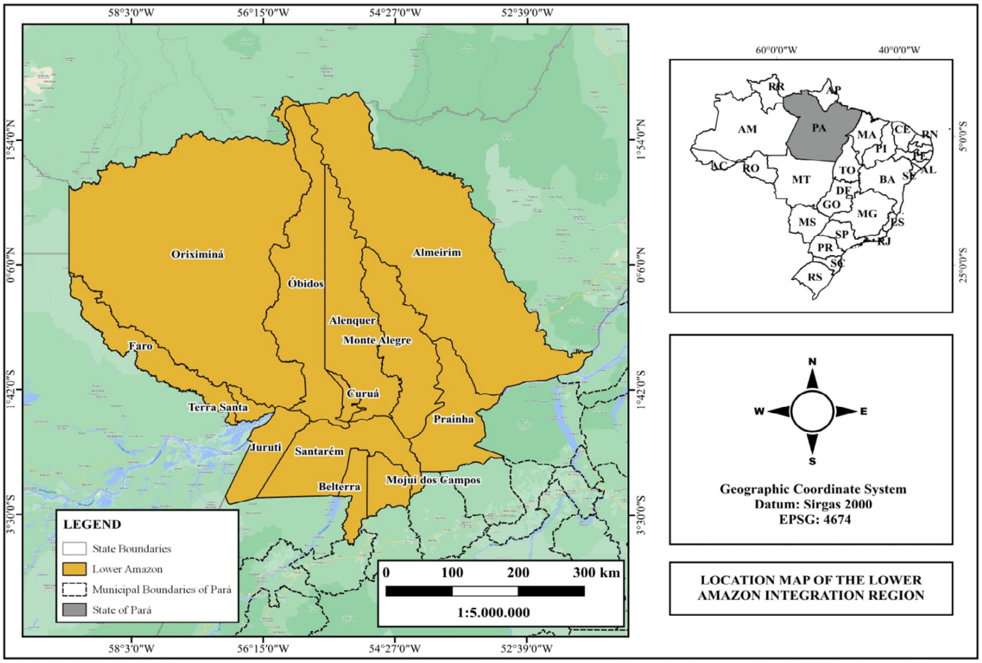

FIGURE 1 – Location map of the Lower Amazon Integration Region in the state of Pará

SOURCE: Elaborated by the Authors, 2020. Based on vector data: IBGE.

TABLE 1 – Summary of municipalities that make up the Lower Amazon Integration Region.

Municipalities	Territorial extension (km²)[1]	Population (inhab.)[2]	Demographic density (inhab./km²)[2]	Per capita GDP (Thousand BRL)[3]
Alenquer	23,645.43	56,789	2.32	11,027.84
Almeirim	72,954.79	33,614	0.46	20,064.73
Belterra	4,398.42	16,318	3.71	9,163.66
Curuá	1,431. 13	12, 254	8.56	8,641.05
Faro	11,771.67	8,177	0.69	8,060.87
Juruti	8,305. 45	47, 086	5.67	18, 567.55
Mojuí dos Campos	4,988. 24	16, 184*	-	9,919.95
Monte Alegre	18,152.56	55,462	3.06	12,223.18
Óbidos	28,021.44	49,333	1.76	12,310.70
Oriximiná	107,603.44	62,794	0.58	23,921.23
Prainha	14,786.95	29,349	1.98	10,407.78
Santarém	17,898.38	294,580	12.87	16,318.44
Terra Santa	1,895.88	16,949	8.94	28,878.63

SOURCE: IBGE ([1]2018; [2]2010a; [3]2017); *Estimated population (IBGE, 2020). Data elaborated by the authors.

2.2. Application of the Urban Sustainability Index System - SISU

As previously mentioned, the SISU tool was adapted and used for the first time in the Amazon region by Pereira & Vieira (2016), for the metropolitan region of Belém-PA, later by Ferreira & Vieira (2018), to identify the panorama of sustainability focused on the metropolitan region of Santarém. Ferreira & Vieira concluded that the applicability of the thematic index system for metropolitan regions in the Amazon provides a good monitoring instrument, as it allows understanding sustainability at the local level based on the indicators, thus enabling its application to other sets of municipalities, with use in large Brazilian cities, by Braga (2006) in 2000; including in Metropolises in the Amazon, by Pereira & Vieira (2016) in the Metropolitan Region of Belém; and Ferreira & Vieira (2018) in the Metropolitan region of Santarém. The SISU uses the following indicators: the Municipal Human Development Index (IDHM) provided by IBGE, the Environmental Quality Index (IQA), composed of six indicators subdivided into nine variables (Table 2) and the Political-Institutional Capacity Index (ICP), represented by four indicators that were subdivided into 10 variables (Table 3).

The analyzes were calculated for the base years (2000 and 2010). However, when information was lacking, time intervals were used as references. For 2000 information was collected for the period between 2000 and 2006 and for 2010, information from the period between 2010 and 2012 was used. All data were collected in duplicate by different people to ensure the reliability of the data to be used.

The analyzes were limited to the years mentioned, since for the replication of another year of study, we would need existing data for all variables, from the same sources collected for previous years. However, one of our main sources of data for municipalities is the Brazilian Institute of Geography and Statistics - IBGE, mainly data from the Demographic Census and the Municipal Human Development Index (IDHM), which do not include surveys and data after the year 2010.

For the collected data that refer to the maximum number of positive responses, considering 1 for yes (when there is the existence of what was evaluated) and 0 for no (when there is no existence), we have respectively:

- It has computers with internet access, all computers have internet access, the city hall website is active;
- Availability of urban management instruments: availability of a master plan, availability of land use and occupation zoning act and a public works construction code;
- Existence of and regularity in the functioning of Municipal Councils for Urban Development and Municipal Housing Councils;
- Existence of an Environment Council and regularity of meetings of the Environment Council.

TABLE 2 –Indicators, variables that make up each indicator, data collection source and years collected for the composition of the Environmental Quality Index (IQA).

