

Multitemporal assessment of burned areas and fire severity in Ourense (August 2025) using Sentinel-2 imagery

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ABSTRACT

This study analyzes the burned area and fire severity of the forest fires that occurred in Ourense in August 2025. The analysis was based on Sentinel-2 imagery, which provides near-infrared (NIR) and short-wave infrared (SWIR) bands suitable for distinguishing between burned and unburned surfaces, as well as different severity levels. Several spectral indices widely applied in wildfire remote sensing were employed, including the Normalized Burn Ratio (NBR), the Burned Area Index for Sentinel-2 (BAIS2), and the Relativized Burn Ratio (RBR), together with their differential forms (e.g., dNBR). Temporal comparisons between pre- and post-fire conditions allowed a multitemporal assessment of fire progression and impact. Field plots were compared with the satellite-derived classification to evaluate accuracy (88%). The results demonstrate that Sentinel-2 data enable a precise delineation of burned areas and a reliable classification of severity levels in forest fires in Ourense. This study confirms the potential of satellite-based indices, supported by limited field validation, to provide rapid and accurate information for forest fires assessment and post-fire management.

1. Introduction

Over the last decades, forest fires have become a major environmental problem due to their ecological, social, and economic impacts, with Spain being particularly vulnerable under climate change (Sobrino et al., 2019; Pausas and Keeley, 2019). Beyond fire size, fire severity is a key parameter, reflecting the intensity of ecosystem damage (Keeley, 2009). Remote sensing has emerged as a reliable and efficient approach to monitor burned areas and assess fire severity, overcoming the limitations of traditional mapping techniques (Chuvieco et al., 2003; Key et al., 2006). Spectral indices based on near-infrared (NIR) and short-wave infrared (SWIR) bands, such as Normalized Burn Ratio (NBR), Burn Area Index (BAI), Burn Area Index Sentinel-2 (BAIS2), Relativized Burn Ratio (RBR), and Relative difference Normalized Burn Ratio (RdNBR), are particularly effective for detecting burned areas and evaluating severity, especially when pre-fire vegetation conditions are considered (Filipponi, 2018; Trigg and Flasse, 2001; Key et al., 2006; Parks et al., 2014; Miller and Thode, 2007).

During August of 2025, Ourense experienced one of its worst forest fire episodes in recent history. In just 16 days, over 100,000 hectares burned across Spain, with Ourense being one of the most affected provinces. Large fires, including the Larouco fire, devastated tens of thousands of hectares, crossed major rivers, destroyed property, and heavily impacted protected areas such as O Invernadeiro and Serra do Courel. These events highlighted the urgent need for rapid and accurate assessment tools to support fire management and ecological recovery.

This study applies the forest fires assessment methodology proposed by Sobrino et al. (2024) in Ourense: Sentinel-2 imagery combined with limited field validation to evaluate the burned area and fire severity. By providing detailed maps and temporal assessments, the work demonstrates the value of high-resolution satellite data for improving our understanding of fire impacts and strengthening national wildfire statistics.

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2. Materials and Methods

2.1. Study Area

The work that is described was carried out in forest fires occurred in Ourense in August 2025. Those fires burned over 100000 Ha (Figure 1), classified mainly as *Pinus pinaster* Ait. (maritime pine) and *Eucalyptus globulus* Labill. (blue gum) stands. The understory vegetation was dominated by *Pteridium aquilinum* (L.) Kuhn and *Ulex europaeus* L. Forest fires are common in this region, which is the Spanish area most often affected by them. Figure 2 shows the burned area mapped by the European Forest Fire Information System (EFFIS), derived from Moderate-Resolution Imaging Spectroradiometer (MODIS) sensor (European Commission, Joint Research Center, 2025) with Sentinel-2 images, together with the land cover extracted from Sentinel-2 data for the Ourense forest fires that occurred in August, 2025 (Malinowski et al., 2020).



