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SPATIO-TEMPORAL EVOLUTION OF LAND USE AND OCUPPANCY IN THE MUNICIPALITY OF SANTALUZ - BA, BRAZIL (2001-2021)

Evolução espaço-temporal do uso e ocupação da terra no município de Santaluz - BA, Brasil (2001-2021)

Evolución espacio-temporal del uso y ocupación del suelo en el municipio de Santaluz – BA, Brasil (2001-2021)

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ABSTRACT

Understanding the effects arising from human disturbances on the land is an essential resource in terms of mitigating these implications for the environment, as it allows establishing guidelines for a more rational use of natural resources. In this context, this study aims to analyze the spatio-temporal dynamics of land use and occupation in the municipality of Santaluz - BA, Brazil, from 2001 to 2021 through a mapping of land use and occupancy. Therefore, the methodological procedures were designed by processing LANDSAT orbital images and classifying these data in a GIS environment through supervised classification using the MAXVER algorithm. The results found that the classes of shrubby caatinga and agricultural crops showed a considerable reduction in area, as the classes of urbanized areas, uncovered areas, caatinga park, continental water and mining were expanded, with growth close to 268% of area occupied by the mining class. Finally, this study showed that remote sensing techniques are substantial in the scope of land use and occupation mapping, as they provide the identification of changes in spatio-temporal patterns in semi-arid environments, subsidizing environmental planning and ordering policies to mitigate these problems.

Keywords: Supervised classification; Semiarid; Remote sensing.

RESUMO

A compreensão dos efeitos advindos das perturbações antrópicas sobre a terra é um recurso essencial quanto à atenuação destas implicações ao meio ambiente, uma vez que permite estabelecer diretrizes do uso mais racional dos recursos naturais. Nesse contexto, este estudo objetiva analisar a dinâmica espaço-temporal do uso e ocupação da terra no município de Santaluz

– BA, Brasil, no período de 2001 a 2021 por meio do mapeamento do uso e ocupação da terra. Para tanto, os procedimentos metodológicos foram traçados por meio do processamento de imagens orbitais LANDSAT e pela classificação destes dados em ambiente SIG mediante a classificação supervisionada por uso do algoritmo MAXVER. Os resultados constataram que as classes de caatinga arbustiva e cultivos agrícolas apresentaram uma considerável redução de área, à proporção que as classes de áreas urbanizadas, áreas descobertas, caatinga parque, água continental e mineração foram expandidas, com destaque para um crescimento próximo de 268% de área ocupada pela classe mineração, legitimado pela consolidação da exploração mineral no intervalo analisado. Por fim, este estudo evidenciou que as técnicas de sensoriamento remoto são substanciais no âmbito dos mapeamentos do uso e ocupação da terra dado que proporciona a identificação das transformações dos padrões espaço-temporais em ambiente semiáridos, subsidiando políticas de planejamento e ordenamento ambiental para mitigar esses problemas.

Palavras-chave: Classificação supervisionada; Semiárido; Sensoriamento remoto.

RESUMEN

Entender los efectos derivados de las perturbaciones humanas en la tierra es un recurso esencial en términos de mitigación de estas implicaciones para el medio ambiente, una vez que permite establecer lineamientos para un uso más racional de los recursos naturales. En ese sentido, este estudio tiene como objetivo analizar la dinámica espacio-temporal del uso y ocupación del suelo en el municipio de Santaluz - BA, Brasil, de 2001 a 2021 mediante el mapeo del uso y ocupación del suelo. Por lo tanto, se trazaron los procedimientos metodológicos mediante el procesamiento de imágenes orbitales LANDSAT y clasificando estos datos en un entorno GIS por medio de la clasificación supervisada utilizando el algoritmo MAXVER. Los resultados encontraron que las clases de caatinga arbustiva y cultivos agrícolas mostraron una reducción en el área, a medida que se ampliaron las clases de áreas urbanizadas, áreas descubiertas, caatinga parque, agua continental y minería, con énfasis en un crecimiento cercano al 268% del área por la clase minería, legitimado por la consolidación de la exploración minera en el intervalo analizado. Finalmente, este estudio mostró que las técnicas de sensores remotos son sustanciales en el ámbito del mapeo de uso y ocupación del suelo, ya que permiten identificar cambios en los patrones espacio-temporales en ambientes semiáridos, subsidiando la planificación ambiental y ordenando políticas para mitigar estos problemas.

Palabras clave: Clasificacíon supervisada; Semi árido; Deteccíon remota.

1 INTRODUCTION

The processes that act in shaping the Earth's space are the result of natural and human actions, which are agents of transformation in a wide variety of natural environments. In this context, environmental disharmonious examples, such as the inadequate use of land and the marked exploitation of natural resources, have been factors that, disregarding the potentialities and vulnerabilities of this universe, contribute to a constant environmental devastation (Ab'saber, 2012; Oliveira et al., 2017).

Assuming that human action in natural or modified environments causes impacts at multiple levels (Ross, 2019), Sá and Angelotti emphasize that the various transformations occurring in the environment are indeed consequences of the significant mismanagement of natural resources through human action, especially in the semi-arid region of Northeast Brazil, where the impacts of human activities have become increasingly noticeable.

Environmental degradation in semi-arid regions may be associated with a combination of factors, such as physical-geographical conditions and the improper management of natural resources through human action (Karnieli et al., 2014). In this context, it is worth emphasizing that these factors can lead to severe harm to the environment, resulting in some situations in environmental scenarios with irreversible processes (Fensterseifer; Roggen, 2019; Ross, 2019; Adeyemi; Oyeleye, 2021).

In this context, it is worth noting that semi-arid environments are heavily exposed to human activities, with emphasis on deforestation, wildfires, mineral exploitation, improper agricultural and livestock systems, and desertification (Oliveira, 2015; Oliveira et al., 2017). The continuous and systematic removal of native vegetation directly interferes with the natural fertility patterns of the land, compromising the biological development of the soil (Travassos; Sousa, 2014).

From this perspective, considering the effects of anthropogenic disturbances on the earth is a fundamental resource for mitigating environmental impacts on the environment (Mariano et al., 2018), as establishing guidelines for a more rational use of natural resources leads to less environmental degradation (Ross, 2019).

