Dynamics of land use and occupation in areas of expansion of soybean cultivation in the Chapadinha microregion, state of Maranhão (Brazil).

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Abstract

This study examines the dynamics of land use and cover in Chapadinha, Maranhão, Brazil, focusing on the years 1985, 2009, and 2021. The region, part of the Cerrado biome, is undergoing significant changes due to agricultural expansion and climate change, exacerbated by a lack of targeted public policies. The study employs geoprocessing techniques to analyze landscape transformations, using data from the MapBiomas Project and GIS software. The results show a decrease in Forest Formation from 84.5% in 1985 to 83.6% in 2021, with a corresponding increase in agricultural and urbanized areas. Soy cultivation, in particular, has expanded significantly, from virtually non-existent in 1985 to covering 2.0% of the area in 2021. This expansion is linked to the migration of southern producers and the arrival of large companies in the region. The study highlights the environmental impacts of these changes, including deforestation, biodiversity loss, and soil degradation. It emphasizes the need for sustainable agricultural practices to mitigate these effects and ensure the preservation of natural resources in Chapadinha.

Research Question and Hypothesis

A significant portion of the state of Maranhão, particularly the municipalities located in the cerrado biome, such as Chapadinha, faces a scenario characterized by social vulnerability and a lack of information regarding the dynamics of land use and cover (Souza et al., 2020; Silva et al., 2021). These areas are increasingly under pressure due to the impacts of climate change and agricultural expansion. The absence of targeted public policies and effective governmental actions exacerbates the situation, raising concerns about the disorderly use of land.

Human interaction with the environment, especially regarding the use of natural resources, results in a series of environmental impacts, such as the reduction of biodiversity and ecosystem services, which can affect rainfall patterns and increase greenhouse gas emissions, among other problems (Fiorese, 2021). In the Chapadinha, there are still significant gaps in knowledge about landscape dynamics. It is possible that changes in land use and occupation are linked to a complex interaction between economic development and environmental preservation, especially in a context of agricultural expansion and social vulnerability.

Given this scenario, we propose the hypothesis that the application of geoprocessing techniques will allow for a detailed analysis of landscape transformations, enabling the identification of patterns and relationships between economic growth and changes in land use and cover. This approach can generate essential data for the planning and environmental management of the municipality, contributing to a more sustainable and balanced development.

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 area encompassed the municipalitie of Chapadinha (Latitude: 3° 44' 26" South, Longitude: 43° 21' 33" West), with a territorial extension of 3247.385 km², (Figure 1). This region, located in the Cerrado Biome, is characterized by the Aw and Aw' climate, according to the Köppen classification, with average annual precipitation of 1400 mm and average air temperature between 23°C and 29°C (Alvares et al., 2013; Corrêa et al., 2023). Additionally, it assumes significant socioeconomic relevance for the state of Maranhão, being recognized for its vast agricultural poles.
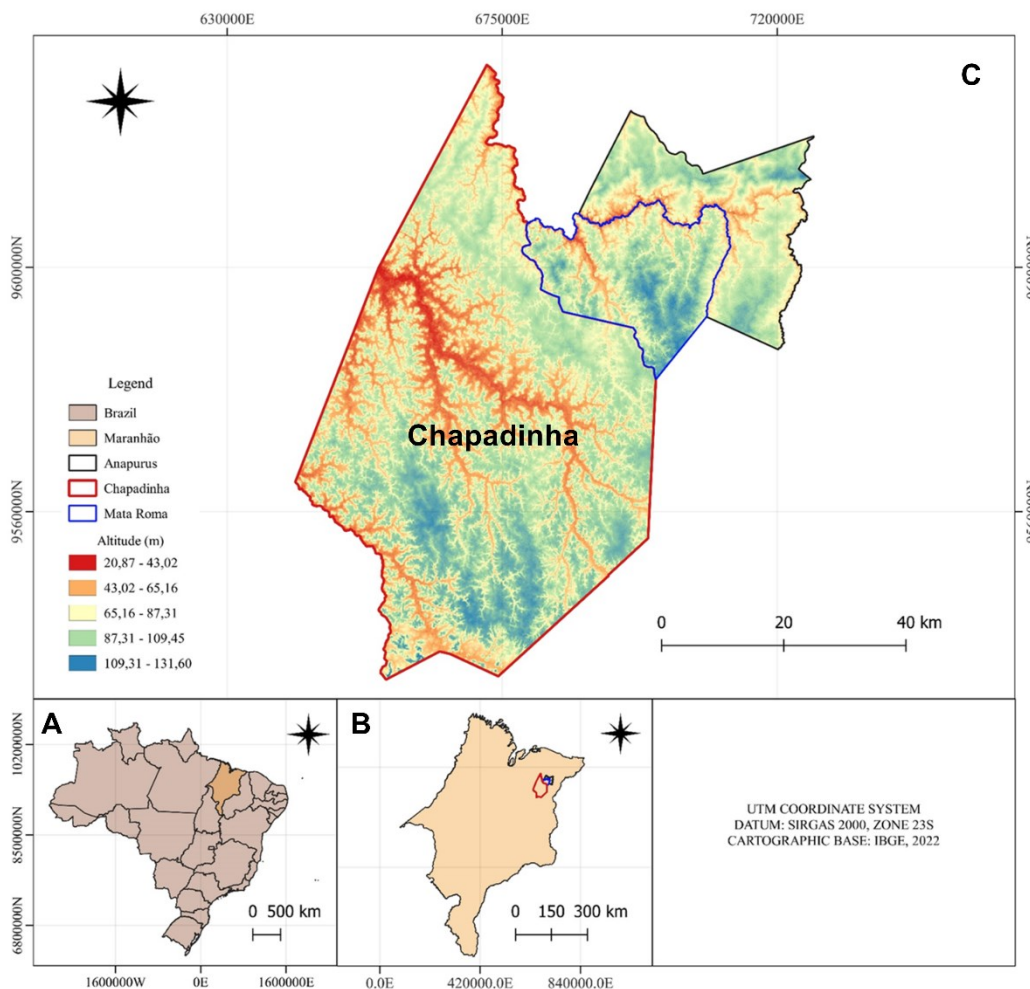
Figure 1. Location and Altitude of the Municipality of Chapadinha and Surrounding Areas in the Context of the State of Maranhão and Brazil: (A) Positioning of Maranhão in Brazil, (B) Detail of Chapadinha in Maranhão, (C) Altitude Map of Chapadinha, Anapurus, and Mata Roma.