Figure 1: Study area focused on Ourense province, Spain

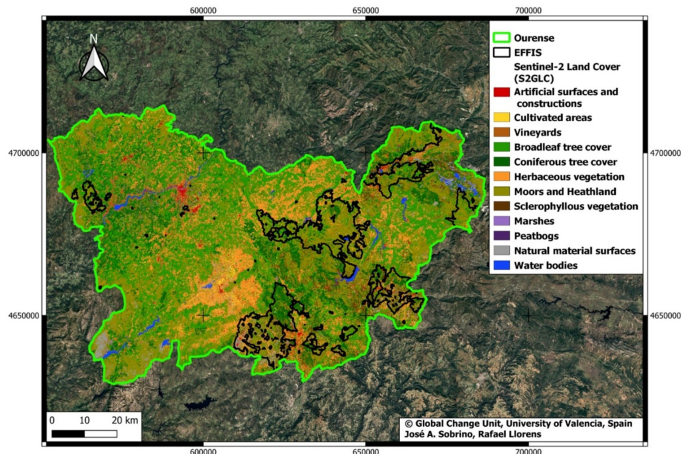


Figure 2: Burned area extracted by the European Forest Fire Information System (EFFIS) and the Land Cover (extracted by Sentinel-2 images) for the Ourense forest fires occurred in August, 2025.

2.2. Methodology

This study applies the methodology developed and validated by Sobrinho et al. (2024), hereafter referred to as the Global Change Unit (UCG) approach, to estimate burned area and fire severity using the differenced Normalized Burn Ratio 2 (dNBR2) spectral index derived from Sentinel-2 imagery, as defined below:

$$NBR2 = \frac{(B11 - B12)}{B11 + B12} \quad (1)$$

$$dNBR2 = NBR2_{PRE} - NBR2_{POST} \quad (2)$$

B11 and B12 correspond to the Sentinel-2 SWIR1 (1610nm) and SWIR2 (2190 nm) channels. The overall error rate (average of omission and commission) was 5%, validated using severity plots obtained from different fires that occurred between 2018 and 2023. For this purpose, Sentinel-2 Level-2A imagery with a spatial resolution of 20 m, atmospherically corrected with the Sen2Cor processor, was used. Based on the Scene Classification map (SCL), all pixels not corresponding to “Dark Area Pixels”, “Vegetation”, “Not vegetated”, or “Unclassified” were excluded (Richter and Schlöpfer, 2005).

Fire severity was analysed on four dates: during and after the fire events (August 16, August 23, September 5, and September 25, 2025) and compared with field plots collected for the Outomuro forest fire (Ourense) on August 20, 21, 23, and 24, 2025. A pre-fire image acquired on August 1, 2025, was used for change detection. This reference image was selected based on minimal cloud cover and the absence of residual burn scars from previous fire events that could affect severity classification.

The field plot methodology assesses fire severity based on the percentage of burned vegetation (Ruiz-Gallardo et al., 2004; Ryan and Noste, 1985). Table 1 presents the classification of fire severity levels according to the percentage of burned vegetation.

Table 1
Percentage of burn vegetation and brief description (for each field fire severity class), based on Ruiz-Gallardo et al. (2004).

Field fire severity class	Percentage of burn vegetation	Description
Null severity	Global vegetation $\approx 0\%$	No effects on vegetation
Low	$0\% \leq \text{Global vegetation} < 50\%$ $0\% \leq \text{Tree canopy} < 30\%$	- Shrub canopy specially affected by the fire - Some trees may be just scorched on the stem base or even intact
Moderate	$50\% \leq \text{Global vegetation} < 90\%$ $30\% \leq \text{Tree canopy} < 75\%$	Most or all of the shrub canopy may have been killed
High	Global vegetation $\geq 90\%$ Tree canopy $\geq 75\%$	Mostly killed vegetation

3. Results and discussion

Figures 3, 4, 5, and 6 show the fire severity results for August 16 and 23 (during the active fire events) and for September 5 and 25, 2025 (after the fires were mostly contained). According to EFFIS data, the forest fires started in early August and were largely extinguished by early September

