FRAMEWORK SERVICE CONTRACT FOR
*COPERNICUS EMERGENCY MANAGEMENT SERVICE
RISK & RECOVERY MAPPING*
TECHNICAL REPORT
***EMSN166: Post-Wildfire damage assessment in East
Macedonia, Greece***

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ACRONYMS

Acronyms	Signification
AOI	Area of Interest
AU	Authorized User
CEMS	Copernicus Emergency Management Service
EMSN	Emergency Management Service No rush
EMSR	Emergency Management Service Rush
GSD	Ground Sampling Distance
HR	High Resolution
IWG-SEM	International Working Group on Satellite-based Emergency Mapping
JRC	Joint Research Centre
LULC	Land Use Land Cover
MMU	Minimum Mapping Unit
NA	Not Applicable
NBR	Normalized Burn Ratio
NIR	Near Infrared
NDVI	Normalized Difference Vegetation Index
ONA	Off Nadir Angle
OSM	OpenStreetMap
RM	Rapid Mapping
RRM	Risk and Recovery Mapping
SP	Service Provider
SRF	Service Request Form
STD	Standard
SWIR	Short Wavelength Infrared
VHR	Very High Resolution

1 INTRODUCTION

1.1 ACTIVATION DETAILS

COPERNICUS RISK AND RECOVERY MAPPING ACTIVATION	
ACTIVATION DETAILS	
Activation Name	EMSN166: Post-wildfire damage assessment in East Macedonia, Greece
Authorized User	General Secretariat for Civil Protection, Emergency Planning and Response Directorate, Ministry of Climate Crisis and Civil Protection GR aantonakos@gscp.gr +30 213 1510170
Date and Time of Activation (UTC)	24.08.2023 07:17
EVENT DETAILS	
Event Type(s)	Wildfire
Location	East Macedonia, Greece
Date and Time of the Event (UTC)	19.08.2023 02:49

Table 1-1: Activation Details

1.2 EVENT DESCRIPTION AND CONTEXT

On the early morning (04:49 local time) of the 19 August 2023, a wildfire started in a forest area near Aristino village in the Greek regional unit of Evros, East Macedonia & Thrace near the northeastern border with Turkey.
Seven towns had to be evacuated a few hours after the declaration of the forest fire near the town of Alexandroupoli. The first evacuation order was directed towards the villages of Nipsa, Aetochori and Pefka, followed by another message, sent around 4:00 p.m., which urged the evacuation of Loutros, Agnantia, Aristino and Doriko villages, reported the Greek newspaper 'Kathimerini'.

Figure 1-1 The forest fire raging near the town of Alexandroupoli, East Macedonia, Greece[1]

Given the severity of the event, the Authorised User (AU) triggered Copernicus EMS Rapid Mapping service. Through the EMSR686 activation, after an initial First Estimate Product (derived from Sentinel-3 imagery), a Delineation and nine Delineation Monitoring Products have been delivered from 21/08/2023 to 03/09/2023 (https://rapidmapping.emergency.copernicus.eu/EMSR686/download).

Updated information on the status and results of the EMSR686 can be found in the Situational Report available at https://rapidmapping.emergency.copernicus.eu/EMSR686/reporting.

The EMSR686 activation was closed and the fire have been considered as extinguished the 08/09/2023. Around 93,880 ha of burnt areas were detected.
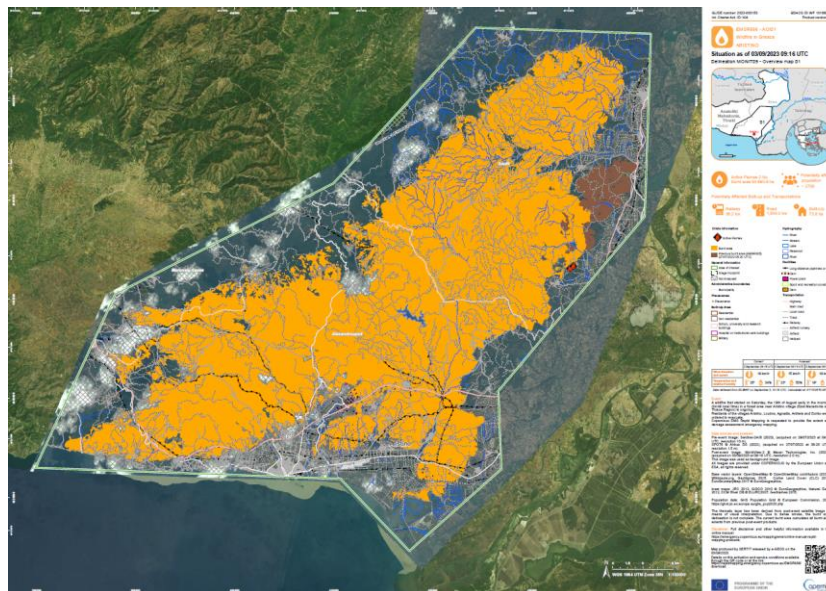
Figure 1-2 EMSR686 Delineation Monit09 Product, as of 03.09.2023

