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MAPPING AND GEOSPATIAL DISTRIBUTION OF AÇAÍ TREES (EUTERPE OLERACEA MART) IN THE TOCANTINA-PA AMAZON

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ABSTRACT
The article aims to map and analyze açaí management and planting systems in floodplain and terra firma areas in the Tocantina Amazon, specifically in the municipality of Mocajuba, Pará. To achieve this work, remote sensing and geoprocessing techniques were used, where we sought characterize the spatial and temporal distribution of açaí groves and evaluate changes in the landscape over the years. The application of the spectral indices NDVI (Normalized Difference Vegetation Index), NDWI (Normalized Difference Water Index) and NDBI (Normalized Difference Construction Index) proved to be fundamental to identify areas with greater plant biomass, humidity levels and urban expansion, respectively. The results point to the importance of sustainable management practices to guarantee productivity and environmental preservation. It is concluded that the analysis of spectral indices proved to be effective in detecting variations in vegetation cover and water availability, providing crucial information for the planning and management of plantations in the region.

Keywords: Politics Publishes. Credit. Income. Schooling.

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INTRODUCTION

Açaí (Euterpe oleracea Mart.) and the main non-timber forest product in Pará, is a crop whose dynamics is driven mainly by extractivists and family farmers, characterized by intense soil use (Costa, 2017). The fruit can be found scattered throughout the forest or concentrated in low-lying areas, such as islands and streams, where the soil is wet or humid. Furthermore, it is common to find it in ecotone areas, transition regions influenced by the seasonality of rivers, or planted in plateau areas, located in regions of dry land, higher elevations and with drier soils (Rennó et al., 2008).

Homma (2010) highlight that sustainable management is vital to guarantee the profitability and sustainability of cultivation. It is important to define the appropriate type of management for extractive colonies, aiming to achieve maximum sustainable productivity (PMS) and the economic optimum. The increase in açaí consumption has led to the intensification of cultivation near Belém, reducing the extraction of palm hearts and focusing on the selection of quality fruits for the market. This intensive management, however, can compromise the economic continuity of families in the long term, negatively affecting investments in education, food and hygiene.

Açaí production in the state of Pará, especially in the municipality of Mocajuba, reveals not only the economic importance of this crop, but also the challenges and opportunities associated with its management. With production reaching important figures, açaí cultivation becomes a pillar for the local economy, generating employment and income for thousands of families. However, the growing demand for this fruit, both in the domestic and foreign markets, imposes the need for sustainable management practices that guarantee the preservation of the Amazon ecosystem.

For this study, mapping and analyzing the distribution of permanent crops, such as açaí, in floodplain and terra firma areas in the Amazon region represent significant challenges. The use of advanced remote sensing and geoprocessing techniques can play a fundamental role in the characterization of these plantations, in addition to allowing the assessment of changes in the landscape and crop diversity (Ferreira, 2017) and also geoprocessing, through techniques such as classification of land use and the use of spectral indices (NDVI, NDWI and NDBI) prove to be a crucial tool to help improve these practices.

The Normalized Difference Vegetation Index (NDVI) assesses the health of vegetation, helping to identify areas with greater plant biomass, essential for monitoring the productivity and vigor of açaí groves (Santos, 2019). The Normalized Difference Water Index (NDWI) identifies areas with higher humidity, crucial for the water management of plantations (Oliveira et al., 2020). The Normalized Difference Construction Index (NDBI) detects urbanized areas, avoiding disorderly expansion into cultivated areas (Silva, 2018).

Therefore, the use of geoprocessing, in this research, stands out as an essential tool for monitoring landscape change and açaí cultivation, promoting more sustainable and efficient agriculture. According to Santos (2019), remote sensing allows detailed analysis of large areas, facilitating the identification of cultivation patterns and changes in vegetation cover, which is crucial for the adequate management of açaí plantations. Furthermore, the use of Geographic Information Systems (GIS) makes it possible to create thematic maps that show the distribution of plantations and the density of trees, as observed by Oliveira et al. (2020).These maps are essential for making informed decisions about the management and conservation of cultivated areas. Temporal analysis, according to Silva (2018), reveals trends and patterns of change over time, while spatial modeling, highlighted by Ferreira (2017), helps to predict future land use scenarios. Thus, the integration of these techniques not only improves the management of açaí plantations, but also ensures environmental conservation and long-term sustainability.

These studies are essential for the development of sustainable management and conservation strategies, which encompass sustainable agricultural practices, environmental conservation policies and the promotion of the preservation of natural resources. The objective of the article is to characterize the dimension and spatial distribution of occurrences , as well as evaluating changes in the landscape and cultivars, in addition to mapping and quantifying the use and coverage classes, and comparing with the occurrences of the classes, in the municipalities of Mocajuba, State of Pará, where there is a large occurrence of productive açaí groves.

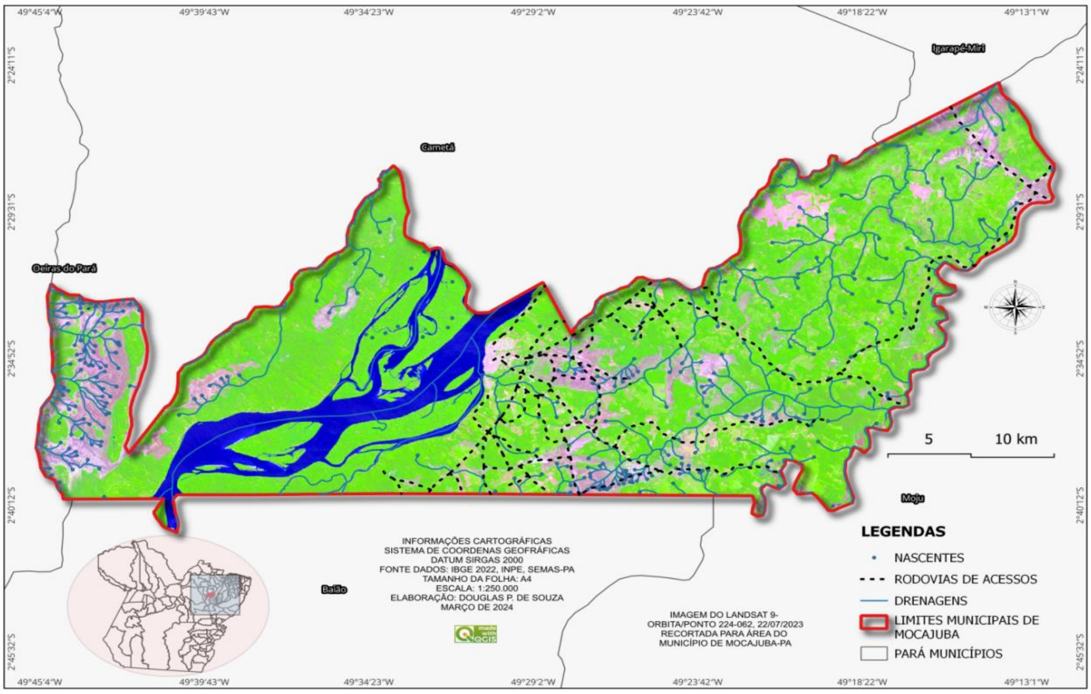
MATERIAL AND METHODS

GEOLOCATION

The area of the present study is the municipality of Mocajuba, in the northeast region of the state of Pará, bordering Baião, Cametá, Igarapé Miri and Mojú, Oeiras do Pará, in lower Tocantins. Mocajuba has an area of 871 km² and an estimated population of 31,530 people and is part of the Tocantins integration region (IBGE, 2020).

Revista
ARACÊ
ISSN: 2358-2472

Figure 01: Location Map of the municipality of Mocajuba, State of Pará.



Source: Authors (2024)

DATA ACQUISITION AND MANIPULATION

- Vector Data

The vector data (.shp) were acquired from the IBGE portal, available at: https://www.ibge.gov.br/ . MENU Geosciences>Territory organization> territorial networks> PA MUNICIPALITIES AND BR FEDERAÇÃO.

The vector information of the folder in a WinRar file PA MUNICIPALITIES, The file with the ".shp" extension is decompressed and allocated in the Qgis Sig environment, being exported to a specific directory, only the geometry of the municipality of Mocajuba

- Raster Data (Images)

For the development of this method, optical images from the LANDSAT 5 E 8-9 Satellite were used (Acquisition via the Glovis portal - American Geological Survey-USGS digital platform).

Landsat 5 and 8-9 are Earth observation satellites. Built, launched and operated by a collaboration of NASA and USGS. Data collection is performed by two main sensors that are adjusted to prescribed bands. The satellite operates in visible light, near infrared; Shortwave infrared to Thermal Infrared (Longwave). Landsat 8 bands are preset to 11 bands in total, differentiated by the wavelength of your view. Each band represents a unique

Revista ARACÊ
ISSN: 2358-2472

piece of the electromagnetic spectrum, defined by wavelength. This enables multispectral imaging that goes beyond the visible light that our eyes can see. It also allows us to combine these bands to see the invisible, make important calculations, or gather just visible light data to produce a natural color image.

Through the GloVis website, which stands for Global Visualization Viewer or Global Viewer, it is possible to search and download satellite images, Landsat 4-5, Landsat 8-9, among other options.

GloVis is one of the oldest viewers known and has been completely redesigned to be agile, uncomplicated and highly intuitive.

Para obter os dados matriciais do sensor Landsat, se faz necessário cadastro na plataforma aplicativo do serviço geológico americano, através do link de acesso *https://glovis.usgs.gov/.* o obtain matrix data from the Landsat sensor, it is necessary to register on the American Geological Service application platform, using the access link https://glovis.usgs.gov/.

The choice of Landsat images for this research becomes an essential tool in monitoring environmental changes over time, offering a unique combination of temporal and spatial resolution that allows for detailed analysis. In the case of the municipality of Mocajuba, this technology plays a crucial role in understanding the transformations that have occurred in its landscape over the years.

