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REVISTA BRASILEIRA DE GESTÃO E DESENVOLVIMENTO REGIONAL
V.19, N°3, Set-Dez/2023 | Taubaté/SP - Brasil | ISSN 1809-239x

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Received: 09/15/2023
Accepted: 11/06/2023

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ABSTRACT

The combination of social, economic and spatial segregation with extreme weather events increases the consequences of territorialized social asymmetries. The North Coast of São Paulo state (LNSP) is a region susceptible to the association between inequalities present in the territory and the effects of natural catastrophes. The problem investigated is the relationship between the process of occupying space and the increase in risks for the population in São Sebastião. The objective was to analyze the factors that contributed to the environmental disaster that occurred in São Sebastião, LNSP. The research method consisted of the use of secondary economic, social, demographic and climatic data. The results show that the disaster that occurred in São Sebastião resulted from the combination of climatic conditions with the consequences of human actions enhanced by the social and spatial segregation present in the municipality. It is concluded that there is a need for public policies based on social, economic and territorial inclusion, with the non-occupation of land in risk areas. Such public policies imply a logic of urban management with priority for development, with social inclusion and economic and social sustainability.

Keywords: Regional development; spatial segregation; anthropogenic actions; social inequality; socionatural catastrophes.

INTRODUCTION

Demographic expansion, during the process of occupying space, configures the territory and combined with economic activities, outlines the trajectory of regional and local development. Contemporaneously, the North Coast of São Paulo state (LNSP) presents characteristics related to the historical process of occupation of space related to territorial and social exclusion. This process dates back to the mid-20th century, when the intensification of tourism following the modernization of access routes to the region favored the expansion of the urban network, particularly with the construction of summer residences, combined with the attraction of immigrants to work in the region, civil construction and the services sector (Gigliotti; Santos, 2013).

The characterization of this process is fundamental to understanding the social and economic conflicts and contradictions territorialized in each of the municipalities that make up the LNSP (Viera; Santos, 2012 A.). In this way, there is a need to relate the conditions present in the region to the developments of the conservative modernization process of the country and how its effects were distributed in the Metropolitan Region of Paraíba Valley and the North Coast of São Paulo state (RMVPLN) (Vieira; Santos, 2012 A).

The conditions present in the region are associated with the national insertion in the international division of labor, with effects distributed across the territory, based on the logic of spatial reproduction of capital (Rodrigues; Santos, 2012). For Macedo and Porto (2020), from the second half of the 20th century onwards, cities and regions began to be conceived and organized in connection with capital. This logic is present on the LNSP, one of the regions that has shown the highest population growth in the state of São Paulo in the last 5 decades. Demographic expansion in the region is associated with economic transformations such as the expansion of tourist, port and oil activities.

The effects of the accelerated process of space occupation and urbanization of the LNSP imply the need to broadly measure the implications produced for the population living in the region. The premise of this paper is that research focuses on economic or social aspects do not imply disregarding the scope of the effects of social reproduction on all dimensions present in the region, including the environmental one. As an area of interdisciplinary, multidisciplinary and transdisciplinary knowledge, regional development corresponds to the elaboration of analyzes capable of integrating different fields of research. When

outlining the LNSP as an area for research, the authors adopt the perspective previously indicated as conceptual and methodological support, to enable the most effective way of investigating the effects of the region's modernization process.

However, considering the limits of scientific communication carried out per paper corresponds to cutting out a fraction of the regional dynamics included in a previous trajectory of investigation. This choice also adheres to the most recent social repercussions of this process and inscribed in the environmental and spatial limits of the region. Thus, the floods and landslides caused by heavy rains on the LNSP, in February 2023, which caused economic and social damage, when 65 people lost their lives, defined the question investigated and the objective of the paper (Costa 2023; Lacerda, 2023). The problem investigated is the relationship between the process of occupying space and the increase in risks for the population of São Sebastião. The objective of this paper is to analyze the factors that contributed to the environmental disaster that occurred on the North Coast, in São Sebastião.

So that, this objective can be achieved, the paper presents an analysis of territorial dynamics and regional development with the region's main locus being the 4 municipalities on the LNSP: Caraguatatuba, Ilhabela, São Sebastião and Ubatuba. Data on the economic population growth of the urban area of the municipalities are presented, with a specific analysis in São Sebastião. The paper is organized into 5 sections. In addition to the introduction, the literature review that supports the paper, the research method carried out, the analysis of the results and the final considerations are presented.

REGIONAL DEVELOPMENT AND TERRITORIAL DYNAMICS

Dallabrida and Becker (2008) conceptualize the definitions of area, region and territory, concepts that will be used in this paper. Area refers to the totality of places, or an inseparable set of systems of objects and systems of actions. Region locus of certain functions of the total society at a given time. It is a specification of a totality, area. Territory corresponds to the territorialized, appropriate area, appropriate extension of space or the political name for the area of a country or region.

And this territory needs to be thought of as a dynamic area, highlighting here some basic concepts of this dynamization process. Territorialization is the process of appropriation of area, whether by the public or private sector. However, every form of occupation or appropriation of space causes different

forms of deterritorialization, considering the effects of disputes over control of resources present in the territory (Santos; Pontes, 2016). In relation to re-territorialization, it is possible to state that it is the process of settling those deterritorialized, giving them, once again, the sense of appropriating something they lost or never had. The territorial dynamics of development operates in different ways in how local actors organize themselves to act in the territorial planning process, in the geographer's language, or, in the economist's, to act in the local development process. And local or regional development is a determined process of territorialization that includes the dimension of re-territorialization, capable of stimulating potential and contributing to overcoming local challenges (Dallabrida; Becker, 2008).

The concepts adopted make it possible to combine perception and evaluation originating in geography with a historical and economic approach. This operation is strategic, considering the multidimensional age of development (Sachs, 2008). The complexity of the territory encourages us to overcome disciplinary assessment in favor of the perspective of regional science, a term corresponding to the consolidation of the trajectory of investigations into regional development, as outlined by Santos (2023). The contradictions of capital materialize in the territory, with diverse effects associated with the dynamics of the reproduction of capital in area (Harvey, 2006). Care with the approach and associated concepts derives from the need to connect the territorialization of capital dynamics concerning the deterritorialization and re-territorialization of the populations affected in this process.