	Environmental Quality Index			
Indicators	**Variables**	**Source of data (2000 – 2006)**	**Source of data (2010 – 2012)**	**Collected data**
Vegetation cover	Relationship between remaining vegetation cover and domain area of original vegetation cover (%)	National Institute for Space Research (INPE 2000)	INPE (2010)	The value used for this variable was the percentage of remaining forest cover up to the study year
Sanitation services	Access to the public water supply network (%)	Brazilian Institute for Geography and Statistics (IBGE 2000)	IBGE (2010)	Proportionality[1] of households with general water distribution network
	Adequate sanitation facility (%)	IBGE (2000)	IBGE (2010)	Provided by IBGE It is called: Adequate sanitary sewage
	Access to regular solid waste collection (%)	IBGE (2000)	IBGE (2010)	Proportionality of households with solid waste collection
Industrial pressure	Energy intensity (KWh/BRL)	Institute for Economic Social and Environmental Development of Pará (IDESP 2014) data from 2000.	IDESP (2014) data from 2010	Total energy consumption was divided by the municipal GDP for the study year
Intra-household pressure	Average number of residents per room	IBGE (2000)	IBGE (2010)	Information: Average number of residents in occupied private households
	Average number of residents per household	IBGE (2000)	IBGE (2010)	Weighted average between average rooms per household per average number of residents per household
Pressure for domestic consumption	Intensity in household energy use (KWh/inhab.)	IDESP (2014) and IBGE (2000)	IDESP (2014) and IBGE (2010)	Household consumption was divided by the population for the study year

SOURCE: Adapted from Ferreira & Vieira (2018).

1 Proportionality is calculated as the number of households that have the service surveyed over the total number of households in the municipality.

TABLE 3 – Indicators, variables that make up each indicator, source of data collection and years collected for the composition of the Political--Institutional Capacity Index (ICP).

	Political-Institutional Capacity Index			
Indicators	**Variables**	**Source of Data (2000 – 2006)**	**Source of Data (2010 – 2012)**	**Data collected**
Political and fiscal autonomy	Fiscal autonomy	National Treasury Department (STN 2002)	STN (2010)	Ratio between own collection and resources arising from intergovernmental transfers.
	Electoral weight	IBGE (2000) Superior Electoral Court (TSE 2000)	IBGE (2012) and TSE (2012)	Ratio between the proportion of voters and the proportion of the population
Municipal Public Management	Percentage of employees with higher education (%)	IBGE (2002)	IBGE (2011)	Proportion of employees with higher education in relation to the total number of employees
	Degree of computerization of the local public administration	IBGE (2004; 2006)	IBGE (2012)	Maximum number of positive answers (1 for yes and 0 for no)
	Existence of urban management instruments	IBGE (2001)	IBGE (2012)	Maximum number of positive answers (1 for yes and 0 for no)
	Existence and regularity in the functioning of the Municipal Councils for Urban Development and Housing	IBGE (2001)	IBGE (2011; 2012)	Maximum number of positive answers (1 for yes and 0 for no)
Municipal Public Management	Existence and regularity of meetings of the Environment Council	IBGE (2001)	IBGE (2012)	Maximum number of positive answers (1 for yes and 0 for no)
	Municipal Conservation Units (CU) per 100,000 inhabitants	Ministry of the Environment (MMA 2020) data from 2000.	MMA (2020) data from 2012.	Ratio between the number of CU's per 100 thousand inhabitants
Information and political participation	Environmental entities registered in the National Registry of Environmental Entities (CNEA)	MMA (2020) data from 2000.	MMA (2020) data from 2010.	Those entities registered with the CNEA until 2012 were considered.
	Electoral political participation (%)	TSE (2000)	TSE (2012)	Proportion of valid votes for mayor in municipal elections

SOURCE: Adapted from Ferreira & Vieira (2018).

2.3. Obtaining thematic indexes

According to Braga (2006), thematic indexes for SISU were obtained from the following steps:

i. identification of the extreme values for each of the variables (outliers) and replacement by the corresponding values for the upper limit of the 2.5%

percentile and for the lower limit of the percentile, 97.5%, as appropriate;

ii. after replacing the extreme values, standardization was performed to facilitate comparisons by aggregating the variables into a single numeric scale;

iii. standardization performed using the z-score method;

Standardization by z-score was performed using the formula:

$$Z=\frac{x-\bar{x}}{SD_{sample}}$$

Where:

$x=$¿ gross value;

$x=$¿ sample mean;

SD_{sample} = Sample standard deviation.

For the variables that have an inverse relationship with sustainability, that is, the higher the value, the worse the indicator, the inverse formula was used:

$$Z=\frac{x-x}{DP_{sample}}$$

After the statistical tests for adequacy of the variables were carried out, the indicators were standardized according to the maximum-minimum value standardization method, so that the values varied between zero and one. This standardization was done using the formula (CEM, 2020):

$$I_{jk}^{P}=\frac{I_{j,MIN}-I_{jk}}{I_{j,MIN}-I_{j,MAX}}$$

Where:

I = indicator;

j = indicator number;

k = regional;

MIN = minimum value;

MAX = maximum value.

For the variables that have an inverse relationship with sustainability, that is, the higher the value, the worse the condition, the following formula was applied:

$$I_{jk}^{P}=\frac{I_{j,MAX}-I_{jk}}{I_{j,MAX}-I_{j,MIN}}$$

Thus, on a variable performance measurement scale, the best municipality received a score of 1 while the worst received a score of 0 (or the opposite when the variable was unfavorable to sustainability), facilitating comparison and interpretation of results. Finally, the thematic indices were obtained from the simple arithmetic mean of their respective indicators (Braga, 2006).

The municipalities were classified in alphabetical order in the presentation of the indices instead of the order of classification, to facilitate intra-municipal comparisons between the three analyzed indices.

3. Results and discussion

3.1. Urban Sustainability Index System for the municipalities of the Lower Amazon Integration Region

The results obtained through the SISU of the municipalities of the RI Lower Amazon Amazonas for the years 2000 and 2010 are presented in Table 4. As for the IDHM, the highest values were identified for the municipalities of Santarém and Almeirim, with emphasis also on Terra Santa and Oriximiná, which obtained median Municipal Human Development indexes (0.600 to 0.699). There was an increase for all municipalities between 2000 and 2010, with emphasis on Juruti and Curuá, which had an increase of 52.18% and 50.91% in their HDI values, respectively. This increase is mainly due to the advances achieved for the education component in the IDHM of these municipalities, which grew above the national average for the same period (PNDU; IPEA; FJP, 2013). Until the year 2000, only Almeirim, Oriximiná and Santarém were above the limit of municipalities classified with a very low human development index (0 to 0.499), demonstrating, therefore, that all expressed considerable advances towards sustainability in this regard.

