



 **BURN SEVERITY MAPPER**

USER MANUAL



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Introduction

The **Burn Severity Mapper (BSM)** is a [Google Earth Engine \(GEE\)](#)-based app developed within [SeverusPT](#). The project aims to periodically and timely provide relevant and standardized information on burn severity supported by satellite and field observations. Key objectives include developing a spatially explicit framework for assessing, mapping and predicting burn severity for mainland Portugal.

The Burn Severity Mapper app intends to facilitate the creation of burn severity maps based on optical satellite data such as Sentinel-2 or Landsat-8. The app applies a simple (yet powerful) delta approach (i.e., the difference between pre- and post-fire) based on the Normalized Burn Ratio (NBR) spectral index combining the near (NIR) and shortwave infrared (SWIR) bands:

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

Eqn. 1 - Calculation formula for the Normalized Burn Ratio (NBR) spectral index. NIR is the reflectance in the Near Infrared region, and SWIR is the reflectance in the Shortwave Infrared.

BSM calculates the following delta indicators of burn severity:

- Delta NBR (dNBR):

$$dNBR = NBR_{pre-fire} - NBR_{post-fire}$$

- Relative Difference NBR (RdNBR):

$$RdNBR = \frac{dNBR}{\sqrt{|NBR_{pre-fire}|}}$$

- Relativized Burn Ratio (RBR):

$$RBR = \frac{dNBR}{(NBR_{pre-fire} + 1.001)}$$

Eqns. 2 - 4: Equations for delta (d), the relativized difference (Rd) and relative burn ratio (RBR) used to estimate burn severity indicators comparing pre- and post-fire satellite images (or multi-temporal mosaics).

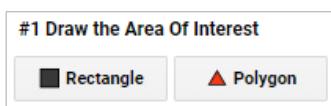
The BSM accelerates the processes and hides the complexities involved in selecting, subsetting, downloading, (pre-)processing, masking, mosaicking and calculating all the necessary spectral indices and severity burn indicators from satellite image time series (SITS).

The app is optimized for mainland Portugal, for which dedicated burned area datasets are available from European (EFFIS) and national (ICNF) sources; however, the BSM app can be used to map burned areas and extract severity data anywhere in the world.

Basic usage


The following steps are required to use the Burn Severity Mapper.

Step #1 – Select the Area of Interest (Aoi) using one of the available geometries:



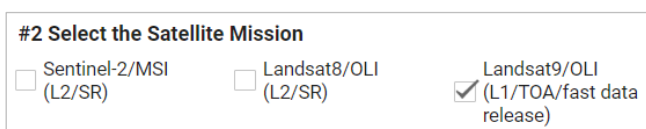
#1 Draw the Area Of Interest

Rectangle Polygon

Satellite images will be searched for this area, and the results will be cropped by the Aoi geometry. The  Clear button allows removing the Aoi drawn.

Step #2 – Select the satellite mission. For now, only two collections are available:

- Sentinel-2 (L2A Surface Reflectance) – [COPERNICUS/S2_SR_HARMONIZED](#)¹
- Landsat-8 (L2 Surface Reflectance/Collection 2) – [LANDSAT/LC08/C02/T1_L2](#)
- Landsat-9 (TOA Reflectance/Collection 2) – [LANDSAT/LC09/C02/T1_TOA](#) (the fastest release data for the Landsat mission)




#2 Select the Satellite Mission

☐ Sentinel-2/MSI (L2/SR) ☐ Landsat8/OLI (L2/SR) ☒ Landsat9/OLI (L1/TOA/fast data release)

If the “Show list...” option is on, a simplified list of the images selected by the spatial and temporal filters will be displayed in the results (below the “Calculate ...” button).

Step #3 – Set the pre- and post-fire date(s) and ranges. This step is critical to get the results since the method is based on the comparison between pre- and post-fire images. BSM will calculate the median composite if more than one image is retrieved by the spatial and temporal search (the most common scenario).

 **NOTE:** Knowing in advance the precise fire ignition/start date is fundamental to achieving good performance.

¹ Google Earth Engine’s Image Collection/Dataset code

Three options are available for setting the fire date and ranges:

a) Fire date with plus/minus pre/post-fire range (in days)

In this case, the user has to set the start date of the fire plus the number of days before and after the fire date to search for available images. The range in days is applied to the pre- and post-fire periods (an equal period is usually considered). A maximum of 120 days is allowed with increments of 5 days.