Historically, Brazilian conservative modernization combined the production of a context marked by accelerated urbanization and economic growth with the centuries-old inequality of national society, renewed under specific conditions, although different from those detected in the colonial or imperial period. Such observation is necessary to avoid anachronism, after all, the analysis of the persistence of social and economic asymmetries must consider the peculiarities of each historical situation and the corresponding impact in relation to regional and local development (Santos; Carniello, 2011).

The modernization of the LNSP corresponds to its integration into the dynamics of capital, with the connection between the São Paulo territories and surrounding states through the reception of investments associated with tourism, services and the oil and gas production chain, as well as the receipt of royalties, resources used by the public authorities of each municipality. The last decades of the 20th century and the first decades of the 21st century are characterized by changes in the conditions of social reproduction in

the region, with the connection of exogenous processes to endogenous conditions on the LNSP (Santos; Vieira; Santos, 2018).

> From the 1960s onwards, the LNSP also began to be influenced by the interests of the tourist sector and real estate speculation (socio-economic vector, national and regional origin), undergoing new expansions of access and paving of roads and the ones already existing – such as the opening of the road section that connects São Sebastião and Bertioga, in 1962, and its subsequent integration with the Rio-Santos highway (technological vector, national and regional origin) (Daudt; Guimarães; Silva, 2023, p. 10).

Understanding this dynamic is fundamental to situate how and why the region was changed by an accelerated process of modernization, with the production of social asymmetries associated with the dispute for control of area and territory delineated with such dynamics. The incorporation of the LNSP into the capital reproduction circuit has its origins in the reproduction of contemporary social life and its association with the dynamics of capital expansion, especially with the value produced from the appropriation of the area (Harvey, 2006). The process of reproduction and expansion of capital invested on the LNSP has as one of its supports the appreciation of area, through urban expansion. The occupation of area by condominiums, hotel chains and vacation homes is connected to mass tourism and its effects on the territory over the last few decades (Rodrigues; Santos, 2019). This process produces restrictive economic conditions for lower-income segments of the population, made up of construction workers and other activities related to tourism, leisure and activities necessary for the continuity of urban expansion and the presence of tourists, especially in the summer season.

The reproduction of the dynamics present on the LNSP implies spatial segregation, as the areas closest to the beaches and best located are occupied by structures related to mass tourism, summer residences and fractions of the population with higher income. The reproduction and expansion of capital is based on this condition, structuring the way in which the territory is configured today. Social and spatial segregation weakens the living conditions of the population present in areas most at risk of flooding and landslides. This condition is not exclusive to the LNSP, which shows how the reproduction of capital replicates the process of social and territorial exclusion, related to the production of value resulting from the form of occupation and valuation of space. This process also implies the generation of fragmented social relations with a low density of social

capital, necessary to collectively confront the adversities inherent to the process of territorialization of regional development on the LNSP, as pointed out by Santos, Viera and Santos when analyzing the social capital of the population of Caraguatatuba (2018).

The elaboration and implementation of public policies to combat the consequences of territorialized social inequality necessarily corresponds to the investigation of the relationship between the process of occupying space and the increase in risks for the population, which we sought to accomplish with the analysis of São Sebastião, with the analysis of the factors that contributed to the environmental and social disaster in 2023.

METHODOLOGY

To achieve the objective of the paper, the methodology consisted of procedures necessary to characterize the population and space analyzed. In relation to population data, data from the IBGE Census from 1980 to 2022 were used. In relation to economic data, the research used IPEADATA, with the values presented deflated by the authors. It was also necessary to use remote sensing and geoprocessing data, necessary given the large territorial extension of São Sebastião and the complexity of its relief, marked by Cenozoic coastal plains and the Sea Mountain Range, with slopes that exceed 45º in its escarpment towards the Atlantic Ocean (Ross; Moroz, 1996), and the dynamics of urbanization.

To obtain the vectors for the area of São Saulo state and São Sebastião, IBGE territorial mesh data was used, referring to the year 2021, available at https://www.ibge.gov. br/geociencias/downloads-geociencias.html. The data from the digital elevation model (SRTM - Shuttle Radar Topography Mission), used to obtain the relief altitude and slope calculation, were obtained from Topodata project of INPE, available at http://www.dsr.inpe.br/topodata/ (Valeriano; Rosseti, 2012), with a 30 x 30 m pixel spatial resolution.

Data on the expansion of the urbanized network in São Sebastião were extracted from the MapBiomas project, available at https://mapbiomas.org/, which uses satellites from the Landsat series to monitor the land use and cover of Brazilian soil, with pixel 30 x 30 m spatial resolution and high temporal resolution (Neves *et al.*, 2020; Souza *et al.*, 2020; Rasan *et al.*, 2021). Data on territorial occupation are available between 1985 and 2021, and the option was made to use the series in

three-year periods, since its beginning in 1985. The classification category of urban infrastructures was selected to measure the expansion of the urbanized network of the municipality.

To categorize the expansion area of urban network of São Sebastião according to its slope, we chose to use the relief classification methodology proposed by Camarinha *et al.* (2014), when analyzing the risks and prediction of landslides on the LNSP, categorized its topography into five categories, being: i) plane (0 to 3º); ii) smooth undulation (3 to 8º); iii) undulation (8 to 20º); iv) heavy undulation (20 to 45º) and; v) mountainous (greater than 45º).

In relation to rainfall data, data from the National Institute of Meteorology (INMET), an agency of the Ministry of Agriculture and Livestock, was used, with an analysis of adding value to production in Brazil through meteorological information.

