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ÍNDICES ESPECTRAIS NDVI E NBR NA DETECÇÃO DE ÁREA QUEIMADA

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RESUMO: A Caatinga é um bioma brasileiro de 734.000 km², que é constantemente ameaçado pela ação antrópica. Neste cenário, o presente estudo avaliou a eficácia dos índices espectrais NDVI e NBR na identificação de cicatrizes de incêndio em uma área de 11.620,5 ha^{-1} no município de Icó, Ceará. Foram utilizadas imagens do satélite Landsat-8, sensor OLI, para análise antes e depois da ocorrência do incêndio. Os índices NDVI e NBR foram calculados e comparados para determinar sua assertividade em detectar áreas atingidas pelo fogo. Os resultados indicaram que o índice NBR demonstrou uma maior precisão na identificação de áreas afetadas pelo fogo, fornecendo uma visualização clara e detalhada das regiões queimadas.

Palavras-chaves: Caatinga, sensoriamento remoto, cicatrizes de incêndio.

NDVI AND NBR SPECTRAL INDICES FOR DETECTING BURNT AREAS

ABSTRACT: The Caatinga is a Brazilian biome of 734,000 km² that is constantly threatened by human action. In this scenario, the present study evaluated the effectiveness of the NDVI and NBR spectral indices in identifying fire scars in an area of 11,620.5 ha in the municipality of Icó, Ceará. Images from the Landsat-8 satellite and the OLI sensor were used for analysis before and after the fire occurred. The NDVI and NBR indices were calculated and compared to determine their accuracy in detecting areas affected by fires. The results indicated that the NBR index demonstrated greater accuracy in identifying areas affected by fire, providing a clear and detailed visualization of the burned regions.

Keywords: Caatinga, remote sensing, fire scars.

1 INTRODUCTION

The Caatinga biome is located entirely in Brazil and covers an area of 734,000 km² (Souza; Artigas; Lima, 2015). It is characterized by high temperatures, soils with limited weathering, low water retention, annual precipitation of less than 800 mm, concentrated and torrential rains, frequent droughts, high evapotranspiration, and reduced phytomass production (Nascimento, 2015). These extreme drought events, together with burning practices

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for pasture management and strong winds, accelerate the spread of fires (Lima, 2013; Aragão et al., 2007).

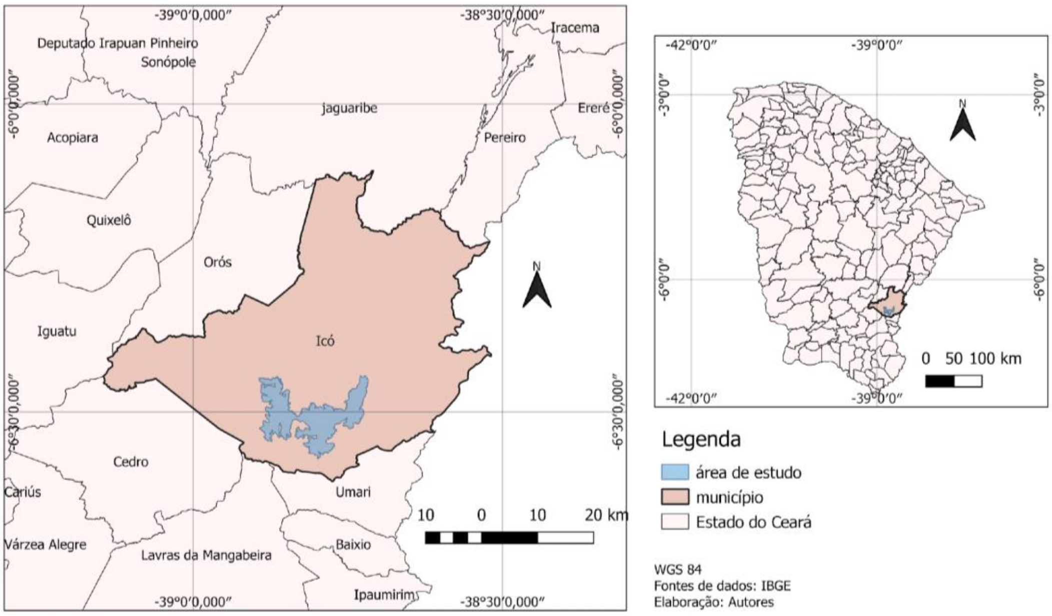
In this context, remote sensing proves to be a valuable tool for assessing the severity of these fires, highlighting changes in the spectral response of affected areas. As highlighted by Santos, Franca-Rocha, and Bento-Gonçalves (2016), the *normalized burn ratio (NBR)* spectral index can help identify burned areas from satellite images and classify these areas since burned vegetation has a different spectral behavior than healthy vegetation does. Similarly, the *normalized difference vegetation index (NBR) vegetation index (NDVI*) consists of a division operation that differentiates pixels that contain healthy vegetation from those that contain unhealthy vegetation.

Therefore, this work aims to compare the effectiveness of the NDVI and NBR indices in analyzing the impact caused by a fire in September 2023 in the Icó region, Ceará.