The data for this study were obtained from the MapBiomas Project Collection 8, which utilizes the Google Earth Engine (GEE) platform for geospatial analysis, and were processed using Geographic Information System (GIS) software. This research focused on the changes in land use and cover in the municipality of Chapadinha, Maranhão, Brazil, during the years 1985, 2009, and 2021. To achieve this, satellite images in TIFF format with a spatial resolution of 30 meters, pertaining to land use and cover in Maranhão, were downloaded and analyzed. The images were then reprojected and spatially clipped to the boundaries of Chapadinha using QGIS 3.22.4 software, with the municipal boundary shapefile provided by the Brazilian Institute of Geography and Statistics (IBGE).

The data were subsequently categorized and analyzed descriptively using Excel® software. The research team, consisting of members from The Goble Program at the Federal University of Maranhão, Chapadinha Campus, and the State Institute of Maranhão (IEMA), calculated the absolute area values (in km²) and the percentage of each category relative to the total area of the municipality. The main categories analyzed were Forest Formation, Savanna Formation, Pasture, Soy, Non-vegetated Area, and Urbanized Area. This approach allowed for a quantification of the changes in these land use and cover categories over the specified years.

Results and data

In 1985, Forest Formation was the predominant land cover in Chapadinha, constituting 84.5% of the area, as depicted in dark green on Figure 2. Savanna Formation, shown in light green, followed at 14.2%. Pasture (yellow on Figure 2), Non-vegetated Area, and Urbanized Area each occupied a minor fraction of 0.2%, while Soy cultivation (bright violet on Figure 2) was almost non-existent.

By 2009, slight alterations in these percentages were observed. Forest Formation experienced a marginal decline to 83.6%, and Savanna Formation decreased to 12.8%. Conversely, the area allocated to Pasture expanded to 1.7%, and Soy cultivation

made its presence known, covering 0.7% of the area. Both Non-vegetated and Urbanized Areas witnessed a slight increase to 0.3%.

The year 2021 saw a continuation of the declining trend in Forest and Savanna Formations, with their coverage reducing to 83.6% and 11.5%, respectively. In contrast, both Pasture and Soy cultivation areas experienced growth, with Pasture covering 1.8% and Soy cultivation expanding to 2.0% of the municipal area. The Non-vegetated and Urbanized Areas persisted in their growth, each constituting 0.5% of the area.