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[1] Source: https://www.ekathimerini.com/news/1218157/wildfire-near-alexandroupoli-rages-for-third-day/

The AU specified in the SRF that he wants to activate the Copernicus EMS Risk and Recovery STD to provide the P07-Wildfire delineation and grading product.

The AOI used during the EMSR686 evolved throughout the activation as the fire progressed (Figure 1-3 left). The last AOI used in EMSR686 is used for this EMSN166 activation (Figure 1-3 right):

• **AOI01- ARISTINO** (in red, 1,709.5 km²)
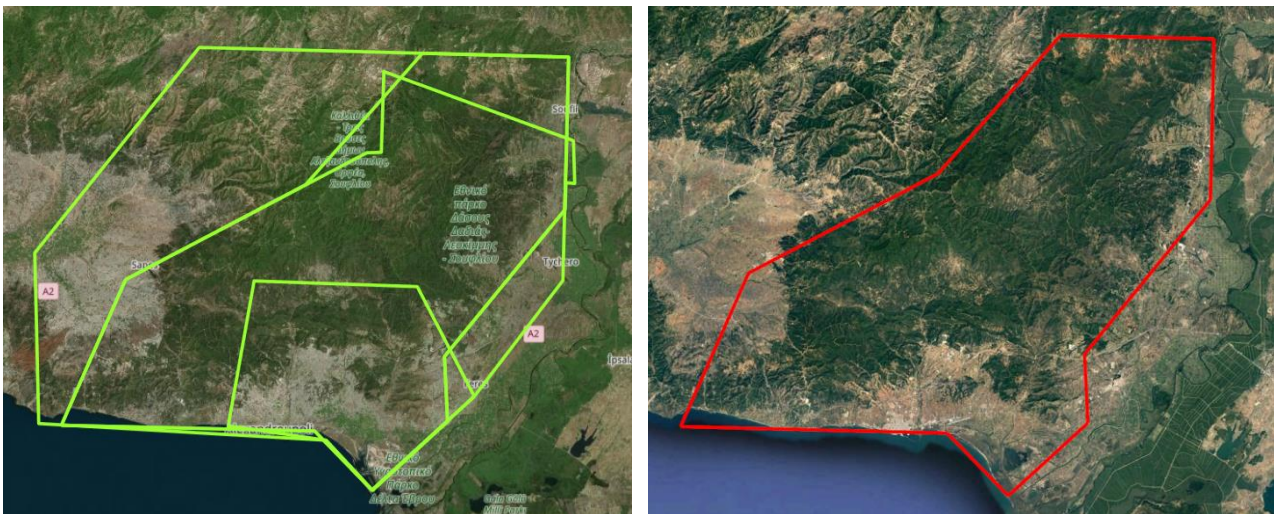
Figure 1-3 AOI01-Aristino (left: EMSR686 ; right: EMSN166)

The size of the AOI exceeds the maximum area for the production of a P07. However, considering the methodology and the imagery that will be used, it was proposed in the feasibility analysis to produce P07 over the whole final burnt area.

1.3   SERVICE REQUEST

1.3.1   OBJECTIVE

The goal of the activation is to provide wildfire delineation and grading products within the AOI01, aiming at providing the ecological value of the affected area, as well as to assess the damages caused by the wildfire event.

1.3.2   FEASABILITY STUDY

The EMSN166 activation was accepted as a result of an accurate feasibility analysis that was carried out to define the requirements necessary to assure the generation of the requested products (see Table 1-2).

