EMERGENCY MAPPING GUIDELINES

Fire Mapping Chapter

Working Paper

Version 1.0 – as of ~~03~~ September 2018

Contents

1. FOREWORD

This chapter is aimed at providing definitions and guidelines on how to map fire extents and to indicate fire severity using satellite imagery. There a two sections to this chapter:

- A fire extent or delineation section
- A fire severity section

The main goal is to propose simple but standard approaches that can be internationally adopted, especially to increase consistency of the thematic information provided by different SEM entities for the same event, streamlining the exploitation of the crisis information by the end users.

The methodology proposed in this document does not mention radiometric calibration or atmospheric correction which could be applied to the imagery before interpreting or processing the imagery for fire severity. Given the time constraints, in rapid mapping this step is rarely carried out.

Furthermore, a Fire working group (WG) was set up within Copernicus EMS Rapid Mapping to try to establish standard methods especially in fire severity mapping. The WG benefitted from ICube-SERTIT's past experiences in the European Framework Program R&D project called PREFER.

Finally, the IWG-SEM Chair, reviewed and discussed the document within the group… In its present state the document should be completed with IWG-SEM membership comments, if any. Hence, at present this document constitutes an initial proposition for an IWG-SEM Fire Chapter, an additional chapter associated with the Guidelines. Below you will find this concise best practices interpretation guide.

A section on continent-wide fire hot spot and fire mapping services could be added in the near future.

2. IWG-SEM Fire delineation section

Satellites are particularly adapted to mapping fire extents with their synoptic yet precise view, over vast areas, where depending on the size of a fire or group of fires low to very high resolution data can play their part. This leads to continental to local detail mapping. Furthermore, satellites at different viewing scales enable repetitive viewing or monitoring.

Fires change the vegetative state of the affected area with spectral changes reflecting this removal or altering of vegetative cover. This is easily recorded by satellite with changes in reflectance depending on the density of the original vegetal cover with ash and soil components coming to the fore after the fire. This depends also on their being a more or less arid climate in the fire affected area. Spectrally speaking there is generally a big decrease in the NIR reflectivity.

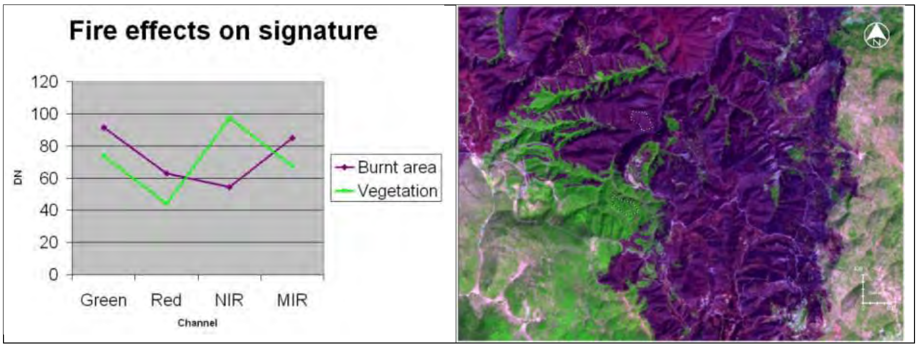


Figure 1: Digital number counts used to compare healthy vegetation (green) with a burnt area (purple) within the same image. One can note a relative increase in the visible and Short Wave InfraRed (MIR) channels and dramatic decrease in values within the Near Infrared channel. The values are derived from a SPOT 5 image acquired the 02 September 2007, ©CNES 2007, distribution AIRBUS DS, all rights reserved.

This shows that a spectral image processing approach can work to map burnt areas. This is very true but it will never be perfect in areas of sparse vegetation and unfortunately other areas can get mixed up. A validation phase is essential.
In rapid mapping the civil security/protection agencies have often asked service providers to encompass all affected areas into an envelope. They have preferred a simplified low number of burnt area polygons, avoiding too much detail and definitely not at the pixel level. This has led to an emphasis on manually digitizing the outside perimeter of burnt areas. Even if they are manually digitized it is often preferable to calculate differential Normalised Difference Vegetation Indices or Normalised Burn Ratio (see description below) to highlight the fire affected areas.

Hence, there are two standard ways of deriving a fire delineation or extent mapping. The choice of method depends on the user and, perhaps, the geometric complexity of (a) burnt area(s).

