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## **SPACE-TEMPORAL ANALYSIS OF SUSTAINABILITY IN MUNICIPALITIES IN THE COASTAL REGION OF RIO GRANDE DO SUL, BRAZIL**

## **ANÁLISE ESPAÇO-TEMPORAL DA SUSTENTABILIDADE NOS MUNICÍPIOS DA REGIÃO COSTEIRA DO RIO GRANDE DO SUL, BRASIL**

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### **Abstract**

The modification of the landscape due to the growing trend of horizontal residential condominiums in the northern part of the coastal region of the state of Rio Grande do Sul is a current concern, because this region is home to rare ecosystems, such as wetlands and large brackish lagoons, characterizing possible environmental vulnerability. This form of occupation also has consequences in relation to social equality, since it integrates areas built for low population density. The Sustainability Barometer serves to measure the degree of sustainability, allowing to consider environmental, economic and social aspects and is considered an important instrument for the analysis of sustainability. The objective of this study was to analyze the spatio-temporal dynamics of the degree of sustainability of the municipalities that integrate the coastal region, for the year 2000 and 2016, using the Sustainability Barometer. The Sustainability Barometer was applied to assess the degree of sustainability of municipalities in the coastal region of Rio Grande do Sul, and the spatial distribution and analysis of the degree of municipal sustainability was carried out through the Moran Index. The study made it possible to understand the negative evolution of the degree of sustainability, between the year 2000 and 2016, the positive and significant spatial correlation of sustainability in both periods and the main weaknesses and potentialities related to the degree of sustainability of each municipality and region.

**Keywords:** Sustainability Barometer. Moran index. Horizontal condominiums. Forms of occupation of the coast of Rio Grande do Sul.

### **Resumo**

A modificação da paisagem pela tendência crescente de condomínios residenciais horizontais, na parte norte da região costeira do estado do Rio Grande do Sul, é uma preocupação atual, devido essa

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região abrigar ecossistemas raros, como áreas úmidas e grandes lagoas salobras, caracterizando possível vulnerabilidade ambiental. Essa forma de ocupação traz também consequências em relação à igualdade social, uma vez que integra áreas construídas para baixa densidade populacional. O Barômetro da Sustentabilidade serve para mensurar o grau de sustentabilidade, permitindo considerar aspectos ambientais, econômicos e sociais e é considerado um importante instrumento para a análise da sustentabilidade. O objetivo desse estudo foi analisar a dinâmica espaço-temporal do grau de sustentabilidade dos municípios que integram a região costeira, para os anos de 2000 e 2016, utilizando o Barômetro da Sustentabilidade. Foi aplicado o Barômetro da Sustentabilidade para avaliar o grau de sustentabilidade dos municípios da região costeira do Rio Grande do Sul, realizada a distribuição e análise espacial do grau de sustentabilidade municipal, através do Índice de Moran. O estudo possibilitou compreender a evolução negativa do grau de sustentabilidade, entre os anos 2000 e 2016, a correlação espacial positiva e significativa da sustentabilidade nos dois períodos e as principais fragilidades e potencialidades relacionadas ao grau de sustentabilidade de cada município e da região.

**Palavras-chave:** Barômetro da Sustentabilidade. Índice de Moran. Condomínios horizontais. Formas de ocupação do litoral do Rio Grande do Sul.

## Introduction

Sustainability is part of a complex system of structures, grouped into three main pillars, which are environmental, economic and social. This idea is part of the sustainability expanded concept, derived from the Triple Bottom Line model. The environmental pillar aims to promote production processes with the least impact on the ecosystem as possible, in order to ensure environmental security for future generations. The economic pillar aims to provide viable, attractive and profitable enterprises, and the social pillar aims the reflection and establishment of fair actions for the social actors involved (ELKINGTON, 1997). Although, it is usual to discuss development unilaterally, mainly focusing exclusively on the economic perspective. However, the expanded concept of sustainability states that this practice can unbalance sustainable development and compromise resources' viability.

The coastal region of Rio Grande do Sul integrates seventeen municipalities and contemplates greater economic development in the northern part, due to the expansion of civil construction and urban processes, justified by demographic expansion, particularly by second-home tourism. This kind of tourism, in the northern part of the coastal region, is characterized by horizontal condominiums, which contribute to local economic development, but can lead to imbalances in the ecosystem and also in relation to social inequality, since it integrates areas built for low population density (IBGE, 2020; LOPES et al., 2018; SOUZA, SILVEIRA, 2015).

The region is very accessible, close to the state capital, Porto Alegre, as well as Caxias do Sul, considered the second most populous city in the state (IBGE, 2020; LOPES et al., 2018; SOUZA, SILVEIRA, 2015). In the last decade, among the regions of Rio Grande do Sul, the coastal region showed the highest population growth (IBGE, 2020; SOUZA, SILVEIRA, 2015). The municipalities Capão da Canoa and Xangri-Lá stand out, where the floating population was greater than the permanent population in 2015 (ZUANAZZI, BARTELS, 2016), a typical characteristic of second-home tourism (LOPES et al., 2018, SOUZA, SILVEIRA, 2015).

The urbanization of the coast is a phenomenon that extends beyond state limits, coinciding with a national tendency to value the coast for political and economic reasons. Urban expansion along the coast of Rio Grande do Sul began in the 1980s (SOUZA; SILVEIRA, 2015), becoming increasingly intense, mainly due to the facility of acquiring properties. The coastal zone of Rio Grande do Sul houses rare ecosystems, such as wetlands and large brackish lakes, which are considered ecosystems of high environmental vulnerability (CALLIARI et al., 2010; GONÇALVES et al., 2018).

Understanding the historical process territories' occupation is important to understand the current scenario, the future trend, beliefs and practices related to sustainable development of the community that occupies these territories. The appropriation of the northern part of the coastal region of Rio Grande do Sul can be classified into four periods, dated before the year 1888 until the

year 2013, which reflect distinct forms of territory occupation. The first period, comprised prior to 1888, are characterized by ranches and farms, with the economy mainly based on agriculture, livestock and fishing. The second period of occupation, comprised between 1888 and 1939, shows an occupation trend focused on therapeutic purposes, since the medicine of that time associated medicinal baths with the cure of diseases. This trend implied the development of infrastructure, resulting in the construction of small hotels and inns in the region (LOPES et al., 2018).