The screenshot shows a configuration window with three radio buttons. The first option, 'Fire date with plus/minus pre/post-fire range (in days)', is selected. Below it are two unselected options: 'Specific pre- and post-fire dates' and 'Compare the post-fire period to the previous year'. The 'Set the fire date:' section features a calendar grid with the 5th of August highlighted. Below the grid, the date 'Aug 5, 2023' is displayed, followed by a text input field containing '05/08/2023' and a calendar icon. Two sliders are present: 'Number of days before the fire date:' and 'Number of days after the fire date:', both set to 60.


b) Specific pre- and post-fire dates

In this case, the user sets four specific dates considering the start and end of the pre- and post-fire periods. This option is more suited in case there are specific targets for the pre- vs post-fire comparison or if the user wants to generate a time series for severity/recovery assessment or monitoring. The order used to set the dates is the pre-fire start, pre-fire end, post-fire start and finally the post-fire end date.

The screenshot shows a configuration window for setting specific dates. It contains four sections, each with a calendar grid, a date display, a text input field, and a calendar icon. 1. 'Pre-fire start date:' shows Aug 5, 2022 (05/08/2022). 2. 'Pre-fire end date:' shows Nov 5, 2022 (05/11/2022). 3. 'Post-fire start date:' shows Aug 5, 2023 (05/08/2023). 4. 'Post-fire end date:' shows Nov 5, 2023 (05/11/2023).

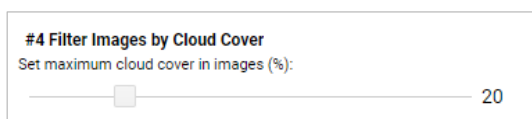
c) Compare the post-fire period to the previous year

This option considers the two inputs: the fire start/ignition date and the number of days after the fire. Then, the pre-fire date is internally set for the same period, but in the year before. This calculation option mainly aims to avoid phenological differences often arising when comparing pre- and post-fire imagery for different seasons of the year.



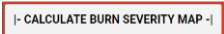
Step #4 - Filter Images by cloud cover. This option allows setting a cloud coverage (%; default: 20%) value to include below which the images are maintained in the selected image stack; otherwise, if above the defined threshold, the images will be discarded. Increments of 1% are allowed.

To set this value, move the slider bar to define the threshold above which the images will be discarded.



i **NOTE:** the cloud cover is based on the entire image, even if the AoI is not covered by clouds. This issue can often have the unintended effect of discarding “good” images. For this reason, we recommend fine-tuning this parameter and seeing the result in the image list (see [Step #2](#) to enable the image list).

i **NOTE:** for Landsat-9, this step is ignored since it is based on TOA images for which the “CLOUD_COVER_LAND” metadata property is not calculated. See more info [here](#).

After setting steps 1 to 4, it is possible to **run the BSM app** and calculate a burn severity map by pressing the button: 

Depending on the size of the area, this will take some seconds to a few minutes. After that, several new layers will appear when clicking on the Layers button:



i NOTE: the slider on the right side allows the user to define the level of transparency of each layer

The [1] index is the number of the run. Every time a new map is generated, the index will be incremented by one (usually, it may take more than one attempt to produce a “good” final map – see [Step 5](#)).

The layers generated by the Burn Severity Mapper app include:

- Burn severity classes, i.e., a reclassified version of delta NBR (dNBR);
- The Relative Burn Ratio NBR (RBR) – Equation 4;
- The Relative Difference/Delta NBR (RdNBR) – Equation 3;
- The Delta NBR (dNBR) – Equation 2;

Using the “Layers” panel, it is possible to turn each layer on/off

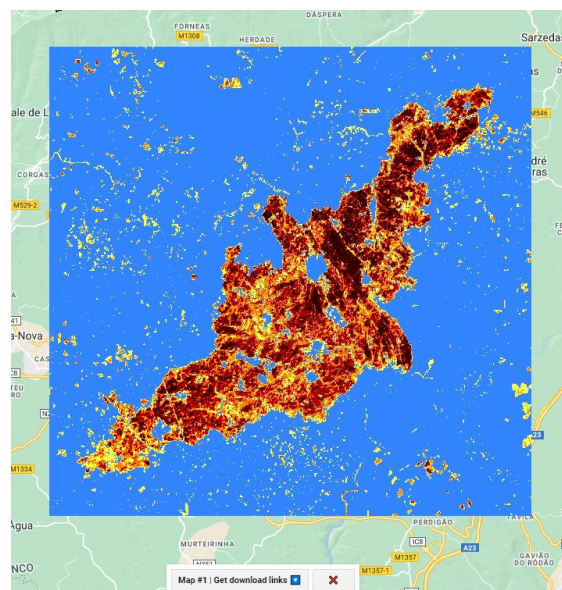


Figure 1 – Example of delta NBR burn severity map with five categories. Notice the “random” changed areas around the burned perimeter.