Therefore, obtaining accurate information about the effects on the dynamics of land use and occupation is a crucial mechanism in understanding this phenomenon (Silva, 2017), with emphasis on remote sensing techniques. These tools, while collecting data about objects on the earth's surface without necessarily requiring a tangible interaction between the sensor and the object (Novo; Ponzoni, 2001), can contribute to understanding the spatiotemporal dynamics of land use and occupation in various environments. They enable the analysis of both the current state and the past state of the earth's surface (Juliev et al., 2019; Koshale; Singh, 2020).

Remote sensing techniques allow for the probing and mapping of environmental impacts, especially those resulting from human action, promoting monitoring and supporting accurate planning regarding the exploitation of natural resources (Ortiz; Freitas, 2007; De Sousa et al., 2008). At the same time, remote sensing modeling can provide a range of tools for ecosystem management, detecting areas requiring urgent attention (Silva, 2017).

In this context of analyzing changes in the landscape, the term land use can be understood as the performance of human activities on the earth's surface, (IBGE, 2013), through the replacement of native vegetation, and consequently, the emergence of new economic and social uses, such as agricultural, industrial, urban settlement activities, and other forms of anthropic occupation (BRASIL, 2012).

International studies, such as multi-temporal analysis of land use and occupation in semi-arid areas in India and Niger, have found a significant increase in arable land at the expense of native vegetation suppression (Nutini et al., 2013; Duraisamy; Bendapudi; Jadhav, 2018). Similarly, Maskooni et al., (2021) diagnosed a drastic reduction in vegetation cover in a semi-arid region of Iran, mainly due to the significant growth of built-up areas between 1993 and 2018.

In the context of the Brazilian northeastern semi-arid region, Torres (2013) revealed a significant reduction in the vegetation classes of arboreal and shrubby caatinga, while the exposed soil class grew significantly in the municipality of Itaporanga - PB between the years 2005 and 2008. The data presented by Torres (2013) denote a plausible deforestation of the vegetation cover and emphasize the strength of this impact on soil degradation, as the greater the suppression of vegetation, the greater the soil degradation will surely be. In this context, Silva et al. (2013) and Fernandes et al. (2015) conducted temporal analyses of land use and occupation in the semi-arid regions of Sergipe and Pernambuco, respectively, using geoprocessing of LANDSAT satellite images and the maximum likelihood algorithm. This approach made it possible to identify a significant growth in pasture, agriculture, and open areas at the expense of deforestation of the caatinga in these aforementioned environments.

In the context of data collection from multi-temporal mappings of land use and occupation in the semi-arid region of Bahia, Pinheiro (2012) analyzed the land use dynamics in the municipality of Correntina (BA) between 1988 and 2008. The study found a decrease of over 20% in areas occupied by natural vegetation, while the agricultural and livestock class expanded by more than 15% in occupied áreas. Similarly, Almeida (2013) demonstrated in the municipality of Casa Nova (BA) that the exposed soil class suffered a considerable increase from 1996 to 2011, indicating a greater soil deterioration and consequently leading to the emergence of areas susceptible to desertification, a serious and recurring problem in arid and semi-arid environments (Martins; Melo, 2012).

Souza e Reis (2020) acknowledged some transitions in the local landscape features, mainly driven by the disharmonious occupation of the territory, highlighting a gradual

increase in cultivated areas and urban areas in the municipality of Senhor do Bonfim (BA) from 1986 to 2017.

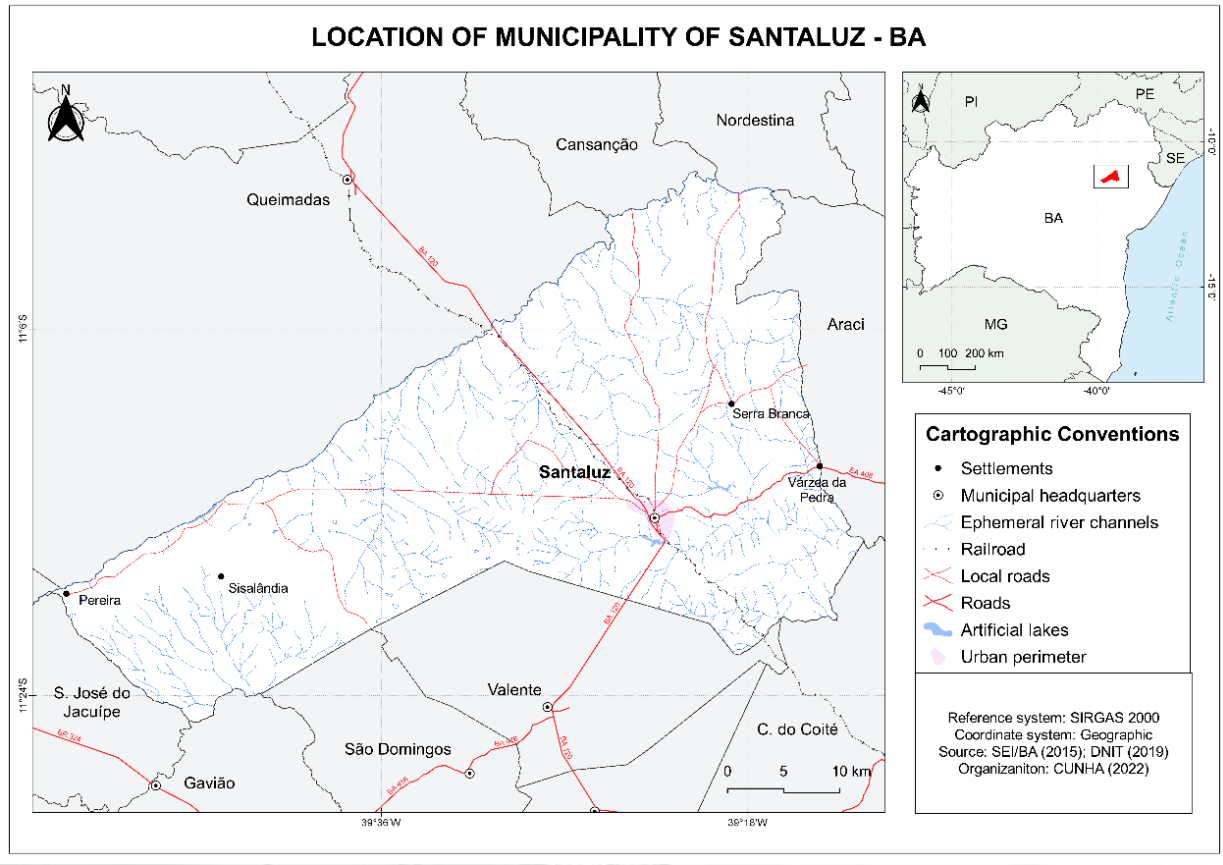
Despite the existence of several studies dedicated to understanding the changes in land use and occupation in the Brazilian semiarid region, there is still much to be researched, especially due to the risk of desertification. This need is more prominent in regions where land use presents a high risk of environmental impacts, such as mining. This is the context of the municipality of Santaluz, located in the semi-arid region of Bahia, which lacks studies focused on the spatiotemporal evolution of land use and occupation. This study aims to analyze the spatiotemporal dynamics of land use and occupation in the municipality of Santaluz - BA, Brazil, from 2001 to 2021, thus contributing to the understanding of the environmental impacts arising from land use and occupation in the Brazilian semi-arid region and aiming to support environmental planning and management (Farias; Silva; Rodriguez, 2013).

