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O CANAL DO SERTÃO DE ALAGOAS E A EXPANSÃO DA IRRIGAÇÃO EM DELMIRO GOUVEIA E PARICONHA

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1 RESUMO

A transposição das águas do Rio São Francisco tem sido fundamental para o fortalecimento da agricultura irrigada no semiárido nordestino. Em Alagoas, o Canal do Sertão representa a principal infraestrutura hídrica voltada à expansão das atividades agrícolas em regiões de baixa disponibilidade de água. Este estudo teve como objetivo analisar a expansão da agricultura irrigada nos municípios de Delmiro Gouveia e Pariconha, localizados no primeiro trecho do Canal do Sertão Alagoano. Foram utilizados dados de uso e cobertura do solo (LULC) do MapBiomas (2006–2022) e imagens Sentinel-2 (2016–2022), processadas por meio do algoritmo Random Forest. A análise incluiu também dados censitários fornecidos pela SEMARH, revisados e validados por meio de visitas de campo. Os resultados indicaram crescimento da área irrigada entre 2016 e 2022 da ordem de 700%, passando de 50 ha para 350 hectares nesse intervalo, concentrando-se principalmente em uma faixa de até dois quilômetros de cada margem do canal. O modelo Random Forest apresentou desempenho satisfatório na identificação das áreas irrigadas, embora com pequenas confusões em zonas úmidas não agrícolas. Conclui-se que o Canal do Sertão tem contribuído de forma significativa para o avanço da agricultura irrigada e o desenvolvimento produtivo regional.

Palavras-Chave: Agricultura irrigada; Sensoriamento Remoto; Infraestrutura Hídrica.

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THE CANAL OF ALAGOAS SEMIARID AND THE EXPANSION OF IRRIGATION IN DELMIRO GOUVEIA AND PARICONHA

2 ABSTRACT

The diversion of water from the São Francisco River has been fundamental to strengthening irrigated agriculture in the semiarid Northeast region. In Alagoas, the Sertão Canal represents the main water infrastructure for expanding agricultural activities in regions with low water availability. This study aimed to analyze the expansion of irrigated agriculture in the municipalities of Delmiro Gouveia and Pariconha, which are located in the first section of the Sertão Canal in Alagoas. Land use and land cover (LULC) data from MapBiomas (2006–2022) and Sentinel-2 imagery (2016–2022) were used and processed using the random forest algorithm. The analysis also included census data provided by SEMARH, which were reviewed and validated through field visits. The results indicated a 700% increase in the irrigated area between 2016 and 2022, from 50 hectares to 350 hectares during this period, concentrated primarily in a strip of up to two kilometers on each bank of the canal. The random forest model performed satisfactorily in identifying irrigated areas, although with minor confusion in nonagricultural wetlands. It is concluded that the Sertão Canal has contributed significantly to the advancement of irrigated agriculture and regional productive development.

Keywords: Irrigated agriculture; Remote Sensing; Water Infrastructure.

3 INTRODUCTION

The semiarid region of Brazil, which occupies a large part of the state of Alagoas, represents approximately 10% of the country's territory and is characterized by an arid climate and irregular variations in precipitation and is considered one of the most densely populated semiarid regions in the world (Medeiros *et al.*, 2023). The region is home to more than 27 million inhabitants, who depend heavily on local natural resources to guarantee their livelihood and promote socioeconomic development. Its economy is based mainly on agricultural and livestock activities, which have low productivity levels because of adverse climatic conditions (Silva *et al*., 2025).

Given the constraints imposed by the arid climate and water scarcity that characterize the semiarid region of Brazil, it is essential to develop strategies that guarantee the sustainable use of water and promote the improvement of the socioeconomic conditions of the local population (Lindoso *et al.*, 2018). In this scenario, the water resources of the São Francisco River are essential for mitigating the impacts of irregular rainfall and strengthening productive activities in the area (Santos; Ioris, 2024). The combination of the river's water potential with the demands of the semiarid region has enabled the execution of important infrastructure projects, such as the Canal do Sertão Alagoano, which aims to ensure water supply, increase irrigated agriculture, and reduce the socioenvironmental vulnerability of rural populations (Traoré *et al*., 2019; Halder; Das; Basu, 2023).

The canal, when completed, will be approximately 250 km long, starting in the municipality of Delmiro Gouveia and extending toward the Alagoas hinterland

(Government of Alagoas, 2024). Currently, approximately 125 km have been built and are divided into four sections. Section I, completed in 2013, covers the municipalities of Delmiro Gouveia, Pariconha, and Água Branca and is the first to receive water from the São Francisco River (Silva *et al*., 2025). It is expected that this water infrastructure will contribute significantly to strengthening irrigated agriculture, with positive effects on the local economy and regional water security (Bomfim; Nascimento, 2023).

