FRAMEWORK SERVICE CONTRACT FOR COPERNICUS EMERGENCY MANAGEMENT SERVICES RISK & RECOVERING MAPPING

TECHNICAL REPORT

EMSN200: Wildfire delineation and grading in East Macedonia and Thrace, Greece (FAST FLEX)

Date	13/8/2024
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ACRONYMS

Acronym	Signification
AoI	Area of Interest
API	Application Programming Interface
BEYOND	Center for Earth Observation Research and Satellite Remote Sensing
CEMS	Copernicus Emergency Management Service
COG	Cloud Optimized Geotiff
DB	Database
dNBR	Delta Normalized Burn Ratio
dNDVI	Delta Normalized Vegetation Index
EEA	European Environment Agency
ELSTAT	Hellenic Statistical Authority
EO	Earth Observation
ESA	European Space Agency
ESA-DAP	European Space Agency – Data Access Portfolio
ESRI	Environmental Systems Research Institute
FFIS	Forest Fire Information System
FWC	Framework Contract
GIS	Geographic Information System
IAASARS	Institute for Astronomy Astrophysics Space Applications and Remote Sensing
IT	Information Technology
JRC	Joint Research Centre
LC	Land Cover
LULC	Land Use Land Cover

Acronym	Signification
NBR	Normalized Burn Ratio
NDVI	Normalized Difference Vegetation Index
NIR	Near-infrared
NOA	National Observatory of Athens
NTUA	National Technical University of Athens
OSM	Open Street Map
QA	Quality Assurance
QC	Quality Control
RED	Red bands
RN	Road Network
STAC	Spatio Temporal Asset Catalogue
SWIR	Short-Wave Infrared
UNSDR	UN for Disaster Reduction
UTM	Universal Transverse Mercator
WGS84	World Geodetic System 1984
WPL	Work package leader

1 EXECUTIVE SUMMARY

This document serves as the technical report for the EMSN200: Wildfire delineation and grading in East Macedonia and Thrace, Greece activation. Its purpose is to provide detailed information on the activation and to comprehensively outline the work carried out in the development of the EMSN200 activation products to enable users to understand the added value of the deliverables and how they can be used effectively.

EMSN200 activation objective was to provide detailed information of the wildfire's impact, spatial distribution, and extent, by producing the following product:

- P01- Wildfire delineation and grading.

In the first and second chapter, the main information regarding the activation is presented alongside information for the activation's geographic location. The third chapter provides a description of the products and the overall deliverables submitted. In the fourth chapter an overview of the products and the overall deliverables submitted is given. In the fifth chapter, the methodology employed for the development of the product is detailed, including the datasets utilized, their pre-processing activities, the analytical workflow, and the data models with all relevant information. The sixth chapter presents the results, organized by product, along with relevant descriptions and statistics. Finally, in the last chapter, the methodology for internal quality control of the products is outlined, along with the corresponding quality results.

The results of the EMSN200 concerns:

- P01- Wildfire delineation and grading: This product delivers information on the delineation of the burnt area and the associated level of damage of the wildfire in Falakro mountain from July 17th to July 23rd, 2024.

2 INTRODUCTION

Table 1: Activation Details

COPERNICUS HAZARD & RECOVERY MAPPING ACTIVATION	
ACTIVATION DETAILS	
Activation Name	EMSN200: Wildfire delineation and grading in East Macedonia and Thrace, Greece
Authorized User	General Secretariat for Civil Protection (npatsioti@gscp.gr; eaggelopoulos@gscp.gr)
Date and Time of Activation (UTC)	29.07.2024, 12:05:58 UTC+02:00
EVENTS DETAILS	
Event Type(s)	WildFire
Location	East Macedonia and Thrace, Greece

2.1 CONTEXT OF ACTIVATION DESCRIPTION

The aim of this activation was to provide detailed information of the wildfire's impact, spatial distribution, and extent in Falakro mountain. The area of interest (AoI) requested by the Authorized User being General Secretariat for Civil Protection is located near small villages such as Volakas, Pyrgi, Vathylakkos and Livadero and is shown in Figure 1. The size of the requested Area of Interest (AoI) is approximately 168 km^2.

