

On the Need of Quick Monitoring for Wildfire Response from City Halls



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Abstract: This case study shows that the assessment of burned areas can be done with remote sensing data free of charges in a simple laptop. Describing the open-source software and the methodology step by step, we expect to make it available for county workers in areas attained by wildfires, where a quick response is much needed, as the availability of information is essential for the immediate planning of mitigation measures, such as restoring road access, allocate funds for the recovery of human dwellings and assess further restoration of the ecological system. The example used is a succession of wildfires in Portugal mainland during the summer of 2017, that kills more than 60 people and seriously damaged local resources. Wildfires devastate forest ecosystems, having direct impact on vegetation cover and animal population. The economic interest is also attained, as resin extraction ends and the pine wood burned become useless for the most noble applications, so its value decreased. The tools described in this paper establish a baseline for major changes in forest ecosystems recover and allows to target priorities. Moreover, the result allows the follow up of the surface fuel loading, enabling the targeting of restoration measures in a time basis planning.

Keywords: Burned Areas Assessment, Image Processing, Mitigation Planning, Remote Sensing.

I. INTRODUCTION

Wildfires and its impact in the destruction of forest habitats can be evaluated with a complex chain of processing that includes ESA satellite SENTINEL-2 Multi Spectral Images free of charges, open-source software and a geographic information system. Remote sensing multispectral images are used in well proved bands conjugations [1-2], with some morphologic tools from image processing and can benefit from the knowledge of ecologists to establish which are the physiographic factors that will drive the vegetation recovery [3] to test any hypothesis. Additionally, remote sensing multispectral images can also be a key to plan sustainable forest restoration management [4-5]. This case study describes the necessary methodology step by step, until it reaches the production of maps that can be crossed with any georeferenced layer available for the same area, such as administrative limits, the road network, local altitude identified in a digital elevation model or the proximity of

water from thematic maps with hydrographic data (reservoirs, lakes, dams), as well as other relevant environmental and physiographic factors [6] cartographed and/or identifiable in remote sensed images. The natural vegetation recovers rather fast, which can be monitored with successive satellite images, allowing the surveillance of surface fuel loading to prevent successive wildfires whenever a situation of new risk is assessed. This paper intends to provide the tools to elaborate a baseline to monitor the recovery of large severely burned areas that support effective ecological restoration projects, as well as the know-how to implement all the necessary steps to support the necessary administrative procedures with georeferenced data in a current laptop.

II. MATERIALS AND METHODS

The area of interest is a mountainous region in the centre of Portugal mainland, around the locality of Pedrógão Grande at latitude 39.917835N and longitude -8.14581W. The remote sensed images used were acquired by ESA's Copernicus Sentinel-2 mission [7], a constellation of two polar-orbiting satellites phased at 180° to each other in the same sun-synchronous orbit operating between latitudes 56° south and 84° north at a mean altitude of 786 km [8].

The constellation allows a revisiting time of 2 to 5 days [9], depending on latitude. Both satellites carry an optical instrument – the Multi Spectral Instrument (MSI) that samples 13 spectral bands at different ground resolutions: four bands at 10 m, six bands at 20 m and three bands at 60 m spatial resolution [10].

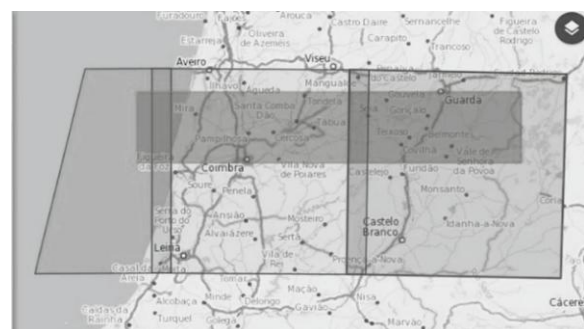


Fig. 1. The three granules used, references TME, TNE and TPE, covering the area of interest (in dark grey) used for the search of available images in SNAP.

The orbital swath width is 290 km and each image that can be downloaded in a short delay after acquisition is a tile or granule of 100x100 km², an ortho-image in UTM/WGS84 projection. The granules have a small area of juxtaposition that is directly handled in the software.

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With level 2A of processing, the product delivered is the corrected bottom-of-atmosphere reflectance, with atmospheric correction already performed since April 2017.

The open-source software platform SentiNel Application Program (SNAP) provided by European Space Agency (ESA) to support Sentinel products was used to manipulate all data used in this study [11]. The version used in this work was SNAP 6.0.0.