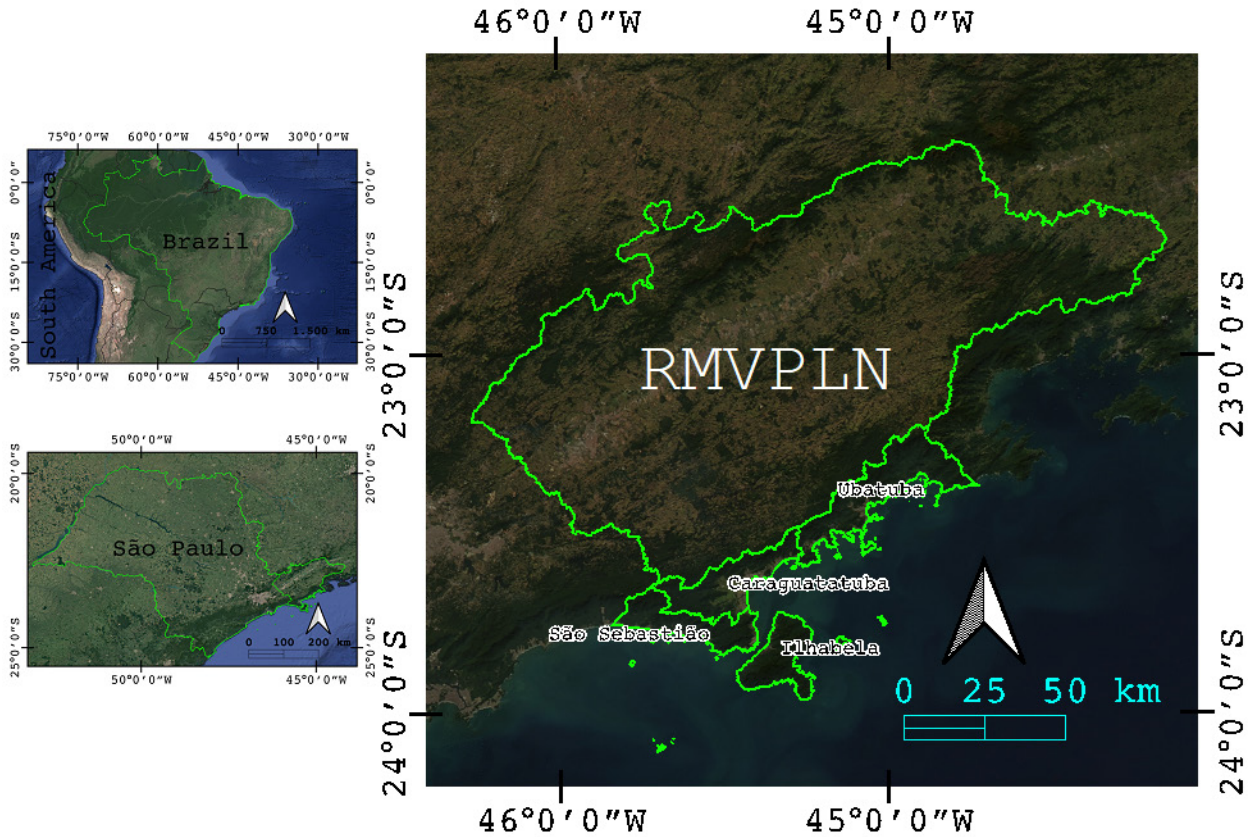
RESULTS AND DISCUSSIONS

Characterization of the study area: population and economic dynamics

The LNSP is made up of four municipalities: Caraguatatuba, Ilhabela, São Sebastião and Ubatuba are included. The RMVPLN was created by state supplementary law 1166, of January 9, 2012. RMVPLN is made up of 39 municipalities (IBGE, 2022).

The municipalities of RMVPLN participated in practically all the processes of Brazilian economic history, a starting point for the *Bandeirantes* of the 16th and 17th centuries, as a path to gold in mining in the 18th century, an important coffee producing region in the 19th century and with an active participation in Brazilian industrialization in the second half of the 20th century (Vieira, 2009). However, growth in the LNSP has always been conditioned by economic flows from other regions of the country, it was a marginal insertion in the gold and coffee cycles, especially due to economic activities developed in other regions such as the South of Minas Gerais and the Paraíba Valley (Souza, 2010). However, the reduction in economic activities in neighboring regions weakened these coastal municipalities, transforming the region into a subsistence economy involving family agricultural production and fishing.

Figure 1 | Map of the state of São Paulo, highlighting the municipalities on the LNSP



Source: IBGE, 2023.

The economic and population growth of the LNSP occurred mainly from the 1950s onwards with the expansion of tourist and port activities related to oil in the region. With the advancement of industrialization in cities such as São José dos Campos, Jacareí and Taubaté, there is an increase in the flow of migrants heading to coastal cities. The renovation and expansion of the port of São Sebastião, in addition to the installation of Almirante Barroso Oil Terminal (TEBAR) – Petrobras, expanded economic activities in the region as a route for the flow of industrial production and for the supply of fuel to nearby industrial regions (SILVA, 1975).

Tables 1 and 2 present the population growth of the municipalities on the North Coast and the comparison between the population growth of RMVPLN, São Paulo state and Brazil.

Table 1 | Population of selected locations, highlighting the municipalities on the LNSP

Municipality/Region	1980	1991	2000	2010	2022
Caraguatatuba	33,802	52,878	78,921	100,840	134,875
Ilha Bela	7,800	13,538	20,836	28,196	34,934
São Sebastião	18,997	33,890	58,038	73,942	81,540
Ubatuba	27,139	47,398	66,861	78,801	92,980
North Coast	87,738	147,704	224,656	281,779	309,395
RMVPLN	1,221,221	1,651,594	1,992,110	2,264,594	2,506,053
São Paulo	25,042,074	31,588,925	37,032,403	41,262,199	44,420,459
Brazil	119.011.052	146,825,475	169,799,170	190,747,731	203,062,512

Source: IBGE Censuses (1980, 1991, 2000, 2010 and 2022).

The population of the North Coast grew from 87,738 inhabitants in 1980, to 309,395 inhabitants in 2022, a growth of 292.45%. In the same period, the population growth of RMVPLN was 125.21%, while that of the state of São Paulo was 77.38% and the national average was equivalent to 70.62%, according to data from the IBGE demographic censuses in the periods consulted, as shown in Table 2.