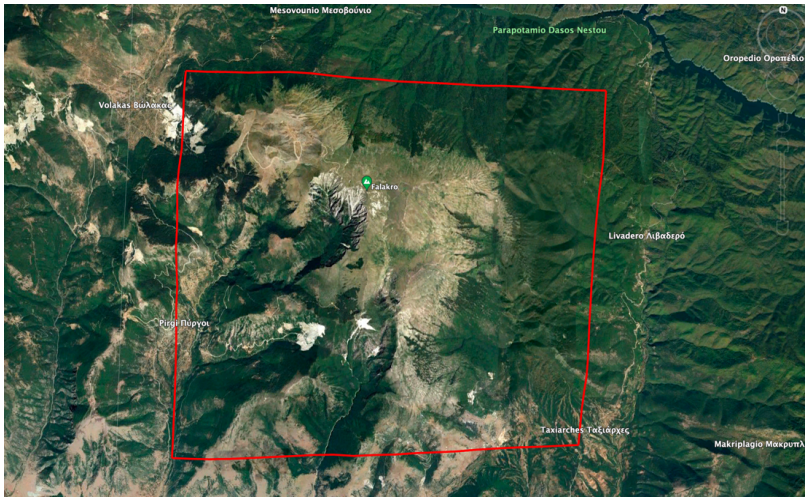

Figure 1: The Area of Interest requested by the Authorized User

2.2 ANALYSIS OF THE CONTEXT OF THE ACTIVATION AND ITS GEOGRAPHIC LOCATION

2.2.1 CONTEXT OF THE ACTIVATION

The current activation revolves around an urgent situation caused by the forest fire due to lightnings on Falakro mountain in East Macedonia and Thrace in the Greek territory which required the analysis of the damage. The wildfire occurred on the afternoon of July 17, 2024, in the area until Tuesday, July 23 when the fire spread was contained. The wildfire was completely extinguished on the 27th of July according to

the fire service. The fire caused significant damage and severe consequences to the local ecosystem. Thus, damage assessment and restoration planning of the affected area is a high priority. The Copernicus EMS Mapping service provided comprehensive fire damage assessment information and products to support the General Civil Protection that requested the mapping in their efforts to recover and plan the restoration of the affected area.

2.2.2 GEOGRAPHIC LOCATION

Falakro, which is in the prefecture of Drama, is the highest mountain of Eastern Macedonia and Thrace. Its highest peak reaches 2,232 meters and the area hosts a popular ski resort which is a major tourist attraction and significantly boosts the local economy. Falakro is also known for its extensive network of long trails, some of which are part of the European route E6.

The climate in the wider area is being categorized as Mediterranean with continental influence due to its high altitude. The mountain's landscape is characterized by rocky outcrops, with peaks designated as protected areas belonging to the Natura 2000 Network, meadows, and bushes. At lower altitudes, pine and broad-leaved forests create a rich natural environment combined with abundant biodiversity, meaning unique fauna and flora of which many species are under specific protection status.

According to the provided data, the majority of the area is mostly covered by grasslands/alpine plants (34.98%), bushes (32.46%) and beech tree (20.52%). Other land covers include black pine (4.32%), oak (3.01%), agriculture crops (2.58%), barren grasslands (1.34%), juniper tree (0,44%), chestnut tree (0.18%) and settlements (0.15%). The area in hectares of each LULC category, as well as percentage of it in the AoI are being shown on the table below (Table 1).

Table 2: Area (ha) and percentage (%) of each LULC category

Vegetation Type	Area (ha)	Percentage of AoI (%)
Grasslands, alpine plants	5889.456	34.98%
Bushes	5465.241	32.46%
Beech tree	3454.363	20.52%
Black pine	726.817	4.32%
Oak	506.491	3.01%
Agriculture crops	434.485	2.58%
Barren grasslands	226.162	1.34%
Juniper tree	74.834	0.44%
Chestnut tree	30.717	0.18%
Settlements	25.917	0.15%
Total	**1683.482**	**100 %**

3 PRODUCT DESCRIPTION AND DELIVERABLES

In this section, the deliverables that are part of the current activation are presented. This includes the data format, a proposed file naming convention, short descriptions and scales where applicable. Coordinate system for all geographical data (vector layers and raster layer) is EPSG: 32635 (UTM35N, WGS84). The publication of data for online deliverables was EPSG: 3857 (Web Mercator Auxiliary Sphere).