2 STUDY AREA

The study area comprises the municipality of Santaluz - BA, which is located between latitudes 11º 10' 05'' S and 11º 45' 15'' S, and longitudes 39º 23' 11'' W and 40º 27' 10'' W. Santaluz is located in the Sisal Identity Territory and is bordered to the north by the municipalities of Cansanção and Nordestina, to the south by the municipalities of Gavião, São Domingos, and Valente, to the east by the municipalities of Araci and Conceição do Coité, and to the west by the municipalities of Capim Grosso, Queimadas, and São José do Jacuípe (SEI, 2016), as shown on the location map below (Figure 01).

Located in the southeastern region of the municipality, the urban site of Santaluz is intersected by the Viação Férrea Federal Leste Brasileiro railway and the BA-120 and BA-408 highways, which connect the municipality to the federal highways BR-324 and BR-116, respectively. These access points, connected to the local roads of the municipality and other highways in the region, represent a significant network for the circulation of people and goods, especially due to the movement of production goods, such as sisal and extracted minerals.

Figure 01 – Location map of the study area, municipality of Santaluz (BA).



Source: Organized by the authors (2022).

According to data from the Instituto Brasileiro de Geografia e Estatística (2021), the municipality under study has an estimated population of 37,704 inhabitants, distributed over a territorial area of 1,623.44 km², resulting in a population density of 23.22 inhabitants per km². In terms of the climatic aspects of the area under study, Santaluz has a semi-arid tropical climate, with rainfall ranging between 400mm and 500mm, and an average annual temperature of 24.2ºC. (SEI, 2016). his climatic type is characterized by the irregular distribution and scarcity of precipitation throughout the year (zanella, 2014), and for this reason, the region has its hydrography marked by the predominant presence of ephemeral and intermittent river channels, such as Riacho da Cruz, Bonsucesso, Carnaíba, and Mulungu.

Intermittent channels are characterized by remaining dry during the dry season, but at certain times, they maintain water flow from surface and subsurface runoff. (Christofoletti, 1980), whereas intermittent streams are characterized by the absence of a constant flow of water for most of the year, holding water only during rainy periods or shortly after precipitation. (Lima; Perez Filho; Cunha, 2014). Perennial channels, on the other hand, are

much less common, with the notable presence of the Itapicuru and Jacuípe rivers, serving as natural territorial boundaries to the northeast and southwest of Santaluz, respectively. (CPRM, 2005). It is important to highlight that the municipality under study has over 60% of its territory located within the hydrographic basin of the Itapicuru River, an important river in Bahia that runs through the central-northern region of the state. The western region of the municipality, in turn, has watercourses draining into the hydrographic basin of the Jacuípe River (INEMA, 2022).

In terms of the geological context, the municipality of Santaluz is structured with the Santa Luz complex, with rocky outcrops consisting of migmatitic orthogneisses and quartzites with greenstone belt basement of the Itapicuru in the central portion of the municipality, the Tanque Novo/Ipirá complex in the southwest region with occurrences of gneisses, quartzites, and schists, and the Caraíba complex, which in the western and central-western region, comprises orthogneisses and calc-alkaline rocks. (RADAMBRASIL, 1983; Argôlo; Pépe, 1988; CPRM, 2005). These complexes, related to the geological scenario of the São Francisco craton, express the considerable mineral potential that the area under study uniquely possesses, due to the occurrence of gold, chromium, and granite (SEI, 2003).

As a result of the factors and soil formation processes, these geological compartments have led to the formation of the following soil classes: Eutrophic Planosol, Eutrophic Neosol, Red-Yellow Latosol, and Haplic Vertisol (IBGE, 2021). These soils cover igneous-metamorphic terrains of the crystalline basement, which are morphologically characterized as a predominantly flat surface, with a wide occurrence of rock outcrops associated with the sertanejo pediplain, interrupted in some areas by the presence of inselbergs and temporary lagoons (Cprm, 2005; Yamana Gold, 2009; SEI, 2016).

In terms of vegetation, local factors such as relief, soil, climate, and hydrography have allowed the formation of a native vegetation characterized by open woodland and shrubby caatinga (SEI, 2016). However, a significant portion of this native vegetation has been cleared and replaced by pastures and agricultural crops, particularly for sisal cultivation (Evangelista, 2010).

3 METHODOLOGY

The methodological procedures of this study were outlined through three central phases. The first phase involved a literature review concerning land use and occupation in

semi-arid environments. The second phase involved obtaining and processing LANDSAT orbital images. Finally, the collected data was classified through digital processing in a Geographic Information System (GIS) environment and field activity, thus providing materials for the production of maps and the discussion of results. The translation has been optimized for standard length, neutral tone, dynamic equivalence, and standard language complexity, taking into account the regional and cultural attributes of the target language.

In the second stage of the project, two satellite images from the LANDSAT 7 and LANDSAT 8 series were used, with a geometric resolution of 30 meters, provided free of charge through the image catalog of the Instituto Nacional de Pesquisas Espaciais (INPE) and the United States Geological Survey (USGS). These images belong to orbit/point 216/068 and correspond to the dates 2001/07/02 and 2021/06/02, respectively.