Table 2 | Percentage of population growth in the selected periods and locations, with emphasis on the municipalities on the LNSP

Municipality/Region	1980/1991	1991/2000	2000/2010	2010/2022	1980/2000	2000/2022	1980/2022
Caraguatatuba	56.43	49.25	27.77	33.75	133.48	70.90	299.01
Ilha Bela	73.56	53.91	35.32	23.90	167.13	67.66	347.87
São Sebastião	78.40	71.25	27.40	10.28	205.51	40.49	329.23
Ubatuba	74.65	41.06	17.86	17.99	146.37	39.06	242.61
North Coast	68.35	52.10	25.43	22.20	156.05	53.27	252,64
RMVPLN	35.24	20.62	13.68	10.66	63.12	25.80	105.21
São Paulo	26.14	17.23	11.42	7.65	47.88	19.95	77.38
Brazil	23.37	15.65	12.34	6.46	42.68	19.59	70.62

Source: Calculated by the authors based on data from the IBGE Censuses (1980, 1991, 2000, 2010 and 2022).

The information shows that Population growth in the municipalities on the North Coast was higher than the average of RMVPLN, state and country. The expansion of the population of the LNSP was mainly driven by the intensification of economic activities in the region. Table 3 shows the evolution of GDP in the selected regions in the period from 1980 to 2020. The municipalities on the North Coast showed economic growth of 765.05% in the period between 1980 and 2020. In the same period, RMVPLN grew 112.15%, state 55.32% and the national growth average reached 87.57%.

Table 3 | Deflated GDP at 2010 prices, BRL 1,000.00

Municipality/Region	Values in BRL 1,000.00			Value in percentage		
	1980	2000	2020	1980/2000	2000/2020	1980/2020
Caraguatatuba	488.61	1,098.28	2,052.80	124.78	86.91	320.13
Ilha Bela	93.24	262.09	5,673.98	181.09	2,064.90	5,985.35
São Sebastião	309.65	4,524.37	1,803.29	1,361.12	-60.14	482.36
Ubatuba	356.45	965.24	1,265.26	170.79	31.08	254.96
North Coast	1,247.95	6,849.98	10,795.33	448.90	57.60	765.05
Paraíba Valley	30,505.86	66,446.97	64,719.36	117.82	-2.60	112.15
São Paulo	684,540.87	886,359.58	1,063,262.50	29.48	19.96	55.32
Brazil	1,855,421.84	2,643,750.06	3,480,233.33	42.49	31.64	87.57

Source: IPEADATA - Prices BRL 1,000.00 (2010).

The data in Table 3 indicate that the economic growth of the region's municipalities is more concentrated in Ilhabela and São Sebastião, resulting from the expansion of enterprises related to oil exploration and port activities. However, Caraguatatuba and Ubatuba also show economic growth well above the RMVPLN, state and national average. The sector with the greatest impact on these municipalities is tourism, as in the case of Ubatuba, which has no direct relationship with oil or port activities.

Tables 1, 2 and 3 showed that the municipalities on the North Coast showed high rates of population growth when compared to the average of other Brazilian locations, including the national average. This population growth over the last four decades is directly linked to the expansion of economic activities. Among the consequences produced by economic growth is the expansion of the urban area of municipalities and, consequently, the expansion of the challenges of regional urban planning.

As shown in the previous tables, the municipalities on the North Coast showed high rates of population growth, thus increasing the demand for housing in these municipalities. This population

growth was also accompanied by an expansion in the number of occupied households, as shown in Tables 4 and 5. In the period from 1980 to 2022, the number of occupied households grew 550.31% on the North Coast, well above the average for RMVPLN de 229.65%, state 179.70% and national 187.37%.

Table 4 | Total permanent households occupied in the selected periods and locations, with emphasis on the municipalities on the LNSP

Municipality/Region	1980	1991	2000	2010	2022
Brazil	25,210,639	34,734,715	44,776,740	57,320,555	72,446,745
São Paulo	5,800,817	8,039,661	10,358,598	12,825,453	16,224,602
RMVPLN	263,900	398,508	534,488	684,425	869,951
LNSP	19,116	36,291	62,312	89,677	124,314
Caraguatatuba	7,313	13,075	22,164	31,947	48,634
Ilha Bela	1,669	3,393	5,736	9,022	12,710
São Sebastião	4,356	8,363	16,262	23,605	28,961
Ubatuba	5,778	11,460	18,150	25,103	34,009

Source: IBGE Censuses (1980, 1991, 2000, 2010 and 2022).

Table 5 | Percentage of growth in the number of permanent households occupied in the selected periods and locations, with emphasis on the municipalities on the LNSP

Municipality/region	1980/1991	1991/2000	2000/2010	2010/2022	1980/2000	2000/2022	1980/2022
Brazil	37.78	28.91	28.01	26.39	77.61	61.80	187.37
São Paulo	38.60	28.84	23.81	26.50	78.57	56.63	179.70
RMVPLN	51.01	34.12	28.05	27.11	102.53	62.76	229.65
LNSP	89.85	71.70	43.92	38.62	225.97	99.50	550.31
Caraguatatuba	78.79	69.51	44.14	52.23	203.08	119.43	565.03
Ilha Bela	103.30	69.05	57.29	40.88	243.68	121.58	661.53
São Sebastião	91.99	94.45	45.15	22.69	273.32	78.09	564.85
Ubatuba	98.34	58.38	38.31	35.48	214.12	87.38	488.59

Source: Calculated by the authors based on IBGE Census data.

After comparison, similarities are found between the population growth data and those relating to the growth in the number of occupied households. It is observed that population growth was accompanied by an increase in the number of occupied homes. However, there is another important variable for determining the urban area in municipalities, the expansion of the number of households with occasional

occupation. Tables 6 and 7 show the evolution in the number of occupied homes for occasional use. In the period between 1980 and 2022, the number of households with this use grew by 510.23%, with emphasis in Ubatuba, where the number of households for occasional use is higher than for permanent use.