TABLE 4 – System of Urban Sustainability Indexes observed for the municipalities of the RI Baixo Amazonas for the years 2000 and 2010.

	2000			2010		
Municipalities	**IDHM**	**ICP**	**IQA**	**IDHM**	**ICP**	**IQA**
Alenquer	0.433	0.25	0.54	0.564 🟩	0.38 🟩	0.52 🟥
Almeirim	0.526	0.19	0.88	0.642 🟩	0.53 🟩	0.80 🟥
Belterra	0.396	0.30	0.56	0.588 🟩	0.48 🟩	0.63 🟩
Curuá	0.383	0.15	0.44	0.578 🟩	0.38 🟩	0.42 🟥
Juruti	0.389	0.14	0.39	0.592 🟩	0.50 🟩	0.49 🟩
Monte Alegre	0.467	0.30	0.58	0.589 🟩	0.30 🟨	0.48 🟥
Óbidos	0.452	0.24	0.57	0.594 🟩	0.37 🟩	0.50 🟥
Oriximiná	0.517	0.45	0.69	0.623 🟩	0.51 🟩	0.68 🟥
Prainha	0.361	0.16	0.50	0.523 🟩	0.41 🟩	0.45 🟥
Santarém	0.555	0.78	0.53	0.691 🟩	0.77 🟥	0.56 🟩
Terra Santa	0.490	0.13	0.52	0.635 🟩	0.15 🟩	0.54 🟩

LEGEND: increase in index 🟩; decrease in index 🟥; unchanged index 🟨.

SOURCE: elaborated by the authors, 2020.

Regarding the ICP, despite the reduction in this index due to the decrease in fiscal autonomy and electoral weight, the municipality of Santarém obtained the highest indexes (0.78 and 0.77, for the years 2000 and 2010, in that order), data consistent with those found by Ferreira & Vieira (2018). These results are also similar to those found by Braga (2006) and Pereira & Vieira (2016), for the capitals of metropolitan regions, such as Belém and other capitals outside the state, such as São Paulo and Belo Horizonte. Although Santarém is not the capital of a state, it is considered a hub city in providing services and administrative structure both for the other municipalities that make up the Lower Amazon RI (12 municipalities) and for the municipalities of the Tapajós RI (6 municipalities) (Ferreira & Vieira, 2018).

With regard to the other municipalities in the region, like Santarém, Monte Alegre did not have an increase in the ICP in the years investigated, but its index remained unchanged because this municipality improved in some variables, such as electoral weight, percentage of employees with higher education and existence and regularity of meetings of the Environmental Council, at the same time that it reduced the degree of computerization of the local public administration, electoral-political participation and, more representatively, its fiscal autonomy, with the increase in resources from intergovernmental, federal and state transfers, which is a condition for the municipality to establish priorities (Braga, 2006). The municipality with the lowest performance in terms of political-institutional capacity was Terra Santa, registering the worst averages for the index (0.13 and 0.15, respectively). Nevertheless, it has made significant progress in 10 years, characterized by an increase in fiscal autonomy, electoral weight and in municipal public management variables, except for existence of the Municipal Council for Urban Development and Housing, which justify the increase in this index.

As for the municipalities with the greatest performance in ICP for the investigated period, Juruti, Almeirim, Prainha and Curuá stand out with increases of 257.14%, 178.95%, 156.25% and 153.33%, respectively. These results are mainly determined by the increase in fiscal autonomy (except for Curuá), electoral weight (except for Almeirim), in municipal public management, existence and regularity of meetings of the Environment Council and political-electoral participation. Despite the significant advances, these municipalities still have a much lower ICP than that measured for Santarém, which highlights the importance of the latter in offering goods and services to its population and the smaller cities in its surroundings, political centrality, characterized by the presence of institutions and official bodies linked to political decisions (Nunes *et al.*, 2016). This also demonstrates the non-occurrence of homogeneous urbanization of the territory, which leads municipalities to concentrate urban policies on solving their problems on a smaller scale, becoming unable to face the challenges of sustainability (Pereira & Vieira, 2016).

The process of governance involves devising ways to identify goals and then identifying the means to achieve those goals, focusing on four key functions (goal setting, goal coordination, implementation, evaluation, and reactions and feedback). By identifying these goals, one can assess how governance is carried out in different political systems, where gaps in governance will emerge, and then also consider mechanisms to improve the quality of performance of the public sector, as well as its partners in the process of governance (Peters, 2013).

Thus, we highlight the importance of governance for the formulation and execution of effective policies for the progress of these municipalities, in order to contemplate the various social actors involved in the process, as institutional development and the strengthening of the democratic management of the city are the principles that guide good urban governance, in addition to directly impacting environmental governance from the involvement of different actors, institutions and stakeholders in the adoption of a set of practices guided by the principles of sustainability aimed at the conservation of environmental conditions (Jacobi & Sinisgalli, 2012; Bursztyn & Bursztyn , 2012; Sotto *et al.*, 2019).

From this perspective, these municipalities do not have good governance for sustainability, as the improvement of ICP does not converge to an improvement in the quality of life and environmental well-being of the municipalities. There may not even be an understanding of governance, or there may be an internal flaw in the governance of these municipalities.

Detailed observation of the natural data that make up the ICP (Table 5) makes it possible to identify the main weaknesses faced by these municipalities and the advances in terms of sustainability, although they present a low index of political-institutional capacity.

TABLE 5 –Indicators, variables of each indicator and results for 2000 and 2010 of ICP for Lower Amazon RI.