For the analysis of the study area over a 20-year period (2001 to 2021), orbital images were selected based on the same time of year and month to avoid disharmonious changes in class classification. Additionally, images with the lowest maximum cloud cover were chosen for the Enhanced Thematic Mapper Plus (ETM+) and Operational Land Imager (OLI) sensors, as cloud occurrence leads to a reduction in the useful area of the image due to behavioral similarity to water bodies as well as terrain obstruction (SILVA, 2017).

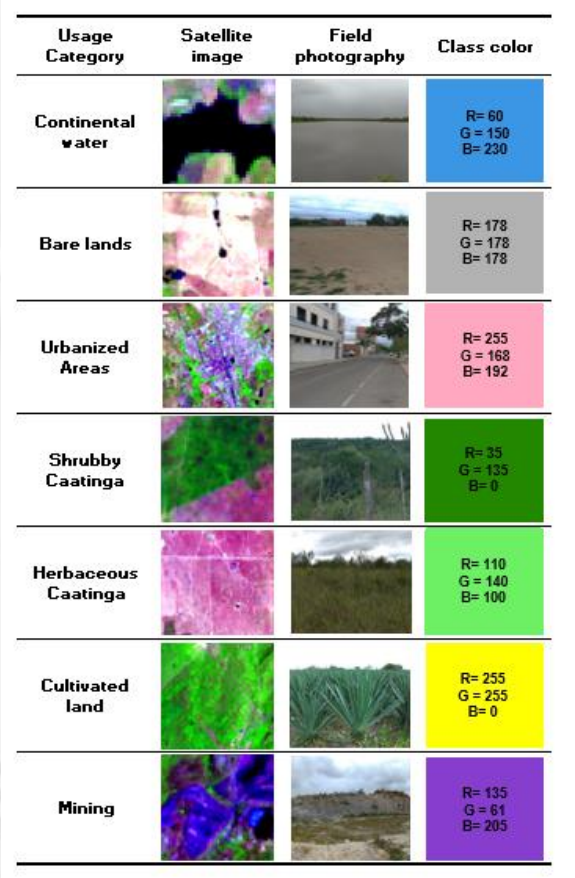
After downloading these images, pre-processing was carried out to improve the images through the integration of bands and geometric correction techniques (MARTINS, 2018). After performing these procedures, a cut was made based on the municipal mesh in shapefile format, obtained from SEI/BA (2015), and the spectral bands were merged to generate the best color composition, preferring the R1G2B3 spectral band for both images, as it better represented the target under study.

Next, the supervised classification method was chosen, applied with the assistance of the Semi-Automatic Classification Plugin tool in QGIS 3.14 software. This method involves calculating the statistical probability of the spectral signatures of the previously structured classes by recognizing the classes in the image and understanding the area under study (Matsukuma, 2002)

In the third stage of the project, seven classes of land use and occupation were identified and selected for the study area: continental water, uncovered areas, urbanized areas, shrubland, park-like caatinga, agricultural crops, and mining. This selection was based on the Technical Manual of Land Use and Occupation, organized by the Instituto Brasileiro de Geografia e Estatística (IBGE, 2013), as shown in the interpretation chart of the adopted classes (Figure 02).

In this classification, the maximum likelihood algorithm (MAXVER) was applied, which is a precise algorithm with satisfactory performance in land use and land cover mappings (Pereira; Guimarães, 2018). This classifier weighs the distances between the means of the pixel values of the samples, calculates the variance, and the spectral response relationship to classify an unknown pixel based on statistical patterns (Santos, 2005; Meneses; Sano, 2012; Facco; Benedetti, 2016).

Figure 02 – Chart of the defined categories of use and occupation for the area under study



Source: Organized by the authors (2022).

Next, the raster image was vectorized to calculate the area in km² of each polygon using the field calculator tool, in order to understand the spatial distribution of each category throughout the entire municipality of Santaluz.

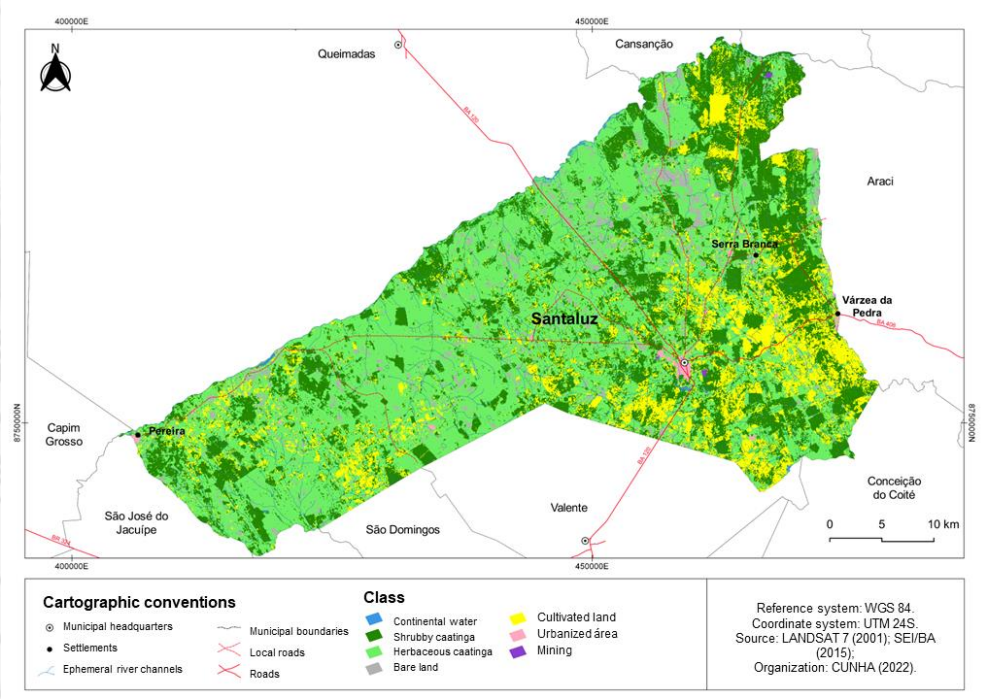
Finally, as a way of validating the mapping carried out, a field activity was developed with the aim of verifying the types of use and occupation present in the area under study, through on-site observation and recording in the detailed sampling point form based on the IBGE Land Use Technical Manual (2013). This stage involved obtaining GPS points, with

the recording of photographs and observations, in order to verify the terrestrial authenticity with the standards of the sample areas as well as to recognize the classification and detect possible distinctions between the classes (BRASILEIRO et al., 2016).