Table 6 | Total number of permanent homes for occasional use in the municipalities of the LNSP

Municipality/Region	1980	1991	2000	2010	2022
LNSP	15,607	43,896	65,651	78,696	95,239
Caraguatatuba	6,697	17,421	24,795	27,902	30,062
Ilha Bela	878	2,362	3,146	4,130	5,011
São Sebastião	2,568	8,972	13,713	16,628	20,674
Ubatuba	5,464	15,141	23,997	30,036	39,492

Source: IBGE Censuses (1980, 1991, 2000, 2010 and 2022).

Table 7 | Percentage of growth in permanent homes for occasional use in the municipalities of the LNSP.

Municipality/Region	1980/1991	1991/2000	2000/2010	2010/2022	1980/2000	2000/2022	1980/2022
LNSP	181.26	49.56	19.87	21.02	320.65	45.07	510.23
Caraguatatuba	160.13	42.33	12.53	7.74	270.24	21.24	348.89
Ilha Bela	169.02	33.19	31.28	21.33	258.31	59.28	470.73
São Sebastião	249.38	52.84	21.26	24.33	434.00	50.76	705.06
Ubatuba	177.10	58.49	25.17	31.48	339.18	64.57	622.77

Source: Calculated by the authors based on IBGE Census data.

The growth of occasional-use homes is the result of the expansion of second-home homes. The phenomenon corresponds to the growth of summer or beach residences, increasingly common for the wealthier classes, mainly residents of RMVPLN and the Metropolitan Region of São Paulo (MRSP). For analysis purposes, the second residence is called an occasional home, that is, those used for weekend rest, vacation or other purposes (Tulip, 2001). Often, these homes are located in gated communities in the plain areas closest to the beaches.

EXPANSION OF THE URBAN NETWORK IN THE MUNICIPALITY OF SÃO SEBASTIÃO

The expansion of the urban network in São Sebastião was very pronounced in the period analyzed, evolving from 4,092km^2 (1985) to 18,276km^2 (2021), representing an increase of 14,185km^2 (346.6%). In the same period, population growth was 254.2%, going from 24,884 to 88,156 inhabitants (SEADE, 2023). This process demonstrates that the expansion of the urban network was faster than population growth. Most likely, part of this urban expansion is related to tourist housing, real estate or property in São Sebastião. The growth of the urbanized network at a faster pace than demographic expansion reflects a process of urbanization with land occupation in São Sebastião associated with tourism activities. In this scenario, properties focused on summer activities (houses, inns and hotels) have a greater impact on the expansion process of the urbanized area than housing for the local population (Vasconcelos; Corodilano, 2008).

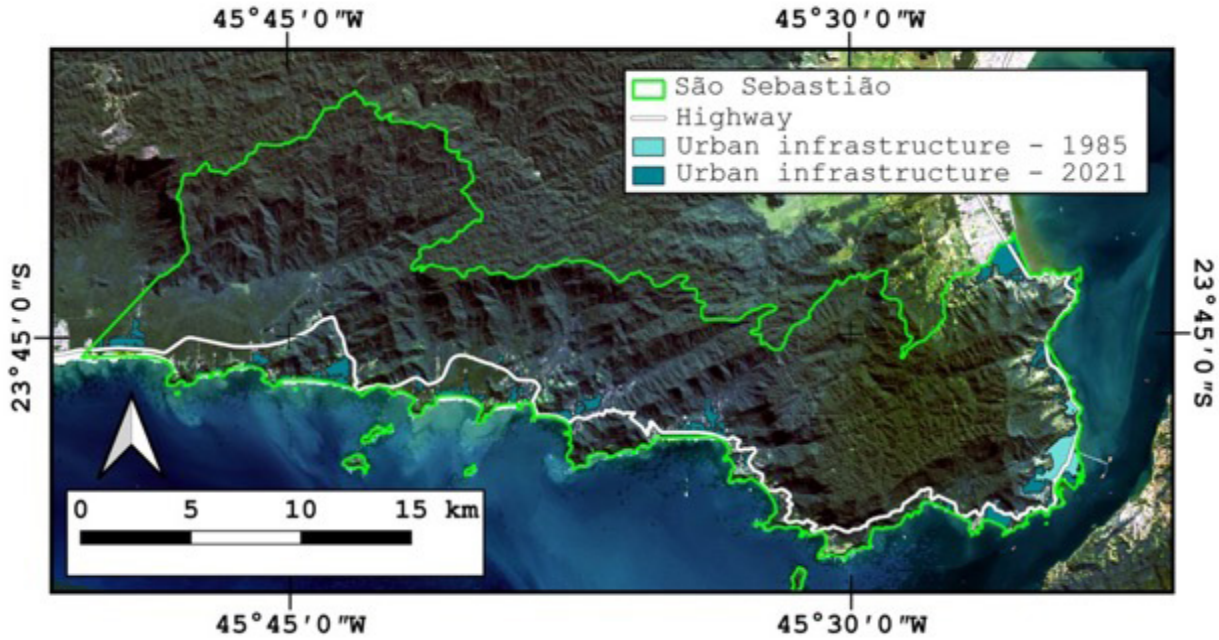
In the 1980s, the urbanization of São Sebastião was concentrated in its central region, in the locations of the São Sebastião Canal and on the banks of the Rio-Santos Highway (BR-101 - also called "Rodovia Mário Covas"), towards Caraguatatuba/SP. Between the central region and Bertioga/SP (to the South), urbanization was very limited, concentrating occasionally close to some beaches such as Baraqueçaba, Maresias, Boiçucanga, Juquery and Bocareia.

In the Southern region of São Sebastião, urbanization between the Rio-Santos Highway (BR-101) and the Sea Mountain Range escarpment, where the slopes are higher and pose greater risks to the process of triggering landslides, were limited (Mendes *et al.*, 2017), except in the central region of the municipality, where the coastal plain is more extensive, and the relief is predominantly plane. Until 1991, considering the entire urbanized area of São Sebastião, only 2.7% were in areas with heavy undulation terrain and a very small fraction (0.2%) in mountainous terrain.