From this period, mainly in the beginning of 1940, there was a progressive improvement in beaches' infrastructure related to accommodation and transport (LOPES et al., 2018; SOUZA, SILVEIRA, 2015). Another fact of the historical process of this period was the introduction of paid vacations for the working class, which became able to travel to the coast for rest during vacations (LOPES et al., 2018). These events mark the beginning of the third period of occupation, comprised between 1940 and 1995, which manifests the beginning of the subdivisions of large territorial areas, strongly initiating second-home tourism in the northern part of the state, mainly due to geographic accessibility in relation to the capital, which provided "dozens of subdivisions along the seafront, with constant improvements in infrastructure and a profound change in the region's landscape" (LOPES et al., 2018, p. 435).

The fourth period of occupation in the northern part of the state's coastal region is comprised between 1995 and 2016, which is still current, is characterized by the presence of horizontal condominiums, evidencing that "the higher classes bring with them these forms of urban occupation, which are becoming recurrent in the region" (LOPES et al., 2018, p. 437). The modification of the landscape by horizontal condominiums in the northern coastal region of the State was intensified from 1995, especially in the municipality of Xangri-lá, after the construction of the road Estrada do Mar (RS-389) in 1991, enabling the connection between the main beaches (LOPES et al., 2018; SOUZA, SILVEIRA, 2015).

Given this scenario, concerns about the damage that permeate the three pillars of sustainability emerges (ELKINGTON, 1997), since the discussion on the construction of horizontal residential condominiums can be unilaterally favored by the economic dimension, enabling an imbalance to sustainable development and compromising the viability of natural resources.

### **Sustainable development and sustainability indicator systems**

The term 'development' can be defined as: advance, growth, progress, that is, it is the "action or effect of developing" (FERREIRA, 2001), while sustainability, as indicated above, concerns to the balance between economic prosperity, environmental quality and social justice (ELKINGTON, 1997). In this sense, sustainable development is a complex challenge.

According to Camino and Muller (1993), in the period that competes for the final two decades of the 20th century, around a hundred concepts related to sustainable development were proposed. According to Scott (2002) this number went to over 300 definitions, bringing the criticism that the term is abstract enough to become vague. However, the most widely used and accepted approach is part of the 1987 Brundtland Report, presented by the United Nations World Commission on Environment and Development (CMMAD, 1991), bringing to light a definition in which "sustainable development is the one that meet the needs of the present generation without compromising the ability of future generations to meet their own needs" (CMMAD, 1991, p. 46).

Sustainability can be measured through a quantitative or qualitative assessment of the system's quality level; sustainable development, on the other hand, are the strategic actions that are planned to increase the quality level in the system, measured through sustainability (FEIL; SCHREIBER, 2017). In this sense, the terms have different definitions, but they complement each other in practice, in which sustainable development can only be planned if the sustainability level is measured. This logic occurs in all systems, for example, corporate sustainability, industrial sustainability, regional or municipal sustainability.

So, in order to understand the sustainable development model's effectiveness, sustainability indicator systems emerge, in which information is converted into data, and so into an indicator - which can be represented by a coefficient, a proportion, or other quantitative form of data presentation, in order to enable calculations and comparison, in relation to the evolution in the implementation of sustainable development strategies (MOTA et al, 2017).

Despite the indicators set, in the environmental, social, economic and territorial scope, representing the essence of measuring a region's sustainability, there is no consensus on the definition of which indicators set is the most appropriate. The Sustainability Barometer is considered

an opportune instrument, which uses a mixture of environmental, economic and social indicators, from a given territory, to measure the sustainability degree. This research method has already been applied in the analysis of the country's sustainability (QUEVEDO, 2016, KRONEMBERGER; CLEVELARIO JUNIOR, 2015, KRONEMBERGER et al., 2008), in the state of Rio Grande do Sul (PENSO-CAMPOS et al., 2021) and several Brazilian municipalities (SILVA et al., 2016; MACHADO et al., 2014; LUCENA et al., 2011; CARDOSO et al., 2014).

Given the environmental concern and policies for the real estate expansion, which permeate the current scenario of the coastal region of Rio Grande do Sul, with an increasing trend for the construction of horizontal residential condominium, and the concern regarding sustainability, we analyzed the spatiotemporal dynamics of the sustainability degree in municipalities from the coastal region, in two temporal periods, using the Sustainability Barometer.

## Methodology

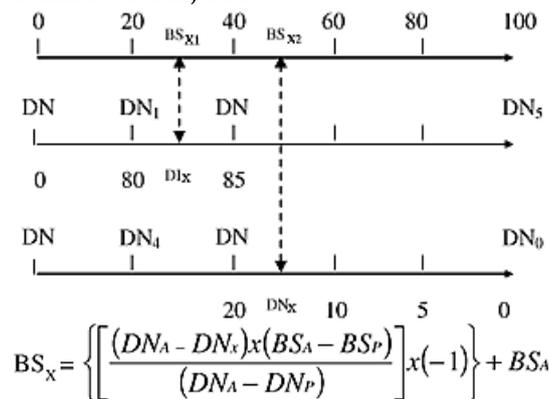
To measure the sustainability degree of the municipalities that compound the coastal region of the State, the Sustainability Barometer instrument was applied, which calculates the Environmental Well-Being Index, the Human Well-Being Index and measures the sustainability degree of a given geographical area. The instrument was applied according to The World Conservation Union (IUCN) protocol, entitled Resource Kit for Sustainability Assessment (GUIJT, 2001), adapted for the study.

The indicators that compound the Environmental Well-Being Index are categorized into: activities that generate environmental impact and land use and coverage. For activities that generate environmental impact, the following indicators were used: index of industry's polluting potential, coefficient of vehicles in circulation (per 1,000 inhabitants), sanitary disposal in a general sewage network or septic tank and waste collection by cleaning service or by garbage container. For land use and land cover, the indicators were: forest area, non-forest natural formation area, agricultural area, non-vegetated area and water body area, all in hectares.

The indicators that compound the Human Well-Being Index were divided into two categories: socioeconomic and human health indicators. The socioeconomic indicators are: average household income per capita, GDP, Gini Coefficient, Illiteracy rate, Idese and HDI. Among the human health indicators, they include: coverage of primary health care services, coefficient of deaths from circulatory disease, coefficient of deaths from respiratory disease, coefficient of deaths from cancer and coefficient of deaths from diabetes mellitus.