The legend is shown in the left side - first for the categorical dNBR layer and then for the continuous dNBR, RdNBR and RBR layers:

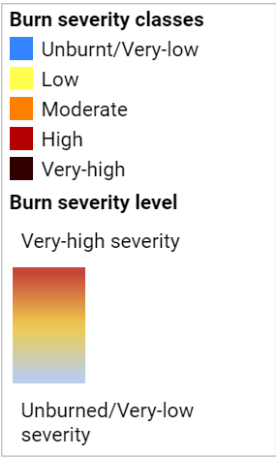


Table 1 - Burn severity classes in the categorical dNBR layer.

dNBR severity class	dNBR interval
1. Unburnt/Very-low	≤ 0.1
2. Low	$]0.10, 0.27]$
3. Moderate	$]0.27, 0.44]$
4. High	$]0.44, 0.66]$
5. Very-high	> 0.66

Table 2 - Main description of burn severity classes.

Low severity: This category often corresponds to dNBR values close to zero or slightly positive. It suggests minimal ecological impact, potential for post-fire regrowth, and relatively mild soil and vegetation damage.
Moderate severity: Moderate burn severity may be associated with dNBR values that are moderately negative. It indicates a more substantial impact on the landscape, with a moderate reduction in vegetation cover and possible soil disturbance.
High severity: severity is typically linked to strongly positive dNBR values. This class denotes significant vegetation damage, including canopy, understory, and notable soil alterations. Post-fire recovery may be more challenging in high-severity areas.
Very-high severity: The highest burn severity level, often represented by highly positive dNBR values, suggests severe impacts on vegetation, including widespread mortality of trees and shrubs and potentially severe soil damage. Recovery in these areas may be prolonged and challenging.

To download the burn severity maps, follow the link at the bottom:



This button will open a secondary panel showing one link for each layer generated (generating these links may take some seconds):

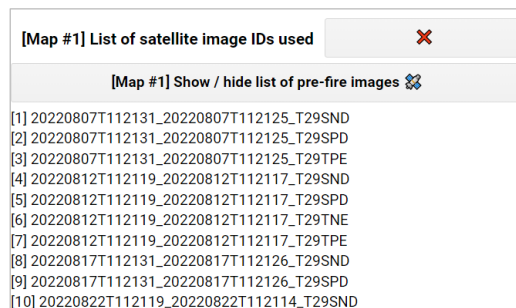
- [1] [Download Delta NBR map \(scale factor: 0.0001\)](#)
- [1] [Download Relativized Delta NBR map \(scale factor: 0.0001\)](#)
- [1] [Download Relative Burn Ratio NBR map \(scale factor: 0.0001\)](#)
- [1] [Download classified Delta NBR map \(categories: 1-5\)](#)
- [1] [Download classified Delta NBR map - vector KML](#)

i INFO: To put the severity indicators back to their “natural” scale, multiply them by the scale factor indicated in each link.

i INFO: The image format is GeoTIFF. The “Burn severity classes” layer can be downloaded in raster format (“Delta NBR map (categories 1-5)”) or vector in KML extension (“Delta NBR map – vector KML”).

⚠ WARNING: If the images are very large, it may be impossible to generate these download links. In these cases, try to process smaller areas and then mosaic them together in a GIS software (e.g., QGIS).

If the option “Show list of pre/post-fire satellite images ...” was activated below the “calculate” the following button will appear:



By pressing the button, a list will appear with the image codes used to make the burn severity layers. One button/panel will appear for each calculation run (i.e., [Map #1], [Map #2], ...).

To remove the image list, press the button again to hide it or the **✖** button to delete it.

Step #5 – Filter/Segment Burned Area

After calculating the burn severity maps with the selected satellite images, “random noise” is expected to occur around the burned area that needs to be removed to isolate the actual burned perimeter.

To do this, the Burn Severity Mapper applies a specially developed algorithm which creates a mask to select pixels only for the burned area. This algorithm combines the focal median ($F_m(layer, k)$) for two layers:

- Delta NBR layer, $F_m(dNBR)$
- Change Vector Analysis magnitude layer, $F_m(magnitude)$

Then, for each layer, a threshold is applied to generate a boolean mask:

$$B(\text{dNBR}) = F_m(\text{dNBR}, k) > t_d$$

$$B(\text{magnitude}) = F_m(\text{magnitude}, k) > t_m$$

where k is the kernel size of the focal median, t_d is the threshold applied to the delta NBR and t_m is the threshold applied to the CVA magnitude layer.