4 RESULTS AND DISCUSSION

Through spectral behavior of targets and field recognition, the distribution of multiple land uses and occupations in Santaluz was identified, as shown in figures 03 and 04, the products achieved in this mapping, and in Table 01, the absolute and relative data of the area occupied by the analyzed categories.

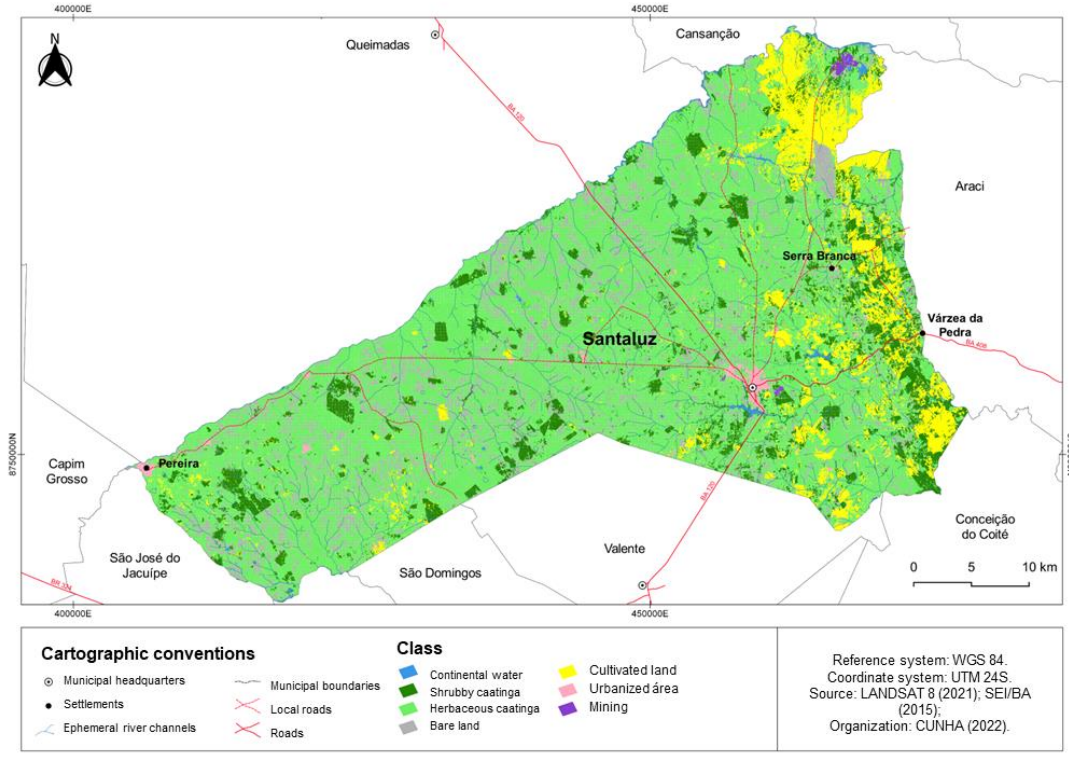
Figure 03 – Land use and land occupation map of the municipality of Santaluz – BA (2001).



Source: Authors (2022).

In the area under study, the analysis category of herbaceous caatinga was predominant throughout the municipal territory during the period studied (2001 to 2021). As a result, this category showed a 28% increase in spatial extension, occupying over 1,050.00 km² of spatial dimension in 2021. The category in question is essentially composed of small and medium-sized plant species, generally sparse and in an open manner, and consists of a natural or anthropized grassy and woody cover (SEI, 2006; IBGE, 2013).

Figure 04 – Land use and land occupation map of the municipality of Santaluz – BA (2021).



Source: Authors (2022).

Table 01 – Defined categories of use and occupation for the area under study.

Land and use occupancy categories in the municipality of Santaluz - BA (2001 - 2021)

Class	2001		2021	
	Area (km²)	Area (%)	Area (km²)	Area (%)
Herbaceous caatinga	822,08	50,64	1.052,39	64,82
Bare land	75,37	4,64	215,54	13,28
Shrubby caatinga	472,67	29,12	171,47	10,56
Cultivated land	242,43	14,93	162,40	10,00
Urbanized area	6,22	0,38	9,93	0,61
Continental water	3,94	0,24	9,04	0,56
Mining	0,72	0,04	2,66	0,16
The total =	**1.623,44**	**100,00**	**1.623,44**	**100,00**

Source: Organized by the authors (2022).

Due to being characterized by a cover that has already been affected by human action, it is worth noting that pasture areas and abandoned pastures have also been included in the category of herbaceous caatinga in this mapping, taking into account the analysis of LANDSAT images with a spatial resolution of 30 meters, the topographic map of

the study area at a scale of 1:100,000, as well as the similarity among the types of cover and land use assignment. Thus, in 2021, more than 64% of the target area's territorial mesh was occupied by this class.

The shrubby caatinga class, on the other hand, showed the greatest reduction in occupied area compared to the weighted categories in this study, having decreased by approximately 63% of the filled surface. Consequently, these areas, which consist of preserved caatinga biome fragments, indicate a lower vulnerability of the environment while also showing a need for greater environmental preservation (Cerqueira, 2015).

It was observed in the field that the physiognomy of the shrubby caatinga can be understood as dense or open with or without the presence of palm trees (Syagrus coronata) and is characterized by the presence of patches of arboreal and shrubby caatinga, generally integrating remnants of natural vegetation areas.

It presents itself as a vegetation of medium and large size, marked by a woody and also thorny stratum, with emphasis on the juazeiro (Ziziphus joazeiro), jurema preta (Mimosa hostilis) and umbuzeiro (Spondias tuberosa). In addition to these, the presence of xerophilous species was also observed, mainly from the cactus family, such as xique-xique (Pilosocereus polygonus) and mandacaru (Cereus jamacaru), which are plant species usually found in the caatinga and were recognized in the field activity.