The granules covering the central part of Portugal near Pedrógão Grande are the references TME, TNE and TPE (Fig. 1). This is a mountainous area with limited access to some more remote villages, where we had in summer 2017 the largest wildfire ever documented here, with 66 people killed, 253 injured, 261 households destroyed, and 50 industrial facilities severely attained.

After an attentive choice of the dates for before and after fire images, and considering only cloud free images, the three granules were multi-mosaicking in SNAP.

The indices used were the Normalized Difference Vegetation Index (NDVI) [12] and the Normalized Burn Ratio (NBR), used in the relativized version of burn severity (RBR) [13], which considers the areas with low vegetal cover pre-fire (rocks, bare soil) to avoid a wrong classification. The NDVI is computed as the difference between the near infrared and the red bands, divided by its sum as in (1).

$$NDVI = \frac{band_{NIR} - band_{red}}{band_{NIR} + band_{red}} \quad (1)$$

In Sentinel-2 the band correspondence is band 8 for near infrared and band 4 for red [14]. For NBR index, the definition [15] uses the short-wave infrared (SWIR), corresponding to band 12 in Sentinel-2, along the near infrared band computed using (2).

$$NBR = \frac{band_{NIR} - band_{SWIR}}{band_{NIR} + band_{SWIR}} \quad (2)$$

The relativized burn severity [16] is the difference in NBR in the images before and after fire, with an additional factor in denominator to avoid bare soil errors as in equation (3).

$$RBR = \frac{NBR_{pre-fire} - NBR_{post-fire}}{NBR_{pre-fire} + 1.001} \quad (3)$$

The water mask, whenever needed, was computed with green (band 3) and near infrared band using (4).

$$WaterMask = \frac{band_{green} - band_{NIR}}{band_{green} + band_{NIR}} \quad (4)$$

So, the subset of bands needed is B3, B4, B8, B12. After the extraction of the dataset and execution of the mosaic, each mosaic is resampled to one of the bands chosen as reference (B3 in our case) with bilinear interpolation and saved in the native format of SNAP, Beam-dimap. The necessary commands can be found in the sequence Raster - Geometric operations - Resampling.

The tile at far left in the case of Portugal cover a large

portion of ocean, so our option was cropping the first 12.000 columns using the Raster - Subset command. The images for each date pretended, pre and post fire, can now be collocated, to have an exact register of the datasets of different dates, with the command Collocation; the same master image will be used for all the dates.

The water mask is implemented as a condition (5), resulting in a binary image with the value 1 only in the water area, 0 elsewhere.

$$if \left(\frac{B3 - B8}{B3 + B8} \right) \geq 0, then 1; else 0 \quad (5)$$

All the datasets were prepared with the same procedure, applying the formulas above to the bands in each date with the command Band maths in the Raster menu, and using the water mask whenever relevant. The sequence of operations is summarized in the block diagram (Fig. 2).