After acquisition, the image processing process is carried out with band composition techniques (composition and fusion) in a GIS environment, for this work we used QGIS version 3.28.15 FIRENZE - QUANTUM GIS, 2023 -, RASTER tool > MISCELÂNEA > the bands (B1, B2, B3,B4,B5, for Landsat 5) and bands (B2,B3,B4,B5,B6,B8, for Landsat 8), placing the files in separate bands. And regarding its Radiometric resolution, with regard to pixel information, the source information was preserved, such as the Int16 format (16 Bits) and the change to the SRC SIRGAS 2000 reference system (EPSG: 4674).

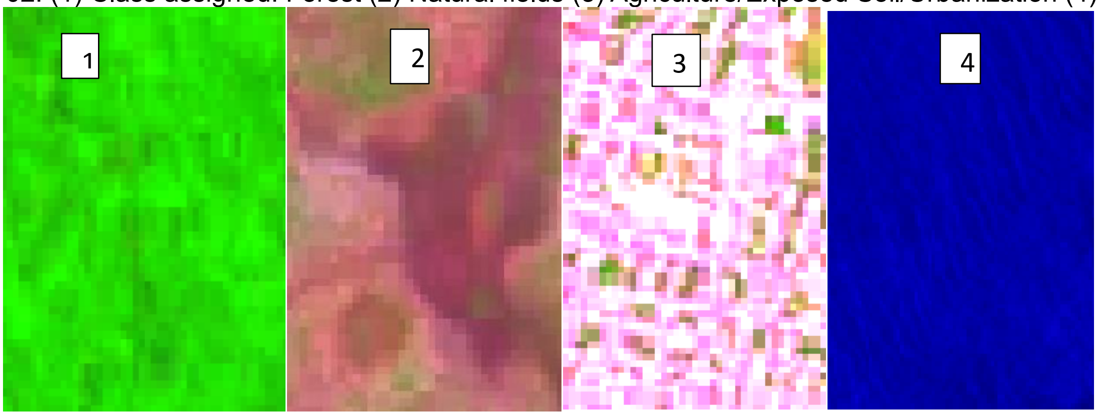
CLASSIFICATION OF LAND USE AND COVERAGE

To classify land use and cover, open data was selected, in Raster and vector format (Shapefile), and the free software QGIS version 3.28.15 FIRENZE - QUANTUM GIS, 2023 was used. To obtain these Classes using QGIS, we sought an internal tool that would provide reasonable results both from the point of view of the targets actually identified and the processing performance. And for each class (Forests, Natural Fields,

Revista ARACÊ
ISSN: 2358-2472

Agriculture/Exposed Soil/Urbanization and Hydrography) 60 samples were collected, vectorized in a new shapefile layer, for each class assigned values (1,2,3,4). Where:

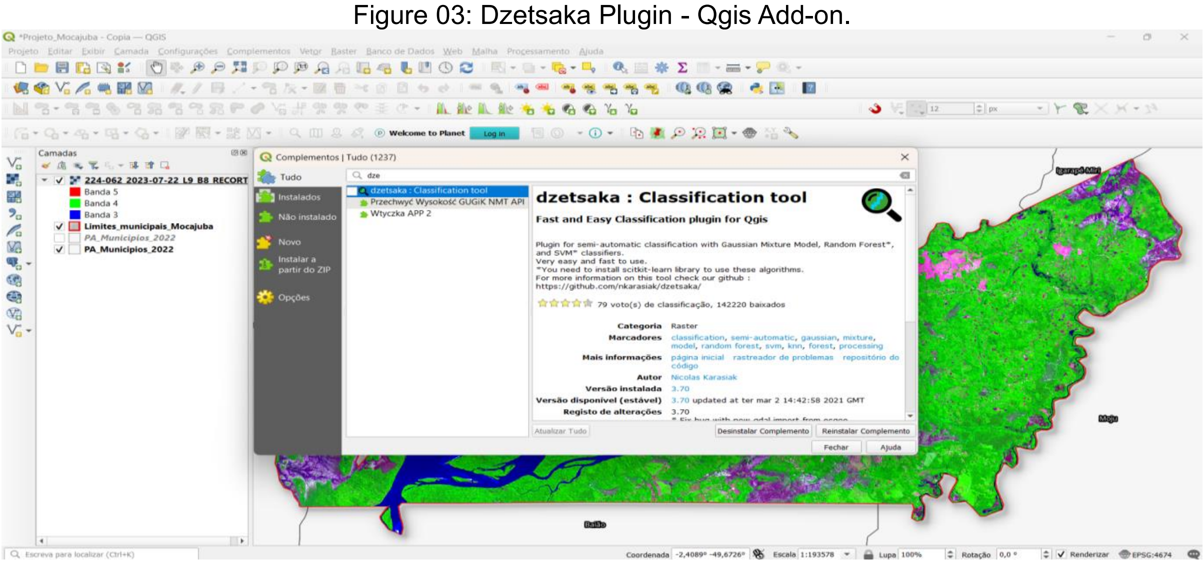
Figure 02: (1) Class assigned: Forest (2) Natural fields (3) Agriculture/Exposed Soil/Urbanization (4) Water



Source: Authors (2024

Therefore, we decided to use the QGIS “Dzetsaka” classification tool, which is a plug-in for semi-automatic classification facilitated using a Gaussian mixture model. When using the tool, it is required to create a layer to obtain a sample of the areas to be classified for each year, which will be used to train the procedure algorithm

Figure 03: Dzetsaka Plugin - Qgis Add-on.



Source: Authors (2024)

APPLICATION OF SPECTRAL INDICES (NDVI, NDWI, NDBI) IN THE RESEARCH CONTEXT

In the context of this research, the spectral indices NDVI (Normalized Difference Vegetation Index), NDWI (Normalized Difference Water Index) and NDBI (Normalized

Revista ARACÊ
ISSN: 2358-2472

Difference Construction Index) play fundamental roles in the characterization and monitoring of açaí groves in floodplain areas and dry land. NDVI is widely used to identify and quantify plant biomass, being especially useful in assessing plant health and detecting changes in plant cover over time (Silva et al., 2018). The application of NDVI will allow the identification of areas with greater vegetation density, assisting in the planning and sustainable management of açaí plantations. On the other hand, NDWI is used to detect the presence of water in vegetation and soil, being an essential tool for monitoring floodplain areas, which are characterized by high levels of humidity (Rocha et al., 2020). NDWI analysis will provide critical information on water availability, contributing to the efficient management of water resources in crop areas.

Furthermore, with regard to the NDVI result, these must present values between -1 and 1, in which indexes close to 1 represent healthy vegetation and values close to -1 demonstrate impacted vegetation or even exposed soil.

To generate NDVI through the LANDSAT satellite image, bands B3 and B4 are used, which correspond to the Red (red) and NIR (near infrared) spectral range.

To generate the NDWI through the Landsat 8-9 satellite image, bands (3 and 5) and (4 and 3) for Landsat 5 were used, which correspond to the spectral range of GREEN (green) and NIR (near infrared).)In the QGIS software we will use the “Raster” tool > “raster calculator” and enter the formula (B2-B4)/(B2+B3) .

The index to be calculated aims to highlight the water bodies that will be recognized through the NDWI index (normalized water difference index), which is based on near-infrared and green reflectance.

- NDBI- Normalized Difference Cumulative Index

  In this way, to recognize the built spaces in the municipality of Mocajuba, the NDBI index (Normalized Difference Built-Up Index; Gao, 1996) will be used, which will act based on the spectral response of these areas, to be obtained between the near infrared bands and mid-infrared, (Zha et al., 2003).

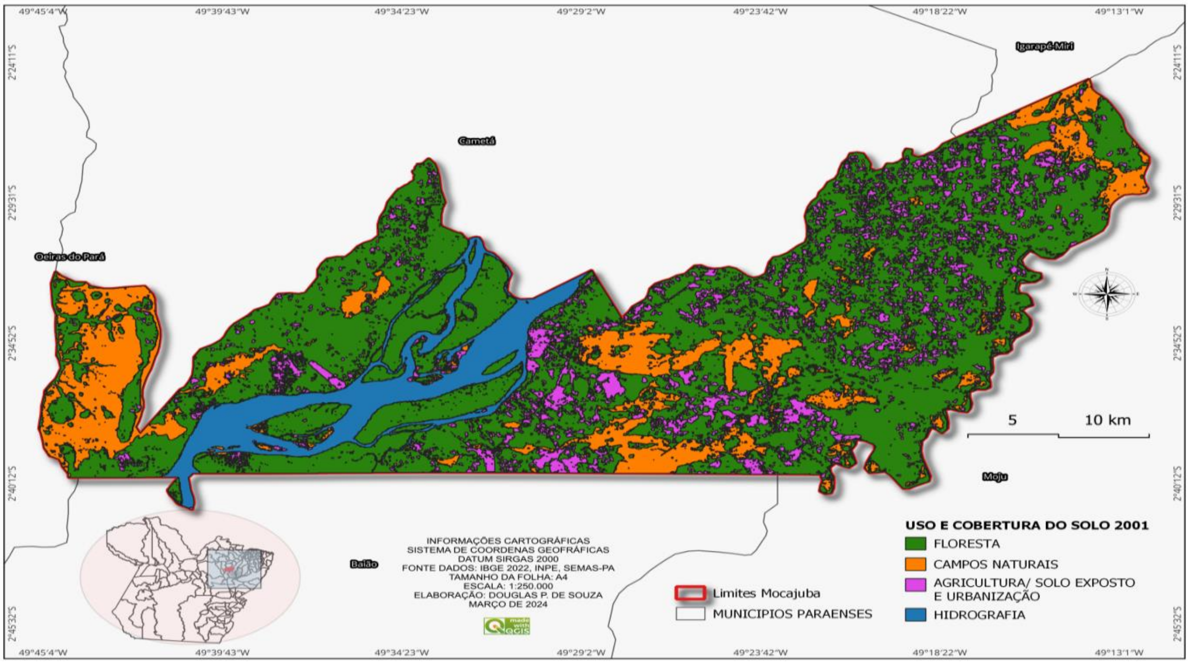
To generate the NDBI through the LANDSAT satellite image, bands B6 and B5 were used for Landsat 8 and 9, B5 and B4- Landsat 5, which correspond to the spectral range of MIR (medium infrared) and NIR (near infrared). In the QGIS software we will use the Raster tool” > “raster calculator” and enter the formula (B6-B5)/(B6+B5).