2 MATERIALS AND METHODS

The research was developed in the municipality of Icó, located in the South Central Region of the state of Ceará, with geographic coordinates positioned at 6°32'36" South latitude and 38°51'16" West longitude. The region is characterized by a semiarid climate and is immersed in the Caatinga biome. The specific focus of the study was an area corresponding to 11,620.62 h-1, as shown in Figure 1.

Figure 1. Location map of the study area



To carry out this study, two images from the Landsat-8 satellite, *the Operational Land Imager (OLI) sensor, were used* through the database of the United States Geological Survey *(USGS). Survey - USGS)*. The dates refer to 09/09/2023 and 24/10/2023 (before and after the fire that occurred on 28/09/2024).

Two spectral indices were calculated: NBR and NDVI (Equations 1 and 2, respectively). Mapping of burned areas via NBR was developed on the basis of knowledge of the spectral response behavior of burned areas in the near-infrared and shortwave infrared regions.

$$NBR=(NIR- SWIR)/(NIR+ SWIR) \qquad (1)$$

where NIR-band 5 is the near-*infrared band* and SWIR *is the* short*wave infrared* band (band 7 of Landsat-8).

$$NDVI = (NIR- RED)/(NIR+ RED) \qquad (2)$$

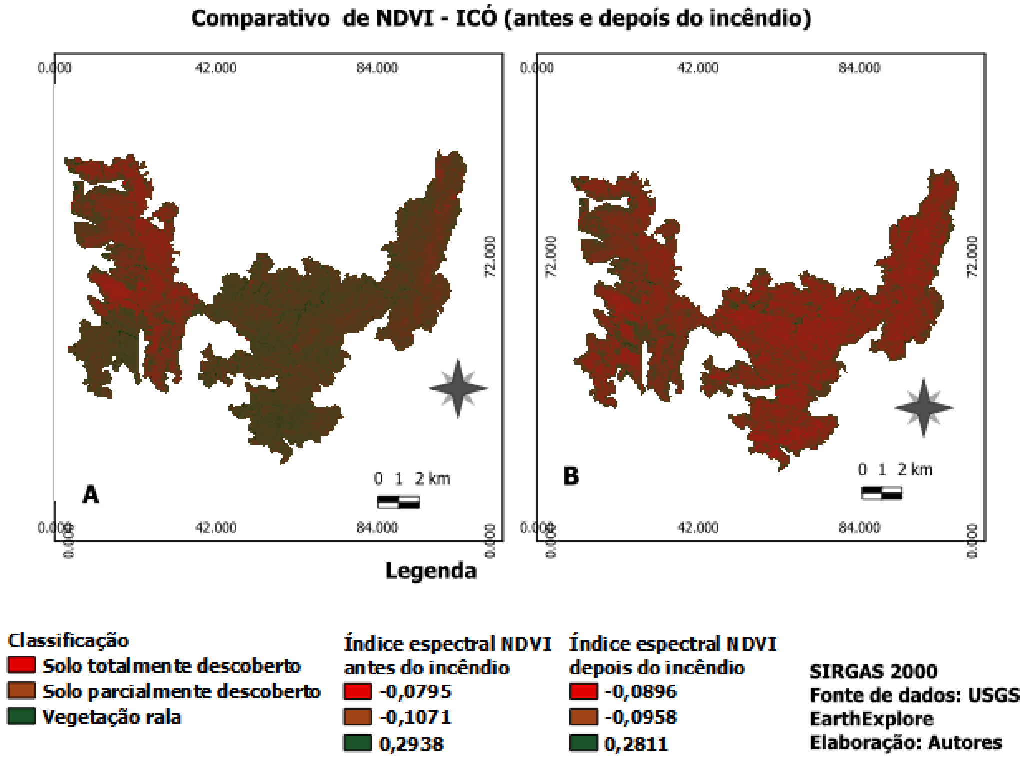
where NIR - band 5, near infrared *band infrared)* and RED - (*red)* is the red band, band 4.

The NDVI calculation allowed characterization of the burned area, serving as a comparison parameter.

3 RESULTS AND DISCUSSION

Figures 2A and 2B show maps generated from the NDVI, illustrating the extent of the impact of the fire. The figures show areas characterized by NDVI values close to 1 (one), indicative of dense vegetation, as well as negative values or values close to 0, indicating areas where there is little or no chlorophyll activity, as in the case of areas affected by fires. (Santos et al., 2018).

Figure 2. NDVI calculated for the fire area with images from the Landsat 8 OLI sensor: (A) images from September 9, 2023; (B) images from October 24, 2023.