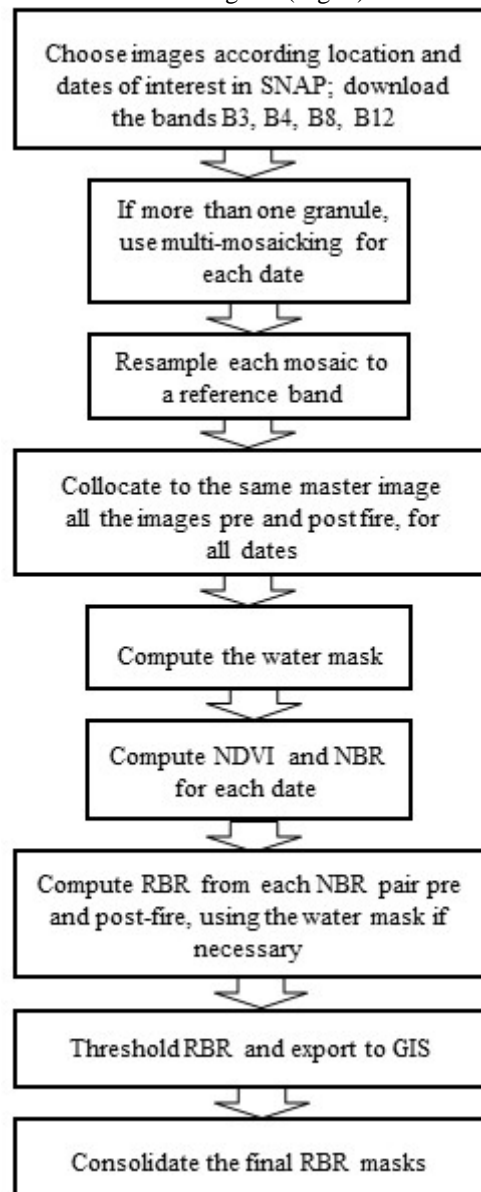


Fig. 2. Block diagram with the sequence of operations in SNAP and ArcGIS

III. RESULTS

The first index used allow to make a quick assessment of the area burned and establish a baseline for the follow up of the posterior vegetation regrow, as NDVI is sensitive for small changes in land cover radiometric characteristics. The second index RBR, is used in this example to have a temporal sequence of the events, in this case with a one-month interval, but could have a more frequent sampling if there are images available.

A. NDVI

First results with NDVI for the initial fire at Pedrógão Grande at 2017 that starts in June 17 can be observed with the pre-fire image captured June, and July 4 for the post-fire image (Fig. 3).

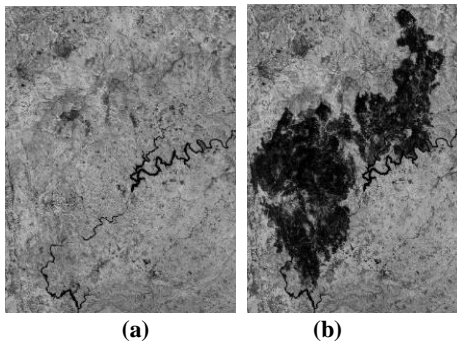


Fig. 3. Close-up of a burned area using NDVI index and images from two dates (a) pre-fire June 14 and (b) post-fire July 4. All the burned area lost its vegetation and the value of NDVI drop significantly, becoming near zero in the post-fire image.

Comparing the histograms of both NDVI images, the histogram of the second image (Fig. 4 b) shows a clear deviation to the left, reflecting all the pixels accounting for burning areas now with low NDVI intensity that were previously forested.

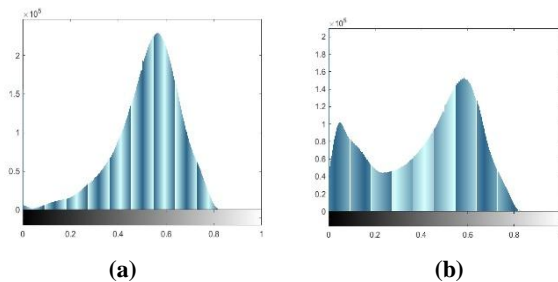


Fig. 4. Histogram of the NDVI image (a) before the fire, and (b) after the fire. A shift to the left in the histogram shows the presence of lower NDVI values in the image acquired post-fire.

In late summer, several fires took place around the same region, with smaller dimensions. We can observe in the sequence of mosaics of three granules prepared as described in the previous section the difference in NDVI intensity, as the initial larger area begins to recover its vegetation (Fig. 5).

The evolution in the NDVI signal of the initial area that was prone to fire in June, in the center of the image, can be observed in Fig. 5 b) and c); with a very low intensity in July image (Fig. 5 b), it becomes much less dark in October (Fig. 5 c), regaining intensity as the first small vegetation begins contributing to the NDVI.

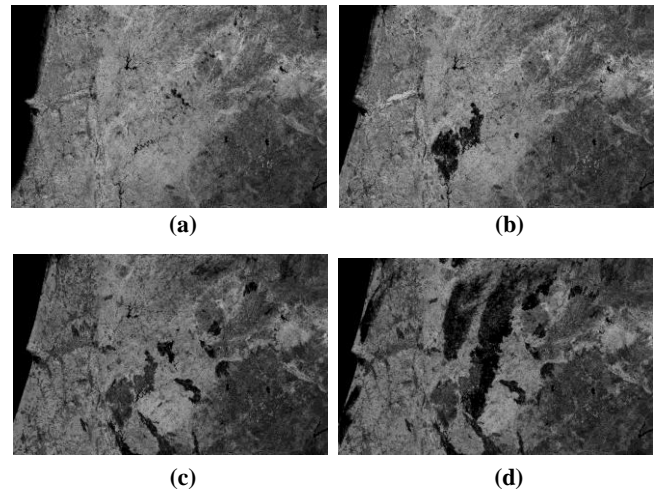


Fig. 5. Evolution of NDVI through summer 2017: between June 14 (a) and July 4 (b), a first large area is burned. After some smaller fires in August and September that can be seen in (c), several big fires occur late October, localized with an image of October 27 (d). The pine areas near the coast were planted by royal decree around 1250; more than 85% of the 11.000 ha were consumed by the fire.