REQUESTED PRODUCTS						
Product Code	Product description	Scale	Image resolution class/Sensor type	Input Data (obligatory)	AOI (km²)	Delivery time (days)
P07	Wildfire delineation and grading	1:25000	VHR, HR	Image data	25-500	5-10

Table 1-2 Technical details for requested standard products

Moreover, the AU highlighted during previous activations (EMSN159, EMSN170) that P07 results produced with satellite images without SWIR band (and thus dNDVI fire severity methodology) can be underestimated. It was proposed in this EMSN166 activation to produce two P07:

- A P07 where the fire severity was calculated with Sentinel-2 image (with SWIR band and the dNBR methodology),

- A P07 where the fire severity was calculated with a SPOT-6 image (without SWIR band and with the dNDVI methodology).

Following the feasibility study, the service provider committed the delivery of the following products:

- **P07-Wildfire delineation and grading based on dNBR method,**
- **P07-Wildfire delineation and grading based on dNDVI method.**

It was highlighted that the request expressed through the EMSN166 SRF could be satisfied with a derogation to exceed the maximum area for the production of a P07.

FEASIBILITY OF REQUESTED PRODUCTS						
PRODUCT CODE	PRODUCT DESCRIPTION	SCALE	AOI(s)	AOI (km²)	Other details	Feasible/ Not Feasible
P07	Wildfire delineation and grading	1:25000	AOI01- Aristino	1709.5	Spot-6 post-event image	✔
P07	Wildfire delineation and grading	1:25000	AOI01- Aristino	1709.5	Sentinel-2 post-event image	✔

Table 1-3 Technical feasibility statement for the EMSN166 Activation

1.3.3   PRODUCTS DESCRIPTION

Products generated within this activation are described in Table 1-4.

	AOI	Product description
P07	AOI01	The **wildfire delineation and grading** product shows the delineation of the burnt area and the associated level of damage as derived from post-event optical VHR image. The P07 product shows that the majority of the analyzed area have been assessed as high damage by analyzing the variation of the **NBR**.
P07	AOI01	The **wildfire delineation and grading** product shows the delineation of the burnt area and the associated level of damage as derived from post-event optical VHR image. The P07 product shows that the majority of the analyzed area have been assessed as negligible to slight damage by analyzing the variation of the **NDVI.**

Table 1-4 Products description

The final delivery includes the products reported in Table 1-5.

Product Name		AOI	Description	Type	Scale	Num.
RRM OVERVIEW MAP	1	AOI01	P07-Wildfire delineation and grading	Overview Map	1:100000	2
GDB	2	-	Geodatabase with results	GDB	-	1
Technical Specifications FWC	3	AOI01	.geojson and shapefiles of: - AOI01 - P07 Delineation product - P07 Grading product	Vector	1:25000	6
	4	-	Symbology used for delivered vectors	.lyr, .sld files	-	8

Product Name		AOI	Description	Type	Scale	Num.
	5	-	Consequence tables of: - P07 Wildfire delineation and grading	.xlsx files	-	2
	6	-	Metadata for the GDB and all the feature classes within the gdb and maps delivered	.xml files	-	9
	7	-	Flyer	Report	-	1
	8	-	Factsheet	Report	-	1
	9	-	Final Report	Report	-	1

Table 1-5 Deliverables description

2   INPUT DATA

Input data for EMSN166 consist in both pre- and post-event Sentinel-2 images used for the P07-Wildfire delineation and grading based on the dNBR approach and in post-event SPOT-6 images used for the P07-Wildfire delineation and grading based on the dNDVI approach. Ancillary datasets retrieved from OpenStreetMap (and EMSR686) were used to improve the readability of the cartographic products.

2.1   EO DATA

Data type	Sensor	Acquisition date and time (UTC)	GSD (m)	Off-nadir angle (°)	Cloud cover (%)	RRM STD Products
PRE-EVENT SATELLITE IMAGERY	Sentinel-2	19.07.2023 09:05	10	N/A	0.0	P07
POST-EVENT SATELLITE IMAGERY	Sentinel-2	12.09.2023 09:06	10	N/A	0.0	P07
	SPOT-6	21.09.2023 08:34	1.5	24.8	12.2	P07
	SPOT-6	03.10.2023 08:41	1.5	7.8	0.0	P07

Table 2-1 EO Data for EMSN166 P07 product

Data type	Sensor	Acquisition date (or interval)	Request submission date and time (UTC)	Reception date and time (UTC)
PRE-EVENT SATELLITE IMAGERY	Sentinel-2	19.07.2023 09:05	N/A	13.09.2023 09:29 UTC
POST-EVENT SATELLITE IMAGERY	Sentinel-2	12.09.2023 09:06	N/A	13.09.2023 09:29 UTC
	SPOT-6	21.09.2023 08:34	13.09.2023 09:29 UTC	05.10.2023 09:05 UTC
	SPOT-6	03.10.2023 08:41	13.09.2023 09:29 UTC	05.10.2023 09:05 UTC