The transposition of the indicators' numerical value to the Sustainability Barometer Scale was carried out through simple linear interpolation, according to Equation 1, which allows to relate the Indicator Performance (DN<sub>x</sub>) with the Sustainability Barometer scale (BS<sub>x</sub>). Thus, the Performance Scale (EDC) can show an increasing or decreasing trend, that is, direct or indirect logic. In this case, an example of direct logic can be expressed in the statement: the higher the percentage of adequate sanitary destination, the better for the environment, while an example of inverse logic is: the higher the index of the industry's polluting potential, the worse becomes it is to the environment.

**Equation 1:** Representation of the formula to calculate the degree of the Sustainability Barometer for the coastal region of Rio Grande do Sul, 2020



Source: Adapted from Kronemberger et al. (2008)

In the formula, “DNx” represents the performance of the indicator for the municipalities, “a” is the lower limit and “p” the upper limit of the interval that contains X. The results were presented in tables and in thematic maps. A spatial analysis of the municipal sustainability degree was performed through the Global Moran Index, which is a measure of spatial autocorrelation, whose null hypothesis is spatial independence, the result between 0 and 1 indicates direct correlation, and between 0 and -1 indicates inverse correlation. The first order spatial proximity matrix was used, contiguity as a matrix construction strategy and the pseudo-significance test, through 999 permutations, to consider the statistical validity of the Moran Index (BRASIL, 2007).

Land use and land cover indicators were collected from Mapbiomas (2020), vehicle coefficient, industry's polluting potential index and Idese on the FEE website (2020), coverage of sanitary services and mortality on the DATASUS website (2020) and the other variables on the IBGE website (2020), all indicators were gathered in an Excel database, in which the lines represent the municipalities and the columns include each variable.

### Socioeconomic and environmental characteristics of the study area

The population of the coastal region was 458,713 inhabitants in 2000 and 560,897 in 2016, with an increase of 22.3% (IBGE, 2020). The average of the municipal Idese of the coastal region was 0.704 in 2014 (FEE, 2020), an approximate index of the HDI calculated in 2010, with 0.710 points (ATLAS BRASIL, 2020), both representing a medium to high development pattern. The average illiteracy rate was 6.21%, the average household income per capita was R\$722.14, the Gini index was 0.50 and the region's total GDP was R\$325,545.24 (IBGE, 2020).

Basic health care, which represents coverage and access to public services at the primary level of health, has an average coverage of 76.9%. The region's average mortality rate due to cardiovascular diseases was 0.94%, 0.91% for cancer, 0.24% for diabetes mellitus and 0.17% for chronic respiratory diseases (BRASIL, 2020). The average of adequate sanitary destination in the region was 64.4%, garbage collection 94.8% (IBGE, 2020), the polluting potential of the industry 0.2% and the total number of vehicles in circulation is 317,440 (about 0.56 per inhabitant) (FEE, 2020)

Land use and coverage, in the coastal region, has a total forest area of 121,619.79 (ha), non-forest natural formation of 515,211.15 (ha), agriculture and livestock of 507,766.65 (ha), non-vegetated area of 121,195.83 (ha) and 192,840.79 (ha) of water bodies (MAPBIOMAS, 2020). The coastal region of Rio Grande do Sul has a long sandy strip of 622 km, integrating beaches and lagoons, such as Patos Lagoon and Mirim Lagoon in addition to the sandy dunes (IBGE, 2020).

Another characteristic of the region is the almost continuous strip of recreational beaches, occasionally interspersed by rivers, but in very linear pattern. Even so, the road network is very connected, playing an important role in the economy and transport for several cities in the state. Among the main highways, four of them stand out for tourism and the economy, which are: the RS-486, known as Rota do Sol, which connects the mountain chains (Serra Gaúcha) to the coastal region; the BR-289, known as Freeway, which facilitates the connection between the municipality of Osório to the Metropolitan Region of Porto Alegre; the RS-389, known as Estrada do Mar, which connects cities such as Osório, Capão da Canoa, Arroio do Sal, Torres and Xangri-lá; the BR-101, which crosses

different municipalities in the north of the coastal region, and provides one of the routes between Rio Grande do Sul state and other states in the country.

## Results and Discussion

The coastal region of Rio Grande do Sul is composed by 17 municipalities. The municipalities that compound the northern part of the region, from north to south, are: Torres, Arroio do Sal, Terra de Areia, Capão da Canoa, Xangri-lá, Osório, Imbé, Tramandaí, Cidreira and Balneário Pinhal. The municipalities that compound the southern part are: Palmares do Sul, Mostardas, Tavares, São José do Norte, Rio Grande, Santa Vitória do Palmar and Chuí.

The sustainability degree was calculated for all municipalities in the coastal region, and the analysis took into account the comparison between the sustainability degree of the northern and southern parts of the coastal region, in two time periods: 2000 and 2016. It was proposed in order to compare the sustainability degree of the northern part with that of the southern part, due to differences in municipal characteristics (Table 1) and in the occupation of these territories.

**Table 1:** Mean and standard deviation (SD) of indicators for the coastal region of Rio Grande do Sul, categorized according to the geographic location of the municipality (north or south), 2020.

	North		South	
	Mean	SD	Mean	SD
Illiteracy rate (IBGE, 2020)	4.40	1.45	8.80	5.13
Gini Coefficient (IBGE, 2020)	0.50	0.05	0.51	0.05
Vehicle fleet in circulation (FEE, 2020)	14774.40	10405.88	24242.28	38801.29
Industry Pollutant Potential Index (FEE, 2020)	0.01	0.02	0.54	1.30
Human development Index (ATLAS BRASIL, 2020)	0.733	0.024	0.677	0.042
Average household income per capita (IBGE, 2020)	788.56	114.72	627.25	109.93
Percentage of garbage collected (BRASIL, 2020)	99.11	0.64	88.83	8.60
Gross domestic product (IBGE, 2020)	17.844.33	3687.64	21.014.56	8817.08
Percentage of coverage of primary health care services (BRASIL, 2020)	75.25	13.24	79.36	20.13
Percentage of adequate sanitary destination (BRASIL, 2020)	53.75	20.65	79.77	10.43

Source: data from IBGE (2020), FEE (2020) and Atlas Brasil (2020).

The population of the municipalities in the coastal region of Rio Grande do Sul showed an increase between 2000 and 2016, with greater concentration in the northern part, especially in the municipalities of Xangri-lá (76.0%), Arroio do Sal (69.2%), Balneário Pinhal (67.6%), Imbé (65.8%), Cidreira (63.4%) and Capão da Canoa (56.7%) (Table 2). There was a decrease in the sustainability degree of the coastal region between 2000 and 2016, with a decrease from 62.7 to 57.2 degrees in the northern part, and from 57.0 to 55.0 degrees in the southern part, which includes the worst sustainability indices in both periods.