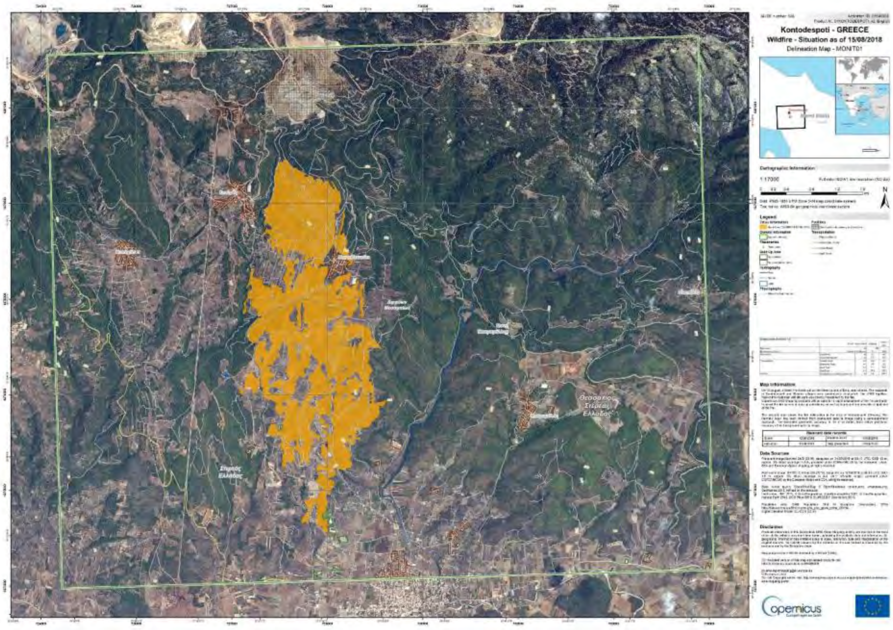


Figure 2: Fire delineation/extent map over Kontodespoti, Greece. The complex fire limit was manually interpreted.

3. Fire Severity Mapping

Firstly, 2 different approaches to mapping fire severity need to be distinguished depending on the characteristics of the images being used:

- Images with SWIR channel (Sentinel-2, Landsat-8, Worldview-4 in some cases, …)
- Images without SWIR channels (SPOT 6/7, Pléiades, Wv-2, WV-3, WV-4 in most of the cases).

The method with SWIR channels is straight forward and widely used in the scientific community; the method without SWIR is a stop gap that indicates vegetation presence or not within the fire affected areas before and after a fire. This is the burn scar and its neighbourhood. Unfortunately, the vast majority of agile, rapidly available satellite images do not have a SWIR channel.

3.1 Procedure with SWIR channels

As already stated, to optimize the step of digitising the burn scar you can use the result of the severity method described below to help you. Furthermore, you can combine this with the best band combination with which to observe this kind of event is SWIR-NIR-RED (12-8-4 for Sentinel-2 for example) (Fig. 3). The workflow given below as an example taken from a fire mapping activation in France.

a) Use Pre and Post fire images acquired as close as possible to the fire event.
b) Calculate Normalised Burn Ratio (NBR)[1] index for pre and post-fire images:

$$NBR = NIR - SWIR / NIR + SWIR$$

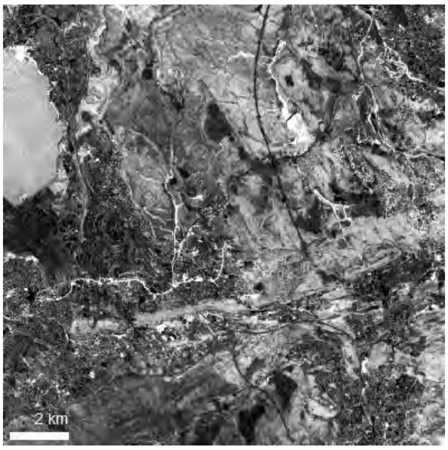
c) Then calculate the difference dNBR:

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

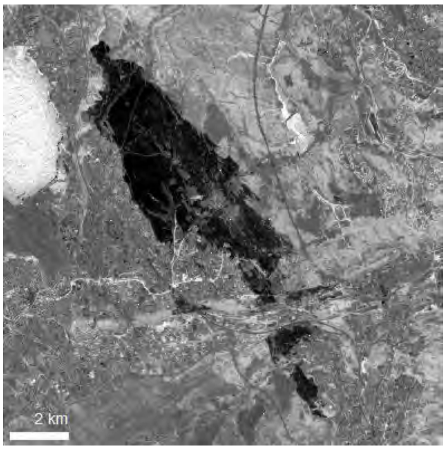
[1] Key, C.H.; N. Benson; D. Ohlen; S. Howard; R. McKinley; Zhu Z., 2002, The normalized burn ratio and relationships to burn severity: ecology, remote sensing and implementation, Proceedings of the Ninth Forest Service Remote Sensing Applications Conference. American Society for Photogrammetry and Remote Sensing, Bethesda, MD, J.D. Greer, ed. Rapid Delivery of Remote Sensing Products

Sentinel-2A (24/07/2016)

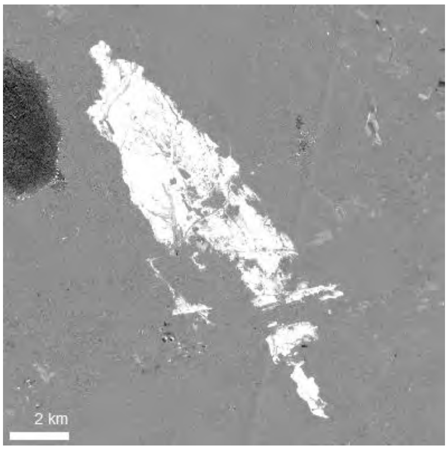
Sentinel-2A (13/08/2016)



Sentinel-2A-NBR (24/07/2016)



Sentinel-2A-NBR (13/08/2016)



dNBR derived from Sentinel-2A acquired the 24/07/2016 and the 13/08/2016

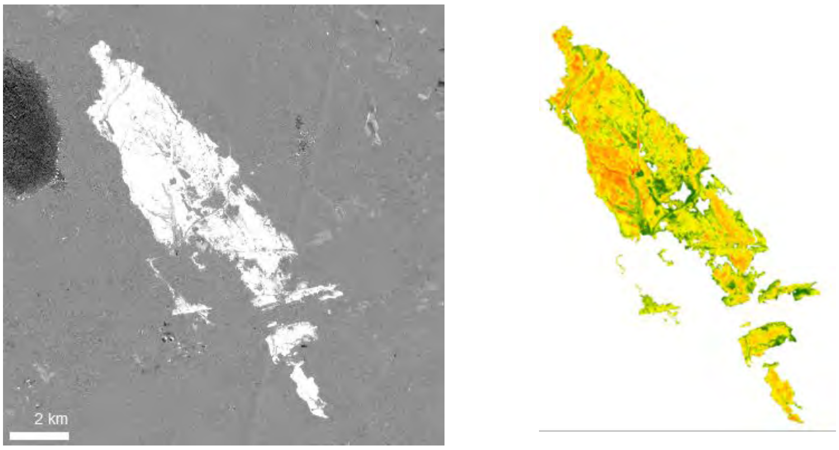
Figure 3: Optimal pre and post Sentinel 2 band combinations, resulting pre and post NBR's and resulting dNBR to help in digitising the fire affected areas.

d) Classify with the predetermined classes by US Forest Service

The dNBR was calculated and classified according to the US Forest Service classification illustrated in the table 1 below and figure 4.

Table 1: US Forest Service dNBR fire severity classification

dNBR	Fire severity	
<= 0.1	Unburned	
0.1 to 0.27	Severity low	
0.27 to 0.44	Severity low to moderate	
0.44 to 0.66	Severity moderate to high	
> 0.66	High severity	



dNBR before classification　　　　dNBR after classification

Figure 4: Deriving a dNBR based fire severity index

e) Clip the Severity result by the fire extent.

Either the images are pre-clipped or clipped after dNBR calculation (Fig. 4).

The authors of this IWG-SEM guide recommend reducing the number of fire severity classes in order to simplify the product, corresponding to this rapid mapping production environment. The unburnt class has been removed and the low to moderate and moderate to high classes are grouped into a 'Damaged' class. The removal of the unburnt class indicates that when doing the fire extent product only burnt areas should be mapped.