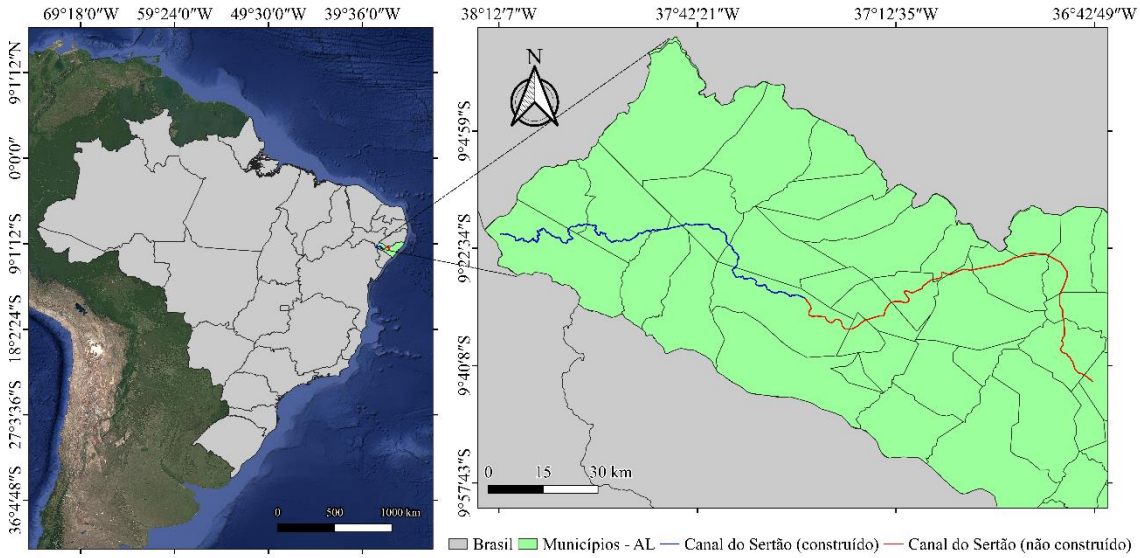
Despite its potential for territorial transformation, studies that systematically evaluate the expansion of irrigated agriculture in the areas influenced by the Sertão Canal are still scarce, especially from the perspective of monitoring land use and land cover (Silva *et al*., 2025). The use of remote sensing and supervised classification techniques has proven effective in detecting changes in agricultural systems and measuring the expansion of irrigated areas (Zurqani). *et al*., 2021; Svoboda *et al*., 2022). Furthermore, the integration of orbital data with institutional databases, such as surveys of irrigators conducted by the Secretariat of Environment and Water Resources of Alagoas (SEMARH), contributes to increasing the reliability of the analyses (Silva *et al.*, 2025).

Given this context, the present study aimed to analyze the expansion of irrigated agriculture in the municipalities of Delmiro Gouveia and Pariconha, which are located in the first section of the Canal do Sertão Alagoano. To this end, data from MapBiomas (2006–2022) and Sentinel-2 images processed with the random forest algorithm (2016–2022) were used, combining remote sensing techniques and machine learning.

4 MATERIALS AND METHODS

When completed, the Alagoas Sertão Canal will be 250 km long. Currently, approximately 125 km have been constructed and are divided into 4 sections (the constructed route is illustrated in blue on the maps of the state of Alagoas; Figure 1). The canal's intake system is located far west of Alagoas in the municipality of Delmiro Gouveia. The water intake is located in the Moxotó dam reservoir. The pumping station is approximately 252 meters above sea level. The water is pumped to the “lung reservoir” at 288 m and then flows down by gravity to the beginning of the canal, which is 286 m deep. The design flow rate is 32 $m^3\ s^{-1}$, with 12 motor-pump sets. However, currently, only one motor-pump set is in operation.

Figure 1. Location map of the Sertão Canal, which comprises the study area in the interior of the state of Alagoas, Northeast Brazil.



Source: The authors (2025).

In this research, the expansion of agriculture is analyzed in the first section. Construction work began in 2002. In 2013, Section I, corresponding to the first 45 km, was completed, extending from the water intake in Delmiro Gouveia to Pariconha and Água Branca.

The methodology for generating land use and land cover maps (LULC) consisted of the steps of data acquisition, processing, analysis, and validation. Initially, data from MapBiomas and Sentinel-2 images were used, followed by supervised classification with the random forest algorithm. Next, the classified areas were quantified, validated, and statistically analyzed. Census data from irrigators provided by SEMARH were also processed, removing duplicates and generating statistics. Finally, the results were validated through different approaches, including visual inspection, in situ validation with visits to agricultural areas, and comparison with census data.