Table 2-2 EMSN166 Imagery procurement details

2.2   OTHER INPUT AND ANCILLARY DATA

Data source	Provider	Format	Availability	Use
Transportation	OSM	Vector	www.osm.org	Reference for map production
Hydrography	OSM	Vector	www.osm.org	Reference for map production

| Data source	Provider	Format	Availability	Use
Settlements and Facilities	OSM	Vector	www.osm.org	Reference for map production

Table 2-3 Input and ancillary data for EMSN166 products

3   METHODOLOGY

3.1   P07 – WILDFIRE DELINEATION AND GRADING

The P07-Wildfire delineation and grading products provide an assessment of the event's impact, its spatial distribution, and extent. The product covers any event type related to wildfire and provides generic information about the affected land. The product is directly derived from the image data, acquired as soon as possible after the emergency event (once extinguished), and consists of the collection of burnt areas together with damage grade information.

Figure 3-1 below shows an example proving that given the large spectral difference between vegetated and burnt areas, the spectral image processing approach is applicable in mapping burnt areas.
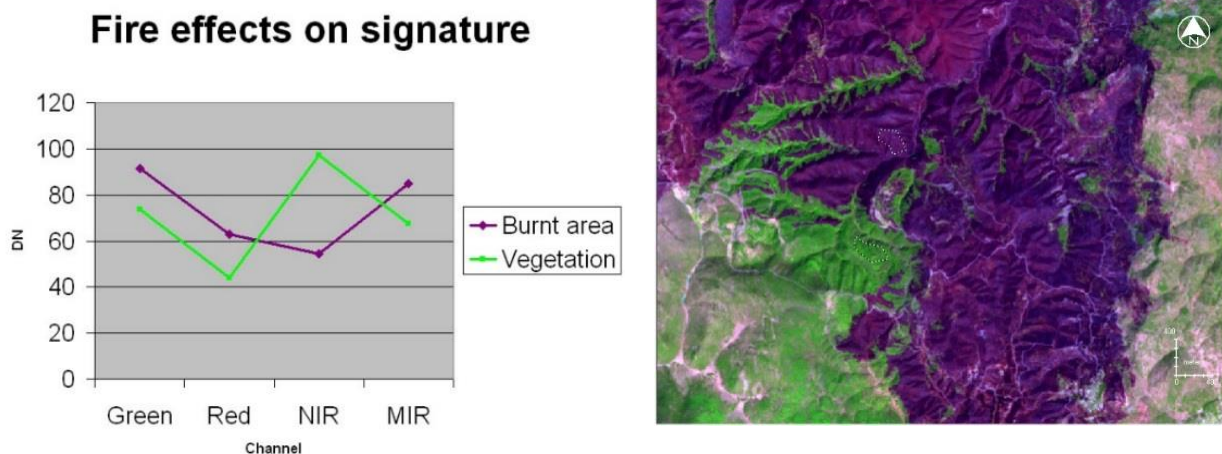
Figure 3-1 Digital number counts used to compare healthy vegetation (green) with a burnt area (purple) within the same image. One can note a relative increase in the visible and Short Wave InfraRed (SWIR) channels and dramatic decrease in values within the Near Infrared channel. The values are derived from a SPOT-5 image acquired on the 02 September 2007, ©CNES 2007, distribution AIRBUS DS, all rights reserved.

Despite this approach being suitable in most cases, it will never be perfect in areas of sparse vegetation, and unfortunately other areas can get mixed up. To obtain the most accurate results a manual validation phase is essential in the P07 production workflow.

3.1.1   WILDFIRE DELINEATION

The wildfire delineation product is based on change detection between dates prior and after the fire event. The first step is to select two sets of images relevant for the burnt area detection. Images should be acquired as close as possible to the event and to each other, to ensure a highly discriminable burnt scar and similar vegetation states in its surroundings for both dates.