**Table 2:** Municipalities in the coastal region of Rio Grande do Sul state, by population in 2000 and 2016, and population variation.

Region	Municipality	Population		Absolute variation	% variation
		2000	2016		
North	Arroio do Sal	5273	8921	3648	69.2
	Balneário Pinhal	7452	12493	5041	67.6
	Capão da Canoa	30498	47792	17294	56.7
	Cidreira	8882	14511	5629	63.4
	Imbé	12242	20294	8052	65.8
	Osório	36131	44190	8059	22.3
	Terra de Areia	11453	10711	-742	-6.5
	Torres	30880	37342	6462	20.9
	Tramandaí	31040	46962	15922	51.3
	Xangri-lá	8197	14430	6233	76.0
South	Chuí	5167	6413	1246	24.1
	Mostardas	11658	12758	1100	9.4
	Palmares do Sul	10854	11431	577	5.3
	Rio Grande	186544	208641	22097	11.8
	Santa Vitória do Palmar	33304	31352	-1952	-5.9
	São José do Norte	23796	27095	3299	13.9
	Tavares	5342	5561	219	4.1

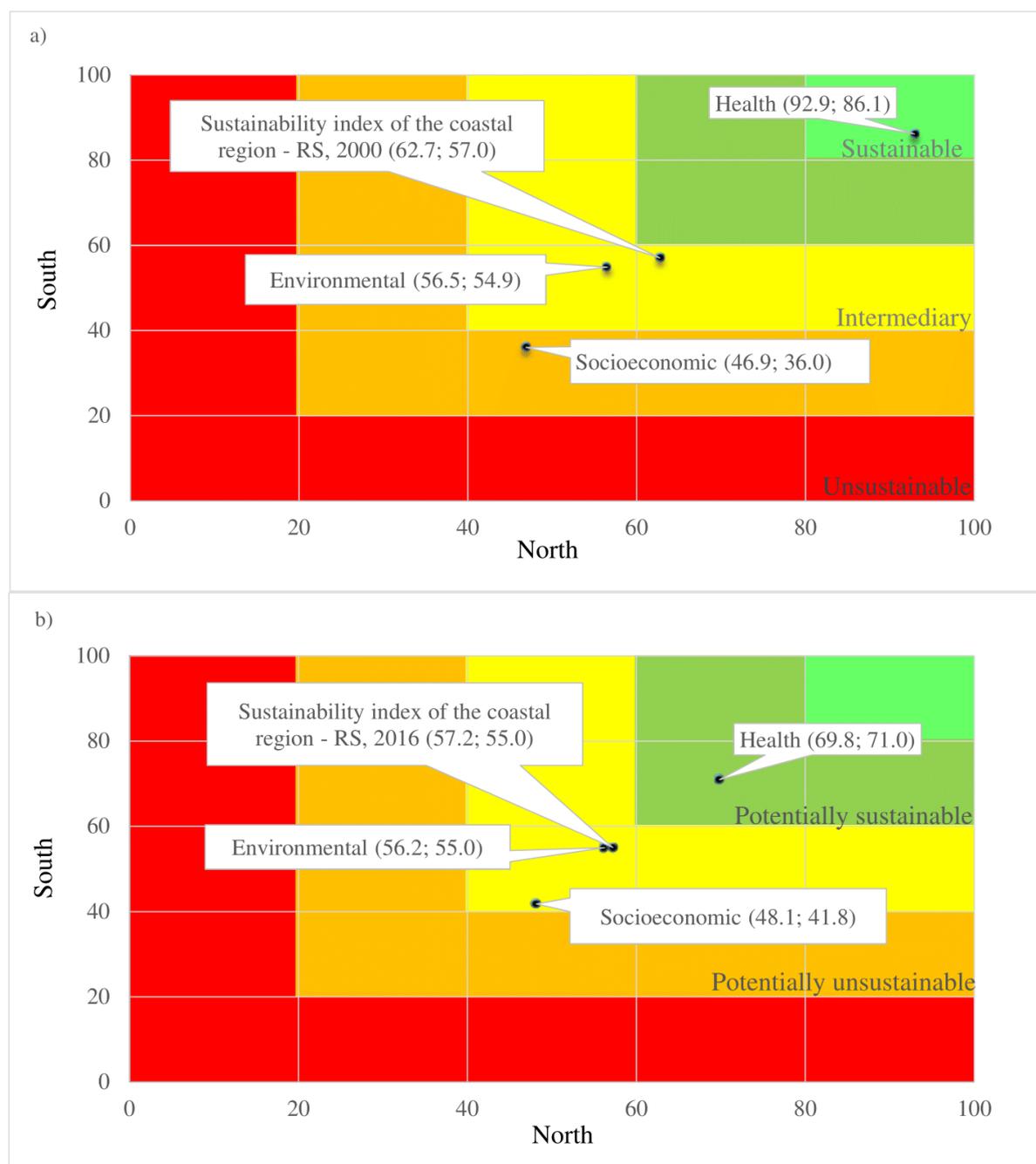
Source: data from IBGE (2020).

In general, the sustainability degree of the coastal region showed a negative evolution, from 59.8 degrees to 56.1 degrees, classified as an intermediate degree of sustainability (Figure 1). A study in the western mesoregion of the state of Pará, which includes 50 municipalities, also showed a negative trend for the sustainability degree between 2000 and 2010 (HACHMANN; RIPPEL, 2015). This assessment is important to avoid a decreasing trend, based on the diagnosis of the main local problems related to sustainable development, aiming the implementation of related public policies.

Studies have diagnosed the degree of “potentially sustainable” sustainability in some regions of the country (CARDOSO et al., 2016, BATALHÃO et al., 2015, OLIVEIRA et al., 2015, BATALHÃO; TEIXEIRA, 2013). However, the coastal region is categorized with an intermediate sustainability degree, the same category indicated for Brazil (QUEVEDO, 2016, KRONEMBERGER; CLEVELARIO JUNIOR, 2015, KRONEMBERGER et al., 2008).

This result was also pointed out, using the Sustainability Barometer, in a study on the sustainability degree of the municipality of Rondonópolis, Mato Grosso (SILVA et al., 2016), in the municipalities of Barretos and Jaboticabal, in the state of São Paulo, in 2000 and 2010 (MACHADO et al., 2014), in the municipality of João Pessoa, Paraíba (LUCENA et al., 2011), in the municipality of Mojú, Pará (CARDOSO et al., 2014) and for the Jurumirim hydrographic basin, which integrates the municipality of Angra dos Reis, Rio de Janeiro (KRONEMBERGER et al., 2004).

