



## Thirty-one years of land use, coverage, and occupation in the municipality of Santa Cruz Cabralia, Bahia

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### ABSTRACT

Understanding changes in land use is crucial for environmental planning and sustainable development and for balancing human needs with conservation efforts. This study aimed to analyze land use, land cover, and land occupation in the Santa Cruz Cabralia municipality between 1990 and 2021 by employing geoprocessing techniques for coverage, use, and occupation analysis and mapping, as well as classification of coverage classes. The data were acquired through the MapBiomas platform and processed using QGIS software, facilitating map creation and statistical data analysis. The results indicate significant changes in land use and occupation within the municipality during this period. The key highlights include 1) the implementation and expansion of silviculture, 2) the expansion of urbanization, 3) the trend of decreasing watercourses, and 4) the reduction of native vegetation. The findings contribute to understanding how quickly human activities, occupation, and environmental management challenges have evolved in the region of the Brazilian Discovery Cities.

**Keywords:** land use change; geoprocessing techniques; silviculture expansion

## Trinta e um anos de uso do solo, cobertura e ocupação no município de Santa Cruz Cabralia, Bahia

### RESUMO

Compreender as mudanças no uso do solo é de extrema importância para o planejamento ambiental e desenvolvimento sustentável, equilibrando as necessidades humanas e a conservação. Este trabalho teve como objetivo analisar o uso, cobertura e ocupação do solo no município de Santa Cruz Cabralia no período entre 1990 e 2021, utilizando técnicas de geoprocessamento para análise e mapeamento da cobertura, uso e ocupação, além da

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classificação das classes de cobertura. Os dados foram adquiridos por meio da plataforma do MapBiomas e processados no software QGIS, que possibilitou a confecção dos mapas e análises dos dados estatísticos. Os resultados indicam que o município passou por várias mudanças consideráveis em seu uso e ocupação do solo nesse período. Os principais destaques foram: 1) implantação e expansão da silvicultura, 2) expansão da urbanização, 3) tendência de diminuição dos cursos d'água, 4) redução da vegetação nativa. Os resultados obtidos proporcionam o entendimento das evoluções das atividades humanas, formas de ocupação e os problemas gerados na gestão e qualidade ambiental da região.

**Palavras-chave:** mudança de uso do solo; técnicas de geoprocessamento; expansão da silvicultura

## **Treinta y un años de uso, cobertura y ocupación del suelo en el municipio De Santa Cruz Cabrália, Bahia**

### **RESUMEN**

Comprender los cambios en el uso del suelo es de suma importancia para la planificación ambiental y el desarrollo sostenible, equilibrando las necesidades humanas y la conservación. Este trabajo tuvo como objetivo analizar el uso, la cobertura y la ocupación del suelo en el municipio de Santa Cruz Cabrália en el período comprendido entre 1990 y 2021, utilizando técnicas de geoprosesamiento para el análisis y el mapeo de la cobertura, el uso y la ocupación, además de la clasificación de las clases de cobertura. Los datos fueron adquiridos a través de la plataforma de MapBiomas y procesados en el software QGIS, lo que permitió la confección de mapas y análisis de datos estadísticos. Los resultados indican que el municipio experimentó varios cambios significativos en su uso y ocupación del suelo en este período. Los principales aspectos destacados fueron: 1) la implementación y expansión de la silvicultura, 2) la expansión de la urbanización, 3) la tendencia a la disminución de los cursos de agua, 4) la reducción de la vegetación nativa. Los resultados obtenidos proporcionan la comprensión de las evoluciones de las actividades humanas, las formas de ocupación y los problemas generados en la gestión y la calidad ambiental de la región

**Palabras clave:** cambio de uso del suelo; técnicas de geoprosesamiento; expansión de la silvicultura

### **INTRODUCTION**

Coastal zones in Brazil boast rich biodiversity and significant environmental value, housing diverse ecosystems such as mangroves, beaches, dune fields, and estuaries. Many of these environments are protected as permanent preservation areas (PPAs), necessitating proper management of land use, occupation, governance, and territorial control (Dias and Oliveira, 2013; Mencia et al. 2023). Additionally, they are considered national heritage by the 1988 Constitution, playing a crucial role in economic activities such as commerce, transportation, and urban and rural settlements. However, occupation can lead to alterations in land cover, affecting usage, patterns, and spatial distribution (Benfica et al. 2023; Mencia et al. 2023).