In the framework of the EMSN166 activation, the *Normalised Burn Ratio* (NBR) and the *Normalized Difference Vegetation Index* (NDVI) were calculated for each image. The NBR is calculated as:

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

While the NDVI is calculated as:

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

These two indices represent the vegetation health state and have strong capabilities in extracting wildfires burned areas and impacts. The burnt area delineation produced within EMSR686 was used as a basis and reviewed manually by combining all pre and post-event data as well as the two indices (dNBR and dNDVI) calculated. The final resolution of the burnt area delineation is based on the most accurate post-event data (i.e. SPOT-6). Objects under the Minimum Mapping Unit (MMU) equal to 2500 m2 were removed.

The classification into "fire" and "not fire" classes was not easy due to the complexity of the event.

The fire partially occurred in an area already affected in July 2022 (EMSR605). The delineation of the recent burnt areas without including wrongly past burnt areas was not easy. During the rapid mapping activation (EMSR686), several monitoring were done and a couple of them highlighted active fires in the area already affected in 2022 (Figure 3-2). This confirms that previous burnt areas were impacted again during this fire event.
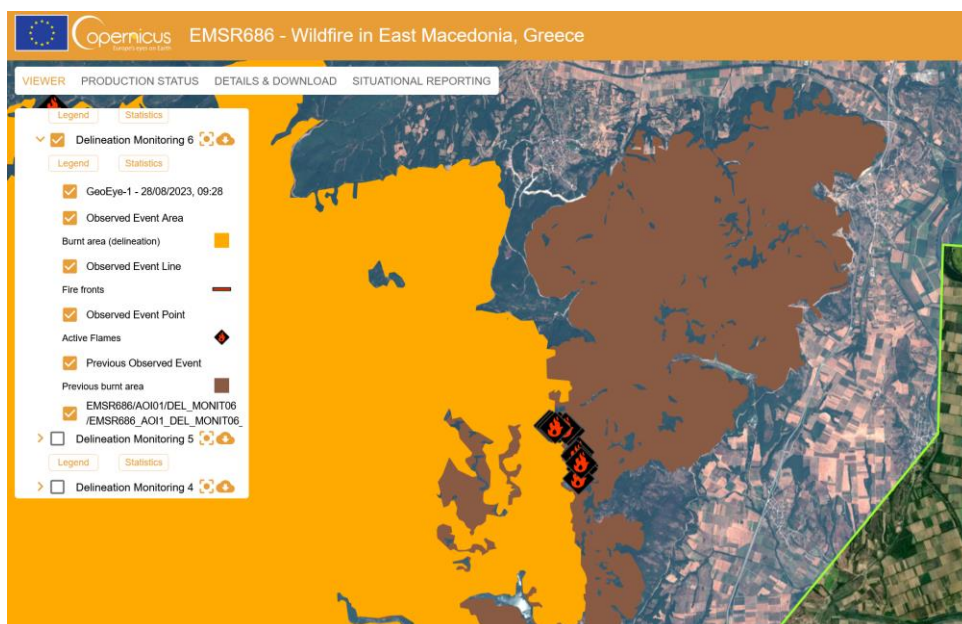
Figure 3-2 Active fires detected on a GeoEye-1 acquired on the 28.08.2023 over the previous burnt area (EMSR686 DEL MONIT6)

Moreover, another challenge was to exclude non-affected vegetation patches within the global burnt area without excluding areas where only the trunks could have been burned. The SP made the choice to first delineate the global boundaries of the burnt area. And then, vegetation patches larger than the MMU (2500 m²) and areas with a high spectral signature in NIR and SWIR bands were excluded (Figure 3-3).

a. Pre-event Sentinel-2 (SWIR-NIR-R)

b. Post-event Sentinel-2 (SWIR-NIR-R)

c. Post-event SPOT-6 (NIR-R-G)