Figure 1: Sustainability index for the coastal region of Rio Grande do Sul, 2000 (a) and 2016 (b).



Legend: degree of sustainability resulting from the application of the Sustainability Barometer.

The municipalities in the northern part that showed the best performance were Cidreira, in 2000, and Balneário Pinhal, in 2016. The municipalities with the worst sustainability indicators were Terra de Areia, in 2000, and Xangri-lá, in 2016. In the southern part, Chuí was the municipality with the best performance and Tavares with the worst performance, in both periods (Table 03).

The data show that the municipalities that need the implementation and/or emerging implementation of sustainable development policies, due to the decreasing trend in the sustainability degree between the periods, are Imbé (-15.4%), in the northern part, and Rio Grande (-7.5%) in the southern part. The municipalities with the best index of increase in the sustainability degree, between the two periods, were Arroio do Sal (1.4%) in the northern part and São José do Norte (6.0%) in the southern part (Table 3).

**Table 3:** Sustainability index in the coastal region of Rio Grande do Sul, 2000 and 2016.

Region	Municipality	Degree of sustainability 2000		Degree of sustainability 2016		% variation
		Municipality	Region	Municipality	Region	
North	Arroio do Sal	59.8		60.6		1.4
	Balneário Pinhal	64.5		57.5		-10.9
	Capão da Canoa	62.9		58.4		-7.1
	Cidreira	63.6		55.8		-12.1
	Imbé	67.2	62.7	56.8	57.2	-15.4
	Osório	66.9		60.8		-9.2
	Terra de Areia	55.5		52.8		-4.7
	Torres	63.4		60.1		-5.1
	Tramandaí	60.5		53.2		-12.1
	Xangri-lá	63.1		56.0		-11.2
South	Chuí	63.6		59.2		-6.9
	Mostardas	56.4		53.0		-6.0
	Palmares do Sul	57.9		54.1		-6.6
	Rio Grande	63.2	57.0	58.4	55.0	-7.5
	Santa Vitória do Palmar	55.8		53.5		-4.2
	São José do Norte	51.4		54.5		6.0
	Tavares	51.0		52.5		3.0

Legend: sustainability degree resulting from the application of the Sustainability Barometer.

The analysis of the sustainability degree by analyzed theme shows that the degree of environmental sustainability was greater in the northern part of the coastal region, in both periods. In the northern part, the municipality with the best environmental sustainability indicator was Cidreira, in 2000, and Balneário Pinhal, in 2016. The worst environmental sustainability indicators were evidenced in the municipalities of Terra de Areia, in 2000, and in Xangri-lá, in 2016. The municipality of Arroio do Sal (7.1%) had the accentuated increase in the degree of environmental sustainability between the two periods, while Xangri-lá (-7.0%) had the most negative variation between the municipalities (Table 4).

**Table 4:** Sustainability index, of the environmental theme, in the coastal region of Rio Grande do Sul, 2000 and 2016.

Region	Municipality	Theme					
		Environmental		Socioeconomic		Health	
		2000	2016	2000	2016	2000	2016
North	Arroio do Sal	53.4	57.2	50.2	50.1	82.9	79.4
	Balneário Pinhal	60.9	62.1	41.5	41.8	98.6	68
	Capão da Canoa	57.9	55.3	45.8	50.6	92.3	73.2
	Cidreira	61.2	58.4	45.5	44.8	89.4	64.5
	Imbé	59.1	58	54	49.6	97.4	63.4
	Osório	58.8	57.8	53.8	53.6	97.4	74.7
	Terra de Areia	49.8	51.9	33.6	41.6	91.8	68
	Torres	53.9	56	52.1	51.9	94	77.3
	Tramandaí	56.9	56.1	42.1	44.7	89.1	58
	Xangri-lá	53.2	49.5	50.3	52.6	96.2	71.9
South	Chuí	57.1	54.2	51.6	49	89.7	80.6
	Mostardas	47.6	50.1	34	40.1	99.1	73.7
	Palmares do Sul	58.3	59.2	40.6	45.6	78	55
	Rio Grande	60.3	59.6	48.1	51.4	86.3	64.5
	Santa Vitória do Palmar	51	49.3	36.8	42.4	87.2	74.2
	São José do Norte	54.4	58.9	16.7	29.3	87.7	76.9
	Tavares	55.4	53.5	24.3	34.9	75	71.8
North Region	56.5	56.2	46.9	48.1	92.9	69.8	
South Region	54.9	55	36	41.8	86.1	70.9	

Legend: sustainability degree resulting from the application of the Sustainability Barometer.

The analysis of socioeconomic sustainability indicates that the northern part of the coastal region has a higher degree of socioeconomic sustainability, compared to the southern part, in both periods. In the northern part, the municipality with the highest degree of socioeconomic sustainability was Imbé, in 2000, although it had the highest percentage of decrease in the socioeconomic sustainability degree (-8.1%), among the municipalities, in both two periods of analysis. Osório was the municipality with the highest socioeconomic sustainability degree in 2016 and Terra de Areia had the worst performance levels in both periods. However, Terra de Areia presented the most positive variation, in the sustainability degree, among the municipalities in the northern part, given the resulting difference in 2000 and 2016 (Table 4).

The socioeconomic sustainability, among the municipalities in the southern part, was higher in Chuí, in 2000, however it was the municipality that showed the highest decrease (-5.1%) in the socioeconomic sustainability degree between the first and second period. Rio Grande had the best indicator in 2016 and São José do Norte had the worst degrees of socioeconomic sustainability in both periods, but with a positive trend (75.8%) between 2000 and 2016 (Table 4).

Sustainability, considering the human health theme, suggests negative trend in the sustainability degree between 2000 and 2016. The northern part showed the highest degree in 2000 and the southern part in 2016. In the northern part, the best sustainability indicator of human health was found for the municipality of Balneário Pinhal in 2000 and for Arroio do Sal in 2016. The lowest performance level was expressed in the municipality of Arroio do Sal in 2000 and Tramandaí in 2016. All municipalities showed a negative trend for human health sustainability, with less impact in Arroio do Sal (-4.2%) and greater in Imbé (-34.9%) (Table 4).