Revista ARACÊ
ISSN: 2358-2472

RESULTS AND DISCUSSION

The results of the soil use and coverage classifications, together with the spectral indices, prove to be the main point of the research, enhancing and sizing the areas for Açaí cultivation in the Municipality of Mocajuba- PA. Such information can indicate areas with greater water scarcity, more “arid” regions, human occupations in sensitive environments, such as Natural Fields and the entire spatial dynamics of land use. Below are the cartographic maps (figures 04 to 22) with the classifications carried out for each year of the research

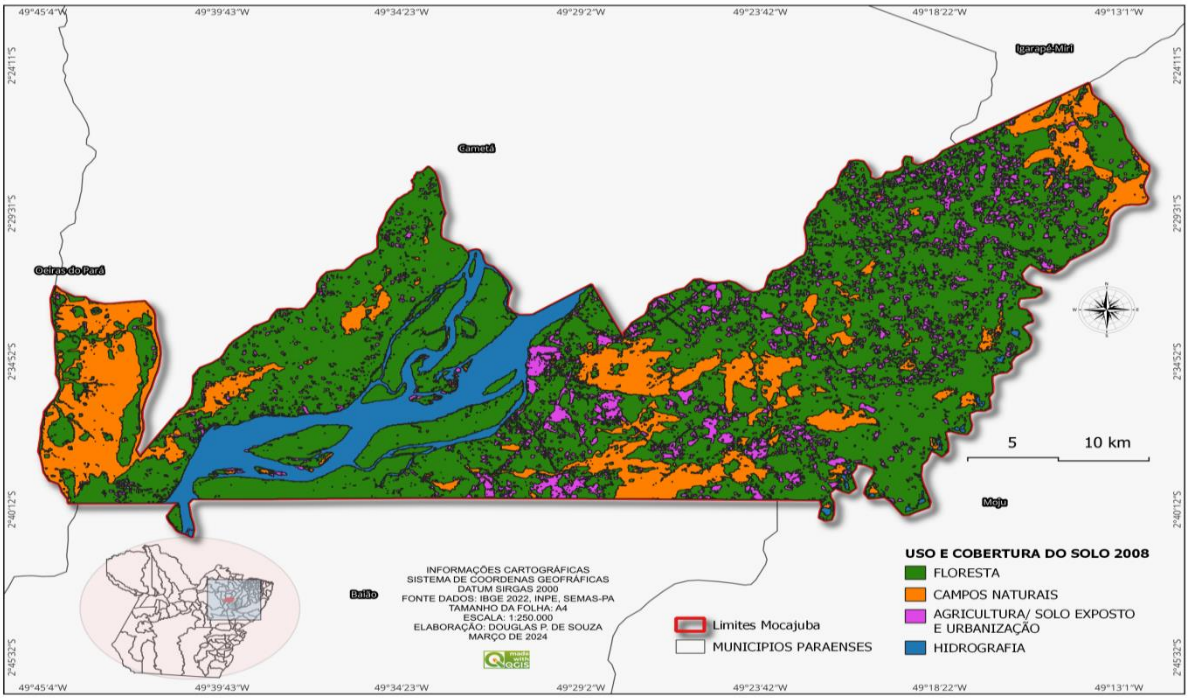
Figure 04: Classification 2001, Mocajuba-Pa.



Source: Douglas Portal 2024

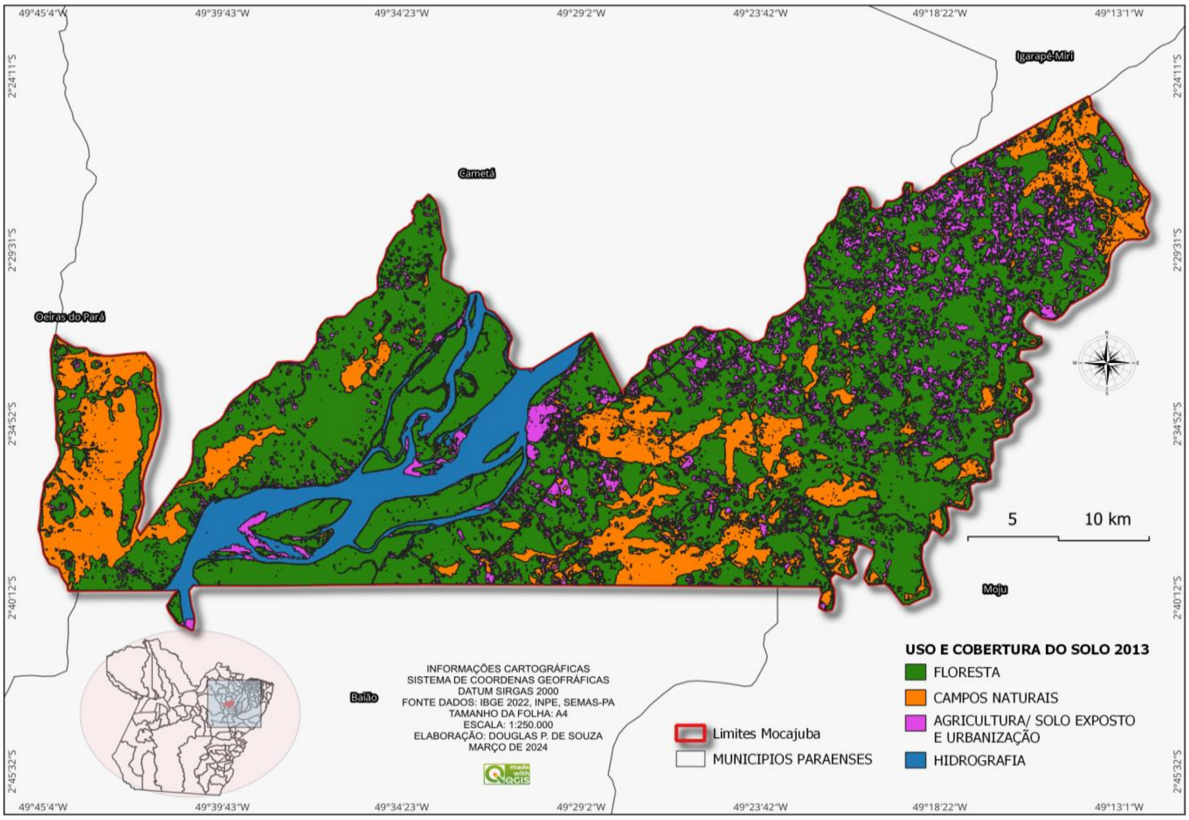
Revista ARACÊ
ISSN: 2358-2472

Figure 05: Classification 2008, Mocajuba-Pa.



Source: Douglas Portal 2024.

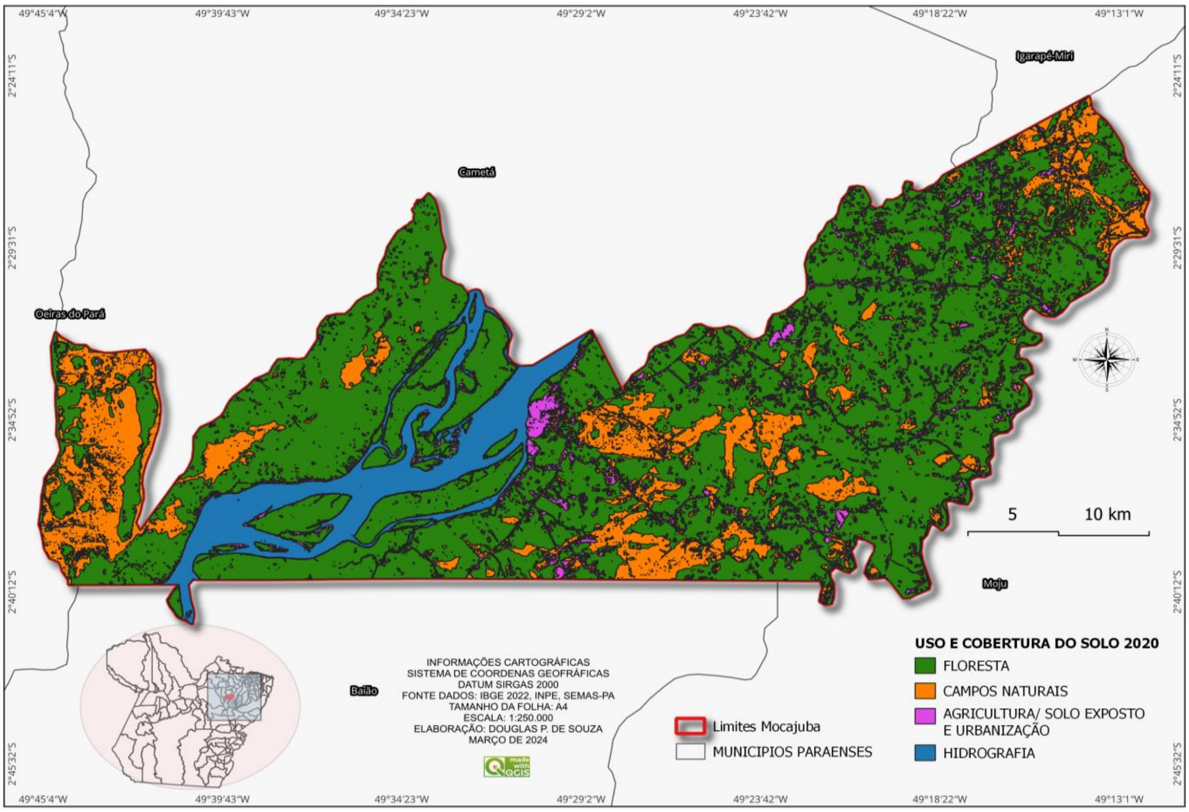
Figure 06: Classification 2013. Mocajuba-Pa.



Source: Douglas Portal 2024.