In relation to the class of open areas, which comprise areas with exposed soil, covered by bare rock, and areas without vegetative cover (IBGE, 2013), it occupied 215.54 km², filling about 13% of the municipal area for the year 2021, whereas in 2001, this category occupied 75.37 km². These natural and non-natural areas, associated with bare rocks as well as areas that have suffered from anthropic degradation through intensive deforestation, burning, improper land use through agricultural practices, and mineral exploitation (NIMER, 1988), can give rise to degrading processes applied to the land, vegetative cover, and biodiversity (Sá e Angelotti, 2009).

In this context, due to the fragility of semi-arid environments and their significant environmental vulnerability to erosive, morphogenetic, and degrading processes (Cerqueira, 2015), the worsening of these processes may lead to the emergence of desertification areas characterized by soils that have lost their productive capacity as a result of intensified environmental degradation caused by human activity (Perez-Marin et., 2013).

Based on economic, social, and biological indicators, Lemos (2001) conducted a study on degradation indices in municipalities in the Northeast region. The research found that the municipality of Santaluz had one of the highest environmental degradation indices

among all municipalities in Bahia, indicating that the suppression of vegetation for agricultural crops and/or pastures has been an intensifying factor in the environmental degradation process in semi-arid areas (Lemos, 2001).

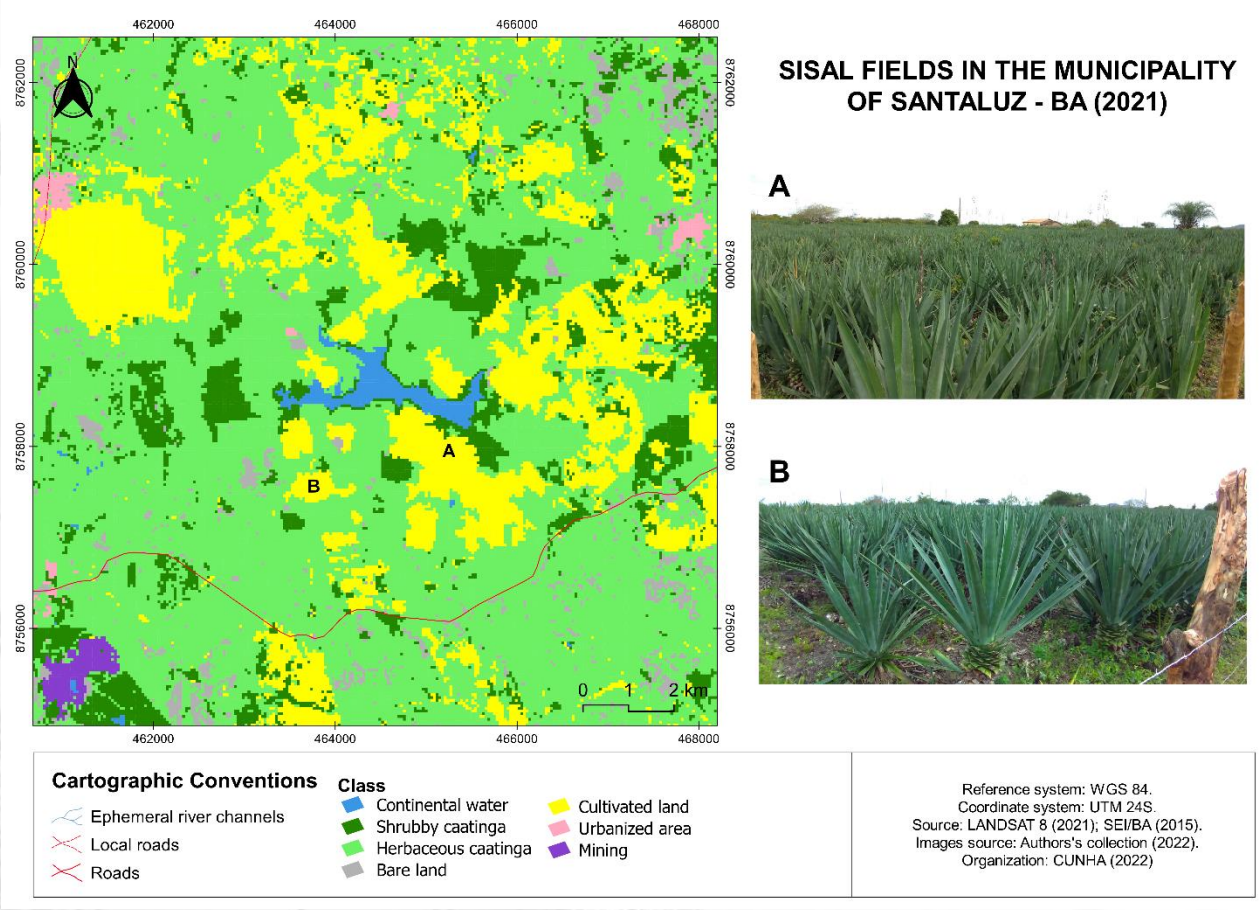
Therefore, taking into consideration the aspect of the high environmental degradation rate in Santaluz for the year 2001 and a considerable evolution of bare surfaces throughout the studied interval, resulting in an increase of approximately 185% compared to 2021 (Table 01), it is possible to infer that this growth has contributed to a worsening of environmental degradation processes in the soil exposure scenario

In terms of agricultural crop types, there has been a nearly 33% reduction in occupied area. In 2001, the land area under study was occupied by 242.43 km², corresponding to 14.9% of the municipal territory, while in 2021 the aforementioned crop type occupied 162.40 km², equivalent to 10% of the municipal area. The area under study has been prominent in the cultivation of sisal (Agave sisalana) in the region, mainly due to its resistance to prolonged drought and irregular rainfall in semi-arid environments (Evangelista, 2010). It is noteworthy that for an extended period, the largest continuous commercial cultivation of Sisal (Agave sisalana) in Bahia was located in the municipality of Santaluz, especially in the eastern and northeastern regions of the municipality (SEI, 2006; Cunha; Reis; Souza, 2021).