From the mid-1990s and early 2000s, there was a strong increase in urban expansion in risky areas prone to the occurrence of natural disasters, with the region now having 5.1% of its area in heavy undulation terrain (+ 88.8%), and 0.7% in regions with mountainous terrain (+250%), areas that facilitate the process of triggering landslides (Vieira *et al.*, 2018). The greatest expansion of urbanization occurred in the southern portion of the municipality.

In the 2010s we can observe the (relative) stabilization of the growth of the urbanized area of São Sebastião in regions with plane and smooth undulation, while in regions with undulating and heavy undulation relief the expansion of the urbanized network continued. The continuity of urban expansion in these areas was accompanied by the suppression of native vegetation on the slopes and the installation of urban infrastructure, combining factors that increase the risk and vulnerability for the local population (Camarinha *et al.*, 2014).

Figure 2 | Urbanized infrastructure area in São Sebastião (1985 and 2021)

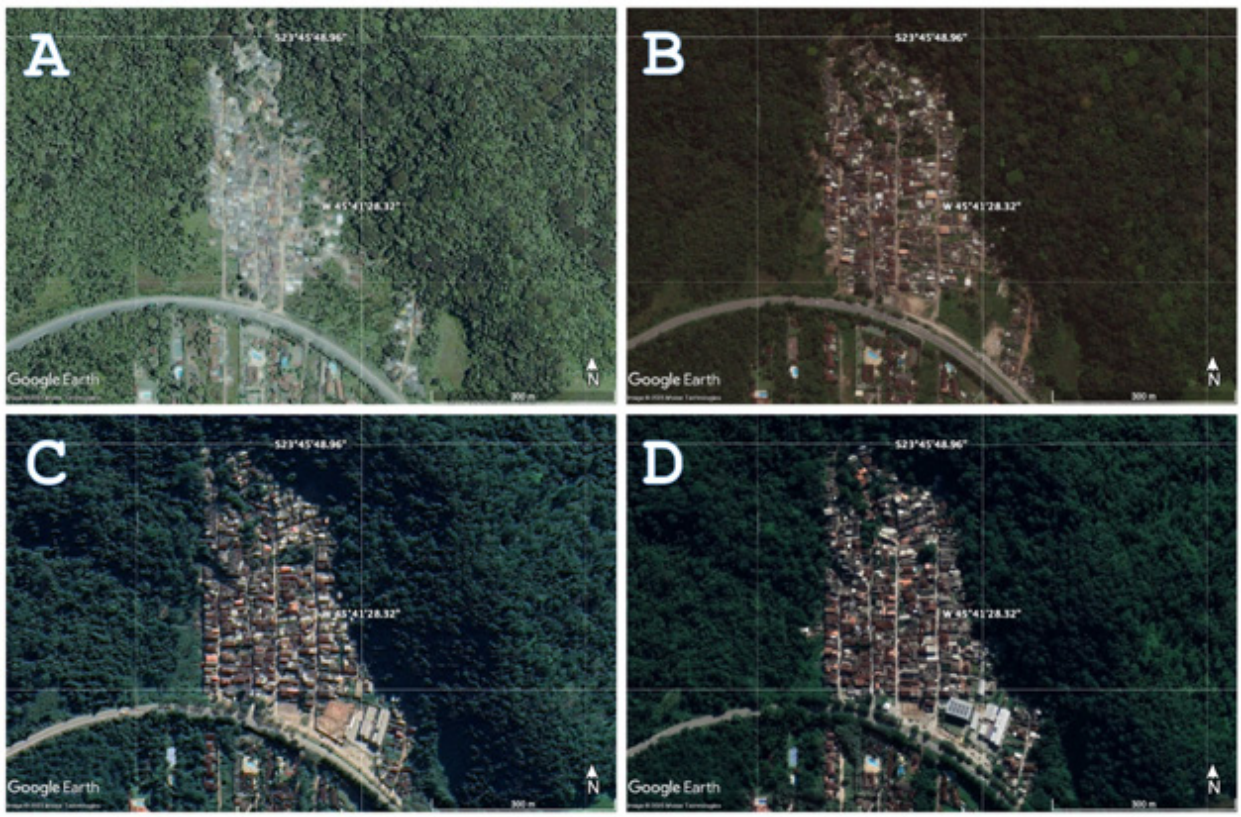


Source: MAPBIOMAS, 2023.

Vila Sahy, where on 02/19/2023 heavy rains triggered landslides that caused the death of 65 people, was one of the locations that underwent a strong urbanization process (Figure 2). This neighborhood had 5.51 ha of urbanized area in 2002, evolving to 11.76 ha in 2022 (+113.4%). In this neighborhood, the buildings are characterized by being densely concentrated and disorganized, typical characteristics of expansion in irregular or risky areas (Pasternak; D'Ottaviano, 2016). The greatest expansion of the neighborhood occurred from the mid-2000s, when new residences occupied regions with higher altitudes and slopes, factors that, associated with high intensity of precipitation triggered landslides in February 2023 (Batista; Julien, 2019; Costa, 2023). This demonstrates that inadequate management of land use and cover, associated with the environmental impacts created by it, led to the genesis of the necessary conditions for the outbreak of natural disasters (Cunha; Guerra, 2003).

Disorderly urban expansion in risk areas on the North Coast exposes the population to risks, as it associates the lack of urban planning, precarious construction and the economic and social vulnerability of these populations (Oliveira-Folharini *et al.*, 2018). In this scenario, anthropogenic factors such as cutting and embankment the terrain, inadequate construction practices and pipe leaks accelerate the landslide triggering process when associated with extreme precipitation events (Mendes *et al.*, 2018). The expansion of the urbanization area of São Sebastião can be seen in Figure 3.