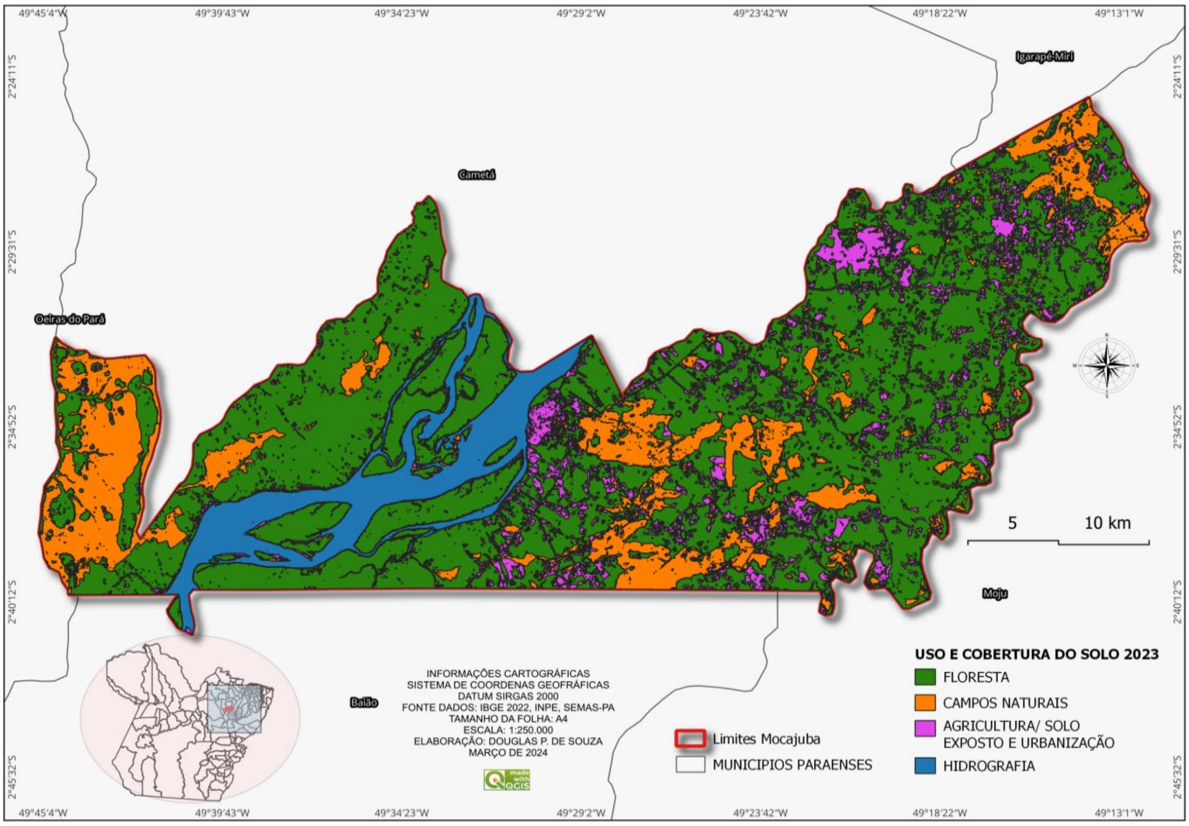
Revista
ARACÊ
ISSN: 2358-2472

Figure 07: 2020 Classification, Mocajuba-Pa



Source: Douglas Portal 2024

Figure 08: Classification 2023, Mocajuba-Pa.



Source: Douglas Portal 2024

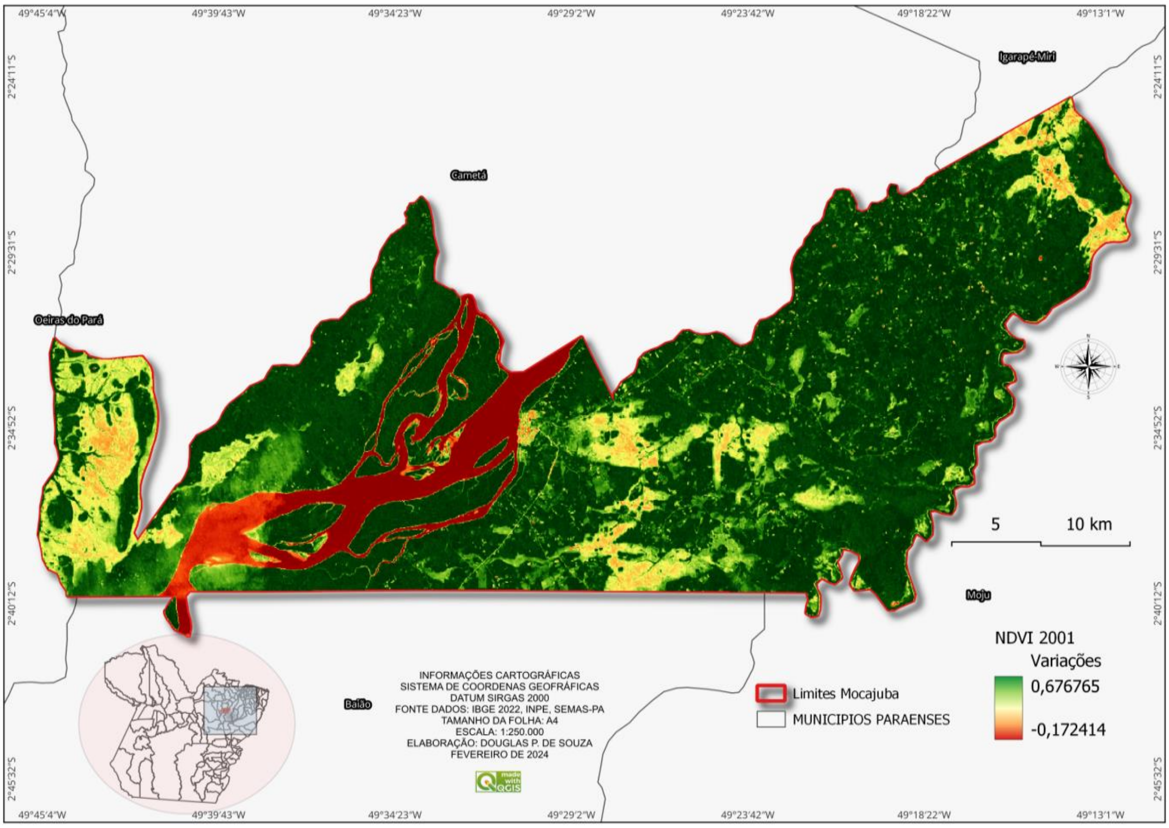
Revista ARACÊ
ISSN: 2358-2472

A pesquisa realizada, focou também na geração de índices espectrais como NDVI (Índice de Vegetação por Diferença Normalizada), NDWI (Índice de Diferença Normalizada de Água) e NDBI (Índice de Diferença Normalizada de Áreas Construídas), além da classificação de uso e cobertura do solo. Utilizando imagens de satélite Landsat, onde foi possível obter resultados sobre a vegetação, corpos d'água e áreas urbanizadas no municipio.

The research carried out also focused on the generation of spectral indices such as NDVI (Normalized Difference Vegetation Index), NDWI (Normalized Difference Water Index) and NDBI (Normalized Difference Index of Built Areas), in addition to the classification of use and coverage. of the soil. Using Landsat satellite images, it was possible to obtain results on vegetation, bodies of water and urbanized areas in the municipality.

NDVI is an important indicator of vegetation health. High NDVI values, which vary between 0.3 and 0.8, indicate dense and healthy vegetation, while lower values may suggest degraded areas or areas with little vegetation cover. In Mocajuba, the NDVI results showed that most of the municipality has healthy vegetation, which is a positive indication for the maintenance of biodiversity and environmental sustainability.

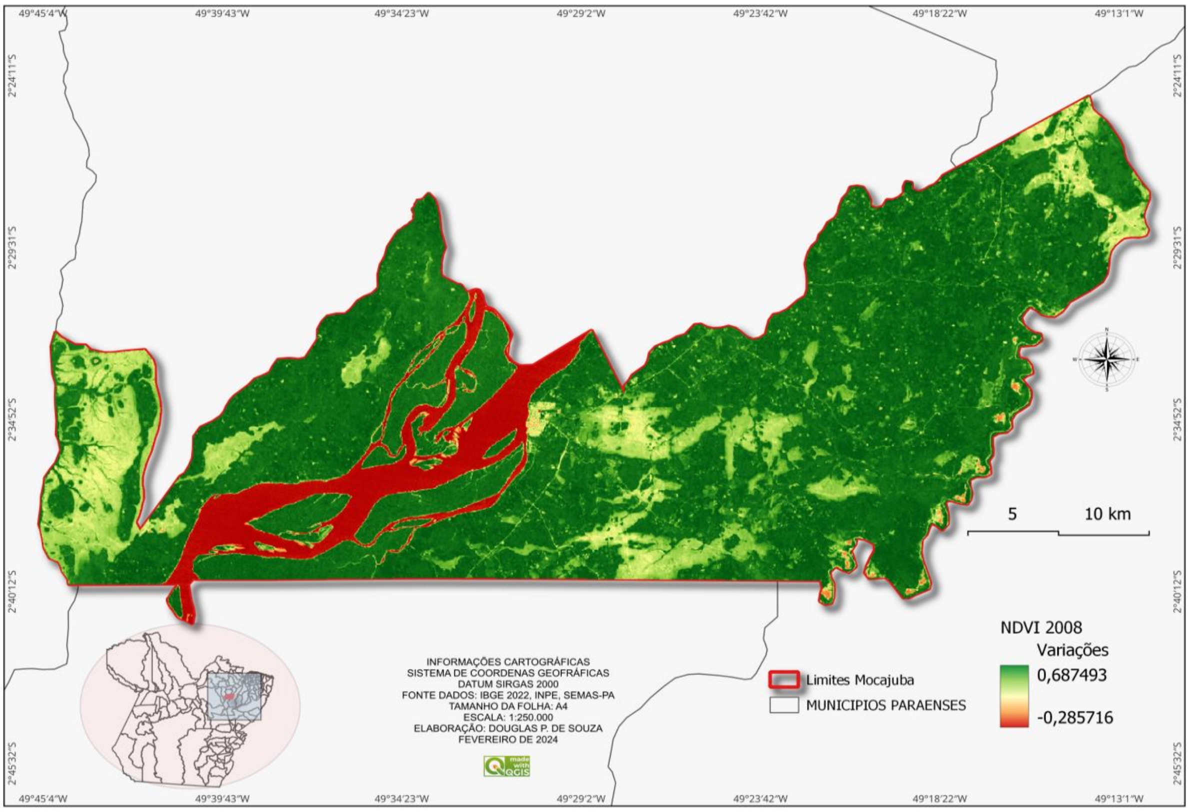
Figure 09: NDVI Index 2001, Mocajuba-Pa.