A line shapefile was used to represent the entire length of the already constructed section of the Alagoas Sertão Canal, available on the website "Alagoas em Dados e Informações" (https://dados.al.gov.br/; accessed on March 19, 2025). An individual file was subsequently generated for the first section, defined on the basis of the canal's layout. The section lengths were delimited on the basis of official data published by the state government (https://parcerias.al.gov.br/projeto-canal-do-sertao/; accessed on March 19, 2025). Using the line shapefile as a reference, buffers with a radius of 5 km were created on each side of the canal using the buffer tool of the QGIS software (version 3.30). This approach aimed to delimit the canal's area of influence.

Land use and land cover maps were initially obtained using a classification methodology based on data provided by the MapBiomas platform and processed in the GEE interface. MapBiomas data are derived from Landsat-5/TM and Landsat-8/OLI sensor images, with a spatial resolution of 30 meters (Silva *et al.*, 2024). For this study, Collection 8.0 of MapBiomas Brazil, which offers 38 land use and land cover classes and subclasses, was used. LULC maps were created for the period from 2006 to 2022, covering the classes Water, Forest, Non-Vegeted Area, Land Use Mosaic, Pasture, and Agriculture. The areas corresponding to

each class were quantified in hectares from the extraction of spatial data from raster files using QGIS software. The information was subsequently converted to XLSX format and organized into tables, allowing for the analysis of territorial transformations that occurred throughout the evaluated period.

The second stage of the study consisted of generating maps using the random forest classification model, which is based on mosaics of Sentinel-2 satellite images from 2016 to 2022. Images from the months of October to December were selected, which are months within the region's dry season (i.e., August to February). The mosaics were created on the GEE platform (https://earthengine.google.com/) using a JavaScript script and the time series of Sentinel-2 images available in the GEE database. To minimize cloud interference in the orbital images and identify irrigated agricultural areas, quality filters were applied to select images with the lowest percentage of cloud cover in the study area. Thus, mosaics were generated for the months of October to December of each year, covering the entire length of the canal.

Supervised classification was performed using the Python programming language, integrating libraries specialized in geospatial data manipulation and machine learning, such as rasterio, geopandas, numpy, and scikit-learn (Kavzoglu; Bilucan, 2023). The random forest model was trained with 100 decision trees and a random seed to ensure the reproducibility of the results. During training, the classifier learned to differentiate LULC classes on the basis of the spectral values of the pixel bands. After training, the classification was applied to the complete image, generating supervised LULC maps for each year. The resulting classifications were saved in raster files in TIFF format. The model's performance was evaluated using the following metrics: accuracy, recall, and F1 score.

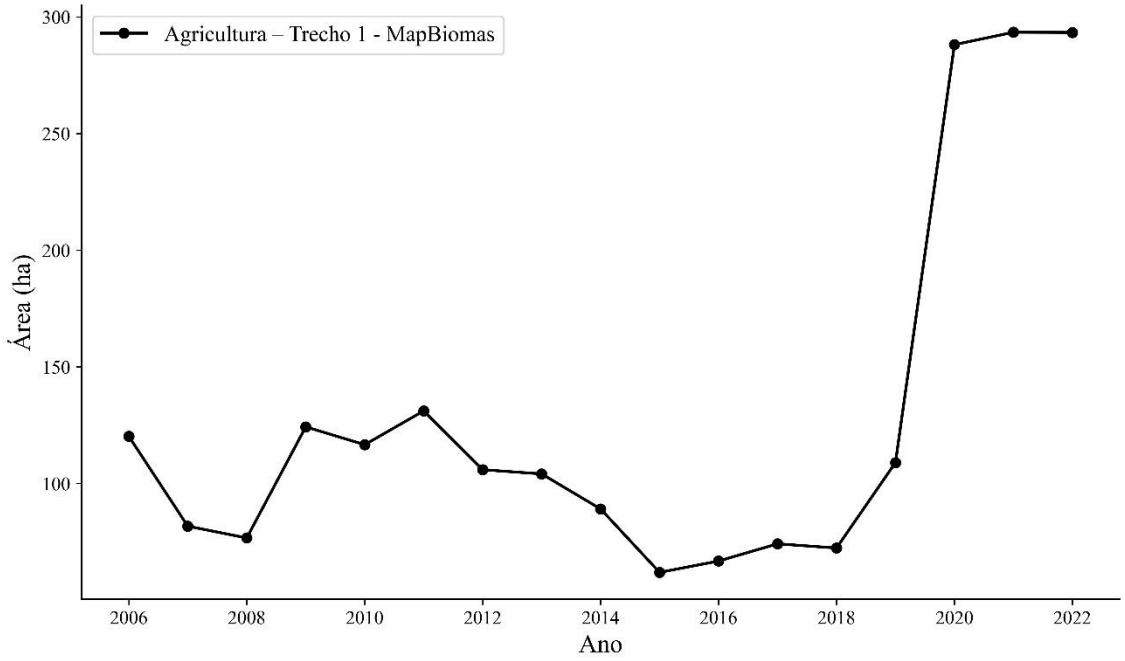
In situ survey data from irrigated areas were used to validate the findings obtained from aerial imagery. This was achieved using a database of water rights granted for the canal and a database of water intake points along the canal. The data were provided by the Secretariat of the Environment and Water Resources (SEMARH) of the state government of Alagoas. Between 2014 and 2023, SEMARH conducted aerial surveys of water intakes and a census of irrigators. An aerial survey was carried out using an unmanned aerial vehicle (UAV) along 110 km of the canal to identify users on the basis of the location of water intake points, i.e., the presence of siphons and/or installed pumps.