In the southern part of the coastal region, sustainability in human health was higher in the municipality of Mostardas in 2000 and Chuí in 2016. The worst indicators were found for the municipality of Tavares in 2000 and for Palmares de Sul in 2016. All municipalities showed a negative trend for human health sustainability, with lower tenacity in Tavares (-4.2%) and higher in Palmares do Sul (-29.5%) (Table 4).

Considering the evolution of the sustainability degree in the period between 2000 and 2016, among the three analyzed themes, in relation to the municipalities in the northern region, 40% increased the degree of sustainability in the environmental theme, 50% in the socioeconomic theme and none (0%) in the health theme. Regarding the municipalities in the southern region, 57% increased the degree of sustainability in the environmental theme, 85.7% in the socioeconomic theme and none (0%) in the health theme (Table 5).

The negative trend, between the first and second period, for the degree of human health sustainability, shows that related public policies need to be urgently implemented, to prevent the continuation of a decreasing trend. However, the human health theme is the one with the highest sustainability degree (Figure 1).

Briefly, among the municipalities in the northern part of the coastal region, Arroio do Sal had the highest positive change (increase of 1.4%) in the overall sustainability, the greatest positive change (increase of 7.1%) in the degree of environmental sustainability degree. It was the municipality in the northern part that showed the lowest degree of health sustainability in 2000 and the highest in 2016, and the greatest positive variation (smallest decrease, of -4.2%) in the degree health sustainability, among the municipalities in the northern part of the coastal region.

**Table 5:** Evolution of the sustainability degree in municipalities from the coastal region of Rio Grande do Sul, between 2000 and 2016.

Region	Municipality	Theme		
		Environmental	Socioeconomic	Health
North	Arroio do Sal	>	<	<
	Balneário Pinhal	>	>	<
	Capão da Canoa	<	>	<
	Cidreira	<	<	<
	Imbé	<	<	<
	Osório	<	<	<
	Terra de Areia	>	>	<
	Torres	>	<	<
	Tramandaí	<	>	<
	Xangri-lá	<	>	<
South	Chuí	<	<	<
	Mostardas	>	>	<
	Palmares do Sul	>	>	<
	Rio Grande	<	>	<
	Santa Vitória do Palmar	<	>	<
	São José do Norte	>	>	<
	Tavares	<	>	<

Legend: green color = increase in the sustainability degree; red color = decrease in the sustainability degree.

Balneário Pinhal was the municipality with the highest health sustainability degree in 2000 and the highest environmental sustainability degree in 2016, Cidreira was the municipality with the highest environmental sustainability in 2000 and Osório was the municipality with the highest degree of overall sustainability and on the socioeconomic theme in 2016.

Imbé was the municipality with the highest sustainability degree in 2000, the highest negative variation (-15.4%) in the sustainability degree between the two periods, the highest degree of socioeconomic sustainability in 2000, the highest negative variation (-8.1% – the greatest decrease (-34.9%) in the health sustainability degree. Tramandaí was the municipality with the lowest health sustainability degree in 2016.

Xangri-lá was the municipality with the largest population growth (76.0%) in the entire coastal region between the two analyzed periods, which in 2015 showed a floating population higher than the permanent population (ZUANAZZI; BARTELS, 2016), a typical characteristic of second-home tourism (LOPES et al., 2018; SOUZA; SILVEIRA, 2015). It was also highlighted by the lowest environmental sustainability degree in 2016, and the highest negative variation (-7.0%) in environmental sustainability degree between the two periods, possibly related to landscape changes caused by the construction horizontal condominiums, which in the coastal region of the State was mainly driven by the municipality of Xangri-lá from 1995 and after the conclusion of the road Estrada do Mar, in 1991 (LOPES et al., 2018; SOUZA; SILVEIRA, 2015).

Terra de Areia was the municipality with the lowest sustainability degree in 2000 and 2016, the lowest environmental sustainability degree in 2000, and the lowest socioeconomic sustainability degree in 2000 and 2016, but with a positive variation (increase of 23.7%) in the in this parameter between the two periods. The main agriculture activity in this municipality is the pineapple cultivation, and there is a local movement that aims to recognize the uniqueness the pineapple from Terra de Areia, in order to strengthen the city's economy and tourism, strengthened by the National Pineapple Festival, which takes place every two years ago, and started more than two decades ago (AMBROSINI et al., 2017).

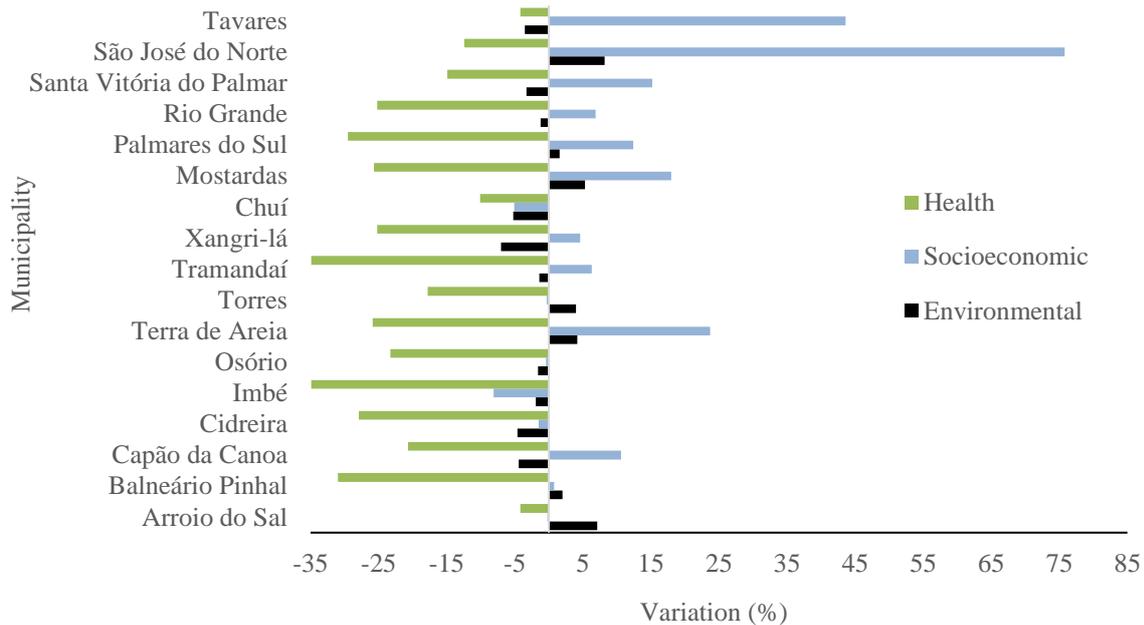
Among the municipalities in the southern part of the coastal region, São José do Norte was the municipality with the highest positive variation (increase of 6.0%) in the sustainability degree, the highest positive variation (increase of 8.2%) in the degree of sustainability in environmental theme, lower degree of socioeconomic sustainability in 2000 and 2016, but with the highest positive variation (increase of 75.8%) in this parameter among the municipalities, considering data from the first and second years analyzed.