The products generated within this activation are described in Table 3.

Table 3: Product Description

Product	AOI	Product description
P01	AOI01 - Falakro Mountain	The wildfire delineation and grading products, directly derived from the image data Sentinel-2 and acquired before and immediately after the event, offer an evaluation of the impact, as well as its spatial distribution and scope. The final product showed the delineation of the burnt area and the associated level of damage, as long as the impacted LULC. The damage of the affected areas is being assessed by analyzing the variation of the NBR and NDVI indices. Relevant information on LULC, areas that have been affected by wildfires in the past road network, hydrography, protected areas of Natura 2000 network, settlements, wildlife sanctuaries, etc. will be used to enable adequate and detailed assessment of the damages.

The final delivery includes the products reported in Table 4.

Table 4: Deliverables

Deliverable	Product	Data type	Description	File name
Geospatial data	**P01**	**ESRI GDB**	Geodatabase that includes the feature classes for: · The fire extent Representation scale: 1:25,000 · The fire severity/damage grade per LULC category Representation scale: 1:25,000	P01_WDG_FireDelineation P01_WDG_FireGrading
	P01	**LYR, SLD**	Symbology files (one per GDB-feature class, one per raster layer)	
Map and Global Scene	**P01**	**ArcGIS Map and Global Scene**	· Comprising all vector and raster layers of all products combined per scenario. · Published in the JRC ESRI Enterprise environment.	EMSN200_Map EMSN200_Scene
Printable Maps	**P01**	**GeoPDF**	A1 Format, portrait, 200dpi	P01_WDG
EO imagery data		**Geotiff**	Sentinel-2	EMSN200_RGB_PreFire EMSN200_RGB_PostFire
Raster data	**P01**	**GeoTIFF**	Fire severity/damage grade (Cell size 10m)	P01_WDG_FireGradingRaser
Reporting		**PDF**	Technical Report	EMSN200_TECHNICAL REPORT.pdf
		PDF	Factsheet	EMSN200_Factsheet.pdf
QA	**P01**	**SHP/ GDB**	QA sampling data set	QC_68polygons QC_FireDelineation_ControlPoints QC_FireDelineation_ExpertPoints QC_FireDelineation_PointDistance QC_FireGrading
Metadata		**XML**	Metadata for GDB	EMSN200_FLEX_UTM35N
Ancillary data		**Land Use/ Land Cover**	Vector, scale 1:25,000	EMSN200_LULC
		Transportation	Vector, scale 1:25,000	EMSN200_Roads
		Hydrography	Vector, scale 1:25,000	EMSN200_Waterways
		NATURA2000	Vector, scale 1:100000	EMSN200_NATURA2000

		Diachronic Burned Scar Maps (BSM)	Vector, scale 1:25,000	EMSN200_BSM
		Wildlife Sanctuaries Settlements	Vec Vector, scale 1:25,000 Vector, scale 1:25,000	EMSN200_WildlifeSanctuaries EMSN200_Settlements

4 INPUT DATA

4.1 IMAGE DATA

The table below (Table 5) shows the Sentinel-2 images that were suggested to delineate the burned area and grade the fire (P01) and which of them were actually used for the production pf the layers according to availability and cloud coverage.

