

Land use and coverage in Urbano Santos, Maranhão, Brazil

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## **Abstract**

The land use and occupation process is a vital subject for study that aids in understanding human dynamics and their interaction with the environment. Hence, the aim of this research is to assess the alterations in land use and occupation within the municipality of Urbano Santos – MA over a 26-year span, employing geoprocessing techniques. Thermal maps were generated using the geospatial delineation of cartographic products from the MapBiomass Project, utilizing QGIS 3.16.1 software. The identified land use and cover classes included soy cultivation, temporary crops, urban areas, forest formation, and water bodies. The findings indicate a progressive degradation of Forest Formation and Water Bodies, alongside an expansion of Urban Infrastructure. Additionally, the study notes fluctuations in the area of soy cultivation, with a rapid and seemingly disorganized increase in Temporary Crops. This work is intended to serve as a foundation to further discussions on the topic within the municipality and the wider region.

## **Research Question and Hypothesis**

Understanding the dynamics of land use and occupation is crucial for guiding sustainable strategies and preserving ecosystems. According to Shimabukuro et al., (2023), linking historical land use characteristics with satellite image spectral and temporal responses is key to gathering reliable information, offering insights into environmental dynamics. Maranhão state, including Urbano Santos in the Chapadinha Microregion, suffers from a lack of information on land dynamics, effective government action, and public policy, leading to disorganized land use. This is concerning amid climate change and agricultural expansion (Lima et al., 2016), combined with social vulnerability.

Various land uses, such as market expansion and urban infrastructure advancement, lead to environmental transformations. These can reduce biodiversity and environmental services, altering rainfall and increasing greenhouse gas emissions (Souza et al., 2020; Silva et al., 2021). Monitoring and studying landscape changes at global and local levels, like municipalities, is essential. It informs regional development, aiding in public policy and effective actions for improving population quality of life and sustainable development, targeting deforestation, fires, pollution, urban expansion, and rural production.

Knowledge gaps exist in the landscape dynamics of Maranhão's Urbano Santos municipality. Land use changes likely intertwine with complex dynamics between economic development and natural resource preservation amid agricultural expansion and social vulnerability. We hypothesize that geoprocessing techniques will enable precise landscape transformation analysis over the past 26 years, identifying patterns and relationships between economic growth and landscape changes to guide sustainable planning in the municipality.

## **Materials and Methods**

This study is an integral part of the university extension project "Globe and Steam in Chapadinha (PJ036-2023)" from the Center of Sciences of Chapadinha at the Federal University of Maranhão, whose main goal is to promote NASA's GLOBE program and implement the Land Cover protocol, as well as conducting research on land use and occupation in collaboration with high school students from Chapadinha, with the

Instituto de Educação, Ciência e Tecnologia do Maranhão (IEMA), Brazil, serving as the central hub of activities.

This initiative integrates the GLOBE Observer Land Cover protocol, along with NASA's resources, to bolster sustainable agricultural practices, thereby mitigating environmental impacts and conserving the natural resources of Chapadinha. Training was carried out in the form of a workshop with IEMA students, with the participation of previously trained UFMA monitors. Preparation of materials, as well as tools and equipment, has been streamlined for efficiency and reliability, according to the reality of the school and student.

The study encompasses the municipality of Urbano Santos, located in the eastern mesoregion of the Brazilian state of Maranhão (Figure 1). The region, covering an expanse of 1,208 km<sup>2</sup>, was recorded to have a population of 33,495 by the Brazilian Institute of Geography and Statistics (IBGE) in 2022. The prevailing climate, classified as Aw (Tropical with a dry winter) by Köppen, has an average air temperature of 26°C and an annual average rainfall of 1,600 mm (Alvares et al., 2013; Corrêa et al., 2023). The main geomorphological feature is the Coastal Tablelands (Lopes et al., 2020).