The occupation of the extreme south of Bahia has been significant since the colonial period, with the establishment of urban centers and a history of intense urbanization. These environmental, social, and

economic changes have resulted in the exploitation of natural resources and land use. Furthermore, during the early centuries of occupation, forests served as a limiting factor for regional settlement, hindering the urbanization process (Oliveira et al. 2021). The municipality of Santa Cruz Cabrália is situated within the Atlantic Forest Biosphere Reserve, encompassing areas designated as Natural World Heritage sites located within the Central Corridor of the Atlantic Forest (CCAF). It also includes conservation units (CUs) as part of the mosaic of protected areas in the extreme south of Bahia. Tourism is a significant economic driver in the region, drawing visitors with its picturesque beaches and rich cultural heritage, thereby making substantial contributions to the local economy. However, over the past three decades, the municipality and surrounding region have seen a diversified socioeconomic landscape, propelled by various economic activities, including fishing, silviculture, agriculture, extractivism, sugarcane cultivation, handicrafts, and mining (BAHIA, 2016).

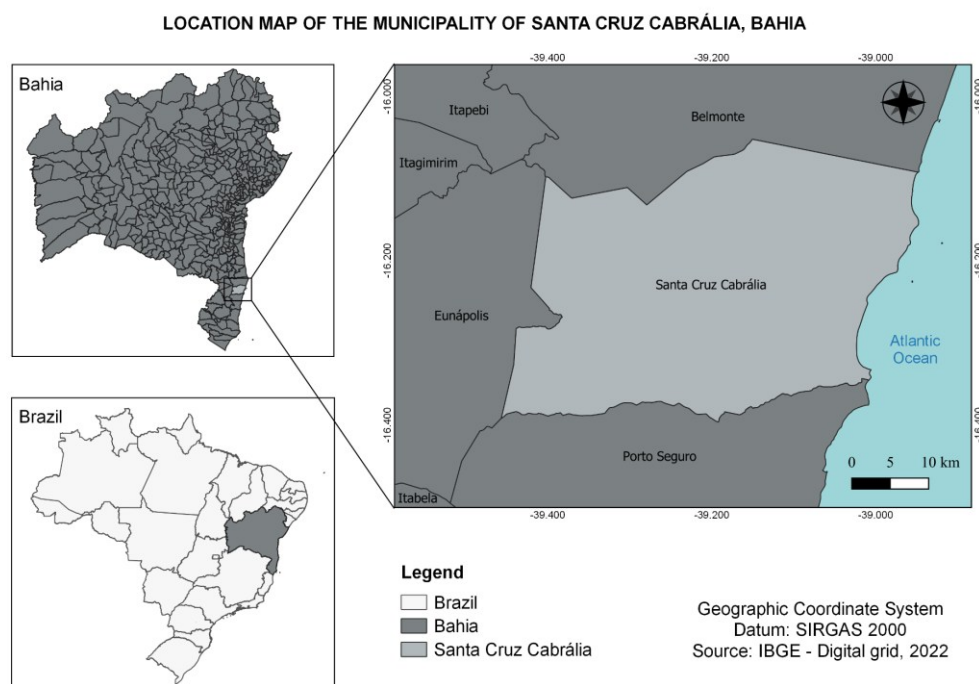
In coastal environments, the implementation of new land use often occurs without adequate planning considering environmental issues. Due to the high environmental fragility of these areas, modifications caused by human action result in irreversible damage to environmental systems (Amorim and Oliveira, 2013; Silva et al. 2020; Benfica et al. 2023; Mencia et al. 2023). The increase in tourism activity in the extreme south of Bahia has resulted in significant environmental impacts, such as the devastation of primary forests and the extinction of native species (Cerqueira Neto and Silva, 2015; Ramos et al. 2022; Benfica et al. 2023). Another established economic activity in the Discovery Coast region is eucalyptus silviculture, encouraged by federal and state policies since the mid-1970s (Almeida and Teixeira, 2010). In Santa Cruz Cabrália, silviculture stands out as a complex agro-industrial sector for eucalyptus and cellulose production and has been implemented and developed in the region since the 1990s. This sector is associated with constant stimulation and expansion of areas dedicated to eucalyptus planting (BAHIA, 2016; Ramos et al. 2022).