To help understand the relationship between the dNBR classes and ~~EMS~~ the proposed IWG-SEM classes, they are illustrated below in figure ~~3~~5.

dNBR	Fire severity	
<= 0.1	Unburned	(green)
0.1 to 0.27	Severity low	(yellow)
0.27 to 0.44	Severity low to moderate	(light orange)
0.44 to 0.66	Severity moderate to high	(orange)
> 0.66	High severity	(red)

EMS classes	
Unburned	
Possibly damaged	(yellow)
Damaged (low to moderate and moderate to high)	(orange)
Destroyed	(red)

Figure 5: Comparison between dNBR and EMS severity classes

3.2 Procedure without SWIR channels

The aim of this exercise was to propose, if possible, a method that involved less subjectivity in presenting a fire severity map using indices and thresholds in images not containing a Short Wave Infrared (SWIR) band. The class grouping is specific to Copernicus EMS Rapid Mapping and can of course be adapted to circumstances.

The testing of NDVI's and difference NDVI's (dNDVI) are analysed and illustrated below.

A test was carried out on a wild fire affected area dealt with during the EMSR-221and EMSR-252 over Corsica:

http://emergency.copernicus.eu/mapping/list-of-components/EMSR221

Code de champ modifié

The activation's delineation vector was used to delimit the area to be analysed. Furthermore, to complement the fire severity analysis, enabling a comparison between non-SWIR/SWIR data, Sentinel-2 imagery were sourced that cover the area close to the events (table 2). The operator validated fire severity results derived from the Sentinel-2 data are considered to be the layer of reference.

Table 2: List of satellite data used for the EMSR-221 and EMSR-252 Corsica test

Activation	Sensor	Date	Resolution
EMSR 252	Sentinel - 2	24/10/2017	10 m
	Sentinel - 2	29/10/2016	10 m
	SPOT6/7	24/10/2017	1.5 m
EMSR221	Sentinel - 2	24/10/2017	10 m
	Sentinel - 2	29/10/2016	10 m
	SPOT6/7	30/05/2017	1.5 m
	SPOT6/7	15/08/2017	1.5 m

The results of the image processing and classification, which as displayed in figures 5 & 6, indicate that the simple use of the post fire NDVI has the worst results with large shadowed areas being classed as badly affected contrary to the classic post image classification and the dNBR results. Otherwise, the dNDVI results look promising when compared to the dNBR results. Moreover, the dNDVI seems to be a good alternative helping to detect if vegetation is still photosynthetic in shadowy areas.

Furthermore, the correlation of the dNDVI and the dNBR has been noted through scatterplots that show that they are someway related. Hence, dNDVI is a good way of calculating fire severity and could be used in a fire severity classification procedure when no SWIR is available.

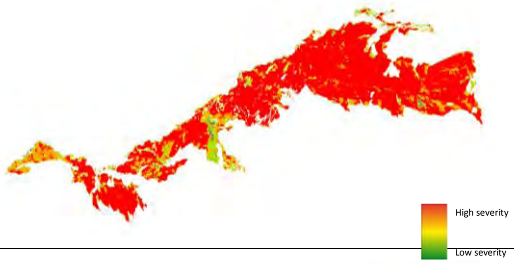
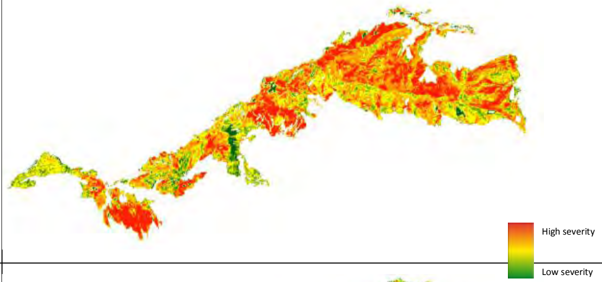
Methodology	TEST over EMSR 221 – Corsica
Classic EMS based on post event VHR image using supervised classification	
Classification based on pre and post-event Sentinel-2 NBR data (dNBR)	
Classification based on SPOT 6/7 NDVIs differences (NDVI pre-NDVI post)	
Classification based on S2 NDVIs differences (NDVI pre-NDVI post)	

Figure 6: Results of different fire severity methodologies applied to the EMSR 221 – Corsica fire delineation area.

Furthermore, comparison of dNDVI values obtained from Sentinel-2 and Spot-6 dNDVI in the burn scar shows a high similarity which for rapid mapping purposes they can be used in combination (Fig. ~~8~~7). The three classes correspond to dNBR derived nomenclatures and classes used in Copernicus EMS Rapid Mapping and their dNDVI correspondences are described in table 3.