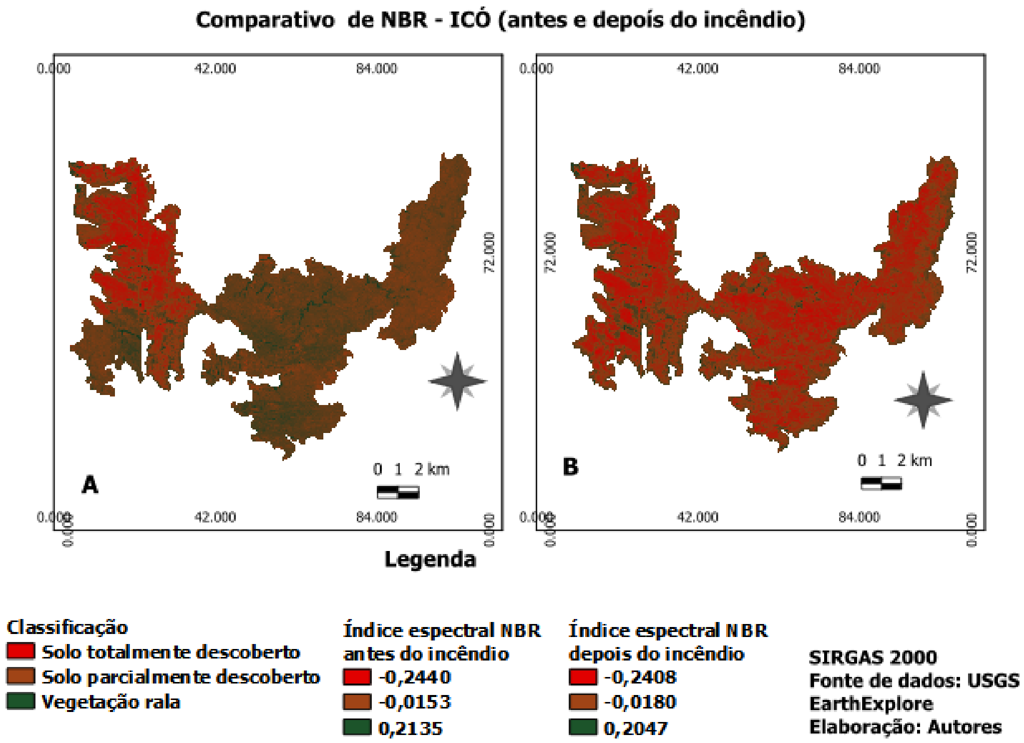


When the map generated from the NDVI is analyzed, the postfire image has a higher concentration of pixels with values closer to -1. This can be explained by the fact that most of the radiation received by the vegetation and captured by band 4 (the red band of the OLI sensor, 640 to 670 nm) is absorbed by the photosynthetic pigments present in the leaves, which are mainly chlorophyll. Because the fire causes partial or total incineration of the plant biomass present in the area, the wavelengths that would normally be absorbed by the chlorophyll are now reflected and captured by the satellite's OLI sensor.

Thus, variations in NDVI values reflect differences in vegetation cover, which are intrinsically related to the presence and availability of natural resources essential for vegetative development, as discussed by Gurgel, Ferreira and Luiz (2003).

Therefore, Figures 3A and 3B present the maps generated from NBR (before and after the fire, respectively). Areas with negative NBR values, although very close to zero, are observed. Notably, the study area had already been affected by fire before the fire, and part of the soil had already been uncovered.

Figure 3. NBR calculated for the fire area with images from the Landsat 8 OLI sensor: (A) images from September 9, 2023; (B) images from October 24, 2023.



Key and Benson (2006) highlighted that the NBR index uses reflectance in the 850–880 nm range (band 5 of the OLI sensor) to identify healthy vegetation, which presents a positive response in this spectral range. In contrast, band 7 of the same sensor, which captures another spectral range, is effective in detecting compromised vegetation, which is usually marked by a significant reduction in chlorophyll, a common indicator in areas of burned vegetation, as observed by Santos et al. (2016).

In the context of the NBR image, negative values indicate a predominance of band 7 reflectance over band 5, indicating water stress or fires, whereas positive values reflect the supremacy of band 5, indicating healthy vegetation. Values close to zero reveal similar reflectances between the bands, which are typical of areas with exposed soil, facilitating the detection of burned areas due to the visible contrast. When comparing the two NBR images, this difference in values between the bands allows the quantification of the burned area both before and after the fire, as shown in Table 1.

Table 1. Quantification of the burned area before and after the fire was performed via the NBR index and the NDVI.

Class	Before the fire (NBR ha)	After the Fire (NBR ha)	Before the fire (NDVI ha)	After the fire (NDVI ha)
Completely uncovered soil	2,430.5	8,211.7	1,298.3	7,119.4
Partially uncovered soil	9,119.7	3,364.1	10,255.1	4,447.3
Sparse vegetation	52.3	26.7	49	35.8
Total				11,602.5

The analysis of the spectral indices studied allowed us to identify different burned areas, and it is recommended that the accuracy of both indices be validated on the basis of field data. Similar studies, such as that by Pereira et al. (2015), when evaluating a series of spectral indices, including the normalized difference vegetation index (NDVI) and NBR, to compare their effectiveness and assess fire severity, concluded that NBR is the index best able to differentiate burned areas from other targets. Therefore, they recommend the use of this index for mapping fire-affected areas.

4 CONCLUSIONS

Using the NDVI and NBR indices, it was possible to detect, classify, and map the area affected by a large fire in the municipality of Icó, Ceará. The study demonstrated that these indices can be used to measure the damage caused by a fire, serving as a basis for decision-making by competent authorities.

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