The data provided for this study were processed to remove duplicate information. Situations where the same producer had more than one process for the same location and/or irrigated area, even in different years, were excluded. To expedite this process, a Python code was developed to check the Excel spreadsheet and eliminate duplicate information regarding owner names, latitudes, and longitudes. After all the data were processed, they were used to generate the graphs presented in this work.

5 RESULTS AND DISCUSSION

MapBiomas shows a distinct behavior in relation to the SEMARH data and the random forest model, indicating a sharp decrease in agricultural area between 2012 and 2018, precisely during the period in which agricultural growth was expected because of the construction of the Canal do Sertão (Figure 2).

Figure 2. Annual evolution of the agricultural area (ha) within a 5 km radius on each side of section I of the Sertão Canal, according to data obtained from MapBiomas for the period 2006 to 2022.

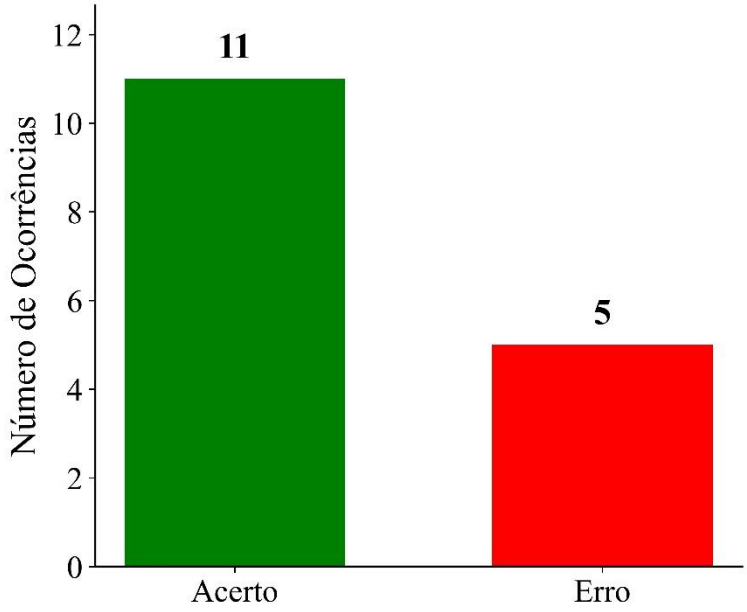


Source: The authors (2025).

However, it is important to highlight that MapBiomas does not specifically distinguish irrigated agricultural areas but rather agriculture areas in general on the basis of the annual average of the values of each pixel. In regions such as the Sertão of Alagoas, where agricultural activity occurs in short and specific periods of the year, this methodology presents significant limitations. The use of annual composites tends to lead to the underestimation of seasonal agricultural areas, making accurate identification of the zones that are actually cultivated and irrigated difficult.

Field visits were conducted along the first stretch of the Sertão Canal, with the aim of contacting producers located in areas classified as irrigated by the random forest model. Visits to various randomly selected areas were limited by the impossibility of accessing private property; thus, only points where farmers authorized entry could be validated. The model presented errors at five points in this first stretch (Figure 3). However, these errors occurred mainly in areas farther from the canal, where the model tends to confuse lowland regions, which maintain green vegetation because of moisture accumulation, with effectively irrigated areas. The eleven properties correctly identified as irrigated were located near the canal banks, suggesting that the area of influence of the Sertão Canal extends approximately two kilometers from its banks.