	Political- Fiscal Autonomy			
	Fiscal Autonomy		**Electoral Weight**	
Municipalities	**2000**	**2010**	**2000**	**2010**
Alenquer	0.023	0.035	1.22	0.978
Almeirim	0.094	0.272	1.21	0.954
Belterra	0.027	0.036	1.02	1.255
Curuá	0.025	0.010	0.92	1.126
Juruti	0.002	0.292	0.86	0.878
Monte Alegre	0.046	0.020	0.87	1.148
Óbidos	0.045	0.041	1.02	1.008
Oriximiná	0.236	0.190	1.07	0.970
Prainha	0.014	0.066	0.86	1.082
Santarém	0.367	0.152	1.07	0.989
Terra Santa	0.034	0.039	0.90	1.004

	Municipal Public Management			
	Employees with higher education (%)	**Degree of computerization of the local public administration**	**Existence of urban management instruments**	**Existence and regularity in the functioning of Municipal Councils for Urban Development and Housing**

	2000	2010	2000	2010	2000	2010	2000	2010
Alenquer	1.80	8.29 🟩	2	2 🟨	1	3 🟩	0	0 🟨
Almeirim	0.65	11.88 🟩	2	2 🟨	0	2 🟩	0	2 🟩
Belterra	5.12	12.88 🟩	1	2 🟩	0	2 🟩	0	1 🟩
Curuá	1.99	11.16 🟩	0	2 🟩	1	3 🟩	0	0 🟨
Juruti	1.25	17.64 🟩	2	2 🟨	0	1 🟩	0	2 🟩
Monte Alegre	10.26	20.54 🟩	3	1 🟥	1	2 🟩	0	0 🟨
Óbidos	1.13	7.73 🟩	2	1 🟥	0	3 🟩	0	2 🟩
Oriximiná	3.57	24.76 🟩		2 🟥	1	2 🟩	0	1 🟩
Prainha	3.59	15.55 🟩	2	2 🟨	0	1 🟩	0	1 🟩
Santarém	11.67	16.95 🟩	2	3 🟩	3	3 🟨	0	1 🟩
Terra Santa	2.32	8.59 🟩	0	1 🟩	0	1 🟩	0	0 🟨

	Municipal Environmental Management				**Information and Political Participation**			
	Existence and regularity of Meetings of the Environment Council		**Municipal conservation units per 100 thousand inhabitants**		**Presence of environmental entities registered in the National Registry of Environmental Entities**		**Electoral political participation (%)**	
	2000	**2010**	**2000**	**2010**	**2000**	**2010**	**2000**	**2010**
Alenquer	0	2 🟩	0	0 🟨	0	0 🟨	69.78	79.37 🟩
Almeirim	0	2 🟩	0	0 🟨	0	0 🟨	59.62	79.61 🟩
Belterra	2	2 🟨	0	0 🟨	0	0 🟨	78.48	79.62 🟩
Curuá	0	1 🟩	0	0 🟨	0	0 🟨	82.05	80.65 🟥
Juruti	0	2 🟩	0	0 🟨	0	0 🟨	77.52	78.64 🟩
Monte Alegre	0	2 🟩	0	0 🟨	0	0 🟨	77.61	45.53 🟥
Óbidos	1	1 🟨	0	0 🟨	0	0 🟨	75.02	73.54 🟥
Oriximiná	2	2 🟨	0	0 🟨	0	0 🟨	77.26	72.95 🟥
Prainha	0	2 🟩	0	0 🟨	0	0 🟨	75.50	79.58 🟩
Santarém	2	2 🟨	0.373	1.003 🟩	1	1 🟨	72.96	76.45 🟩
Terra Santa	0	0 🟨	0	0 🟨	0	0 🟨	86.48	82.40 🟥

LEGEND: increase in index 🟩; redecrease in index 🟥; unchanged index 🟨.

SOURCE: elaborated by the authors, 2020.

With regard to the municipalities that had a significant growth in this index in the study years, it is important to mention their economic bases mainly focused on plant extraction, development of the agricultural sector and mineral extraction activity, with emphasis on the municipality of Juruti, which grew more than 1600% between the years 2000 and 2010 in fiscal autonomy, with a substantial gains from collection of fees and taxes. This fact can be attributed to the economic impact generated after the installation of the multinational Aluminum Company of America (Alcoa), in 2006, which began its bauxite exploration operations in 2009. Since then, the company has transferred to the Municipality of Juruti, approximately BRL 222.6 million by 2019 (ALCOA, 2020).

It should be stressed, however, that the financial gains related to the mining activity do not necessarily represent an improvement in the quality of life of the populations in the areas of direct and indirect influence where such enterprises are installed, notably for traditional communities and quilombola communities.

As an example, we mention the case of Mineração Rio do Norte (MRN) located in the District of Porto Trombetas, in Oriximiná, where community groups representing the quilombola (Boa Vista) community and traditional communities (Boa Nova and Saracá) reported, based on in their experiences and their knowledge, the impacts on water resources caused by mineral extraction activity, which affects water quality due to the formation of tailing ponds. In addition, leaching of large amounts of organic matter and sediments may occur, altering the physical-chemical characteristics of the water, as well as the availability of fishing resources, reducing or even making subsistence fishing unfeasible (Wanderley, 2008; Andrade, 2018).

Thus, the importance of the municipal environmental management indicator evaluated by the ICP is evidenced; It evaluates the existence of Environmental Councils in the municipalities and the regularity in their functioning through the meetings held. Therefore, it is one of the main ways in which organized society has the opportunity to debate issues of social and public interest in the face of the challenges of the environmental crisis, providing a valuable space for discussion and dissemination of environmental information (Nunes *et al.*, 2012).

Regarding IQA, the municipalities of Juruti, Belterra, Santarém and Terra Santa had increases of 25.64%, 12.50%, 5.66%, 3.85%, respectively, during the study period, mainly due to advances in the indicator “health services”, “reduction of industrial pressure” and “intra-household”. On the other hand, the other municipalities had a reduction in this index, especially Monte Alegre (-17.24%), Óbidos (-12.28%) and Prainha (-10%), due to the decrease in vegetation cover, the increase in pressure from domestic and automotive consumption, in addition to the reduction in the percentage of adequate sanitation installations in Monte Alegre and Óbidos. Oriximiná, Curuá and Alenquer also recorded significant increases in the intensity of household energy use and number of vehicles per capita.

The municipality of Almeirim has indices closer to value 1 for both years, 0.88 in 2000 and 0.80 in 2010 (Table 2), although it showed a decrease of 9.09%, mainly due to increase in industrial pressure, reduction of vegetation cover and adequate sanitary facilities. However, it is should be noted that the result of the indices concerns the extreme upper and lower values for a given municipality within the set of analyzed municipalities, and so it is a relative measure and not an absolute one. Thus, although a given municipality obtains an average of 1, it does not necessarily mean that it has perfect environmental conditions, and may even improve its performance (Braga, 2006).