Source: Douglas Portal 2024

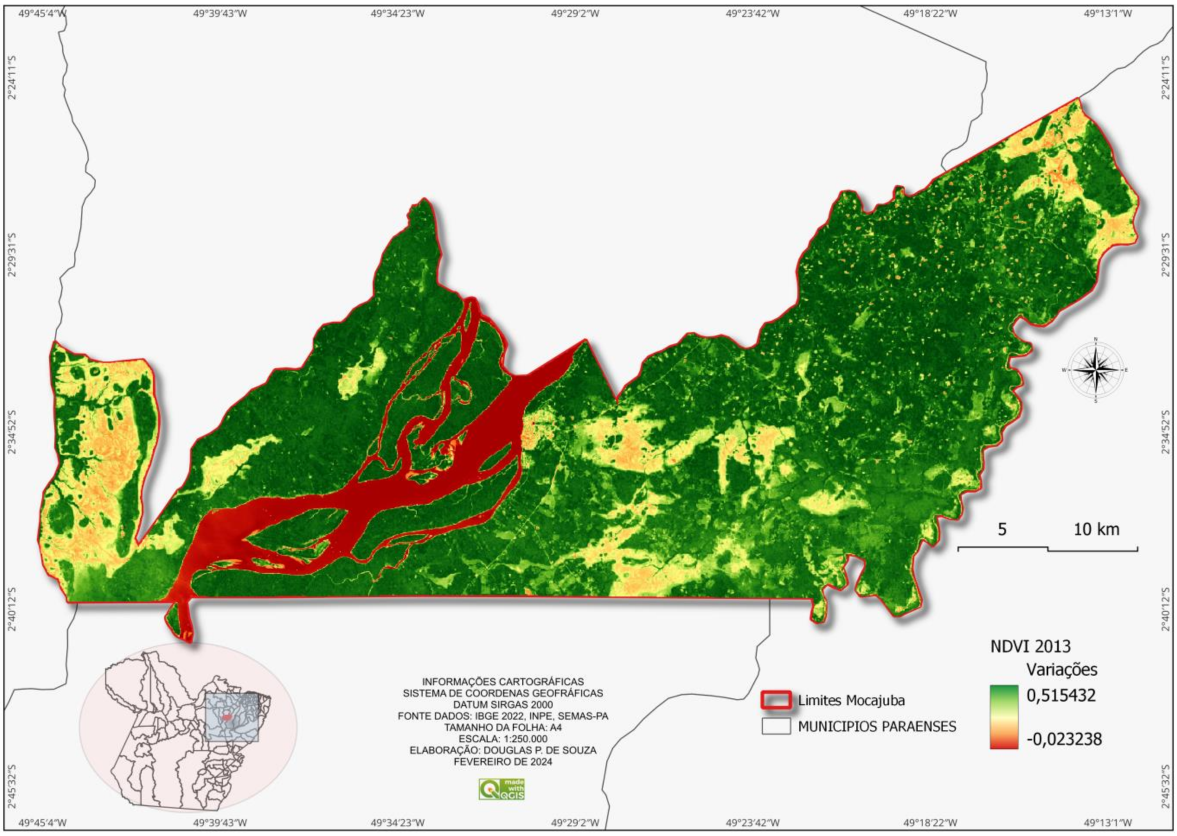
Revista ARACÊ
ISSN: 2358-2472

Figure 10: NDVI Index 2008, Mocajuba-Pa.



Source: Douglas Portal 2024

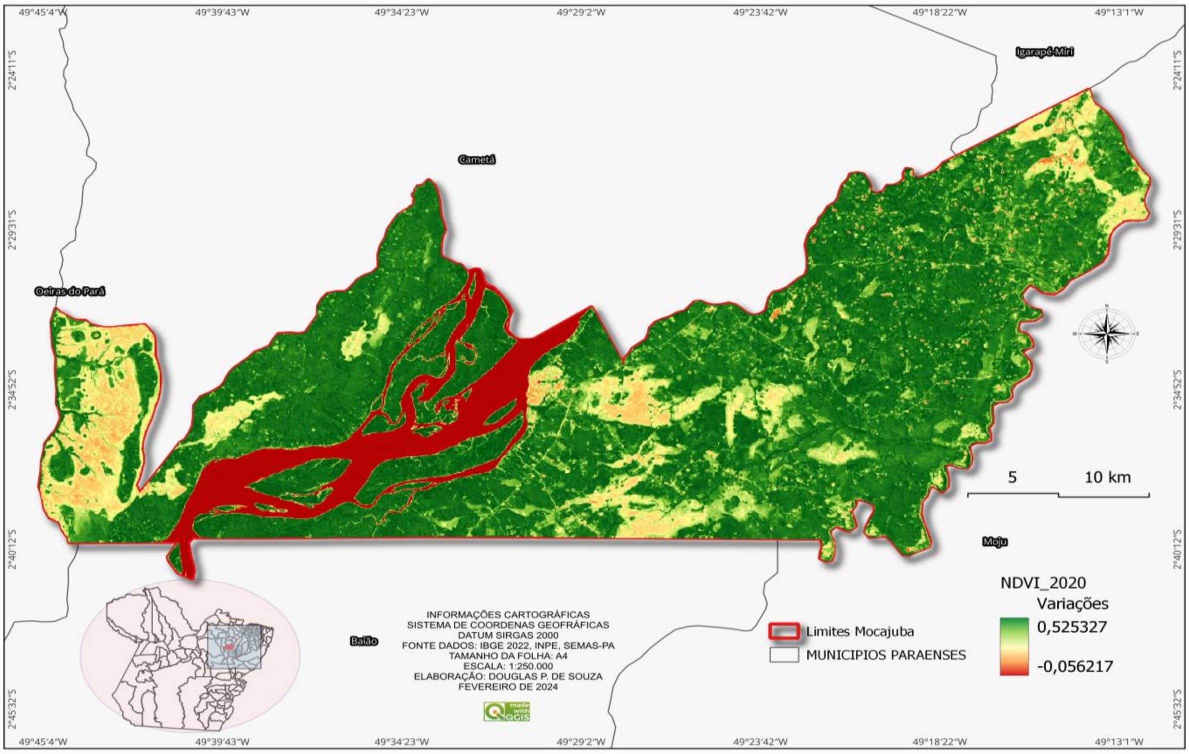
Figure 11: NDVI Index 2013, Mocajuba-Pa



Source: Douglas Portal 2024.

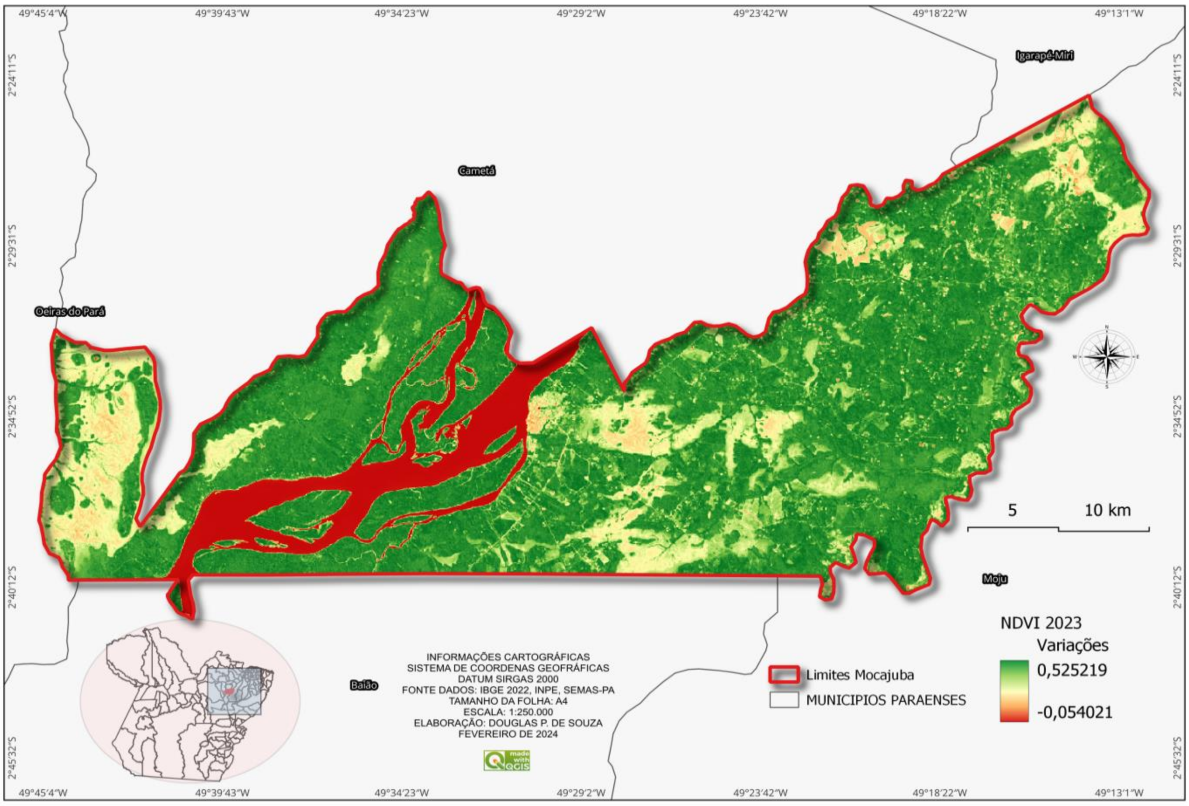
Revista ARACÊ
ISSN: 2358-2472

Figure 12: NDVI Index 2020, Mocajuba-Pa.