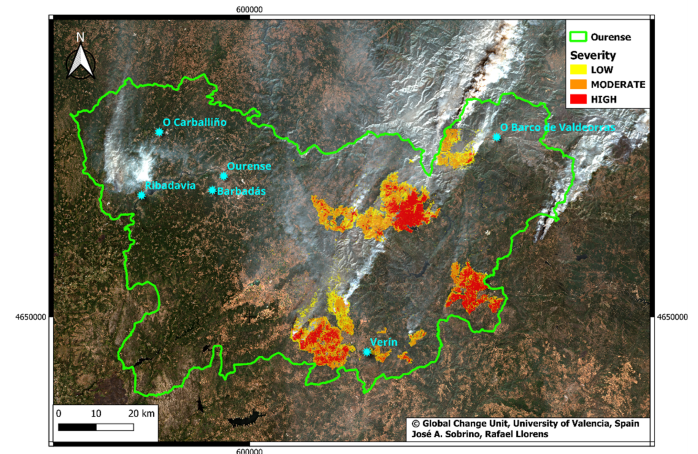


Figure 3: Fire severity map of the forest fires that occurred in Ourense on August 16, 2025.

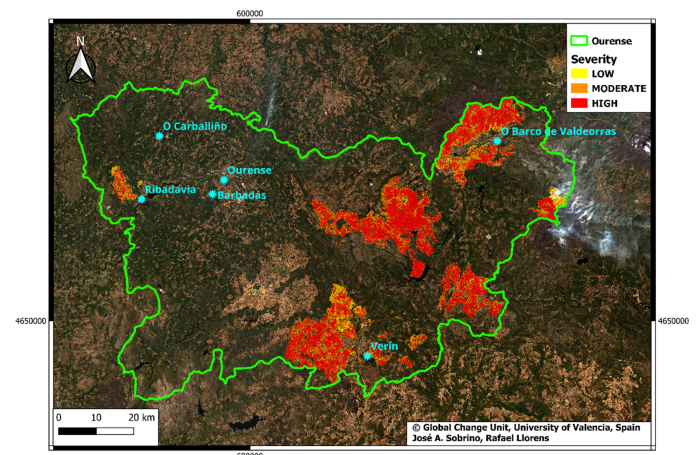


Figure 4: Fire severity map of the forest fires that occurred in Ourense on August 23, 2025.

Figure 7 presents a bar chart showing the burned area by severity class for each date, using the methodology proposed in this work (dNBR2 derived from Sentinel-2, see Equations 1 and 2) and the EFFIS burned area database (dNBR index derived from Sentinel-2 and MODIS). The results indicated that the burned surface increased over time, with moderate severity pixels progressively transitioning into high-severity ones. The observed increase in fire severity classification over time (approximately 1,000 ha of moderate severity on August 23 reclassified as high severity on September 5, 2025) can be explained by the gradual alteration of vegetation spectral properties. As plant tissues lose water content and cellular structure following combustion, reflectance in the near-infrared (NIR) region decreases markedly, while reflectance in the shortwave infrared (SWIR) region increases. This enhanced spectral contrast amplifies burn indices such as dNBR, resulting in the reclassification of areas from moderate to high severity (He, Shen and Anagnostou, 2023). Between September 5 and 25, however, the opposite trend was observed: high-severity areas decreased in favor of low and moderate severity, due to the natural regeneration processes occurring in the burned

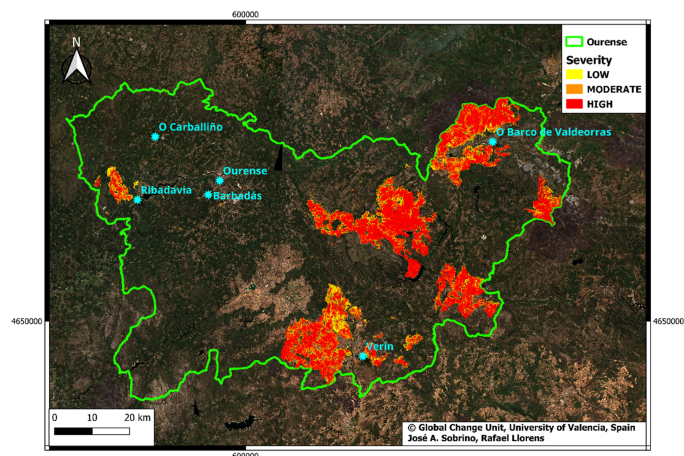


Figure 5: Fire severity map of the forest fires that occurred in Ourense on September 5, 2025.