The aim of this research is to investigate and analyze the patterns of land use, cover, and occupation in the Santa Cruz Cabrália municipality over a 31-year period. Given the strategic significance of the municipality and the extensive landscape changes observed in the region over recent decades, understanding these dynamics is crucial. This study will contribute to a deeper understanding of land management in southern Bahia, particularly in areas experiencing significant levels of occupation and modification.

## METHODOLOGY

Santa Cruz Cabrália is located between the geographical coordinates of 16° 16' 43" S and 39° 1' 39" W, with an area of 1,462.942 km<sup>2</sup>. It is 686.6 kilometers away from the capital, Salvador (Figure 1). Within the geographical site integrated into the Atlantic Forest biome, it has a population density of 19.95 inhabitants/km<sup>2</sup> (IBGE, 2022). According to the Köppen-Geiger climate classification (1928), Santa Cruz Cabrália is characterized by a type Af climate (hot and humid rainy), which is typical of the coastal region. Rainfall is well distributed throughout the year, with annual precipitation ranging between 1400 and 1800 mm (SEI, 2010; Mencia et al. 2023; Oliveira et al. 2023). With an average annual temperature of 24°C, the geomorphology of Santa Cruz Cabrália reveals a landscape with tabular features, deep valleys, and areas of accumulation of fluvial sediments (Oiveira et al. 2023). This configuration confers scenic beauty and peculiar characteristics, highlighting the coastal plateaus, precoastal surfaces, and fluvial-marine plains (BAHIA, 2016).

Figure 1: Map showing the location of the Santa Cruz Cabrália municipality.



### *Methodological Procedures*

For the assessment of land use evolution in the municipality of Santa Cruz Cabrália, land use data from 1990, 2000, 2010, and 2021 obtained through MapBiomas were utilized. The platform is part of a project initiated in 2015, a collaboration between various universities, nongovernmental organizations (NGOs),

and private companies. This study contributes to understanding the dynamics of land use and land cover change in Brazil and other tropical countries by using the digital processing of Landsat images through a rapid, reliable, and cost-effective methodology (MAPBIOMAS, 2017).

Data from Collection 7.1 of the MapBiomias Project - Annual Land Use and Land Cover Mapping Project in Brazil, covering the period from 1985 to 2021, were utilized. Study area images were acquired in Geotiff format from the Google Earth Engine platform and derived from MapBiomias mapping for the specified periods. Vector files of the Santa Cruz Cabralia municipality were obtained through the Municipal Mesh from the Brazilian Institute of Geography and Statistics (IBGE). To calculate the areas of the selected classes for this study and create maps, the open-source software QGIS 3.28 was utilized.

The MapBiomias platform provides maps with broad classifications available at various levels, ranging from level 1, with simpler classifications, to level 4, with more detailed classifications. With the aim of simplifying the interpretation of the results, this study adopted the strategy described by Preis et al. (2021), grouping the 17 classifications proposed by MapBiomias into 7 land use categories, as presented in Table 1.

Table 1: Simplification of land use and land cover classifications.