$B(\text{dNBR})$, and $B(\text{dNBR})$ masks are then intersected to generate a single boolean mask B , combining both components. The rationale of this method is to isolate pixels that have undergone an evident change in the surrounding area (hence the application of the focal median):

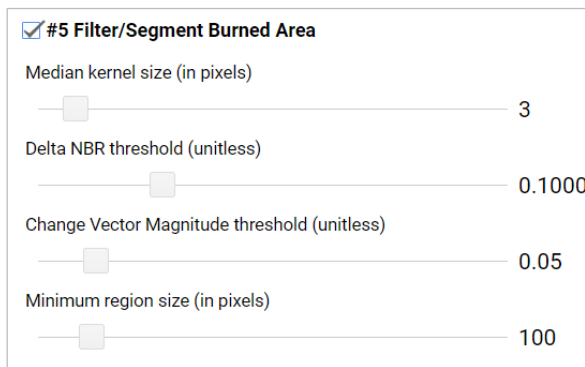
$$B = B(\text{dNBR}) \cap B(\text{magnitude})$$

A final step is performed, which consists of generating a layer of connected components and applying a minimum size for the generated components (or clumps of connected pixels).

$$\text{size}(\text{connected}_{8r}(B)) \geq t_{\text{min_region}}$$

The connected components algorithm in Google Earth Engine identifies clumps of adjacent pixels in an image that share a common attribute (i.e., that verifies both threshold conditions stated above). A pixel connectivity rule has to be defined (4, 8, or 16 neighbours), then pixel aggregation/grouping takes place based on a shared property. For BSM the 8-rule is employed. By applying a threshold, only clumps of pixels with a size (in # of pixels) higher than the minimum region size ($t_{\text{min_region}}$) will be maintained in the final image.

Parameters used to run the filtering/segmentation step:



☒ #5 Filter/Segment Burned Area

Median kernel size (in pixels)	3
Delta NBR threshold (unitless)	0.1000
Change Vector Magnitude threshold (unitless)	0.05
Minimum region size (in pixels)	100

The default parameters can be used to test this segmentation approach; however, fine-tuning is likely needed to extract burned areas more rigorously.

✓ TIP: one additional way of improving the extraction of the actual burned area is to define a new Aol using a polygon that more closely follows the burned perimeter given by the preliminary delta NBR maps. Here is an example:

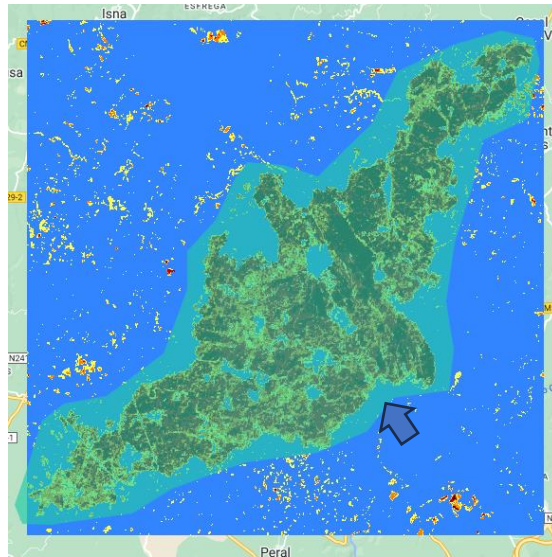
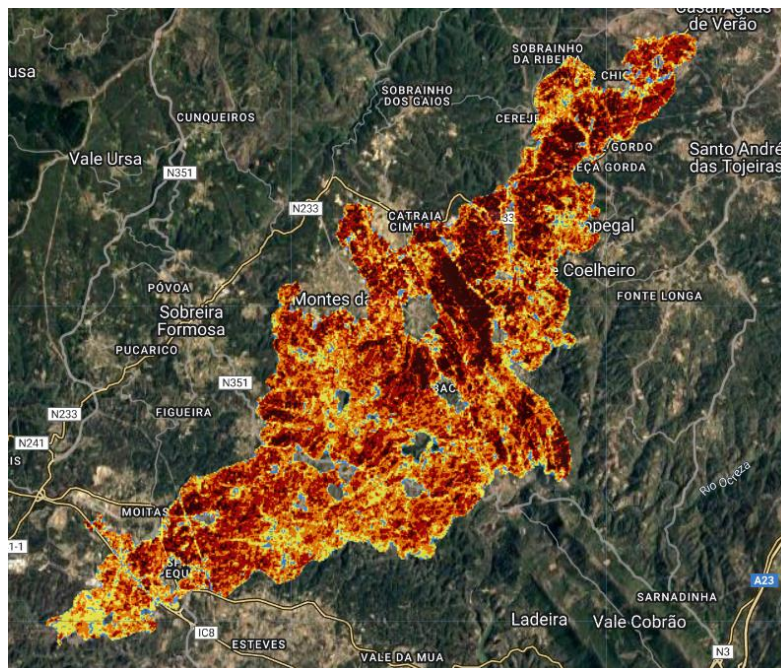