Chuí was the municipality with the highest sustainability degree in 2000 and 2016, the highest negative variation (-5.2%) in the environmental sustainability degree, the highest socioeconomic sustainability degree in 2000, but with the highest negative variation (-5.1%) in the socioeconomic degree between the periods analyzed, and the highest health sustainability degree in 2016.

Mostardas was the municipality with the lowest environmental sustainability degree in 2000 and the highest health sustainability degree in 2000. Palmares do Sul was the city with the lowest health sustainability degree in 2016, but with the highest negative variation (decrease in -29.5%) in health sustainability degree between the analyzed periods. Rio Grande was the municipality with the highest negative variation (-7.5%) in the sustainability degree, the highest environmental sustainability degree in 2000 and 2016, and socioeconomic sustainability degree in 2016.

Tavares was the municipality with the lowest sustainability degree in 2000 and 2016, the lowest health sustainability degree in in 2000 and the highest positive variation (decrease of -4.2%) in the health sustainability degree. All municipalities in the two parts of the coastal region showed a decrease in the health sustainability degree between the first and second analyzed periods. Santa Vitória do Palmar was the municipality with the lowest environmental sustainability degree in 2016. The percentage variation in the sustainability degree between the two periods analyzed, for each municipality and theme, is illustrated in Figure 2.

**Figure 2:** Variation (%) in the municipal sustainability degree, between 2000 and 2016, for the themes: environmental, socioeconomic and health, in the coastal region of Rio Grande do Sul.

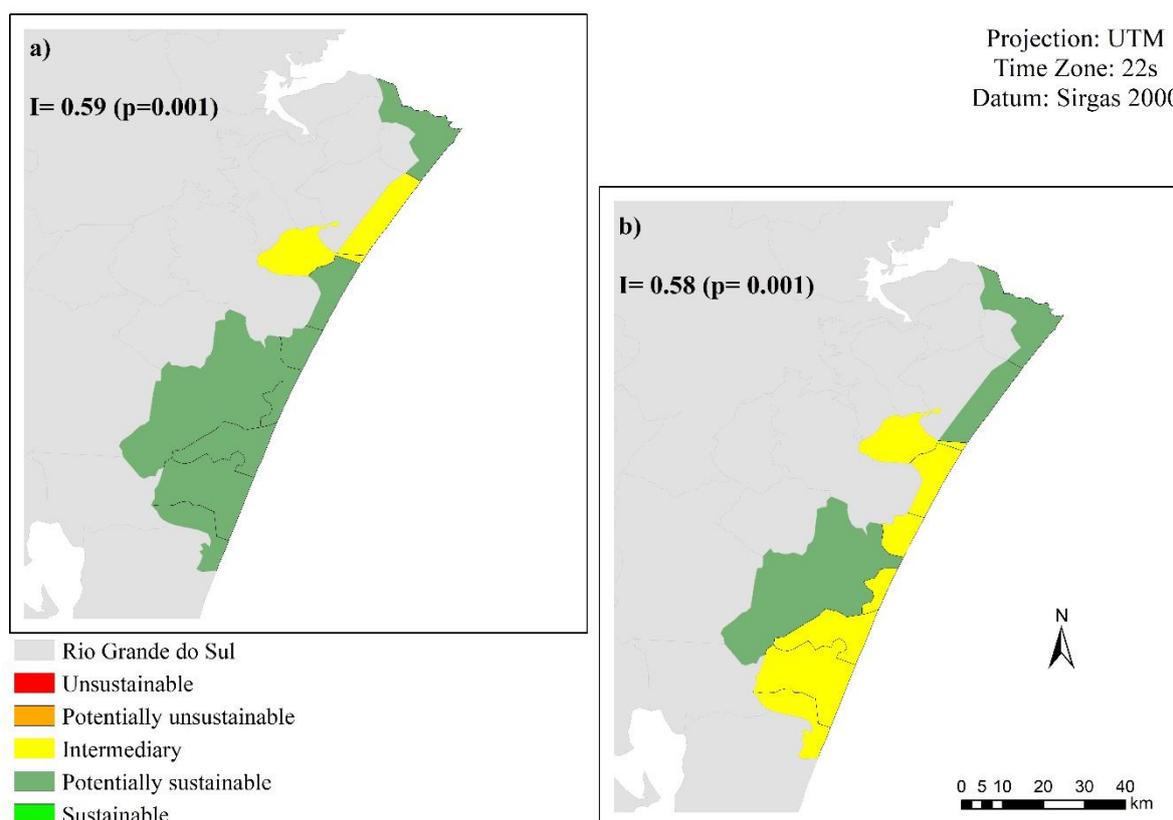


The northern part, in the first period of analysis, showed eight (80%) municipalities classified as potentially sustainable and two (20%) with an intermediate degree of sustainability. In the second period, the negative evolution pointed to three (30%) municipalities classified as potentially sustainable and seven (70%) with an intermediate degree of sustainability. The spatial analysis showed a positive and significant correlation in the two periods ( $p=0.001$ ), the analysis and spatial distribution are shown in Figure 3.

In the first period of analysis, the southern part showed five (71.4%) municipalities classified as intermediate in the sustainability degree and two (28.6%) as potentially sustainable municipalities. In the second period, seven (100%) municipalities were categorized intermediate in the sustainability degree, and the spatial analysis showed a strong and significant positive correlation ( $p=0.001$ ) (Figure 4).

The sustainability degree measured by the Sustainability Barometer allows us to understand which themes are most strongly associated with the sustainable development of the analyzed area, as well as the main weaknesses that require the implementation and/or implementation of emerging public policies (QUEVEDO, 2016; SILVA et al. 2016; CARDOSO et al., 2016; KRONEMBERGER; CLEVELARIO JUNIOR, 2015; BATALHÃO et al. 2015). In both periods, the theme with the highest degree was health, followed by the environmental theme and, finally, the socioeconomic theme.