d. NDVI post-event Sentinel-2
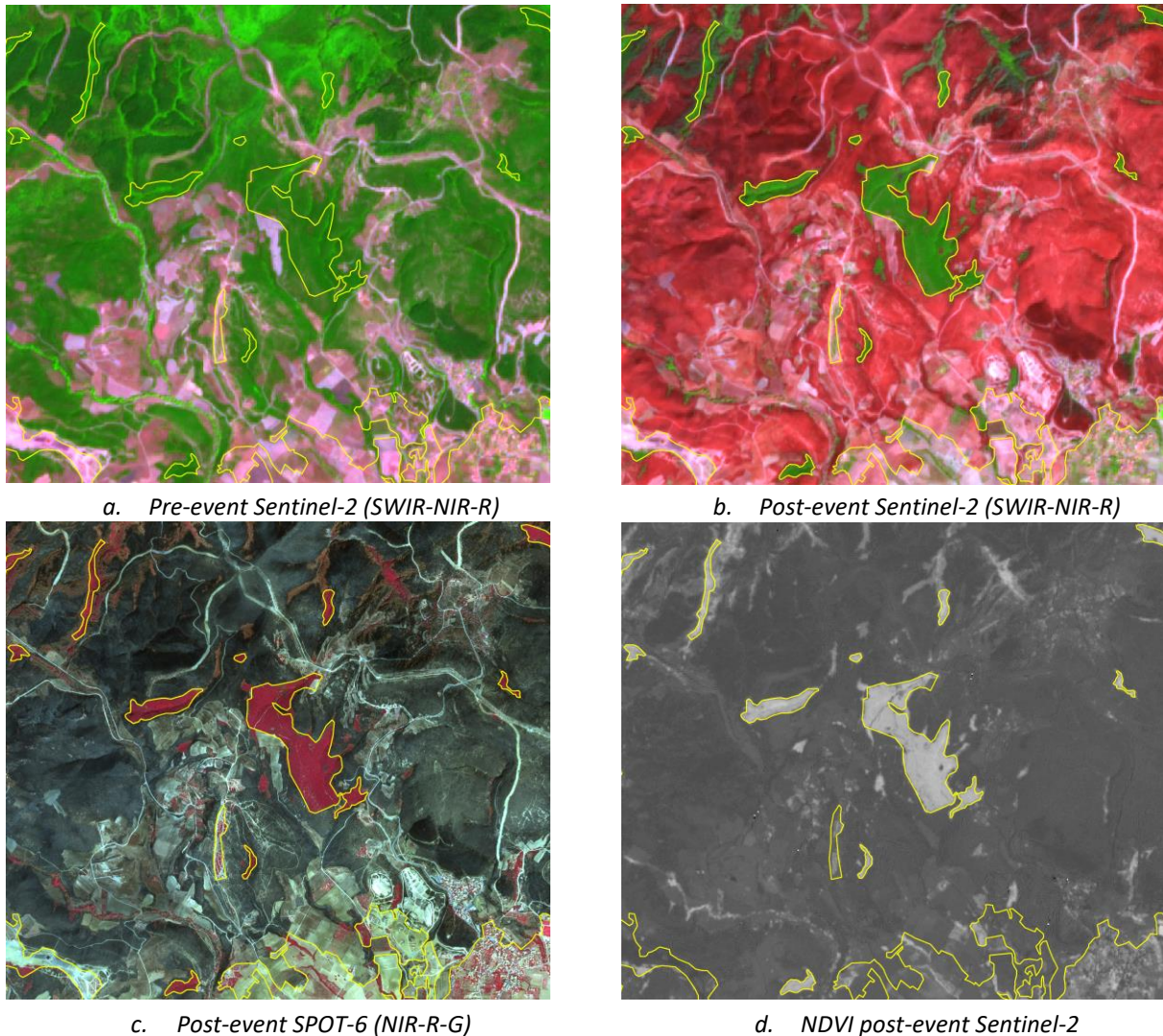
Figure 3-3 Non-affected vegetation patches within the burnt area (yellow boundaries)

Consequently, the burnt area includes small vegetation areas that appear to have not been affected by the fire as their spectral signatures indicate a chlorophyll activity. But it is difficult to imagine that these patches were not affected as the fire completely burnt the surrounding areas (Figure 3-4), at least trunks were probably affected but not the canopy.
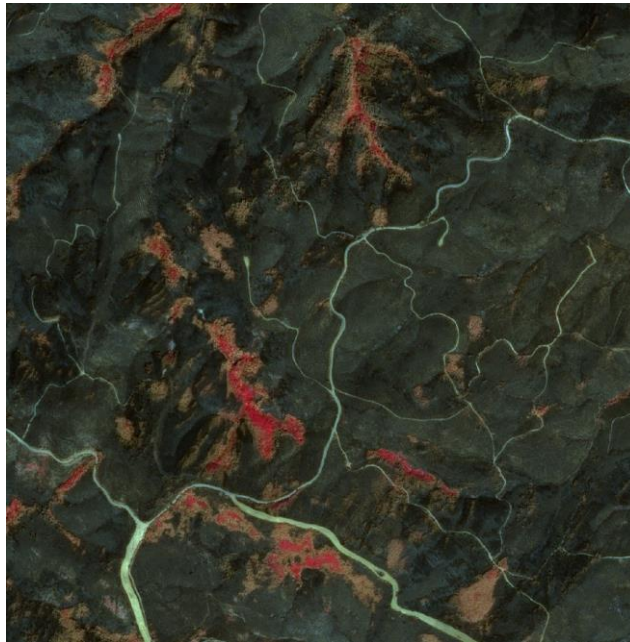
Figure 3-4 Vegetation patches included in the burnt area delineation (Post-event SPOT-6; NIR-R-G)