Furthermore, the IQA of these municipalities had an inverse relationship with the Political-Institutional Capacity index, that is, the municipalities with the highest ICP generally have an unsatisfactory IQA (Table 2). This result indicates that the municipalities have not invested in improving environmental quality (Ferreira & Vieira, 2018), since greater institutional strengthening was expected, which would reflect a significant capacity to devise strategies and adopt measures to promote the sustainability of these municipalities (Pereira & Vieira, 2016).

Analysis of the environmental dimension of municipalities in the Amazon makes it possible to identify and help propose public policies at the municipal, state and federal levels that consider sustainable development and regional sustainability as goals for measuring the use of natural resources (Silva *et al.*, 2015).

In view of the above, based on the analysis of the variables that make up the IQA, it is possible to detail and identify what were the advances and challenges for the municipalities of the RI Lower Amazon, with emphasis on the indicators vegetation cover, pressure for domestic consumption and automotive pressure that presented the worst results in regarding sustainability for all municipalities surveyed (Table 6).

TABLE 6 – Indicators, variables of each indicator and results for 2000 and 2010 that lead to the IQA for RI Lower Amazon.

	Vegetation cover		**Sanitation Services**					
	Relationship between remaining vegetation cover and domain area of original vegetation cover (%)		**Access to the public water supply network (%)**		**Adequate sanitation facility (%)**		**Access to regular solid waste collection (%)**	
Municipalities	**2000**	**2010**	**2000**	**2010**	**2000**	**2010**	**2000**	**2010**
Alenquer	81.09	65.36	34.62	32.67	21.19	18.70	16.35	45.45
Almeirim	92.87	64.02	67.52	69.91	43.11	30.00	60.45	64.81
Belterra	70.93	64.58	29.37	54.93	3.58	20.70	13.91	39.75
Curuá	28.24	25.59	35.31	70.88	0.23	1.10	1.05	18.09
Juruti	66.65	64.84	33.58	56.65	1.28	2.90	10.97	51.32
Monte Alegre	64.75	36.58	31.02	46.38	14.19	16.50	33.51	37.36
Óbidos	73.59	63.14	53.32	57.08	5.68	1.80	23.07	44.45
Oriximiná	93.82	76.69	62.50	50.64	15.42	34.50	50.66	57.93
Prainha	63.88	50.04	40.45	47.53	5.13	4.50	6.19	22.23
Santarém	63.67	58.17	60.77	59.07	28.84	38.10	52.11	75.65
Terra Santa	44.04	40.64	70.19	78.66	8.80	12.40	44.42	74.23

	Industrial Pressure		**Intra-household pressure**			
	Energy intensity (KWh/BRL)		**Average number of residents per room**		**Average number of residents per household**	
	2000	**2010**	**2000**	**2010**	**2000**	**2010**
Alenquer	132.74	75.40	1.41	1.12	5.18	4.34
Almeirim	12.28	23.22	1.17	0.96	5.01	4.25

Belterra	119.77	90.30 🟩	1.21	0.93 🟩	4.89	4.08 🟩
Curuá	35.18	54.88 🟥	1.78	1.34 🟩	5.36	4.62 🟩
Juruti	78.77	32.13 🟩	2.17	1.38 🟩	5.88	4.96 🟩
Monte Alegre	113.14	88.29 🟩	1.27	0.97 🟩	4.81	4.02 🟩
Óbidos	170.25	87.56 🟩	1.43	1.16 🟩	5.11	4.35 🟩
Oriximiná	49.23	23.54 🟩	1.40	1.14 🟩	5.30	4.58 🟩
Prainha	42.10	40.24 🟩	1.62	1.37 🟩	5.67	4.73 🟩
Santarém	382.75	119.02 🟩	1.10	0.90 🟩	4.92	4.19 🟩
Terra Santa	167.66	120.91 🟩	1.71	1.10 🟩	5.84	4.67 🟩

	Pressure for domestic consumption		**Automotive pressure**	
	Intensity in household energy use (KWh/inhab.)		**Number of vehicles per capita**	
	2000	**2010**	**2000**	**2010**
Alenquer	140.03	182.96 🟥	0.045	0.071 🟥
Almeirim	76.32	153.99 🟥	0.055	0.075 🟥
Belterra	81.63	185.82 🟥	0.021	0.059 🟥
Curuá	24.03	135.89 🟥	0.002	0.010 🟥
Juruti	56.34	175.19 🟥	0.003	0.021 🟥
Monte Alegre	98.73	226.43 🟥	0.053	0.119 🟥
Óbidos	118.56	198.78 🟥	0.031	0.059 🟥
Oriximiná	144.66	206.02 🟥	0.048	0.066 🟥
Prainha	37.51	84.92 🟥	0.006	0.015 🟥
Santarém	264.94	361.28 🟥	0.109	0.177 🟥
Terra Santa	146.15	253.05 🟥	0.001	0.010 🟥

LEGEND: increase in index 🟥; decrease in index 🟩. For variables that have an inverse relationship with sustainability i.e. the higher the value, the worse the index: we have: increase in index 🟥; decrease in index 🟩.

SOURCE: elaborated by the authors, 2020.

The main results collected show a reduction in the vegetation cover variable. Nevertheless, all municipalities in the RI Lower Amazon are part of the "Green Municipalities Program (PMV)", created by the Fundo Vale in 2008 as an instrument of action by the company Vale in the territories where it operates. The program was later transformed into a project by the government of the state of Pará, in 2011 (Costa & Fleury, 2015), with the aim of promoting the development of sustainable productive activities with low carbon emissions and high social and environmental responsibility (Guimarães *et al.*, 2011), and between 2017 and 2018, these municipalities reached the deforestation targets, and managed to reduce deforestation to less than 40 km^2 and, therefore, were not included in the list of municipalities with high deforestation rates in the Amazon. For this region, the following are considered Green Municipalities: Almeirim, Belterra, Juruti and Santarém; under pressure: Monte Alegre, Mojuí dos Campos and Prainha and, with a forest base: Alenquer, Curuá, Óbidos, Oriximiná, Terra Santa and Faro.

