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" Evaluation of the NBR method for the detection of burned areas in the Sierra Mazatec, Oaxaca, Mexico."

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Introduction

The Sierra Mazateca is located in the northeastern region of Oaxaca, Mexico, forming part of the larger Sierra Madre Oriental and the Oaxacan-Puebla mountain system. This area holds significant ecological and cultural importance for the Mazatec people, whose livelihoods are deeply connected with the region's diverse ecosystems. The Sierra hosts a variety of vegetation, from tropical rainforests to mountain mesophyll forests, providing essential resources and maintaining the cultural traditions of the Mazatec communities.

For the Mazatec people, the forests and the land are of profound importance. The hills and mountains, known in Mazatec as *nindo* or *naxi*, hold deep spiritual and cultural significance. These areas are considered sacred, delicate, and places that require care. Some of these sites are associated with deities and serve as ceremonial centers, where water sources, flora, and fauna are also concentrated, forming a vital part of their biocultural heritage (Flores, 2021).

Recently, between mid-May and June of this year, the Mazateca region experienced intense forest fires, reaching a critical point in early June. The fires were primarily concentrated in the lower and middle zones, with the highest intensity affecting the towns of Piedras Negras, Llano de Árnica, Cerro Liquidámbar, Agua de Flor, Palo Gordo, Llano de Cedro, and Cerro Izote in the municipality of San José Tenango. Additionally, Agua Golondrina, Agua de Tinta, and Xochitonalco in the municipality of Huautla de Jiménez were impacted, as well as the community of San Agustín Nuevo, part of Santa María la Asunción. Smaller-scale fires also affected Santa María Chilchotla, Huautepec, and San Juan Coatzospam.

This study focuses on the middle zone of the municipality of Huautla de Jiménez, located in the Sierra Mazateca, where a semi-warm, humid climate with year-round rainfall predominates (Flores, 2021). These conditions suggest that the area is a fire-independent ecosystem (Myers, 2006), meaning fire plays a very limited role. It is used only at specific times based on local knowledge, and the soil remains humid due to the consistently rainy climate throughout the year.
The objective of this work is to evaluate methods for assessing the impact of fires on vegetation through the use of satellite imagery. The Normalized Burn Ratio (NBR), an ideal index for detecting burned areas and assessing fire severity (Valdez et al., 2019), is calculated from these images. Additionally, the Differenced Normalized Burn Ratio (ΔNBR) is used to provide further insights into fire severity and to evaluate the areas affected by forest fires (Gonzales, 2022).

Methodology:

Landsat 9 images (OLI/TIRS C2L2) were obtained through the USGS EarthExplorer platform for this study (https://ers.cr.usgs.gov/). The QGIS software was employed for processing the satellite images, generating thematic maps, and performing the NBR and ΔNBR calculations. The selected images correspond to two key moments with cloud cover at 13%:

- Pre-fire: May 04, 2024, chosen as the closest available image to the start of the fires.
- Post-fire: July 7, 2024, selected as the first available image after the fires were controlled.

The first step involved calculating the NBR spectral index, which is widely used for mapping burned areas and determining fire severity levels (Bengtsson et al., S.f.) and was done using bands 5 (near infrared) and 7 (shortwave infrared) of Landsat 9:

$$NBR = \frac{(NIR-SWIR)}{(NIR+SWIR)}$$

Where:

NIR: Near infrared (Landsat 9 sensor Band 5)

SWIR: Mid Infrared (Band 7 of Landsat 9 sensor).

ΔNBR was then calculated, using NBR's from before and after the fire season, May and July respectively. The results indicate fire severity on a scale from -1 to 1, where high values signify healthy vegetation, and low values reflect bare soil or burned areas. Unaffected areas have values close to zero (United Nations, n/d). The following equation was used to calculate ΔNBR:

$$\Delta NBR = NBR_{\text{pre}} - NBR_{\text{post}}$$

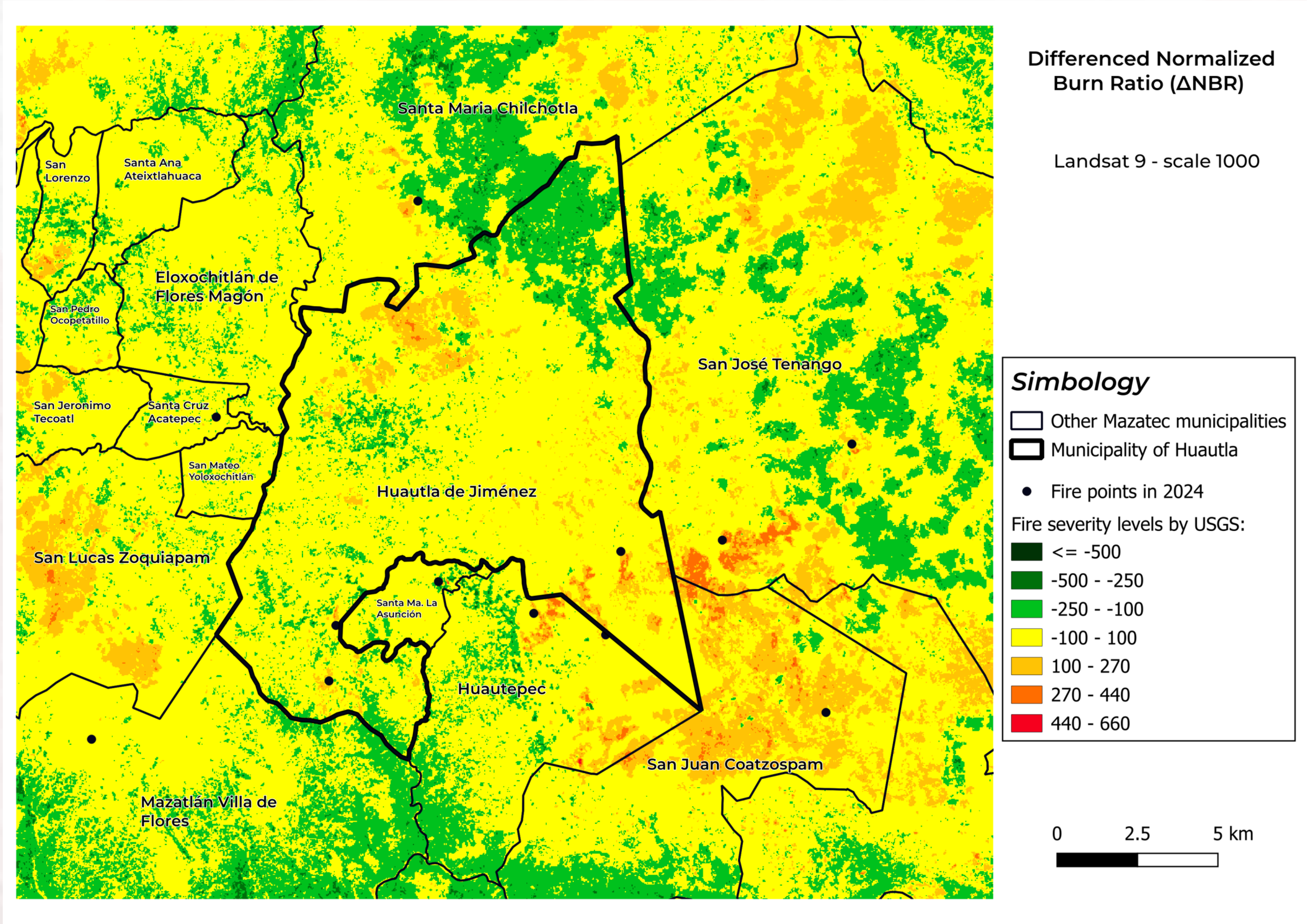
Where:

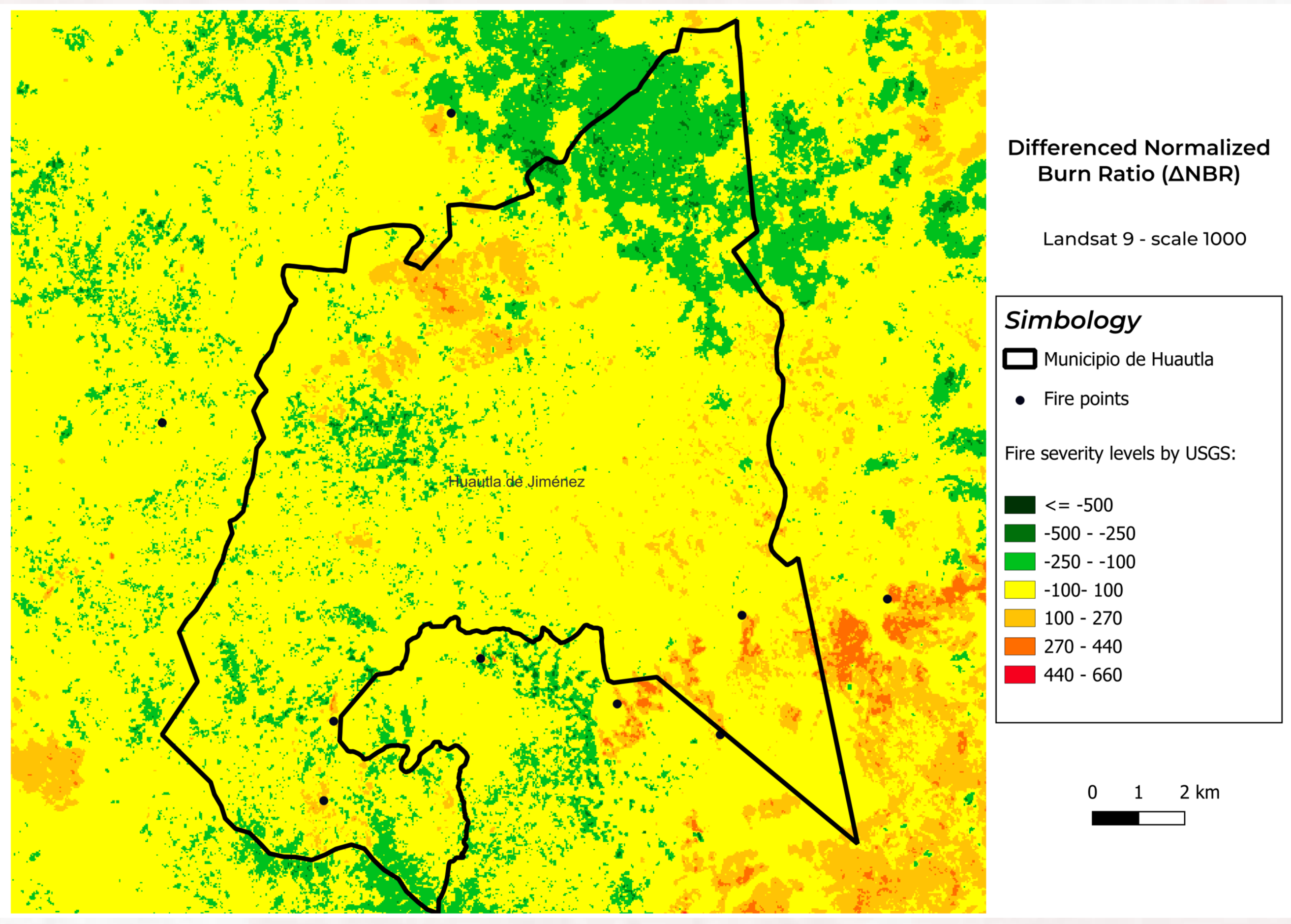
NBR_{pre}, and NBR_{post} are the NBR indices for May and July respectively.

Fire severity classification:

Affected areas were then categorized into different severity levels using ΔNBR values, following a classification provided by the United States Geological Survey (USGS) used to evaluate fire severity (Keeley, J. E. (2009).

Results:





Technological reflections:

Calculating NBR using Landsat images provides valuable tools for indigenous communities like the Mazateca, who may be affected by forest fires. This analysis allows for the assessment of ecological damage caused by fires and helps identify the most impacted areas. For communities that rely on natural resources for subsistence such as trees, medicinal plants, and crops, these results are crucial. By classifying areas that have been severely affected, communities can make informed decisions about the recovery of those ecosystems.

The use of technologies such as NBR and ΔNBR calculations for assessing fires demonstrates how digital innovation can be integrated with the knowledge of local indigenous and rural communities to address contemporary challenges. By providing these data to communities, they can make more informed decisions regarding the impact and extent of fires within their territories, allowing them to adapt traditional practices to the context of climate change.

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