3.1.2 WILDFIRE GRADING

The AU highlighted during previous activations (EMSN159, EMSN170) that P07-Grading results produced with satellite images without SWIR band (and thus dNDVI fire severity methodology) can be underestimated. It was proposed in this EMSN166 activation to produce two fire severity analyses:

- A P07 where the fire severity was calculated with Sentinel-2 image (with SWIR band and the dNBR methodology),

- A P07 where the fire severity was calculated with a SPOT-6 image (without SWIR band and with the dNDVI methodology).

The standard thresholds values were applied in both cases.

The wildfire grading is computed using the wildfire delineation previously mapped and the dNBR or dNDVI layers. Once the indexes are calculated for the reference and crisis images, change detections are applied by subtracting the crisis index layers from their respective reference layer, resulting in dNBR and dNDVI layers.

The damage grades are specific to a given event, being presented by four classes namely:

- Destroyed,
- Highly Damaged,
- Moderately Damaged,
- Negligible to Slight Damaged.

These methods are straightforward, widely used and well described in the IWG-SEM guidelines. The dNBR and dNDVI are calculated and classified according to the adapted IWG-SEM classes, as illustrated by the Table 3-1 below. As four

classes are requested in the standard P07 product, the *Moderate severity* class of the IWG SEM classification is split into two CEMS RRM classes, *Moderate damage* and *High damage.*

IWG-SEM classes	EMS RRM classes		dNDVI	dNBR
Low severity	Negligible to slight damage		<= 0.3	<= 0.27
Moderate severity	Moderate damage		0.3 to 0.41	0.27 to 0.44
	High damage		0.41 to 0.55	0.44 to 0.66
High severity	Destroyed		> 0.55	> 0.66

Table 3-1 Severity classes correspondence table between IWG-SEM and CEMS RRM

4   RESULTS

After a preliminary review of both results by the AU, it has been decided to present only the Grading result obtained with the dNBR approach. As stated in the previous chapter, the dNDVI method can underestimated the fire severity. The AU estimated that the Grading analysis using the dNBR approach was the most reliable result.

4.1   P07 – WILDFIRE DELINEATION AND GRADING

The wildfire has a size of 92 321 ha which is more than 50 % of the AOI. The fire grading based on dNBR thresholding is shown in Table 4-1 and in Figure 4-1. The most important part of the burnt area is classified as High Damage (36%) with the dNBR approach and the surface of the Detroyed vegetation is higher than 4 000 ha.

	Unit of measurement	Destroyed	High damage	Moderate damage	Negligible to slight damage	Total affected
Burnt area	ha	4 587.2	34 842.6	22 153.7	30 737.5	92 321.0