The main causes of deforestation in the Amazon are related to anthropic activities, such as large-scale agriculture, livestock in addition to slash-and-burn agriculture, logging, hydroelectric and mining-metallurgical projects, road construction and urban growth (Santos, 2017; Bispo & Pimentel, 2017), which impoverish biodiversity in the region, in addition to contributing to a greater release of carbon into the atmosphere (Fearnside, 2005; Walker *et al.*, 2020).

Since 2018, the environmental scenario in the country has weakened. The threat to the protection of the Amazon is imminent in the face of setbacks that the Federal environmental policy has been facing, arising from new environmental legislation, presidential provisional measures and partly due to changes in procedures at the level of Federal Government agencies (Fearnside, 2019; Ferrante & Fearnside, 2019). As an example, the transfer of control and inspection of deforestation to the Ministry of Agriculture can be cited, which notably weakens environmental policy, since monitoring and punishing deforestation requires an autonomy that the Ministry of Agriculture does not have (ISA, 2019).

In addition, deforestation is directly responsible for most of the fires that occur in the Amazon region (Copertino *et al.*, 2019). In August 2019, encouraged by the then President of Brazil, farmers and land grabbers in the southwest region of Pará held the “fire day”, with coordinated burning of pastures, invasion of areas and deforestation (ASCEMA, 2020), which increased the number of fire hot spots in more than 266 % in the state for the same period (August/2018 = 2,782; August/2019 = 10,185) (INPE, 2020), which implies a direct relationship with climate change and consequently with the sustainability of human activities (Fearnside, 2018).

In 2020, the Government of the State of Pará instituted the State Plan Amazônia Agora – PEAA (State Decree nº 941/2020), and one of its guidelines is the planning and monitoring of emergency government actions to face deforestation, forest fires and environmental crimes. Such actions are developed within the scope of the State Force to Combat Deforestation – FECC (State Decree No. 551/2020), and constitute the pillar of command and control of the PEAA (SEMAS, 2021; Pará, 2020a; Pará, 2020b). However, these investments have not yet been reverted into a reduction in deforestation and fires in the State. The same technical note reports that in 2020, in the State of Pará, data for PRODES (Project for Monitoring Deforestation in the Legal Amazon by Satellite), revealed an increase of 24.4% in deforestation, which represents 47% of the total deforestation that occurred in the period of August 2019 to July 2020 in the Amazon, while for the Amazon region, the increase was 9.5% for the same period (SEMAS, 2021).

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SEMAS, 2021). However, these investments have not yet been reverted into a reduction in deforestation and fires in the State. The same technical note reports that in 2020, in the State of Pará, data for PRODES (Project for Monitoring Deforestation in the Legal Amazon by Satellite), revealed an increase of 24.4% in deforestation, which represents 47% of the total deforestation that occurred in the period of August 2019 to July 2020 in the Amazon, while for the Amazon region, the increase was 9.5% for the same period (SEMAS, 2021).

In 2021, Pará was the state with the highest absolute contribution to deforestation (5,257 km2) (INPE, 2022). In 2022, an analysis of the first quarter of this year shows that the State of Pará ranked second in the deforestation ranking, with 225.18 km², and an alert was issued. And a worrying factor is that the most deforested category is Non-Designated Public Forests (26.4%), followed by Environmental Protection Areas (26.2%) (Prizibisczki, 2022). Such information is of concern to environmental governance in the State of Pará, state supervision for the control of deforestation and maintenance of vegetation cover and the management of public areas in the Amazon, as these two elements are important indicators of analysis for sustainability in this study, as well as of paramount importance for the maintenance of biodiversity (Antonelli *et al.*, 2018; Vieira *et al.*, 2008) and the way of life of traditional populations in the Amazon.

It should be noted that part of these regulatory and inspection systems are under the jurisdiction of municipal governments, which often do not have the financial, structural or personal resources to act in these systems, or even act fraudulently and with corrupt practice. A recent case was identified in Itaituba - PA (a municipality close to the area of this study), where, as published by Agência Pública, with the use of satellite images, the existence of illegal mining was detected in an area of environmental protection under Federal domain - APA do Tapajós, in Itaituba, since 2014 (Anjos *et al.*, 2022).

On the other hand, the sanitation services sector is one of the sectors that require the greatest amount of resources for investments, due to the benefits of its offer, although the municipalities have reduced the coverage of households served by the water supply network, this does not indicate necessarily the removal or elimination of the network, but it demonstrates that these municipalities have gone through processes of population and urban network expansion (Ferreira & Vieira, 2018). In the "adequate sanitation facility" indicator, the advances do not absolutely indicate investments in this sector, since only the proportionality of households with septic tanks is considered, given the absence of sewage collection, transport and treatment networks in the municipalities (Ferreira & Vieira, 2018). Basic sanitation and sanitary sewage are essential for urban development and quality of life, since they are directly related to the adequate provision of health (Nonato *et al.*, 2017), and are in line with the provisions of SDG number 6 (Clean water and sanitation).

Regarding the "intra-household pressure" indicator, all municipalities showed advances. It is important to measure this indicator, as it represents the pressure exerted on overcrowded households, but it also represents the need to build new residential units, as these households are inhabited by low-income people and also contribute to the formation of subnormal clusters in places that lack an adequate structure and that cannot provide a good quality of life (Braga, 2006). In municipalities of Pará, in particular, these practices are carried out without considering the housing needs and the peculiarities of each of these municipalities (Silva *et al.*, 2018).

As for automotive pressure, all analyzed municipalities had a significant increase in the vehicle fleet, namely motorcycles, which were the most representative. The increase in the number of vehicles in the cities is one of the great challenges for sustainability, as it is usually linked to economic growth and large urban projects (Brasil *et al.*, 2014). However, its effective increase results in higher levels of GHG emissions into the atmosphere, such as methane gas (CH4) and carbon dioxide (CO2), in addition to pollutants that contribute to respiratory diseases and disturbances in ecosystems (UNIETHOS, 2012).