However, for this period, it was found that over 80% of the sisal in the Sisal Identity Territory was already in the final stage of the production cycle (SEI, 2006), which legitimizes the attenuation of agricultural crops for the investigated interval. Furthermore, despite a decrease in the cultivated area from 2001 to 2021, the municipality of Santaluz still remained one of the main agave producers in Bahia (Sousa, 2015).

Furthermore, with just over 90% of all crops in the area under study, sisal (Figure 05), whose fibers are used in the textile industry, stands out in the agricultural production in the area under study as it comprises a portion of over 12,000 hectares of land for harvesting (IBGE, 2020). In addition to sisal production, the municipality of Santaluz stands out in the production of forage cactus (*Opuntia cochenillifera*), cassava (*Manihot esculenta*), watermelon (*Citrullus lanatus*), and beans (*Phaseolus vulgaris*) under temporary crop conditions (IBGE, 2017).

Figure 05 – Sisal fields in the municipality Santaluz – BA



Source: Organized by the authors (2022).

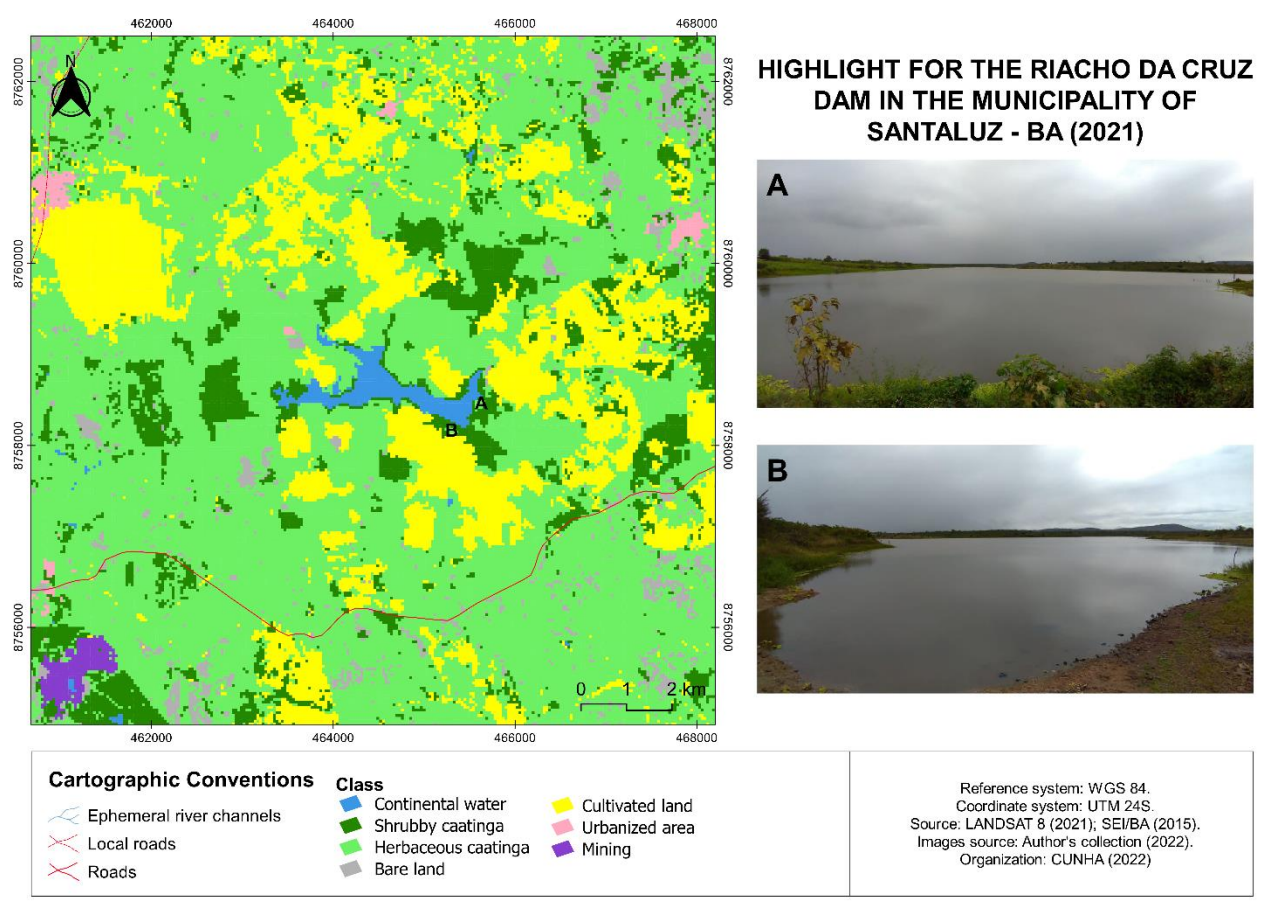
In the context of urbanized areas, there was a significant expansion of approximately 59%, as in 2001 this class occupied 6.22 km², while in 2021 it comprised 9.93 km². This growth is related to the demographic increase of Santaluz over the past 20 years, consequently reflecting the expansion of the urban area.

For this analysis, areas of the municipal seat, district, hamlets, and villages were considered, representing intensively used areas, organized by buildings and road systems (IBGE, 2013), with emphasis on the municipal seat and the main hamlets of Santaluz, such as Pereira, Várzea da Pedra, Serra Branca, and Sisalândia.

In terms of the continental water category, a considerable growth of these areas has been detected, which are expressed through bodies of water, reservoirs, dams, and perennial river channels. Thus, during the studied period, several transformations in land use and occupation were undertaken, resulting in a 129% growth in the area occupied by the continental water category, equivalent to over 5 km².

The aforementioned expansion can be justified due to the construction and expansion of dams and reservoirs in the municipality of Santaluz, such as the construction of the Riacho da Cruz reservoir (Figure 06), the second largest body of water in the entire municipality, as a standard and customary hydraulic solution strategy to address the issue of drought periods.

Figura 06 – Highlight for the Riacho da Cruz Dam in the municipality of Santaluz – BA.