Table 5: Image Data

Satellite Platform	Event related timing	Acq. Date (yyyy-mm-dd)	Cloud Cover	Instrument	Source	Tile	Sensor type	Used for analysis
Sentinel-2 L2A	Post-event	2024-08-05	26%	MSI	ESA	T35TKF	Optical	No
		2024-08-02	1%			T35TKF	Optical	No
		2024-07-28	0%			T35TKF	Optical	Yes
Sentinel-2 L2A	Pre-event	2024-07-16	0%	MSI	ESA	T35TKF	Optical	Yes
		2024-07-13	2%			T35TKF	Optical	No
		2024-07-08	0%			T35TKF	Optical	No

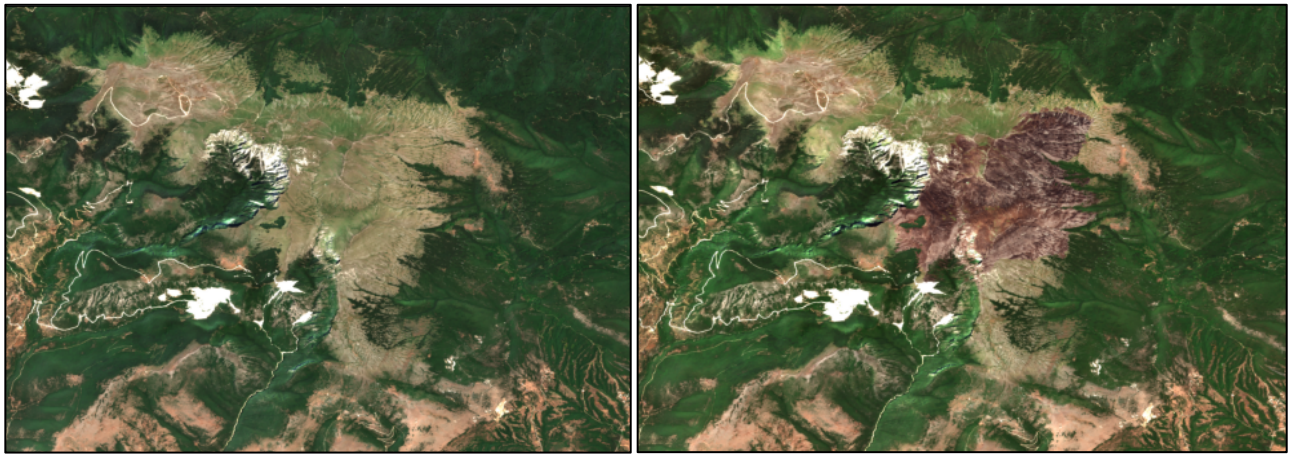

Figure 2: RGB composites for the selected dates for the processing before, on 16-08-2024, and after the event, on 28-08-2024.

4.2 ANCILLARY GEOSPATIAL DATASETS

The following table (Table 6) summarizes the ancillary geospatial data that were provided and collected for this activation. A short description, scale, format and source of the data are given below.

Table 6: Ancillary Geospatial Datasets

Geospatial Data/Dataset	Short Description	Source	Type	Quality Parameters	Usage Frame
Land Use/ Land Cover	Land Use/ Land Cover for the AOI delivered by JRC (Barren lands, Juniper tree, Agriculture crops, Oak, Bushes, Chestnut tree, Grasslands, alpine plants, Settlements, Beech tree, Black pine)	JRC	-	Format: Vector	Damage Grade Assessment
Global open data cartographic initiative	Transportation, Hydrography	OSM	Open data	Varying	Thematic Map
NATURA2000	Protected areas network across the European Union aimed at conserving natural habitats and species	European Environment Agency	Open data	Format: Vector, Scale: 1:100,000	Thematic Map
Diachronic Burned Scar Maps (BSM) [1,2]	Multi-sensor processing chain that produces precise diachronic burnt area and damage assessment products over the Greek territory.	FireHUB5 of BEYOND/NOA	Open data	Format: Vector, Years: 1984-2023, Scale: varying	Thematic Map
Wildlife Sanctuaries	Boundaries of the Wildlife Sanctuaries of Greece and further information about them.	Hellenic Ministry of, Environment & Energy	Open data	Format: Vector	Thematic Map

[1] Kontoes, C., Keramitsoglou, I., Papoutsis, I., Sifakis, N., & Xofis, P. (2013). National Scale Operational Mapping of Burnt Areas as a Tool for the Better Understanding of Contemporary Wildfire Patterns and Regimes. Sensors, 11146–11166.