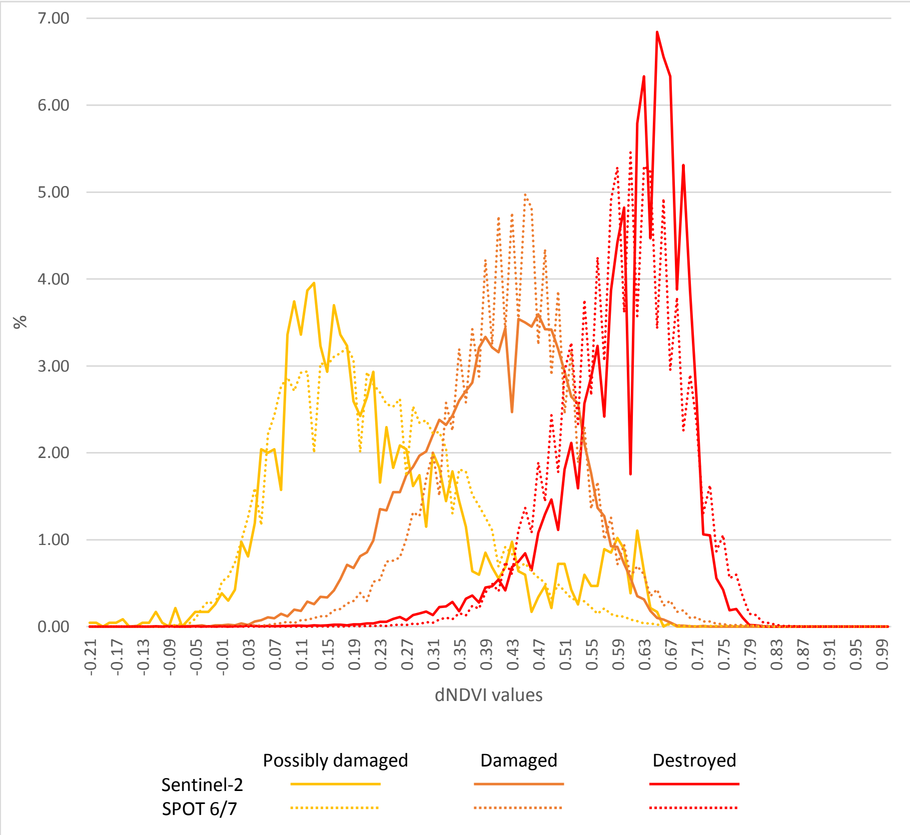


Figure 7: Results of fire severity dNDVI methodology applied to the EMSR 221 – Corsica fire delineation area. The two middle classes are regrouped afterwards