**Figure 3:** Distribution and spatial analysis of the sustainability degree of municipalities in the northern coastal region (RS), 2000 (a) and 2016 (b).

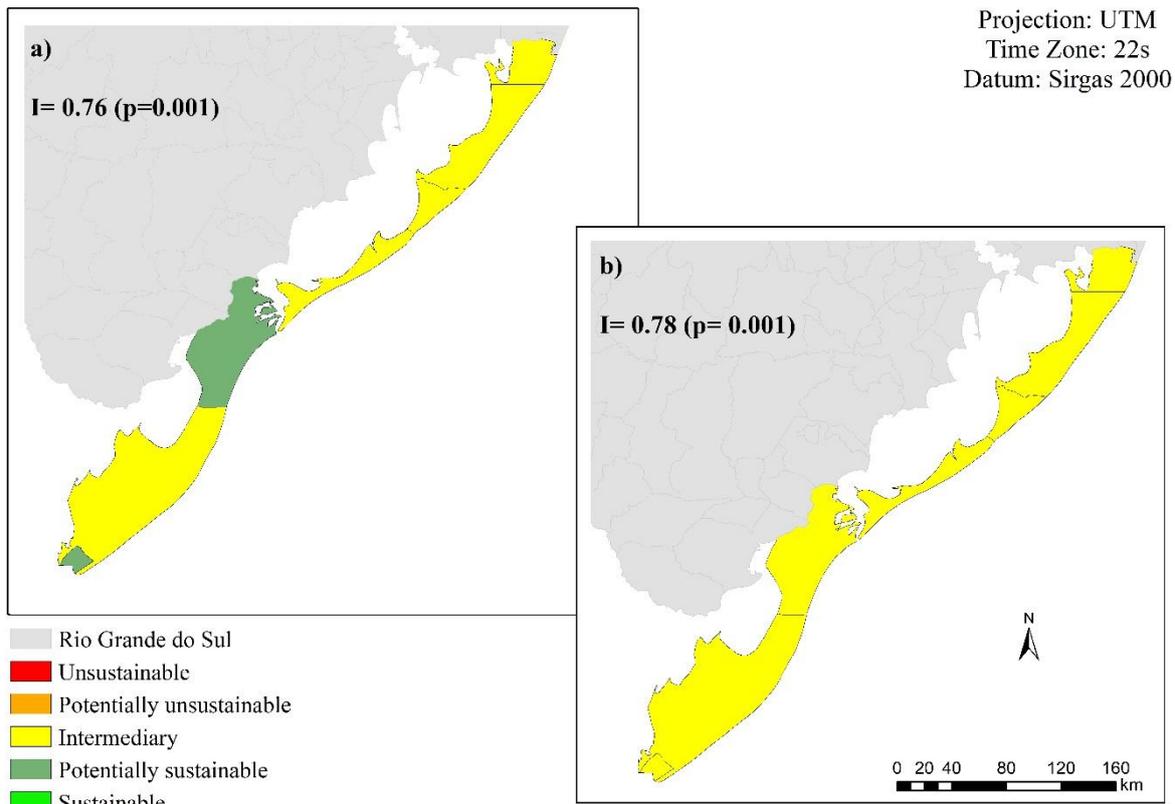


Legend: sustainability degree resulting from the application of the Sustainability Barometer.  $I$  = Moran's Index.

The north coast shows higher economic development, based mainly on real estate speculation, linked to projects affecting areas that should be under state and municipal protection (RIO GRANDE DO SUL, 2000). The two municipalities that lead this kind of economic activity are Xangri-lá and Capão da Canoa. These areas, which were used to construct horizontal condominiums for the upper-middle class, are wetlands composed by large brackish lakes and dunes, ecosystems of great environmental vulnerability (CALLIARI, et al., 2010; RODRIGUES, et al. 2003).

These areas act as environmental buffering systems, regulating the microclimate and serving as a refuge for biodiversity. This biodiversity, mainly aquatic macroinvertebrates, are responsible for a range of ecosystem services' maintenance (CUFFNEY, et al., 2010), many of them responsible for maintaining irrigated rice plantations, the main agricultural crop and income source for the municipalities in the coastal region.

**Figure 4:** Distribution and spatial analysis of the sustainability degree of municipalities in the southern coastal region (RS), 2000 (a) and 2016 (b).



Legend: sustainability degree resulting from the application of the Sustainability Barometer. I = Moran's Index.

The results observed in the analyzed sustainability themes demonstrate that the economic development in the coast northern region, in addition to being unsustainable, does not imply social improvements for the resident population. The use of the Sustainability Barometer was useful to understand the aspects with best and worst performances related to sustainability. It is expected that our results can contribute to the implementation of municipal and regional public policies, in order to reverse the declining trend in the sustainability degree.

## Conclusion

Sustainability is in the balance among the three main pillars, which are the environmental, economic and social, while sustainable development sheds light on the importance of meeting current needs, with awareness of the rational use of renewable and non-renewable resources, so that future generations can have access to the same resources.

In order to understand the effectiveness of sustainability management strategies, sustainability indicator systems emerge, which use information converted into measurable indicators, in order to evaluate and compare the implementation of sustainability actions. For this, the Sustainability Barometer is considered an opportune instrument, which uses an aggregate of environmental, economic and social indicators of a given territory and allows measuring the sustainability degree of a given territory.

In the study, the Sustainability Barometer was applied in the municipalities from the coastal region of Rio Grande do Sul, considering the environmental concern and the policies for the expansion of real estate in the region, with an increasing trend for the construction of horizontal residential condominiums. The results allow us to understand the population evolution, as well as the decrease in the sustainability degree of the coastal region of the State, between the periods 2000 and 2016, and the spatial correlation between the municipalities' sustainability degrees. In addition, it shed light on the municipalities with the best and worst sustainability performance indicators.

The analysis considered the comparison between the municipalities in the northern and southern part of the coastal region, in two periods of time. Among the municipalities in the northern

part, those with the best sustainability performance were Cidreira, in 2000, and Balneário Pinhal, in 2016. The municipalities with the worst sustainability indicators were Terra de Areia, in 2000, and Xangri-lá, in 2016. In the southern part, Chuí had the best performance and Tavares the worst performance, in both periods.

The sustainability degree measured by the Sustainability Barometer allowed us to understand the most positive aspects and those that need improvements regarding sustainable development. It is expected that the results can contribute to the implementation of municipal and regional public policies, in order to modify the current trend of declining sustainability.

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