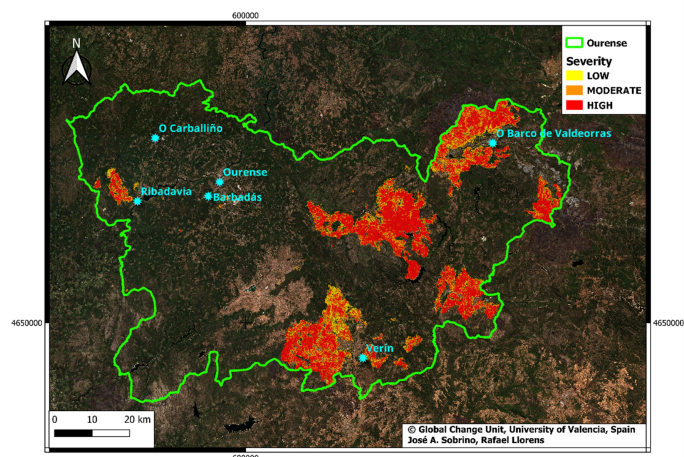


Figure 6: Fire severity map of the forest fires that occurred in Ourense on September 25, 2025.

zones. The differences between the UCG and EFFIS methodologies were below 5% on most dates, indicating a high level of consistency between the two approaches. This strong agreement validates the reliability of the proposed UCG method. However, UCG advances beyond EFFIS by providing **near-real-time severity estimates** and a more adaptive treatment of vegetation variability. By applying specific spectral indices tailored to each severity level and vegetation density—unlike EFFIS, which relies on a single dNBR index—the UCG approach mitigates index saturation and improves the discrimination of burned area severity across diverse ecosystems.

Figure 8 shows the validation areas, confirming an accuracy of 88%, despite the existing limitations. Field plots were collected under specific constraints, mainly due to terrain topography and meteorological conditions, during a forest fire close to Outomuro village (August, 2025). A total of 8 20 × 20 m plots were measured, four corresponding to low severity, one to moderate severity and three to high severity. In addition, since the field plots were visually selected following the protocol of Ruiz-Gallardo et al. (2004), only those clearly representing one of the four severity classes (unburned, low, moderate, or high) were considered valid (see Table 1).

The two most prevalent land cover types in Ourense, Moors and Heathland and Broadleaf Forest, were also those most severely affected by the August 2025 forest fires, with Moors and Heathland showing the highest value of burned area (44.4% equivalent to 45746.10 ha). Post-fire analysis indicates that approximately 14.5% of the total area of Ourense was burned,

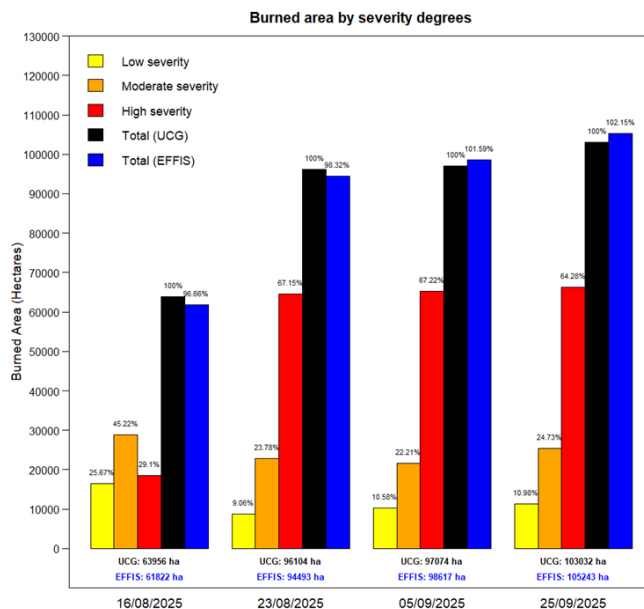


Figure 7: Burned area (hectares) by severity class for each date. 16 August 2025 — Low (16,419.16), Moderate (28,923.96), High (18,613.36), Total (63,957.28); 23 August 2025 — Low (8,711.20), Moderate (22,857.40), High (64,535.20), Total (96,103.80); 5 September 2025 — Low (10,267.60), Moderate (21,555.66), High (66,272.66), Total (98,095.92); 25 September 2025 — Low (11,317.07), Moderate (25,483.06), High (66,231.57), Total (103,031.70).