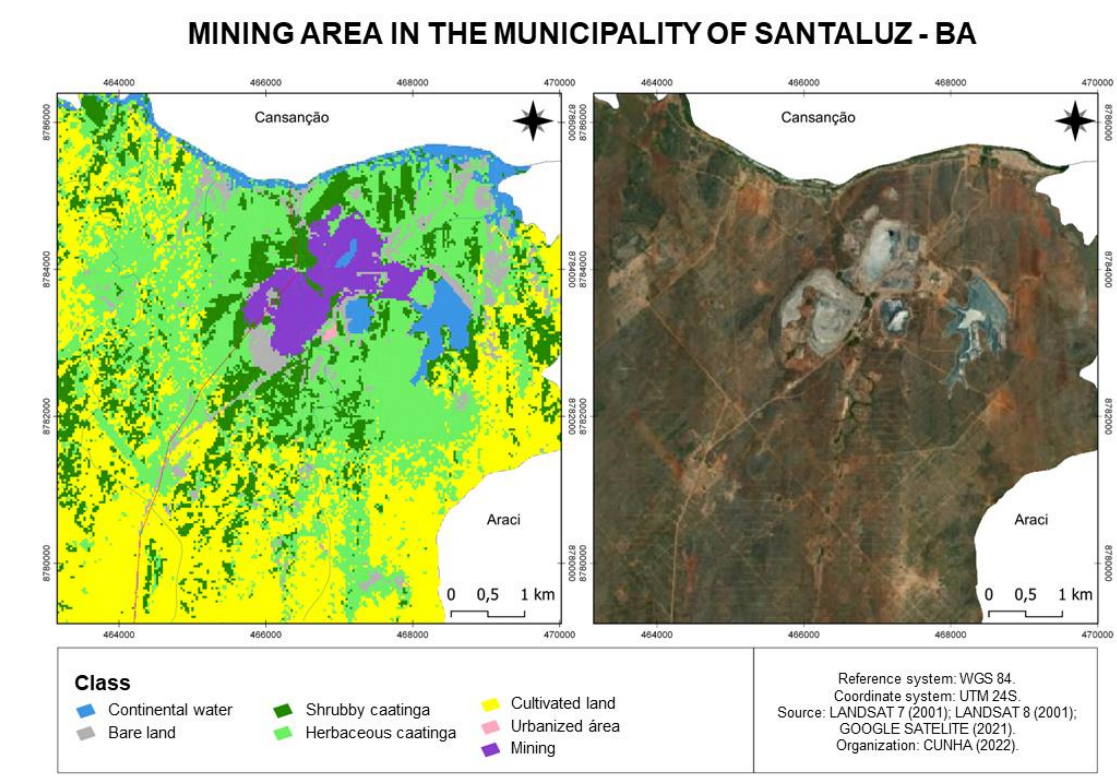


Source: Organized by the authors (2022).

Regarding the use in mining areas, the results indicated that this was the category that showed the highest growth (Figure 07), with an approximate expansion of 268% in area.

This growth is a result of the intense exploitation of gold, chromite, and granite mineral resources in the municipality of Santaluz, since the mentioned municipality has significant mineral potential and stands out in the Sisal Identity Territory in this regard. Therefore, this category is characterized by mineral extraction areas, both through mining and through the mining of ores found in the study area (SEI, 2016; Teixeira, 2019).

Figure 07 – Highlighting the expansion of the mining sector in the area under study.



Source: Organized by the authors (2022).

In the sphere of transformations of the multiple uses in the study area, it is correlated that the development of projects aimed at mineral exploitation brings several perspectives in the socioeconomic scope, since it promotes the generation of many direct and indirect jobs and the expansion of the service network (SEI, 2006). Therefore, it can be inferred that the expansion of urbanized areas, of approximately 3.70 km², is related, among other factors, to the economic development provided by open-pit mining and operational activities initiated in 1990 by Companhia Vale do Rio Doce (Teixeira, 2019), considering that a portion of the workforce employed in companies in this sector are from other regions, especially in the municipal headquarters of Santaluz (Yamana Gold, 2009).

On the other hand, despite the socio-economic development made possible, it is known that several environmental impacts arise as a result of mineral exploitation-induced environmental degradation. According to the Environmental Impact Report prepared by Yamana Gold (2009), mineral extraction through mining in the area under study has inevitably caused impacts related to air, soil, surface and groundwater quality, as well as landscape alteration over the past few years.

In the context of mineral extraction, environmental damage resulting from this activity is also a consequence of mining through artisanal mining and quarries, which is driven by

the discovery of new exploration areas and characterized by the use of rudimentary tools and simple equipment for the exploitation of gold and granite (BRASIL, 2011).

In this scenario, it is important to highlight that the shortage of skilled labor, health problems arising from unhealthiness, and the absence of safety equipment are striking aspects in the model of mineral extraction through artisanal mining (Mattos, 2009).

Furthermore, impacts related to environmental degradation in these land uses in semi-arid environments can be observed through the suppression of native vegetation, soil contamination, alteration of topography, and erosion (MEDEIROS et al., 2019). However, it is important to emphasize that mining activity contributes to the dynamics of the local market, as it represents a source of income for many families in the region (SEI, 2006; Mattos, 2009).

5 FINAL CONSIDERATIONS

In the context of the spatial transformations of the multiple land uses, it was found that the shrub caatinga and agricultural crops classes experienced a significant decline. Considering the reflections and overview derived from this study, it was noted that the shrub caatinga decreased significantly while the park-like caatinga and open areas classes had a considerable growth in area, demonstrating a suppression of native vegetation during the observed period.

Despite the fact that the agricultural crop class has shown a mild reduction in the occupied area, the municipality of Santaluz was one of the main highlights in sisal production throughout the state of Bahia. Mining, on the other hand, was the category that emphatically showed the highest expansion, around 268% in area for the period studied, thus contributing to an increase in environmental degradation in this area.

The application of remote sensing techniques was an important resource in this study as it supported the identification of changes in the spatiotemporal patterns of land use and occupation in the study area, with validation of the classes through field surveys. Therefore, it is worth noting that this tool is substantial for environmental studies in semi-arid regions, as it supports environmental planning and monitoring actions, and especially due to the lack of data and information on land use and occupation in the municipality for earlier periods.

In summary, the research achieved the study's objective by enabling the analysis of the spatiotemporal dynamics of land use and occupation in the municipality of Santaluz, Bahia, taking into account the period from 2001 to 2021. Therefore, the results obtained

through this mapping provide a basis for stimulating new research on the potentialities and vulnerabilities of the environment in the municipality under study.

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