<b>Simplified Land Use</b>	<b>Land Use from MapBiomias</b>
Forest Formation	Forest Formation; Mangrove; Wooded Restinga
Non-Forest Natural Formation	Herbaceous Restinga; Other Non-Forest Formations; Apicum; Wetland and Marshy Area
Silviculture	Silviculture
Pasture	Pasture
Agriculture	Other Temporary Crops; Other Perennial Crops; Coffee; Mosaic of Uses
Non-Vegetated Area	Beach and Dune; Urban Area; Other Non-Vegetated Area
Water Body	River; Lake; and Ocean

## RESULTS AND DISCUSSION

Over the past few decades, there has been a significant increase in the resident population in the municipality of Santa Cruz Cabralia, particularly in the transition from the 1990s to the 2000s. According to the demographic census conducted by IBGE, in 1991, the resident population in the municipality was 6,535 inhabitants. Nine years later, in the 2000s, there was a surge in the population to 23,888 inhabitants, representing an increase of 265.48%. This population growth in the region is related to the commencement

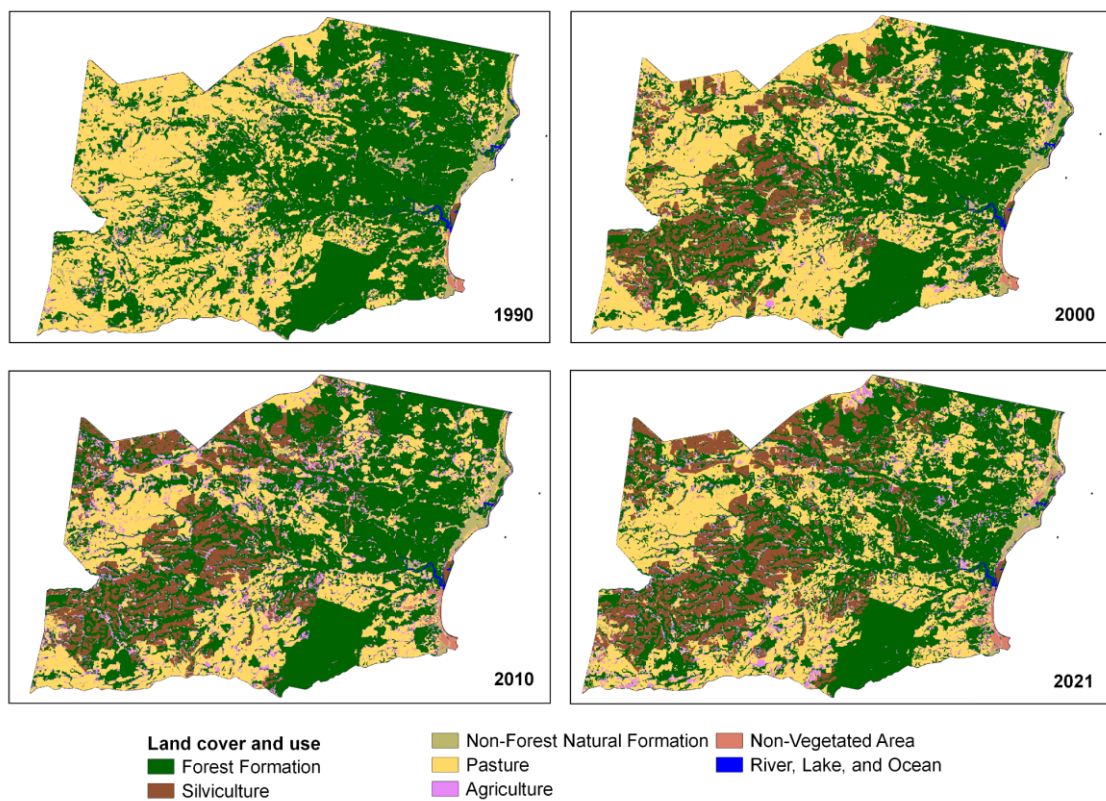


of silviculture activities in 1991 (Cerqueira Neto, 2012). In subsequent years, the population stabilized, showing regular growth, with an increase of 9.94% between 2000 and 2010 (from 23,888 to 26,264 inhabitants) and approximately 11.12% between 2010 and 2022 (from 26,264 to 29,185 inhabitants).