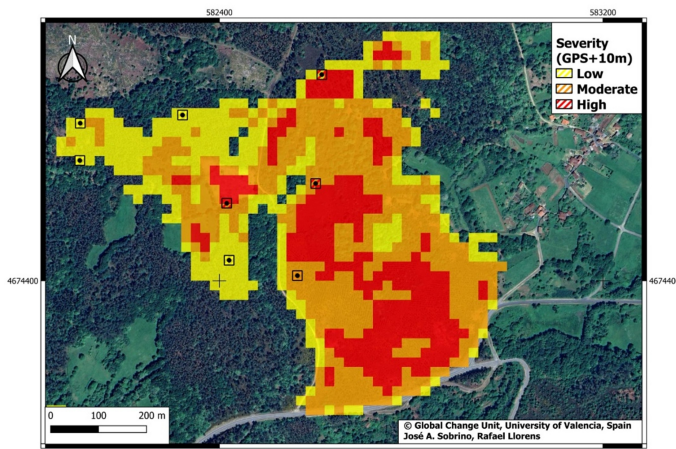


Figure 8: Field plots located on Outomuro (Ourense) in the area affected by the forest fire of August, 2025.

corresponding to 4.4% of the forested area (Broadleaf and Coniferous tree cover).

4. Conclusions

This study demonstrates the effectiveness of Sentinel-2 imagery for assessing burned areas and fire severity during the forest fires that occurred in Ourense in August 2025. The multitemporal analysis enables monitoring of fire progression, revealing an increase in burned area from 63,957 ha on August 16 to 103,031.70 ha on September 25, 2025. The observed escalation in fire severity, particularly the transition from moderate to high severity, highlights the importance of post-fire temporal analysis, as spectral indices are sensitive to ongoing vegetation changes after combustion. Overall, approximately 14.5% of the total provincial area and 4.4% of the forested area were affected by fire. Field validation showed a classification accuracy of 88%, confirming

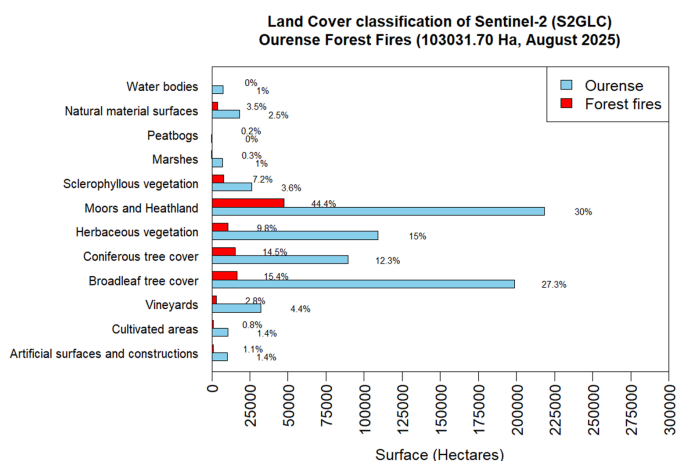


Figure 9: Comparison between the total surface area of Ourense and the burned areas, according to the Sentinel-2 land cover classification.

the reliability of the satellite-based approach despite logistical and terrain constraints.

These findings confirm that high-resolution satellite imagery, combined with field validation, provides rapid, accurate, and spatially detailed information for post-fire assessment. From a management perspective, such information is critical for prioritising restoration actions, optimising resources allocation, and implementing targeted fire prevention measures in the most vulnerable areas.

Finally, the severity and extent of the 2025 Ourense forest fires highlight the growing exposure of Spanish forests to conditions that favour the spread of large wildfires. Prolonged periods of dryness, higher temperatures, and shifts in vegetation structure increase the susceptibility of forest ecosystems to ignition and rapid propagation once a fire starts. Although the causes of individual ignition events are diverse, the prevailing environmental conditions clearly determine their potential magnitude. This reinforces the importance of adaptive forest management, fuel control, and continuous monitoring through remote sensing technologies to mitigate the risk and impact of future fires.

Author Contribution statement

José A. Sobrino: Conceptualization, Methodology, Algorithms, Data Analysis, Writing, Funding acquisition. **Rafael Llorens:** Methodology, Algorithms, Software, Data extraction, Data Analysis, Writing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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