The deficit in urban infrastructure in these municipalities that was identified here has also been mentioned by other studies, such as the one conducted by Marin *et al.* (2014), which investigated corruption and inefficiency in federal transfers, analyzing the expenses of the Ministry of Cities in the Municipalities of Pará between 2003 – 2013 and concluded that the most frequent waste observed in Pará was Embezzlement (19%), which concerns Active Waste (Corruption) and Irregular Bidding (38%) and Lack of Advertising (31%) regarding Passive Waste (Inefficiency), also indicating the occurrence of waste due to Bid rigging that occurred only in Santarém in 2009.

As already highlighted in the introductory topics of this article, in a region of such great sociocultural diversity as the Amazon, with large population, colossal biodiversity and multiplicity of traditional peoples, conflicts and low levels of development, several challenges are faced in the attempt to measure sustainability. Also, the diversity of concepts and the conflicts about the concept of sustainability deserve mention. On the other hand, it is also necessary to consider the need to reformulate the concept of sustainability, which has been misrepresented in order to sustain only the economic bias of development, neglecting social development, environmental quality, appreciation and preservation of cultural diversity, gender equality and diversity, among many other biases that need to be valued and emphasized within the logic of sustainability and are ultimately forgotten, as seen in this research.

In addition, the difficulty of choosing a quantitative tool for analyzing urban sustainability in a region like the Amazon must be stressed here, as this can prevent biodiversity and sociocultural nuances from being captured due to the absence of indicators to measure them.

We also recognize the limitation of the use of standardized macro indicators and their applicability in the Amazon region from a sociocultural perspective, especially with regard to traditional populations. Indigenous, quilombola, riverside populations, farmers, peasants and many others inhabit the Amazon and show an intimate relationship between countryside, forest and city, thus representing the complexity of the Amazon, one of the challenges of measuring sustainability listed by Moran, 2011; Marchand & Tourneau, 2014. Urban areas and their surroundings composed of rural landscapes represent a complex pattern of man-environment relations open to constant changes (Moran, 2011). Such populations have diversified logics and ways of life and, therefore, deserve the applicability of indicators that represent them (Lacerda, 2018).

However, part of these populations is inserted in an urban context (target of this study) and globalized, and we cannot isolate it in this research from other urban populations. Sustainability measurement surveys also require analyzes on temporal and spatial scales that allow comparison with other analyzes carried out in other regions and countries (Guimarães & Feichas, 2009; Moran, 2011; Marchand &Tourneau, 2014). This is the case of this methodology, which has already been applied to other urban agglomerations in the State of Pará, to understand how this region has advanced in sustainability compared to adjacent areas under similar logics and levels of complexity, allowing public policy decision-making at municipal scales.

In light of the knowledge indicated by Lacerda (2018), we recommend the application of specific research that evaluates the quality of life of traditional populations based on specific indicators, otherwise, there may be inadequacy of public policies and, ultimately, a cyclical system of social exclusion or inappropriate inclusion.

3.2. Trends in achieving the SDG targets in 2030

In 2019, the Pluriannual Plan 2020-2023 of the State of Pará was compiled. It was the first state planning instrument that aligned programs and goals according to the Sustainable Development Goals (SDGs) of the 2030 Agenda. This instrument expressed a set of public administration priorities and their results, which will help to improve the management of the exercise of control of the state's municipalities, based on a socioeconomic and environmental statistical diagnosis capable of evaluating and generating metrics for the current situation. In addition, it will contribute to and design, in accordance with the SDGs, a sustainable, inclusive and more developed Pará in the economic and environmental spheres for its citizens by 2030 (FAPESPA, 2020).

Following are initiatives promoted by some municipalities analyzed here that aim to achieve the goals defined by the 2030 Agenda in the state of Pará. The SDGs in the municipalities of Monte Alegre, Prainha and Santarém propose to encourage and discuss with agricultural producers the implementation of more sustainable practices for the development of their activities, promoting organic agriculture and stimulating the participation and autonomy of rural and forest women in the region in the promotion of agroecology. In Santarém, in particular, a project developed by the Federal University of Western Pará (UFOPA) in partnership with the FASE Amazônia program supported women producers as the ones who are entirely responsible for reflecting on their role in guaranteeing food and nutritional security, with emphasis on the members of the Association of Rural Women Workers of Santarém and the Association of Women of the Municipality of Belterra (Amabela), providing them with a place where they could show and sell their productions such as vegetables, fruits, eggs, etc. and also the crafts (Galvão, 2017).

In addition, livestock activity in these municipalities is one of the main economic vectors for small-scale producers. Thus, the ODS proposes the recovery of degraded areas and the protection of springs and sector expansion projects. Although it seems costly, the project will improve the living conditions of residents through technical standards and changes in operating procedures and, by extension, habits aimed at making livestock a sustainable, profitable and economic. In the municipalities of

Monte Alegre, Prainha and Juruti, several activities have been carried out aimed at good intensive cattle breeding practices called “Green Livestock” or “Sustainable Livestock”, together with livestock farmers, promoted by a set of institutions and by municipal governments, with visits and technical guidelines, in addition to lectures and meetings in the composition of the program (Costa, 2020).

Still regarding the municipality of Santarém, it should be noted that it is the only municipality in the RI Lower Amazon that appears on the list of the Index of Sustainable Development of Cities – Brazil, a tool that intends to generate a movement of transformation of Brazilian cities based on the orientation of the municipal political action, defining benchmarks and targets based on management indicators and facilitating the monitoring of the SDGs at the local level. The municipality ranks 751 with 40.85 points, out of a total of 100, regarding compliance with the 17 SDGs (IDSC-BR, 2021). Also included in this list are eleven other municipalities in Pará, with capital Belém holding the best position, 635, and Moju, the worst position, 770.

Since 2017, the municipality of Juruti has being promoting improvements through educational projects such as the Training of Family Farmers in Agroforestry Systems, the Cutia project, “Sustainability School: Knowing is Power”, presented by the International Institute of Education of Brazil (IJUS, 2020). In 2020, the Ingá Project – Sustainability and Management Indicators in the Amazon was launched. It is based on the formation of local human capital, autonomy in the management and leadership of the territory, protection and conservation of native forests and restoration of degraded areas, support for entrepreneurship and the structuring of the observatory of sustainable development indicators in the municipality of Juruti based on the UN Sustainable Development Goals (SDGs) in the territory (IJUS, 2020). The municipal bodies of Juruti seek to provide a better quality of life for the locals with investments for small traders to sell local agricultural products, and promote a general assembly where the population participates in the development of the region (IJUS, 2020). In addition, through the Sustainable Juruti Institute (IJUS), in partnership with the Alcoa Institute, municipal bodies benefit organizations with technical monitoring by a multidisciplinary team, expanding the participation of producers in development processes, increasing the range of family alternatives for work and income, from the perspective of environmental, economic and social sustainability.