Southern Bahia exhibited a landscape that underwent various transformations from 1985 to 2019. The presence of anthropic activities and natural areas that intersect produces a conflicting relationship between conservation, preservation, and environmental impacts (Ramos et al. 2022; Benfica et al. 2023).

The visual representations of land use, occupation, and land cover changes over time in Santa Cruz Cabrália municipality, Bahia, are illustrated in Figure 2 for the years 1990, 2000, 2010, and 2021, respectively. Additionally, the territorial distribution of land use classes is outlined in Table 2.

Figure 2: Land use and occupation map, 1990 to 2021.



authors (2024)

Table 2 provides an overview of the land use and occupation changes in the municipality of Santa Cruz Cabrália over the years 1990, 2000, 2010, and 2021. A significant reduction in forest formation area was evident over this period. In 1990, the forest occupied an area of 786.44 km<sup>2</sup>; however, in the following decade, there was a reduction of 81.54 km<sup>2</sup> in its extent. Between 2000 and 2010, resilience exhibited a negligible increase of 0.02 km<sup>2</sup>. However, between 2010 and 2021, there was a substantial loss, resulting

in a reduction of 29.68 km<sup>2</sup> in the area. This reduction in forest formation is closely related to the significant increase in urban expansion, as evidenced by the growth of nonvegetated areas and can be visually observed in Figure 2. Similar reductions in forest formation are also observed in the neighboring municipality of Porto Seguro. According to Veiga (2016), these reductions are inherent to the formation of peripheral neighborhoods and the occupation of permanent preservation areas, which have been irregularly occupied by immigrant populations. Additionally, there was also a significant increase in agricultural activities, suggesting a scenario of constant landscape changes over this period.

Table 2: Distribution and variation of land use and occupation in the Municipality of Santa Cruz Cabrália.

<b>Classes</b>	Area <b>1990 (km<sup>2</sup>)</b>	Area <b>2000 (km<sup>2</sup>)</b>	Difference <b>(1990-2000)</b>	Area <b>2010 (km<sup>2</sup>)</b>	Difference <b>(2000-2010)</b>	Area <b>2021 (km<sup>2</sup>)</b>	Difference <b>(2010-2021)</b>
Forest Formation	786,44	704,90	-10,36%	704,92	0,002%	675,22	-4,21
Non-Forest Natural							
Formation	24,72	17,80	-27,99%	19,69	10,61%	21,23	7,82%
Silviculture	0,04	148,07	370.075%	187,83	26.51%	224,06	19,60%
Pasture	569,00	506,21	-11,03%	397,53	-21,46	415,90	4,62%
Agriculture	72,44	74,56	2,92%	141,54	89,83%	113,20	-20,02%
Non-Vegetated							
Area	4,57	6,12	33,91	6,53	6,69%	8,86	35,68%
River, Lake, and							
Ocean	4,01	3,61	-9,97	3,21	-11,08%	2,81	-12,46
Tota	1461,22	1461,27		1461,25		1461,28	

authors (2024)

Three distinct periods of development have been observed over these 30 years of intense changes in land use and occupation. Between 1990 and 2000, a significant decrease of 27.99% was noted in the total area encompassing these types of nonforest natural formations. This suggests that these areas might have been converted or degraded for various purposes, such as silviculture, agriculture, and land grabbing, for future implementation. In the subsequent period, between 2000 and 2010, there was an increase of 10.61% in this same area, suggesting the possible effectiveness of measures aimed at the conservation, recovery, or restoration of these ecosystems, as established in Law No. 10.431 of December 20, 2006, which addresses the environmental policy and protection of biodiversity in the state of Bahia (BAHIA, 2006). Between 2010 and 2021, the expansion trend continued to increase by 7.82%, suggesting a possible continuation of these efforts or potential changes in environmental policies, further encouraging the conservation and recovery

of these ecosystems. Decree 15180 of June 2, 2014, which regulates the management of forests and other forms of vegetation in the State of Bahia, established rules that govern the conservation of native vegetation, the exploitation of native and planted forests, and the suppression of native vegetation for alternative land use (BAHIA, 2014).