Source: Douglas Portal 2024.

Figure 13: NDVI Index 2023, Mocajuba-Pa.

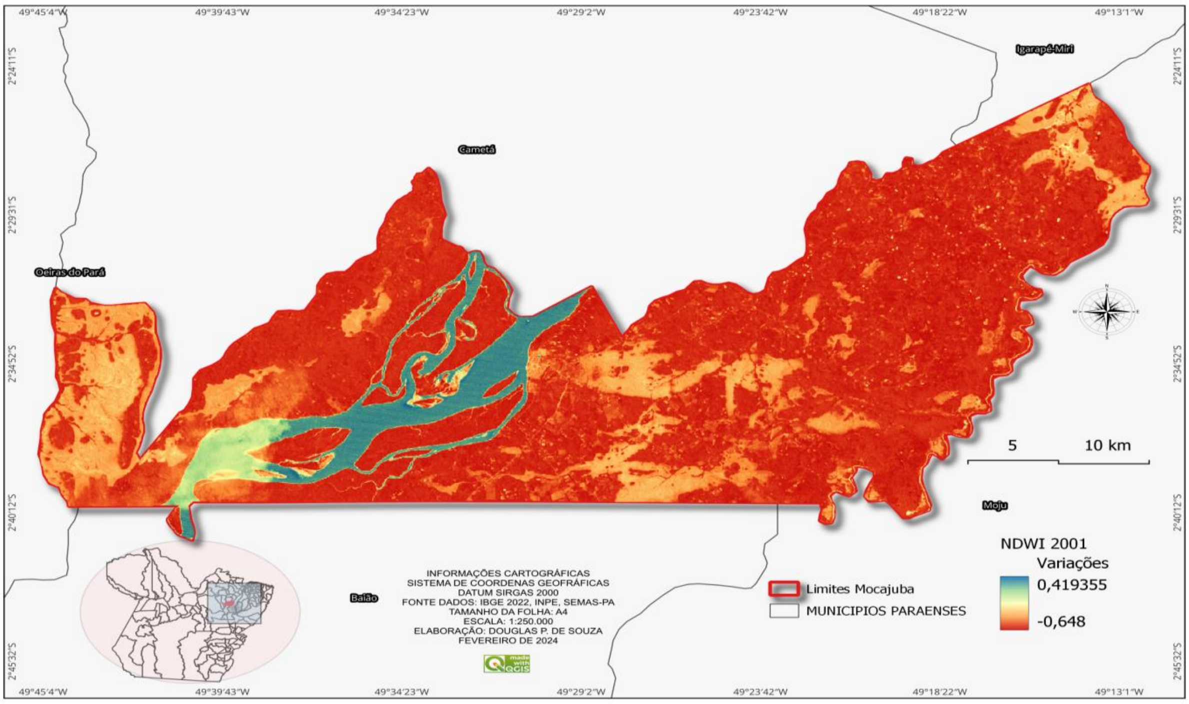


Source: Douglas Portal 2024.

Revista ARACÊ
ISSN: 2358-2472

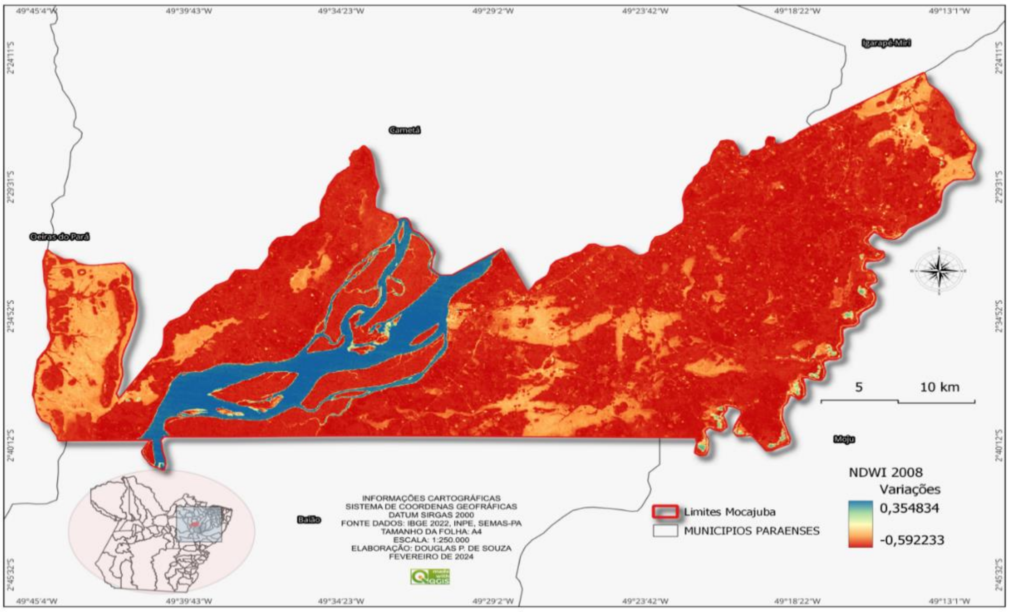
NDWI is used to identify the presence of water on the surface. Positive NDWI values indicate saturated water bodies or soils, while negative values suggest dry areas. The results of the NDWI in Mocajuba clearly identified the rivers, lakes and floodplain areas, which are essential for water resources planning and environmental management in the municipality.

Figure 14: NDWI Index 2001, Mocajuba-Pa



Source: Douglas Portal 2024

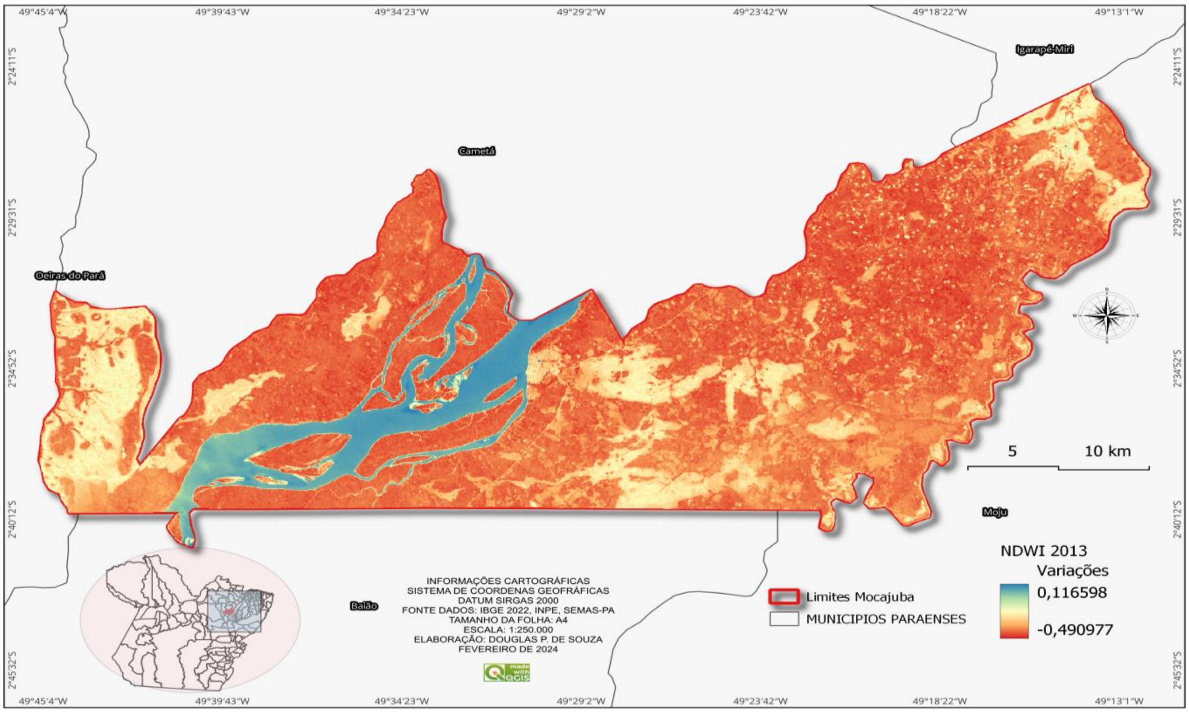
Figura 15: NDWI Index 2008, Mocajuba-Pa



Source: Douglas Portal 2024.