Figure 2 - Example of an Aol polygon around the actual burned area (arrow). After generating the burn severity layers, refining the Aol to extract/segment the burn area perimeter is often advisable.

Here is the resulting burned area after applying the segmentation procedure. The difference compared to the initial map is notorious since only the actual burned area appears.



Additional functionalities


Calculating statistics of burned severity by class

Inside Step #5, the Burn Severity Mapper app can perform basic statistics regarding the segmented burned area and obtain a barplot representing this data. To enable this option, the user needs to activate step 5 and then activate the following option:

☒ Calculate burned area statistics?

These summary stats include:

- Total burned area (in hectares);
- Burned area and percentage by severity class (according to dNBR categorization) in hectares.

Below is an example of a statistics summary generated by this calculation option (left-side figure). Pressing the  button maximizes the plot and allows downloading the data represented in it (right-side):



Adding burned area layers for mainland Portugal

The Burn Severity Mapper, by default, contains a series of layers that represent burned areas for mainland Portugal. Some of these layers are already available when loading the app, and others need to be activated on demand by the user.

Default layers relate to the last 7, 15 and 30 days of wildfires in the European Forest Fire Information System (EFFIS) database. Pressing the Layers button will show these layers:

<input type="checkbox"/>	EFFIS burned areas - last 7 days	<input type="range"/>
<input type="checkbox"/>	EFFIS burned areas - last 15 days	<input type="range"/>
<input type="checkbox"/>	EFFIS burned areas - last 30 days	<input type="range"/>

The checkbox on the left side allows the user to turn these layers on/off, and the slider allows setting the transparency level.

Add burned area layers by year

ICNF burned areas

2020

+ Add layer

Turn OFF all layers

Turn ON all layers

Remove all map layers



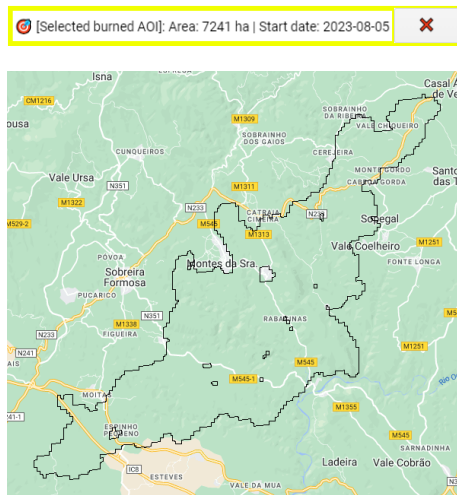
Additional burned area layers can be added to the BSM interface for mainland Portugal based on the Portuguese National Fire Database from the Institute of Nature Conservancy and Forestry (ICNF) and EFFIS. This data is divided annually. The panel on the left side should be used to add this data:

Start by setting the dataset to be used, e.g., **EFFIS burned areas**, then the year (the current year is updated daily from EFFIS centralized database), e.g., **2023** and then press the **+ Add layer** button to add the layer to the BSM interface. EFFIS layers are represented in black outline, while ICNF layers are shown in red. To turn these layers on/off, use the Layers interface. The left panel also allows users to turn all layers on/off or remove them.

Getting the fire ignition/start date and area

Retrieving the fire start date and the burned area for the ancillary wildfire layers (i.e., EFFIS and ICNF databases; only available for mainland Portugal for now) is easy.

Just click over a burned area polygon with the crosshair () , and the following info panel will appear on the top:



Searching for an address or location

Use the top bar in the app to perform a geolocation search:

Search places

Ponte de Lima,

Ponte de Lima, Portugal

-8.55, 41.25

-8.55° W, 41.25° N

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