The contrast with the new burned areas is striking (Fig. 4 d) where the terrain burned just to the limits of the area where the initial fire took place.

B. RBR

The relativized burn ratio was used to have a sequence from month-to-month, computing the normalized burn ratio with images around 1 month apart whenever possible – the regularity of cloudless images in summer allowed for the sequence June 4, July 4, August 3, September 2, October 2, and November 11. The final RBR image for each month, using each pair of NBR dates considered pre- and post-fire for that interval, was segmented using the threshold 0.27 as a condition, with (6).

$$\text{if } RBR > 0.27 \text{ then } RBR; \text{else NaN} \quad (6)$$

Each mosaic with just 3 bands (B3, B8 and B12) took around 4h30 to build in a workstation with a CPU Intel 5160@3.00 GHz and 8 GB RAM, and the resampling took around 50 minutes. The computation of each NBR is almost instantaneously, as well as the water mask, both done with the function Band maths in SNAP. The collocation of each pair of mosaics to compare two dates, although with the simplest resampling method (nearest neighbour), took between 2 and 3 hours.

The RBR was computed only where the water mask had the value 0, and the processing time was less than 1 minute for each mosaic. The final image was exported in geotiff format (more than 2 hours) to use as input in a geographic information system (GIS).

Saving all the bands produced during the procedure to disk took around 6 hours. The final images of RBR were imported to a GIS (ArcGis by ESRI), to consolidate the areas burned through spatial analysis tools.

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In the GIS environment, the geotiff data can be used with other layers of data such as administrative limits, to evaluate precisely the area burned in each county, or making a more exact evaluation of damages in remote areas or visualize the road network superposed to the burned areas and the digital elevation model to assess new and possible alternatives for access. As an example, the area burned shown in Fig. 3 b) becomes the binary mask shown in Fig. 6.

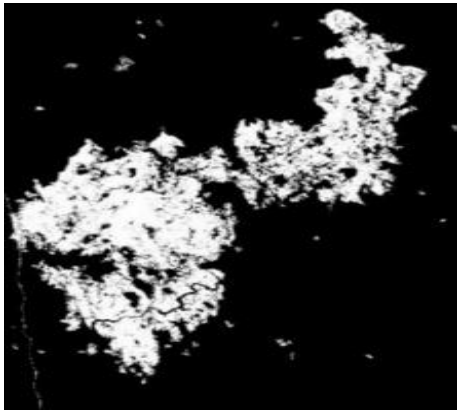


Fig. 6. Binary mask corresponding to the burned area identified in Fig. 3 (b), after consolidation with spatial analysis tools.

The sequence of fires could be isolate by month, as shown in Fig. 7. The image used as background to project the fires is from ESRI Digital Globe, from the satellite GeoEye, available through GIS Servers to Arcgis desktop users.

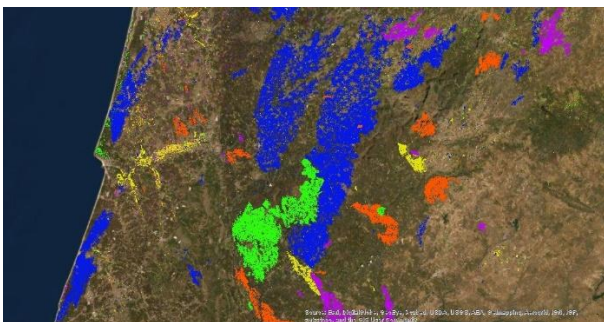


Fig. 7. Fires during the summer 2017 - areas burned in each month, computed from RBR data, coded by color: June (green), July (pink), August (orange), September (yellow) and October (blue).

The images from Sentinel-2 are available in a short delay after acquisition, so it's possible to monitor the evolution of a situation like this in near-real time.

IV. CONCLUSIONS

We describe a procedure to evaluate, and monitor burned areas, to establish a baseline for major changes in the recovery of forest ecosystems, human land use, damages assessment and priorities targeting. Besides the changes in land cover that drives this mapping, mitigation planning by stakeholders and economic interest's developments can both use this information to target efforts in the recovery process, as well as insurance companies that need precise and georeferenced information on damages. A feasible line of work with the usual resources available at most of the 308 City Halls in Portugal was detailed, with open-source software and online

remote sensed data free of charges.