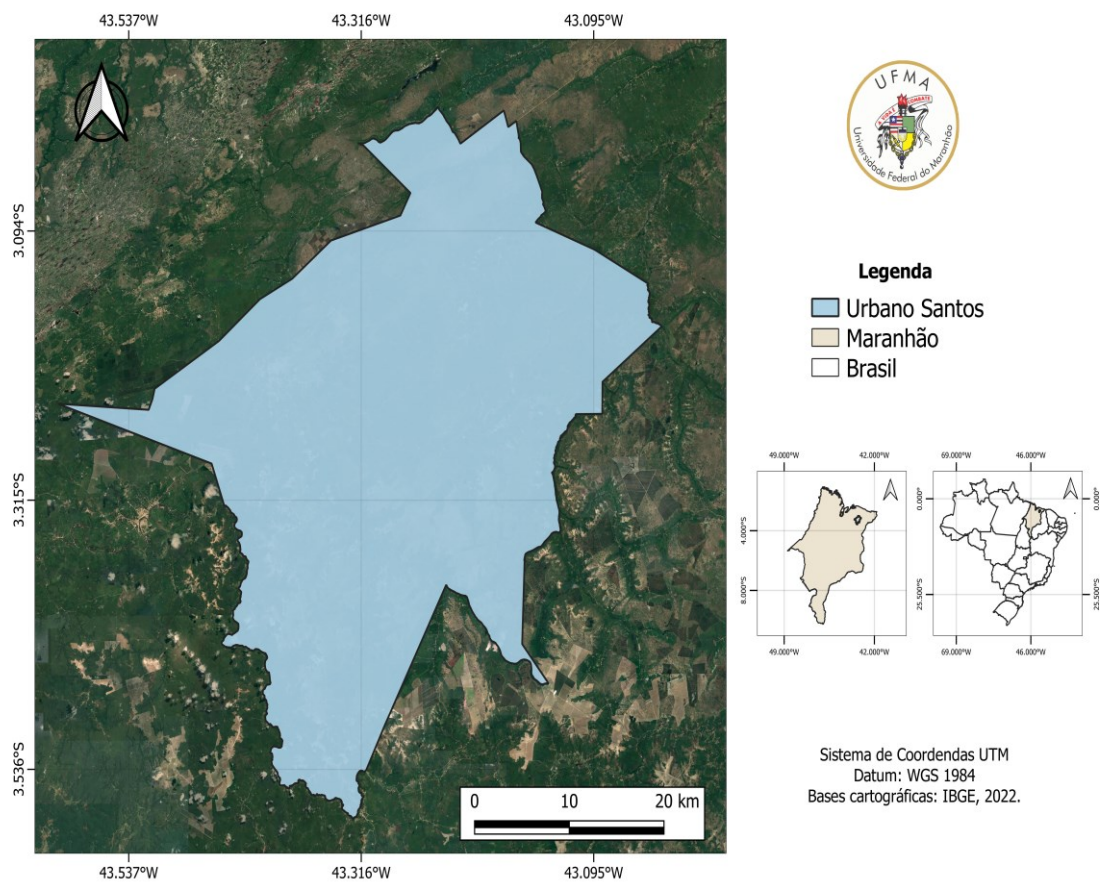


Figure 1. Location of the Municipality of Urbano Santos, Maranhão in Brazil.

This research employed the open-access Landsat image archive in conjunction with the Google Earth Engine cloud computing platform via the MapBiomas Project Collection 7.1 (<https://mapbiomas.org/>). MapBiomas focuses on generating maps for six Brazilian biomes, using a hierarchical system for classifying land use categories that is compatible with both the Food and Agriculture Organization of the United Nations (FAO) (Macdicken, 2015) and the Brazilian Institute of Geography and Statistics (IBGE) (IBGE, 2013).

The dataset used in the study corresponds to the years 1985, 1995, 2005, 2015, and 2021. Consequently, land cover maps for the municipality of Urbano Santos, Maranhão, Brazil, were developed for the years 1995, 2005, 2015, and 2021, spanning a period of 26 years. Five key classes were highlighted for quantification. These thematic maps were generated using geospatial delineation of MapBiomas cartographic products for the region of interest utilizing QGIS software version 3.16.1 (Souza et al., 2020).

The identified land use and cover classes included soy cultivation, temporary crops, urban areas, forest formation, and water bodies. Alongside the cartographic representation of these classes, tables were compiled to display the absolute percentage values relative to the municipality's total area.

## **Results and data**

In 1995, the Forest Formation covered 120,782 hectares, which was virtually the entire land occupation in Urbano Santos (Table 1). Urban Infrastructure accounted for only 0.16% of the territory, equivalent to about 192 hectares. There were no records of soy cultivation or temporary crops. Water bodies totaled 0.14% of the area (175 hectares).

A decade later, in 2005, the Forest Formation remained stable, but Urban Infrastructure grew by 0.10%, reaching 0.26% of the territory. Cultivation of Eucalyptus and soy emerged, occupying small land parcels. The area of water bodies decreased to 0.12% (152 hectares) of the total area.

By 2015, the Forest Formation had reduced to 95.21%, and there was agricultural expansion with Eucalyptus and soy, now occupying 1.68% of the municipality. Temporary Crops rose to 1.83%. Uncontrolled urbanization impacted the landscape dynamics, shrinking the areas of rivers and lakes and increasing Urban Infrastructure to 0.34%.

In 2021, urbanization and infrastructure reached 0.37%. The Forest Formation saw a further reduction of 6.40%, leading to a loss of about 7,729 hectares over 26 years. Water body areas significantly decreased to 0.14% since the beginning of the study. Soy cultivation slightly receded to 1.66%, while Temporary Crops expanded to 2.45%, an increase of 749 hectares of consolidated areas since 2015.