Table 4-1 Break down of affected areas by fire severity grading (dNBR approach)
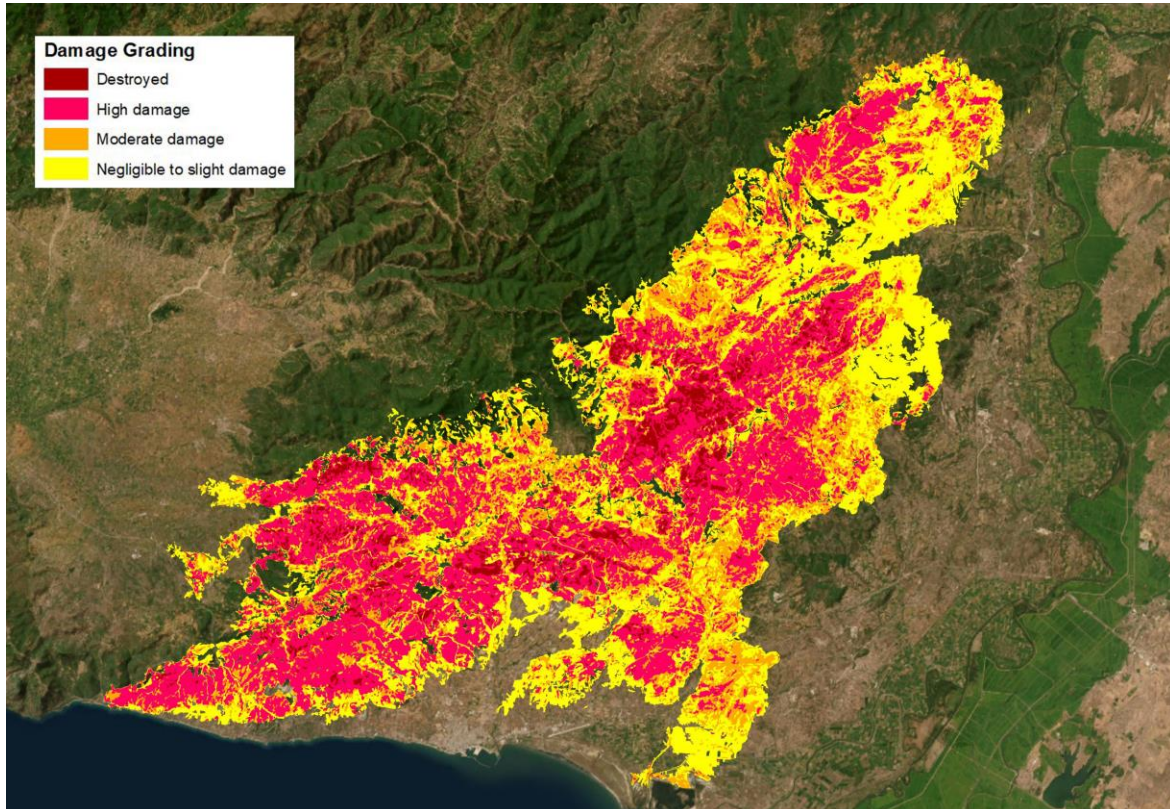
Figure 4-1 Overview of the P07 Wildfire grading (dNBR approach)

5   INTERNAL QUALITY CONTROL

5.1   P07 – WILDFIRE DELINEATION AND GRADING

5.1.1   THEMATIC ACCURACY

Thematic validation is performed to assess the thematic quality of P07 product. The wildfire delineation consists of a layer representing 2 classes: burnt and unburnt areas. Congalton, Russell G. and Kass Green (2002)[2] suggest that in the case of a change/no change map, a binomial class distribution is appropriate for assessing the sample size. An example is also presented; for a 90% accuracy and a confidence level of 95%, a sample size of 298 is required. The thematic accuracy required for P07 is 85%, so a sample size of 300 allows to ensure to reach this accuracy and even to be on the safe side.

The same authors proposed a method for increasing the number of samples in the areas surrounding the burned scar. The number of samples are dispersed as shown in Table 5-1.

Strata	Percentage of total samples	Number of samples
Burnt area	40	120
Direct surroundings	30	90
Rest of the AOI	30	90

Table 5-1 P07 - Sampling strategy

The sampling strategy is stratified and random. The "burnt area" stratum is self-explanatory. The "direct surrounding" stratum corresponds to areas in contact with the burnt area where confusions in the fire delineation are expected to be probable. This area is defined by a buffer of 100m around the burnt area. The "rest of the AOI" stratum is also self-explanatory.

For each sample point, the correctness of the classification was assessed manually on the same image used for production by an operator that was not involved in the previous steps of the production.

The accuracy of the delineation product is assessed through Producer's, User's, and finally Overall accuracies. The Overall accuracy of the product must be over 85%. The result of this validation step is reported below.

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[2] Congalton, Russell G., and Kass Green. *Assessing the accuracy of remotely sensed data: principles and practices.* CRC press, 2002.

		Validation assessment			
		Unburnt	Burnt	Total	User's Accuracy
Damage assessment	Unburnt	121	3	124	97.6%
	Burnt	8	168	176	95.5%
	Total	129	171	300	
	Producer's Accuracy	93.8%	98.2%		OA = 96.33%

Table 5-2 P07-Wildfire delineation validation results

The thematic accuracy of the grading product is the same as the delineation. Grading classes accuracy cannot be evaluated by photo-interpretation. The only situation where a new assessment could be realized is if field data are available for the wildfire event.

5.1.2   GEOMETRIC POSITIONAL ACCURACY

The positional accuracy of P07 product is dependent on the input satellite images positional accuracies. All images were delivered already orthorectified, so no positional accuracy was conducted.