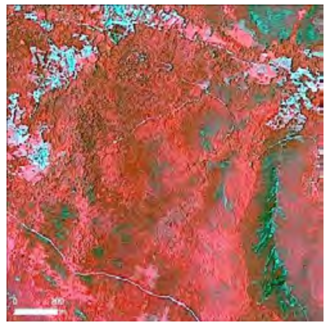
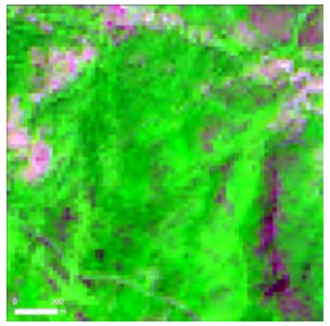
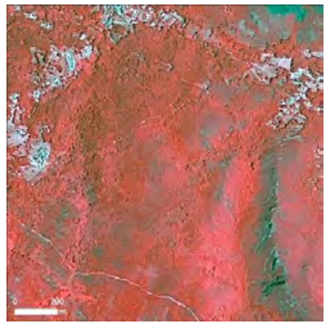
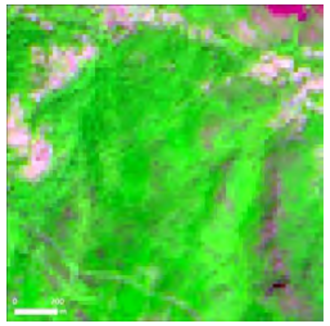
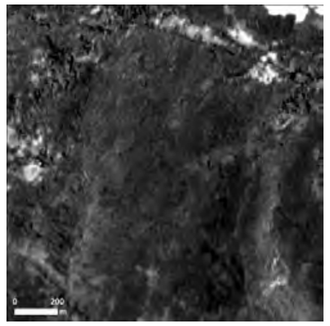
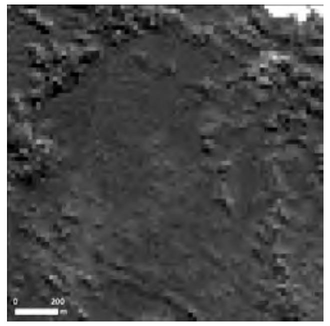
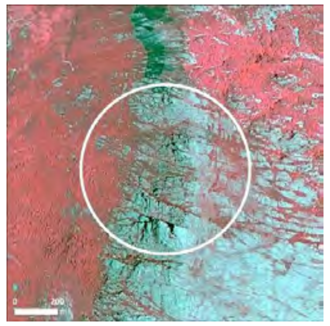
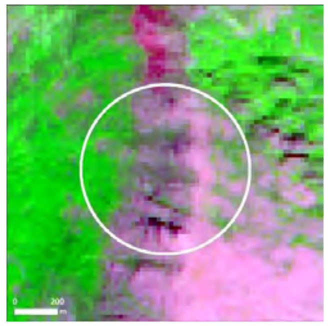
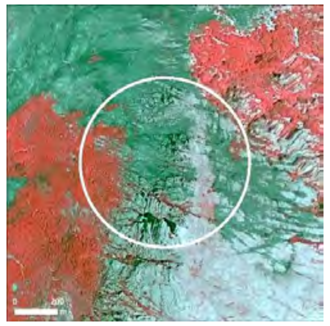
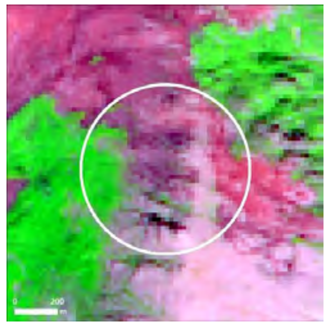
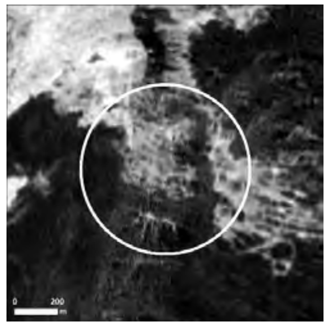
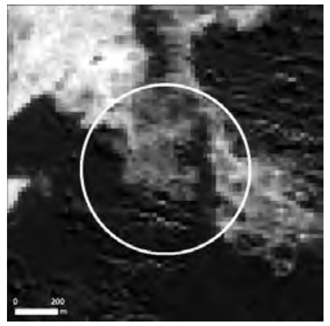
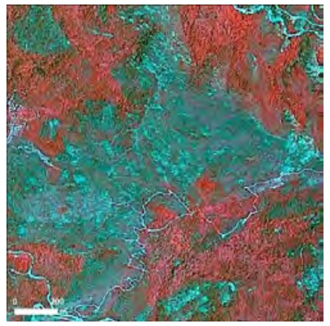
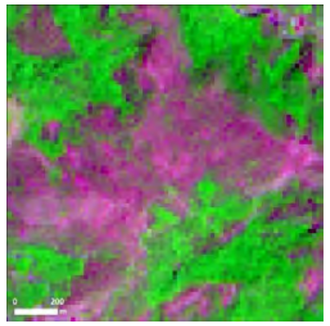
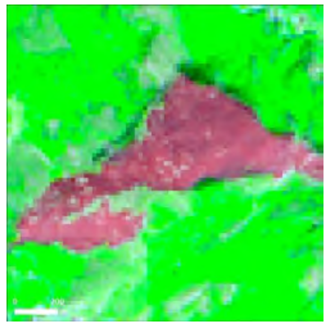
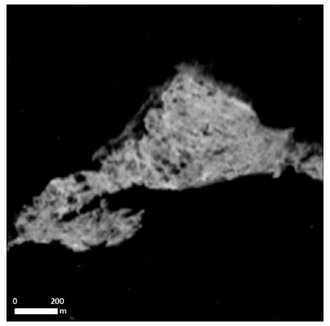
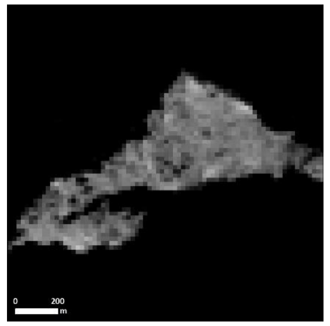
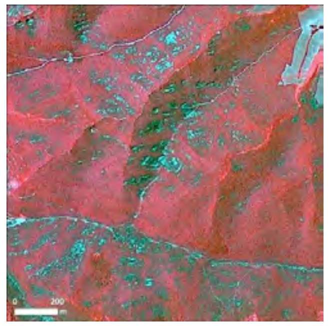
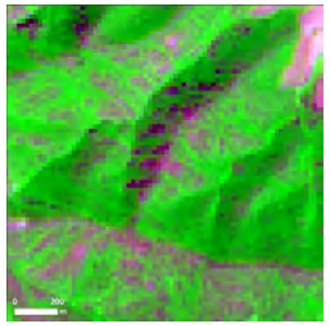
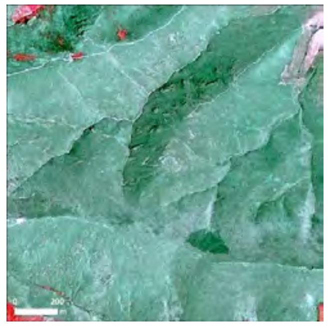
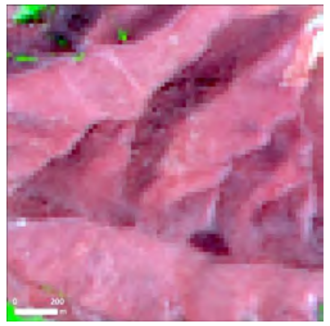
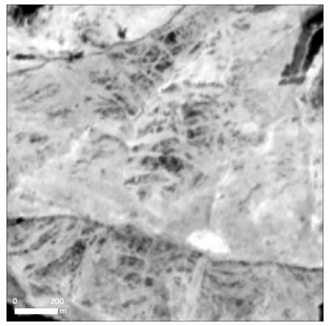
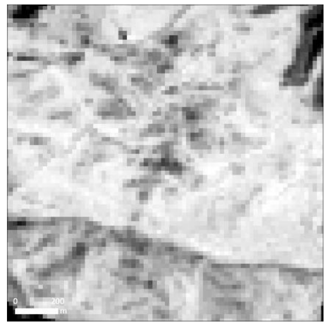
***Table 3: Fire severity class description and corresponding dNDVI values** which work for Sentinel-2 and SPOT 6/7 dNDVI calculation (values can be adjusted depending the images used)*