Table 1. Area of each class for supervised classification of Urbano Santos, Maranhão, Brazil.

Classes (in % of total area)	1995	2005	2015	2021
Forestry Training	99.99%	99.99%	95.21%	93.59%
Urban infrastructure	0.16%	0.26%	0.34%	0.37%
Rivers and Lakes	0.14%	0.02%	0.01%	0.00%
Soybean	0.00%	0.01%	1.68%	1.66%
Temporary Crops	0.00%	0.01%	1.83%	2.45%
Classes (in hectares)	1995	2005	2015	2021
Forestry Training	12,0782.00	12,0793.00	5	11,3053.00
Urban infrastructure	192.00	314.00	406.00	443.00
Rivers and Lakes	175.00	23.00	1.00	2.00
Soybean	0.00	11.00	2025.00	2,005.00
Temporary Crops	0.00	11.00	2206.00	2,955.00

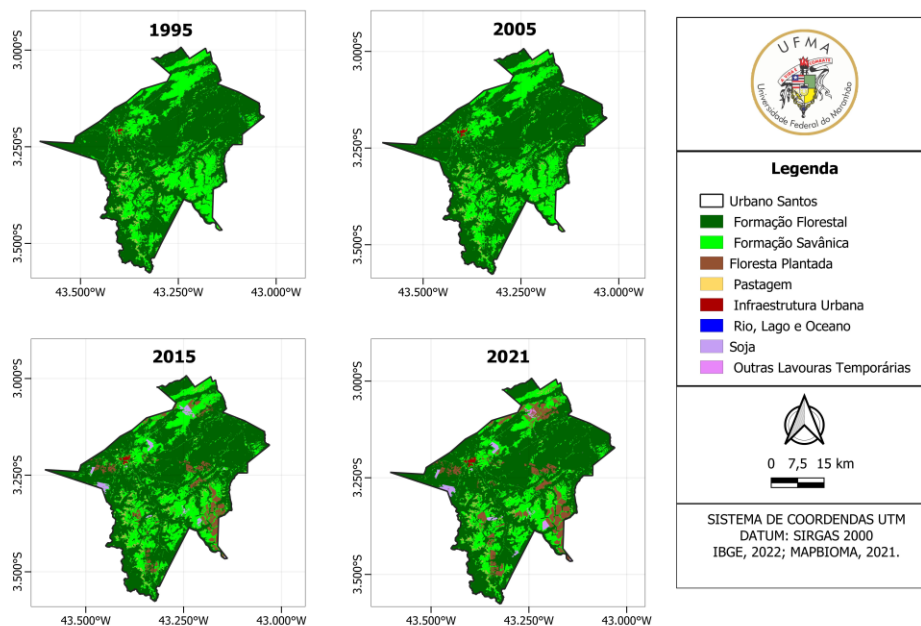


Figure 2. Mapas temáticos de uso e cobertura da terra de Urbano Santos, Maranhão, Brasil.

## **Discussion**

The results indicate significant changes in land use in Urbano Santos. The progressive decline in Forest Formation and water bodies, along with the growth of Urban Infrastructure and cultivation areas, reflects pressure on natural resources. The rapid development of urban infrastructure suggests an expansion of the commercial and industrial sector, as well as agricultural progress, which, although beneficial to the local economy, raises environmental concerns.

The advancement of Eucalyptus and soy plantations denotes a substantial change in the rural landscape and the intensification of agriculture. The increasing and unregulated urbanization along the banks of rivers and lakes heightens environmental and social risks. The reduction of Forest Formation areas, crucial for biodiversity and ecosystem services, signals a warning for conservation policies and sustainable management.

The need for further studies is clear to understand the impact of human actions on land use and occupation and to guide efforts for the region's sustainable development. This research is expected to contribute to the dialogue on environmental management and land use in the Eastern Maranhão mesoregion, promoting practices that minimize environmental impacts and prioritize ecosystem preservation.

## **Conclusion**

The municipality of Urbano Santos - MA has undergone significant transformations in the landscape and land use and cover during the assessed period. A marked state of progressive degradation of Forest Formation vegetation has been noted, occurring alongside a significant expansion of Urban Infrastructure. This phenomenon has paralleled the demographic growth of the local population. Moreover, rivers and lakes have been drastically affected, leading to changes that have negatively impacted the environment, with a substantial reduction in the expanse of these water bodies within the municipal territory. While soy cultivation initially experienced notable growth since its introduction in 2005, there has been a slowdown in its expansion, as evidenced by a 0.02% decrease in cultivated area compared to 2015, indicating potential shifts in the local agricultural landscape. Temporary Crops have seen rapid and seemingly

disorganized growth, encroaching upon previously unused areas, which highlights the opening of new agricultural areas and the suppression of native vegetation.

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