Moreover, the resulting maps allows the follow up of the surface fuel loading in remote areas, enabling the targeting and evaluation of restoration measures in a time basis planning with minimum labour cost and efficiency.

REFERENCES

1. L. Szabó, B. Deák, T. Bíró, G. J. Dyke, S. Szabó, "NDVI as a Proxy for Estimating Sedimentation and Vegetation Spread in Artificial Lakes—Monitoring of Spatial and Temporal Changes by Using Satellite Images Overarching Three Decades", in *Remote Sensing*, May 2020, vol. 12(9), 1468. <https://doi.org/10.3390/rs12091468> [CrossRef]
2. G. M. Gandhi, S. Parthiban, N. Thummalu, A. Christy, "NdvI: Vegetation Change Detection Using Remote Sensing and Gis – A Case Study of Vellore District", in *Procedia Computer Science*, Vol. 57, 2015, pp. 1199-1210, ISSN 1877-0509, <https://doi.org/10.1016/j.procs.2015.07.415> [CrossRef]
3. F. Pérez-Cabello, R. Montorio, D. B. Alves, "Remote sensing techniques to assess post fire vegetation recovery", in *Current Opinion in Environmental Science & Health*, vol. 21, June 2021, ISSN 2468-5844, <https://doi.org/10.1016/j.coesh.2021.100251> [CrossRef]
4. A. M. Lechner, G. M. Foody, D. S. Boyd, "Applications in Remote Sensing to Forest Ecology and Management", in *One Earth*, vol. 2 (5), May 2020, pp. 405-412 [CrossRef]
5. J. Dash, D. Pont, R. Brownlie, "Remote sensing for precision forestry", in *New Zealand Journal of Forestry*, vol. 60(4), pp. 15-24, March 2016,
6. R. Meng, P. E. Dennison, C. M. D'Antonio, M. A. Moritz, "Remote sensing analysis of vegetation recovery following short-interval fires in Southern California shrublands", in *Plos One*, vol. 9(10), Oct 2014 doi: 10.1371/journal.pone.0110637 [CrossRef]
7. Sentinel-2 - Missions - Sentinel Online (esa.int) Accessed Nov 2021
8. User Guides - Sentinel-2 MSI - Overview - Sentinel Online (esa.int), Accessed November 2021
9. Sentinel-2 - Satellite Description - Sentinel Online - Sentinel Online (esa.int) Accessed October 2021
10. SENTINEL-2 User Handbook, ESA Standard Document, ESA 2015
11. Sentinel-2 - Missions - Resolution and Swath - Sentinel Handbook - Sentinel Online (copernicus.eu) Accessed October 2021
12. SNAP Download – STEP (esa.int) Link for the actual version (Nov 2021)
13. A. R. Huete, K. F. Huemmrich, T. Miura, X. Xiao, K. Didan, W. Leeuwen, F. Hall, C. J. Tucker, "Vegetation Index greenness global data set", *White Paper for NASA ESDR/CDR*, April 2006
14. Sentinel 2 Bands and Combinations - GIS Geography, accessed Nov 2021
15. P. Konkathi, A. Shetty, "Assessment of Burn Severity using Different Fire Indices: A Case Study of Bandipur National Park", in *Proc. IEEE Recent Advances in Geoscience and Remote Sensing: Technologies, Standards and Applications (TENGARSS)*, October 2019 DOI: 10.1109/TENGARSS48957.2019.8976036 [CrossRef]
16. S. A. Parks, G. K. Dillon, C. Miller, "A New Metric for Quantifying Burn Severity: The Relativized Burn Ratio", in *Remote Sensing*, vol. 6(3), January 2014, DOI: 10.3390/rs6031827 [CrossRef]

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Maria da Conceição Proença, was born in 1959. She received the M.S. degree in physics from the University of Lisbon, Lisbon, Portugal, and the Ph.D. degree in image processing from the Université Paul-Sabatier, Toulouse, France, in 1983 and 1992, respectively. She is currently a Research Scientist with the Physics Department, Faculty of Sciences, University of Lisbon, where she is involved in research on image processing and geographic information systems (GIS). Her current interests include deep learning for small objects detection and restoration image processing, focused on algorithmic issues for specific data extraction, and multidisciplinary approaches relating social and health sciences with environment variables, using GIS and spatial statistics. Doutora Proença is member of the Portuguese Society for Microscopy and Full Member of Marine and Environmental Sciences Centre (MARE-ULisboa).