dNDVI per fire severity class	Class description	Colour
dNDVI <= 0.3	Possibly damaged	
0.3 > dNDVI <=0.55	Damaged	
dNDVI >0.55	Destroyed	

4. Interpretation guide to fire severity classification

To help in understanding the fire severity classification on the following page image extracts of fire affected landscapes are arranged according to fire severity levels:

- Pre-fire imagery, both with and without SWIR
- Post-fire imagery, both with and without SWIR
- dNDVI and dNBR indices which indicate fire severity

Class	Pre-Fire		Post-Fire		Fire severity indices	
	Spot 6/7 (r: 4 g:3 b:2)	Sentinel-2 (r:12 g:8 b:4)	Spot 6/7 (r: 4 g:3 b:2)	Sentinel-2 (r:12 g:8 b:4)	Spot 6/7 dNDVI	Sentinel-2 dNBR
Unburned						
Possibly damaged						
Damaged						
Destroyed						

5. Acknowledgements

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Fire mapping Lead:

ICube-SERTIT, University of Strasbourg
(http://sertit.u-strasbg.fr/)

Code de champ modifié

Contributors:

European Commission, Directorate-General Joint Research Centre, Disaster Risk Management Unit
(https://ec.europa.eu/jrc/en/research-topic/disaster-risk-management)

Code de champ modifié

e-GEOS, an ASI/TELESPAZIO Company
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GAF AG, an e-GEOS (ASI/TELESPAZIO) Company
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ITHACA - Information Technology for Humanitarian Assistance, Cooperation and Action
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