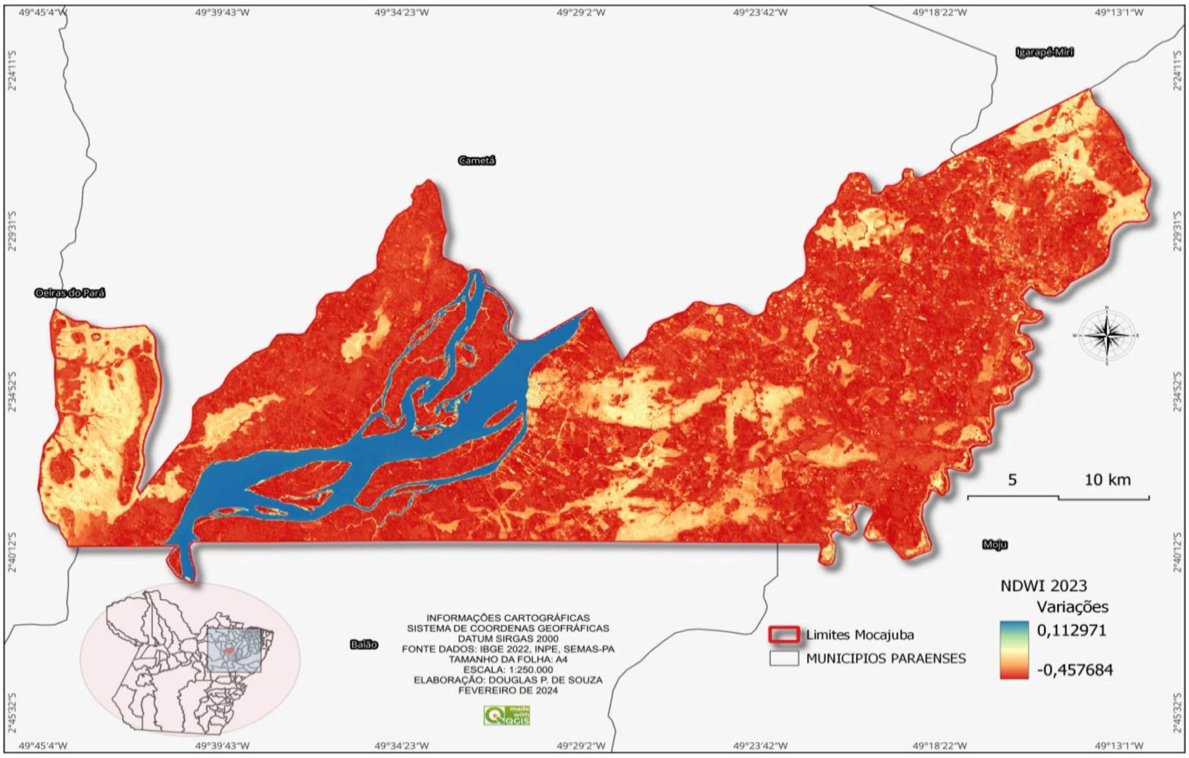
Revista ARACÊ
ISSN: 2358-2472

Figure 16: NDWI Index 2013, Mocajuba-Pa.



Source: Douglas Portal 2024.

Figure 17: NDWI 2023 Index, Mocajuba-Pa.



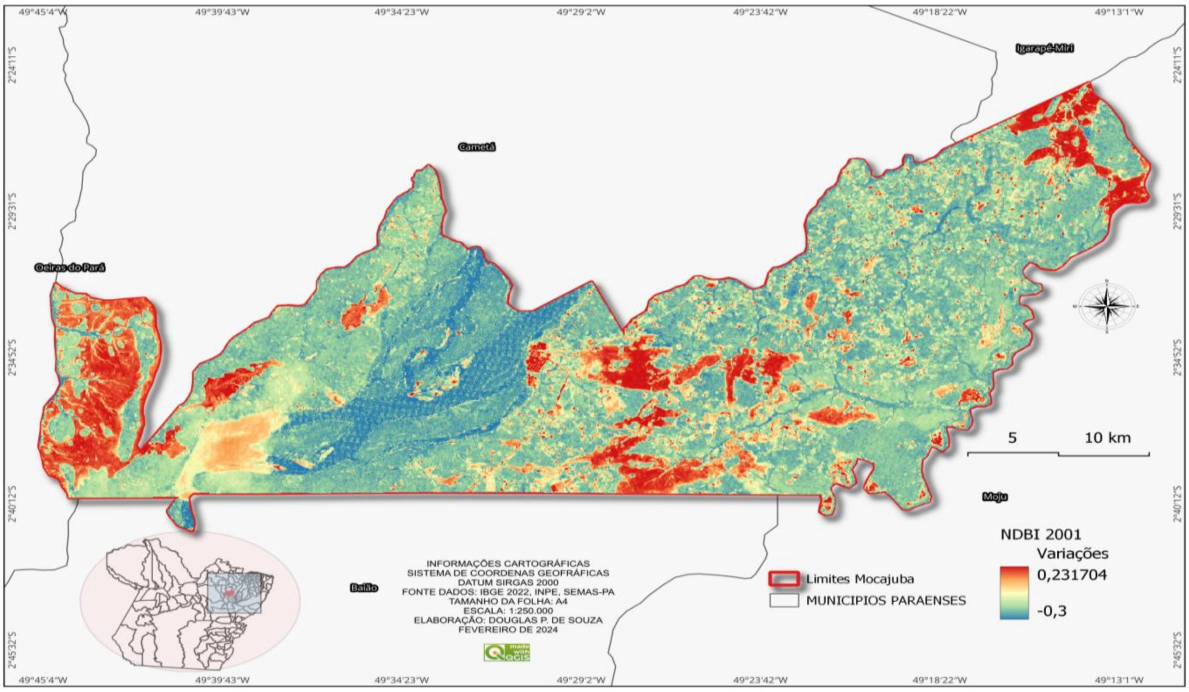
Source: Douglas Portal 2024

O NDBI auxilia na identificação de áreas urbanizadas. Valores elevados de NDBI correspondem a áreas construídas e urbanizadas. Em Mocajuba, os resultados do NDBI

Revista
ARACÊ
ISSN: 2358-2472

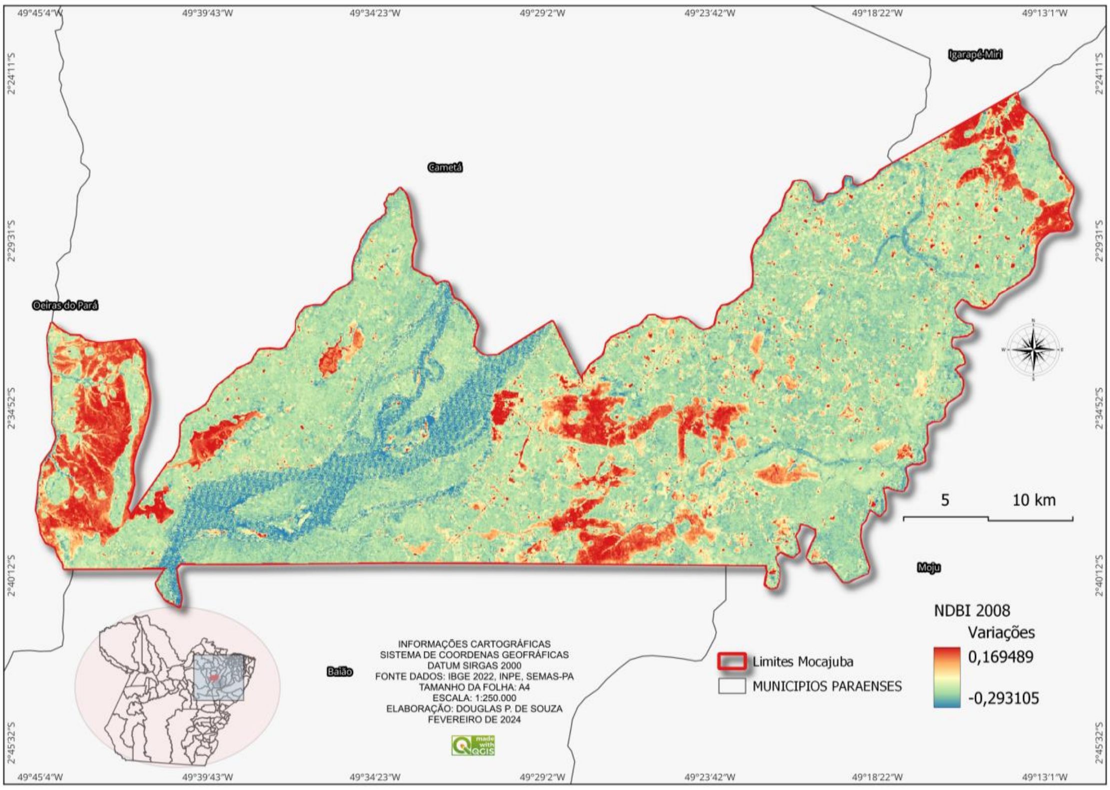
apontaram uma concentração maior de áreas urbanizadas na região central do município, com menor densidade de áreas construídas nas zonas rurais.

Figure 18: NDBI Index 2001, Mocajuba-Pa



Source: Douglas Portal 2024.

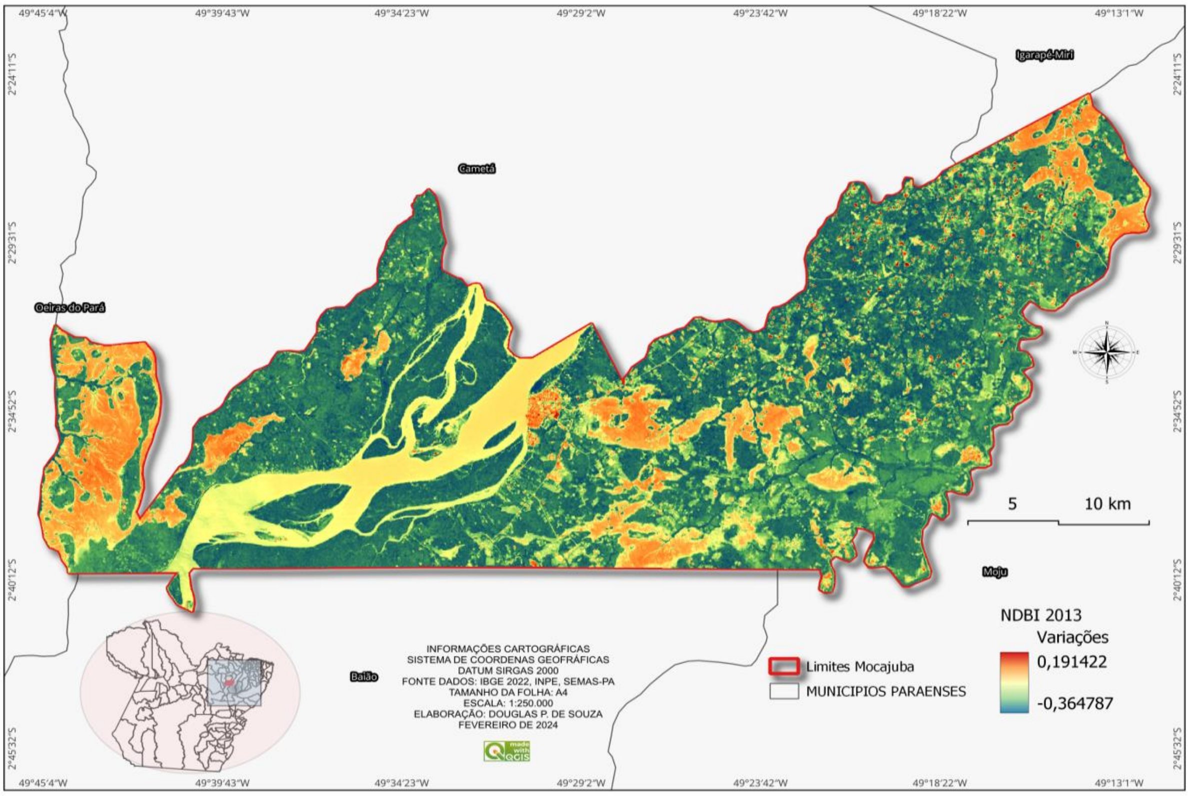
Figure 19: NDBI Index 2008, Mocajuba-Pa.