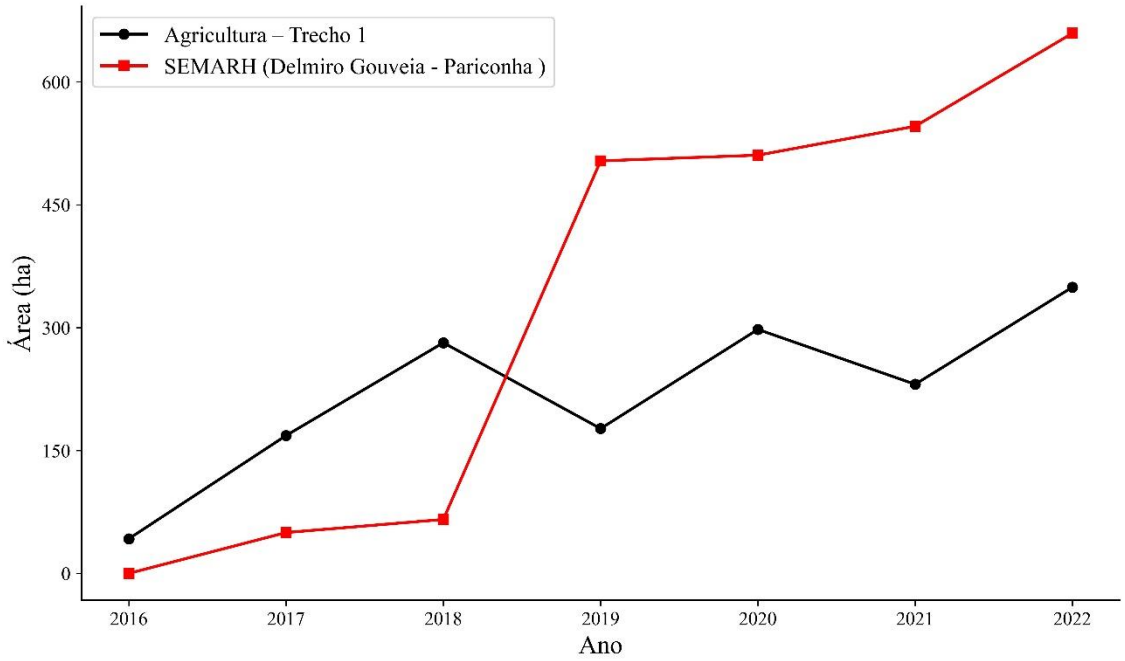
Figure 3. Validation of the random forest model within a 5 km radius on each side of the canal bank in section I based on field visits.



Source: The authors (2025).

Considering the findings regarding the area of influence of the Sertão Canal, the extent of irrigated agriculture was quantified within a two-kilometer radius on each side of the banks. Both the irrigated area data obtained by the model and the records from the SEMARH irrigator census indicate significant growth in the irrigated area in this section of the canal between 2016 and 2022 (Figure 4).

Figure 4. Annual evolution of the irrigated area (ha) in Section I, according to data obtained from the random forest model and census data from SEMARH for the cities of Delmiro Gouveia and Pariconha (Cities that deliver Section I of the canal), for the period from 2016 to 2022.



Source: The authors (2025).

This increase may be directly related to the presence of the Sertão Canal, which has provided greater water availability and, consequently, favored the expansion of irrigated agricultural activities in its surroundings. Easier access to water allows producers who were previously dependent on rainfall to adopt more stable and productive irrigation systems, contributing to the socioeconomic development of the region.

From 2019 onward, the area of irrigated land registered by SEMARH exceeded the area estimated by the random forest model. It is important to consider, however, that the calculation of the irrigated area based on the SEMARH data was performed by adding the irrigated areas reported each year to the values from previous years. This methodology has several limitations, as it does not consider that some farmers may have stopped irrigating in subsequent years, leading to an overestimation of the total irrigated area in more recent years.

6 CONCLUSION

Canal do Sertão Alagoano played a significant role in the expansion of irrigated agriculture in the study area, with substantial growth in irrigated agricultural areas between 2016 and 2022. The canal's area of greatest influence extends to approximately two kilometers from each bank, where properties using irrigation are concentrated.

The results highlight the importance of continuous land use monitoring and the integration of remote sensing data with institutional information to support public policies aimed at the sustainable management of water resources in a region. The methodology used in this study can assist SEMARH in monitoring irrigated areas along the Canal do Sertão Alagoano, aiming at the sustainable expansion of

irrigated agriculture in the semiarid region of Alagoas.

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