Among the land use and occupation classes in the municipality, silviculture stood out as the most prominent throughout this analysis. In 1990, the area occupied by this activity was considerably low, covering only 0.04 km<sup>2</sup>. However, within a decade, this number increased exponentially, with a growth of 370.075%, reaching 148.07 km<sup>2</sup> by the year 2000. The increase during this period is related to the initiation of eucalyptus activities in the extreme south of Bahia in 1991 (Cerqueira Neto, 2012; Ramos et al. 2022; Mencia et al. 2023). The areas occupied by this crop experienced significant growth in subsequent decades, with a 26.51% increase between 2000 and 2010, followed by a growth of 19.6% between 2010 and 2021. The increase in the area dedicated to cultivation in these spaces results in the replacement of regions previously used for agricultural activities, especially when large companies acquire these areas to expand their plantations. In parallel with the growth of silviculture in the region during the decades from 1990 to 2000 and from 2000 to 2010, a correlation is observed in Table 2 between the expansion of forestry activity and a decrease in pasture areas in the region. In the last decade, with a 19.6% increase in the planting area, there was also a decrease in the extensions destined for agriculture of 20.02%. This is intrinsically linked to the expansion of eucalyptus monoculture in the region (Viana and Souza, 2022; Ramos et al. 2022; Mencia et al. 2023).

The nonvegetated areas experienced significant growth over time, with increases of 33.91%, 6.69%, and 35.68% in 2000, 2010, and 2021, respectively. This growth is associated with increased urbanization, resulting in greater development of infrastructure and built-up spaces. The expansion of these areas can have substantial impacts on the environment, especially considering the coastal characteristics of the municipality. The expansion of urban areas overlaps with regions of restinga, as houses, hotels, and resorts are built near the beach. Additionally, due to the considerable presence of vegetation in the region, illegal deforestation has emerged as an option for creating plots destined for the expansion of residences and condominiums (Ribeiro et al. 2023).

In water bodies, there is a clear trend of loss in their extent. From 1990 to 2000, there was a reduction of 9.97%. In subsequent years, this trend of loss intensified, with a decrease of 11.08% in the area between 2000 and 2010 and an even more notable decline of 12.46% between 2010 and 2021. This reduction is directly associated with the growth of urban areas also noted in the neighboring region of Porto Seguro, adjacent to Santa Cruz de Cabrália (Silva et al. 2020). As urban expansion advances, there is a tendency to



modify natural river courses and lakes for the installation of infrastructure, such as roads, and even the covering of springs for land subdivision purposes. Additionally, the loss of area in this class may strongly influence deforestation, as the removal of vegetation cover around water bodies contributes to the erosion and degradation of these environments (Silva et al. 2020; Mencia et al. 2023).

## CONCLUSIONS

The municipality of Santa Cruz Cabralia has undergone several significant changes in its land use and occupation over the past decades. The main highlights include 1) the implementation and expansion of silviculture, 2) urbanization expansion, 3) a trend of watercourse loss, and 4) a reduction in native vegetation.

The results obtained in this research contribute to understanding which regions have undergone the greatest change and how these changes have been delineated around the territory's development, revealing the depth of changes in the municipality's land use and occupation over the past 31 years. There was also a significant expansion of silviculture, with an increase of 560.500%, due to the implementation of companies that have altered land use and occupation with territorial pressures and demands for cultivation space. In addition, there was a 26.89% reduction in degraded pasture areas and a 14.13% increase in the occupation of important natural areas, which are mainly destined for sugarcane and eucalyptus cultivation.

We conclude that this study provides an understanding of how the region was occupied and which development mechanisms guided the process of change in land use and occupation, assisting in decision-making in pursuit of harmonization between human activities and nature's well-being.

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