Source: Douglas Portal 2024.

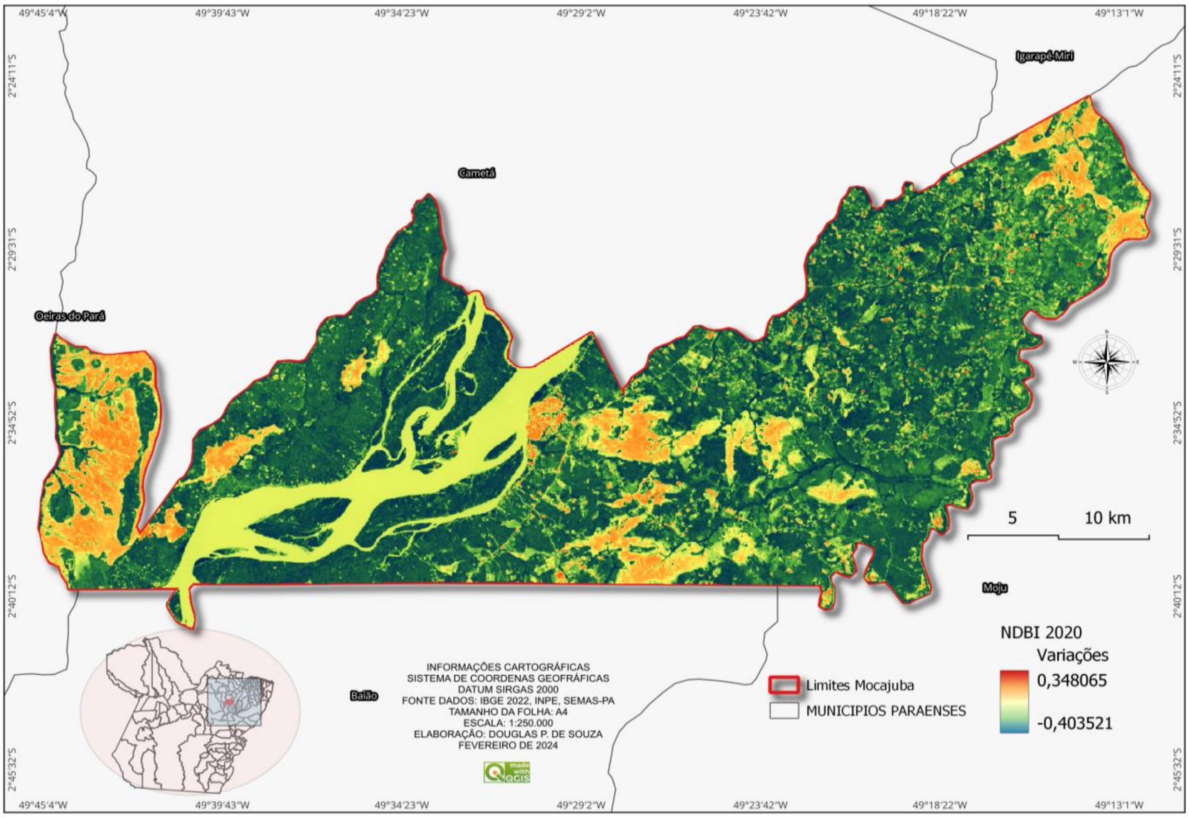
Revista ARACÊ
ISSN: 2358-2472

Figure 20: NDBI Index 2013, Mocajuba-Pa.



Source: Douglas Portal 2024.

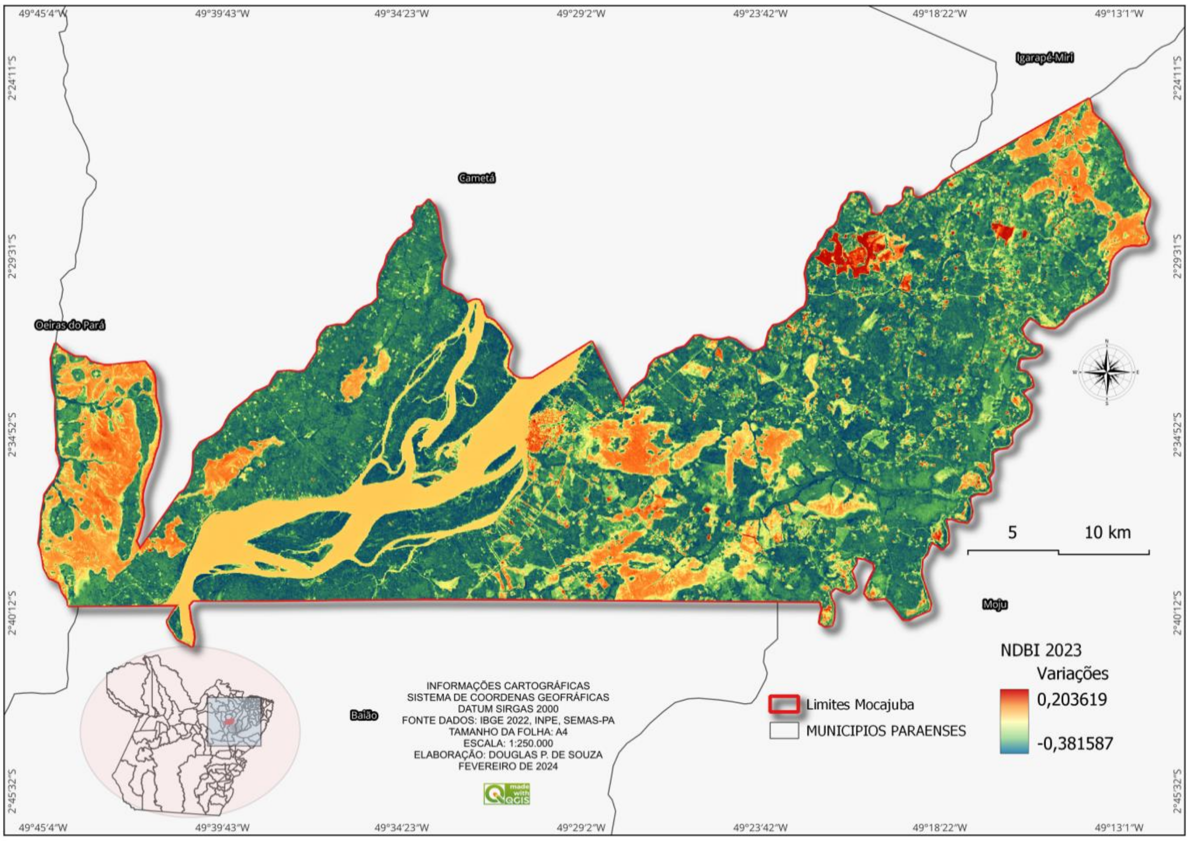
Figure 21: NDBI Index 2020, Mocajuba-Pa.



Source: Douglas Portal 2024.

Revista
ARACÊ
ISSN: 2358-2472

Figure 22: NDBI 2023 Index, Mocajuba-Pa.



Source: Douglas Portal 2024

CONCLUSIONS

This research sought to map and analyze the açaí management and planting system in floodplain and terra firma areas in the Amazon region, focusing on the municipality of Mocajuba-Pará. Using remote sensing and geoprocessing techniques, it was possible to characterize and evaluate changes in the landscape over the years.

In this sense, we conclude that:

- The sustainable management of native açaí groves is extremely important, demonstrating that appropriate agricultural practices are essential to guarantee productivity and environmental preservation;
- The analysis of spectral indices (NDVI, NDWI, NDBI) proved to be effective in identifying areas of greater plant biomass, humidity and urbanization, respectively, providing crucial information for planning and managing plantations;
- Intensive açaí cultivation, despite being an important source of income for local communities, can lead to significant environmental risks, such as loss of biodiversity and soil degradation. Thus, the need for public policies that

Revista ARACÊ
ISSN: 2358-2472

encourage sustainable management practices is reinforced, promoting crop diversification and the conservation of natural resources;

- The use of geotechnologies, such as geoprocessing and remote sensing, proved to be fundamental for the continuous monitoring of cultivated areas and for the assessment of environmental impacts. These tools allow for more efficient and informed management, contributing to the sustainability of açaí cultivation and improving the quality of life of riverside populations;
- The integration of modern spatial analysis techniques with sustainable management practices can provide a more balanced and beneficial açaí production for the environment and society;
- It is necessary that future research could further explore the relationship between the management of açaí groves and other socioeconomic aspects, as well as develop more precise methodologies for quantifying environmental impacts;

Continuing these studies is essential to guarantee the sustainability and resilience of Amazonian ecosystems. However, the research presents some limitations that must be considered, such as:

- ✓ The resolution of the satellite images used may not capture small-scale changes;
- ✓ Climatic and atmospheric factors can influence the results of the indices, even with data normalization, through the Digital Image Processing - PDI techniques applied in the research.

These limitations suggest the need to use high-resolution images, integrate socioeconomic and demographic data, and carry out complementary field studies to obtain a more accurate and systemic analysis and, finally;

- Future research is recommended, using high-resolution satellite images and advanced processing techniques to capture changes on a smaller scale. With these approaches, it will be possible to develop territorial planning policies relevant to production in Mocajuba and initiatives that promote ecosystem management

Revista ARACÊ
ISSN: 2358-2472

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