In Curuá, the city hall updated the municipal fiscal unit through the computerization of data from the Fiscal and Real Estate Sector of the Municipality, to promote the development of the city (Prefeitura de Curuá, 2021). Thus, the public administration has control over taxpayers and starts to apply the tax legislation with equity. Despite the COVID-19 pandemic, the municipality carried out the recovery of urban roads and participated in meetings for the release of agreements for improvements in the city. In addition, in 2020, together with the municipal and state environmental secretaries, operations began at the new waterway port, enabling strategies to improve fishing and agriculture (Prefeitura de Curuá, 2021).

The Municipality of Óbidos is an example of good practice in valuing historical facts such as the “AFRO-BRASILEIRA CULTURE” project, since there are approximately 18 quilombola communities in that municipality, located in upland and floodplain areas (Santos *et al.*, 2020). In addition to the indigenous people who were already living in the area, Moroccans, Italians, Jews, Portuguese and blacks were introduced. The latter gradually faced the denial of their territorialities and socio-spatial identities (Santos *et al.*, 2020).

However, the formation of quilombola communities represents forms of struggle and Re-Existences (Santos *et al.*, 2020), of ascent to formally written recognition of their territories and occupied spaces through land titling, which guarantees the right that their descendants will be able to maintain the cultural richness of generations.

Thus, the project inspires reflection on the contribution of blacks to the country, as well as to the city's cultural and educational technology area. The project developed is an example of good practice in the Northern region, as it seeks to emphasize moral and cultural diversity and comply with educational legislation. Therefore, the municipality intends to contribute to achieving SDG 4 (Quality education), 10 (Reduction of inequalities), 11 (Sustainable cities and communities), 16 (Peace, justice and strong institutions) and 17 (Partnerships and means of implementation) (CNM, 2018).

The authorities of the municipality of Oriximiná intend to implement, by 2030, measures that progressively improve the efficiency of global resources in consumption and production, in order to align with SDG 8 (Decent work and economic growth) and to dissociate economic growth from environmental degradation, since the mineral extractive industry is its main economic activity (Paranatinga, 2019).

In Terra Santa, the Sustainable Territories Program (PTS) promotes sustainable economic development in the region through initiatives that improve the quality of life of citizens in the long term. It is worth mentioning the qualification of Brazil nut production and the improvement of the public health service in the municipality, in partnership with organizations and the local government, for having contributed significantly to mitigating the impacts caused by the COVID-19 pandemic, aligning different SDGs, namely: 08 (Decent work and economic growth), 11 (Sustainable cities and communities) and 17 (Partnerships and means of implementation) (Calencio *et al.*, 2021).

4. Final considerations

The analysis of the sustainability panorama of the municipalities of the Lower Amazon RI through the Urban Sustainability Index System showed that, in the 10-year interval, all 11 municipalities investigated here had increments in their HDI, expressing improvement in terms of income distribution, education and life expectancy of the population. However, these values are still only satisfactory and similar to those found by Pereira & Vieira (2016) for peripheral municipalities in the metropolitan region of Belém, the state capital. Furthermore, the index is not sensitive to analyze and identify inequalities between municipalities, notably with regard to issues such as health, income and education.

A similar situation occurred in ICP, where only Monte Alegre and Santarém did not show advances like nine other municipalities. With regard to the extent of fiscal autonomy and municipal public management, it occurred mainly in municipalities that host large private enterprises in the region, as is the case of Juruti and Oriximiná. However, it should be said that such advances do not generate investments in the improvement of the environmental quality and/or well-being of the populations, since the impacts caused by these installations cause significant environmental setbacks and affect the subsistence of the people. Furthermore, the recorded indices denote the challenge of these municipalities regarding their institutional strengthening.

The results of the IQA varied. For the four municipalities that had an increase in their results, reduction of industrial pressure, expansion of solid waste collection services and reduction of intra-household pressure, were the most representative. On the other hand, adequate sanitary facilities, pressure for domestic consumption, as well as automotive pressure, were the variables that most contributed to the low index of the municipalities. Therefore, a continuous study is necessary in search for excellence, involving those responsible for the areas in the municipalities and the affirmation of commitments that consider the aspects of sustainability to promote the growth of these municipalities, respecting the cultural, social and environmental diversity of the Amazon.

In general, the final overview of sustainability for the RI Lower Amazon allowed identifying that Santarém, Almeirim and Oriximiná were the municipalities that made the most progress in terms of sustainability by obtaining better results for the three indices identified in this study, especially due to the increments obtained in the HDI and ICP for the selected years. As for the less sustainable municipalities, Prainha, Monte Alegre and Curuá are among those that most express the urgency of actions aimed at the integrated development of environmental, socioeconomic and political-institutional quality. Moreover, information regarding initiatives aimed at achieving the SDG targets in the 2030 Agenda is still scarce for all municipalities in the state, especially for the Lower Amazon Integration Region, reflecting the need for studies that can measure the efforts of these municipalities with regard to meeting the SDGs.

We must recognize the difficulty in choosing a quantitative tool for the analysis of urban sustainability in a region of such socio-environmental complexity as the Amazon, and it may not be possible to capture biodiversity and socio-cultural nuances due to the absence of indicators to measure them. However, such a tool, as well as in studies where it was applied in the Amazon region, can provide an important panorama with conclusive information on the aspects that need to be improved in the referred municipalities. The fact that this tool does not provide an indicator capable of assessing the existing biodiversity here and, consequently, subsidies for more effective protection policies, as well as the lack of official information for some variables, such as water resources, restrict the analysis of another important element that must be monitored in depth in the Amazon. In short, the analyses lack elements that consider the characteristics of the populations that make up the territory, quilombolas, indigenous and traditional people, which are so representative in the region.

Finally, we emphasize that the present study will be continued based on the updating of information between years, in order to monitor the progress of these municipalities towards sustainability, as well as the elaboration of panoramas for other areas of the Amazon region.

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