Table 1. Area of each class for supervised classification of Chapadinha

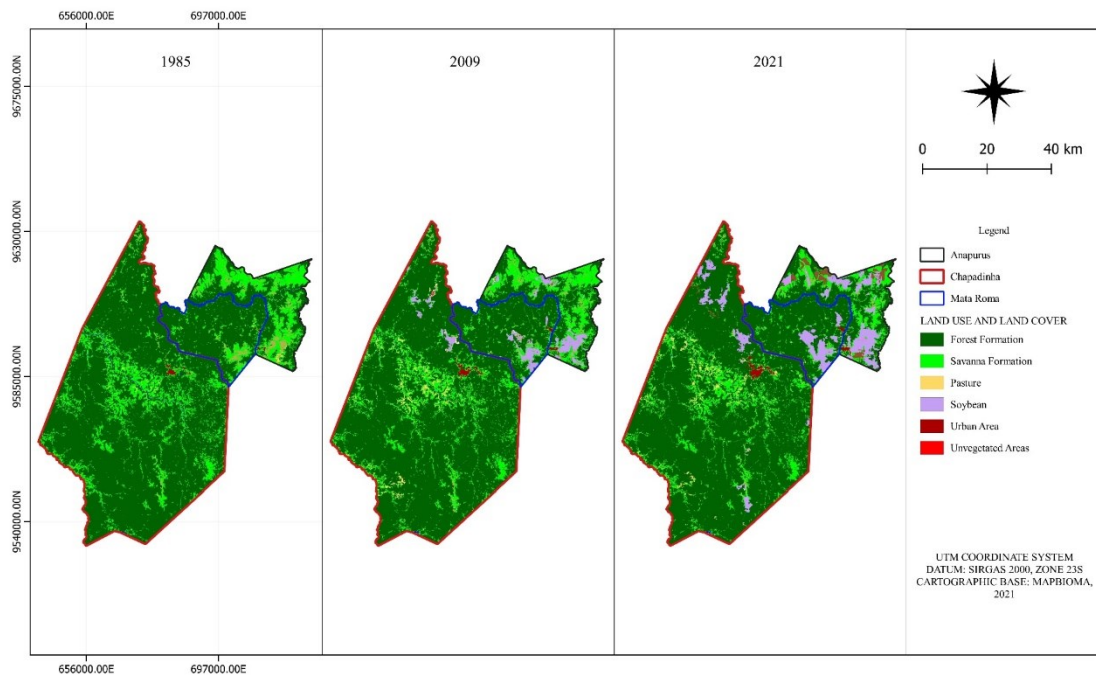| Classes	Areas (%)		
	1985	2009	2021
Florest Formation	84.5%	83.6%	83.6%
Savanna Formation	14.2%	12.8%	11.5%
Pasture	0.2%	1.7%	1.8%
Soybean	0.0%	0.7%	2.0%
Non-vegetated Area	0.2%	0.3%	0.5%
Urbanized Area	0.2%	0.3%	0.5%

Figure 2. Expansion of soybean cultivation in Chapadinha – MA (1985 – 2021)

Discussion

The analysis of land use and cover in the municipality of Chapadinha, Maranhão, Brazil, over the years 1985, 2009, and 2021 reveals several noteworthy trends. These changes highlight a gradual transformation in land use and cover in Chapadinha, with a decrease in natural vegetation and an increase in agricultural and urbanized areas over the 36-year period.

In 1985, the Chapadinha microregion exhibited few impacts from anthropogenic actions on land cover. By 2009, there was a documented increase in pasture area by 1.5% and soybean production by 0.7%. Historical records show that soybean cultivation began to expand into the cities of the Eastern Maranhão mesoregion starting in 1990, due to the migration of southern producers to the municipality of Balsas and the arrival of large national and multinational companies, which includes the city of Chapadinha (Castillo et al., 2021).

From 2009 onwards, there was an increase in soybean cultivation areas in Chapadinha, with a rise of 0.7%. In that year, soybean production reached 6,000 tons. By 2021, there was a significant expansion in the soybean class, with an increase of 2.0% and production of 13,000 tons. Therefore, there is a trend towards the opening of new soybean areas in the Chapadinha microregion, leading to the loss of forested areas.

The expansion of agricultural and livestock production in the Chapadinha microregion, particularly the increase in soybean cultivation, has significant implications for biodiversity and the environment. The conversion of natural ecosystems, such as forests and savannas, into agricultural land leads to the loss of habitat for a wide range of species, resulting in a decline in biodiversity. This loss of biodiversity can disrupt ecosystem services, such as pollination, pest control, and nutrient cycling, which are vital for maintaining agricultural productivity and environmental sustainability.

Conclusion

A significant state of progressive degradation of the Forest Formation vegetation has been observed, accompanying the expansion of infrastructure in Chapadinha and a considerable increase in agricultural and livestock production in the area. This scenario raises concerns about environmental impacts, such as deforestation, biodiversity loss, and soil degradation.

Citations

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