Figure 3 | Evolution of occupation in the Vila Sahy neighborhood between 2002 and 2022. The letters represent the years: **(A)** 02/2002, **(B)** 10/2009, **(C)** 07/2016, **(D)** 02/2022



Source: GOGLE, 2023.

Table 8 presents data related to the progressive expansion of the urban network in areas with a greater risk of landslides, due to the impact on the soil, combined with the characteristics of the occupied land. The data corroborates the argument presented in the paper, regarding the association between the growth of the urban area in risk areas in São Sebastião, with the logic of capital reproduction and its contributions to changes in the region and in the municipality in question. This process resulted in

precarious living conditions for the socially and territorially segregated population, directly affected by the effects resulting from the occupation of areas susceptible to landslides.

Table 8 | Territorial expansion of São Sebastião (1985 and 2021)

Year	Area	Slope				
		0 to 3˚(%)	3 to 8˚(%)	8 to 20˚(%)	20 to 45˚(%)	<45(%)
1985	4,092 km	3,468 km (84.8%)	0.505 km (12.3%)	0.115 km (2.8%)	0.004 km (0.1%)	0,000 km² (0%)
1988	5,063 km	4,235 km (83.6%)	0.663 km (13.1%)	0.153 km (3.0%)	0.012 km (0.2%)	0,000 km (0%)
1991	5,546 km	4,631 km (83.5%)	0.753 km (13.6%)	0.150 km (2.7%)	0.011 km (0.2%)	0,000 km (0%)
1994	8,808 km	7,190 km (81.6%)	1,163 km (13.2%)	0.407 km (4.6%)	0.048 km (0.5%)	0,000 km (0%)
1997	11,423 km	9,146 km (80.1%)	1,604 km (14.0%)	0.593 km (5.2%)	0.080 km (0.7%)	0,000 km (0%)
2000	13,473 km	10,107 km (75.0%)	2,586 km (19.2%)	0.688 km (5.1%)	0.091 km (0.7%)	0,000 km (0%)
2003	15,068 km	11,975 km (79.5%)	2,143 km (14.2%)	0.842 km (5.6%)	0.107 km (0.7%)	0,000 km (0%)
2006	15,986 km	12,642 km (79.1%)	2,297 km (14.4%)	0.933 km (5.8%)	0.114 km (0.7%)	0,000 km (0%)
2009	16,321 km	12,840 km (78.7%)	2,353 km (14.4%)	1,008 km (6.2%)	0.120 km (0.7%)	0,000 km (0%)
2012	16,799 km	13,178 km (78.4%)	2,429 km (14.5%)	1,064 km (6.3%)	0.128 km (0.8%)	0,000 km (0%)
2015	17,211 km	13,413 km (77.9%)	2,518 km 14.6	1,140 km (6.6%)	0.140 km (0.8%)	0,000 km (0%)
2018	17,857 km	13,842 km (77.5%)	2,598 km (14.6%)	1,251 km (7.0%)	0.166 km (0.9%)	0,000 km (0%)
2021	18,276 km	14,142 km 77.4	2,663 km (14.6%)	1,296 km (7.1%)	0.174 km (1.0%)	0,000 km (0%)

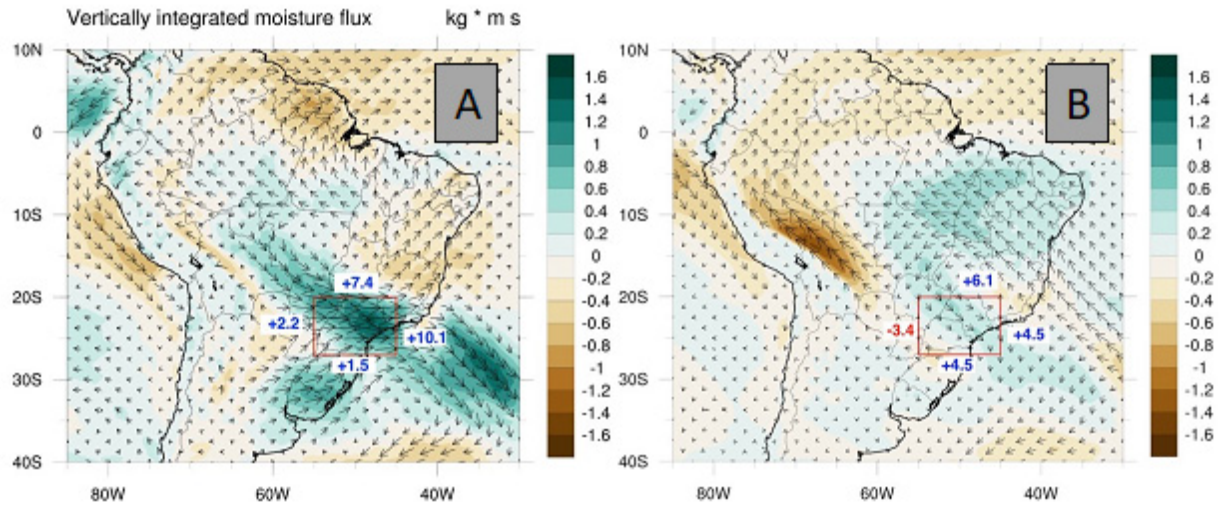
Source: MAPBIOMAS, 2023; TOPODATA-INPE, 2023.

The data presented in Table 8 highlight the fragility of the population residing in risk areas, particularly in relation to periods with heavy rainfall. It is observed that the event in São Sebastião in February (with intense rainfall) was predicted by INMET. However, the rain forecast was lower than what actually occurred. Over a period of 30 days before the event, the general circulation of the atmosphere, under this region of Brazil, was such that it favored the transport of moisture from the Amazon to the Southeast (SE) region of Brazil, including the LNSP (Figure 3). It is observed that moisture transport is very high, higher than climatological values, mainly on the Eastern (+4.5) and Northern (+6.1) edges. This may be the result of climate change, which may be modifying the positioning of this main transport axis (the so-called flying rivers), placing it a little lower than its normal position.

Associated with this moisture transport, anomalously higher than the climatological value, it was intensified by the passage of an extratropical cyclonic system (popularly called the Cold Front), which proved an intensification of wind circulation from the ocean to the interior of the continent. These systems (Cold Front and in its stationary configuration during the summer is called the South Atlantic Convergence Zone), helped in the formation of the intense rains that occurred. Before the invasion of colder air by the Cold Front, an anomalous (positive) warming of seawater temperature in the Tropical Ocean was also observed, which evaporated more and concentrated more moisture under the maritime air. Subsequently, with the entry of the Cold Front and the change in the general circulation of winds, which began to blow from the ocean to the interior of the continent, there was an intensification of rains of topographic origin, due to the positioning of Sea Mountain Range.

From a meteorological point of view, this extreme rainfall event is of the same type that occurred in Caraguatatuba in 1967, in the mountainous region of Rio de Janeiro state (2011), Angra dos Reis (2018) and in São Sebastião (2023). The coupling between the transport of moisture from the Amazon, the passage of Cold Fronts that have become stationary (forming the SACZ) and the presence of the Sea Mountain Range with topographic rains, is recurrent in the region, and may occur further to the South (for example in Caraguatatuba (1967) and São Sebastião (2023) or further North (Mountain region of Rio de Janeiro state (2011) or Angra dos Reis (2018)).

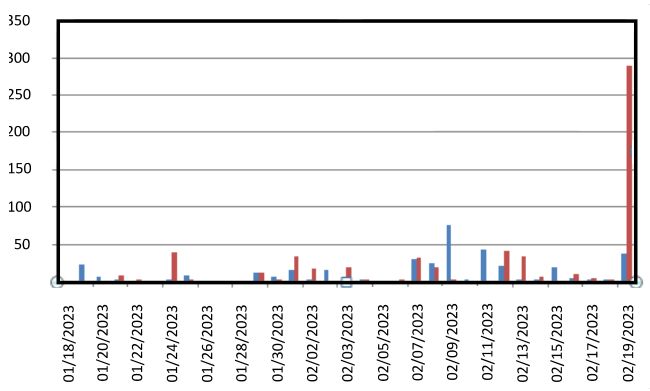
Figure 4 | Amazon Moisture Transport: 30 days (A) and anomaly (B)



Source: ERA5, 2023.

The rainfall that occurred in the region was extremely high, well above the climatological average of the region. In Figure 4, the time series of rain in Bertioga (on the coast) and in Taubaté (in the Paraíba Valley) is presented, showing that there were several days of rain over the 30 days analyzed. This data was obtained from the National Institute of Meteorology (2023). Unfortunately, the São Sebastião weather station was not working at the time. Considering the period of 30 days before the event that triggered the landslides, the accumulated rainfall was 357 mm (for a climatological value of 220 mm) and 571 mm for Bertioga (for a climatological value of 280 mm). Considering the last 5 days (from February 12th to 19th), the values observed were 86 and 385 mm, respectively.

Figure 5 | Time series of precipitation in Taubaté (blue) and Bertioga (red)



Source: INMET, 2023.

The extreme rainfall occurred due to the invasion of a Cold Front with a circulation of the low-pressure atmosphere, moving the advection of humid air from the Atlantic towards the interior of the continent, with the presence of Sea Mountain Range and the intensification of the production of topographic rain. It is worth highlighting the issue of rain over the last 30 days, which greatly moistened the soil and allowed landslides.

The scenario described highlights the association between anthropic actions, resulting from land occupation and the respective conformation of the territory under the logic of the spatial reproduction of capital. The specific conditions, present on the LNSP, demand care in the management of demographic expansion, with the evident restriction on the expansion of the urban network, so as not to occupy risk areas. However, the historical process of development of the region presents a logic contrary to this care, as the valorization of privileged urban areas implies the restriction of spaces suitable for housing for those with more economic resources, especially for summer residences or activities related to the tourism. The tragedy that killed dozens of residents of São Sebastião in 2023, results from the consolidation of a process of urban expansion that exposes the lower-income population to the risks inherent in establishing housing in risky areas. The consolidation of this process corresponds to the perversion of the ideal of development, with social inclusion and economic and social sustainability.

FINAL CONSIDERATIONS

This paper analyzes the economic and social conditions related to the catastrophe that killed dozens of residents of São Sebastião, in February 2023. For the research underlying this paper, the problem was defined as investigating the relationship between the process of occupying space and the increased risks for the population in São Sebastião. The objective of the work was to analyze the factors that contributed to the environmental disaster that occurred in São Sebastião. The research was based on a multidisciplinary and transdisciplinary approach, typical of investigations carried out in the field of knowledge of regional development, as it combines concepts and approaches from disciplinary areas for the production of knowledge. The study contains contributions from economics, history, sociology, geography and meteorology, whose association made it possible to

understand the effects of human actions on the environment, from the expansion of the urban network of São Sebastião to the possible effects of global warming related to human activities.

The approach adopted made it possible to identify the relationship between the rapid transformations driven by the integration of the LNSP into the logic of spatial reproduction of capital and its impact on regional development, including the configuration of the territory, outlined by social segregation, economic and spatial. The configuration of urbanization progressively exposed the population of São Sebastião, residing in risk areas, to the consequences arising from exceptional climatological conditions, such as those that occurred in February 2023 and described in the paper. The disaster that occurred in São Sebastião results, therefore, from the combination of climatic conditions with the consequences of human actions enhanced by the social and spatial segregation present in the municipality. Added to this scenario is the possible impact of global warming, related to the environmental impact of human activities.

The results obtained highlight the need to reorganize the process of land occupation and the logic that organizes the configuration of urban territory, based on prioritizing the reproduction of capital, considering endogenous and exogenous connections. From this study, it can be seen that there is a need for public policies based on social, economic and territorial inclusion, with the limitation of land occupation to areas with little risk. Such public policies imply a logic of urban management with priority for development, with social inclusion and economic and social sustainability. The production of knowledge about the reality of the LNSP is essential to support public management in the face of challenges arising from the combination of economic growth, territorial configuration and climate change.

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