[2] http://ocean.space.noa.gr/diachronic_bsm/

5 METHODOLOGY

5.1 PRODUCT 1-WILDFIRE DELINEATION AND GRADING

5.1.1 ANALYTIC WORKFLOW

The proposed methodology for assessing the burnt area is based on an extensive review of relevant literature, ensuring the application of best practices and innovative techniques in remote sensing and the approach is based on satellite imagery cloud free composites, and calculation of selected indices. Specifically, indices such as NBR shows high effectiveness in identifying burn scars[3], while the utility of NDVI has been highlighted for assessing vegetation health[4]. The employment of pre- and post-fire images to calculate change indices (dNDVI & dNBR) is also supported in literature[5], as well as the fusion of the two indices tend to reduce false positives[6][7]. The overall workflow is depicted in Figure 3.

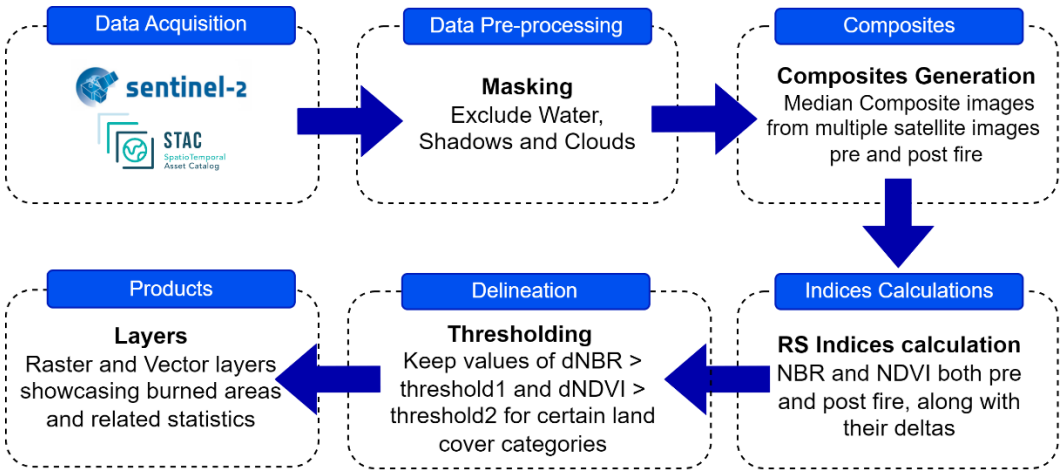

Figure 3: The proposed workflow for mapping burnt areas

Step 01 || Data Acquisition

The process begins with acquiring data using Spatiotemporal Asset Catalogue (STAC) framework, which streamlines the discovery of necessary images efficiently. STAC's RESTful API standard enables programmatic access to catalogues, allowing developers to create applications and services that dynamically discover and retrieve geospatial data. In our specific scenario, we utilized Copernicus Data Space Ecosystem[8] STAC to retrieve images before the wildfire outbreak and images after the fire is completely extinguished. This targeted retrieval helps in effectively analysing and monitoring the

[3] Key, Carl H., and Nathan C. Benson. "Landscape assessment (LA)." FIREMON: Fire effects monitoring and inventory system 164 (2006): LA-1

[4] Tucker, C. J. "The NDVI has been proven to be well correlated with various vegetation parameters, such as green biomass." Rouse et al (1979): 605-790.

[5] Miller, Jay D., and Andrea E. Thode. "Quantifying burn severity in a heterogeneous landscape with a relative version of the delta Normalized Burn Ratio (dNBR)." Remote sensing of Environment 109.1 (2007): 66-80.

[6] Chen, X., Zhu, Z., Ohlen, D., Huang, C., & Shi, H. (2008, November). Use of multiple spectral indices to estimate burn severity in the Black Hills of South Dakota. In Proceedings of Pecora.

[7] Yilmaz, O. S., Acar, U., Sanli, F. B., Gulgen, F., & Ates, A. M. (2023). Mapping burn severity and monitoring CO content in Türkiye's 2021 Wildfires, using Sentinel-2 and Sentinel-5P satellite data on the GEE platform. Earth science informatics, 16(1), 221-240.

[8] https://documentation.dataspace.copernicus.eu/APIs/STAC.html

wildfire's impact over the specified period. The original images are integrated in the project data base as GeoTIFF files.

According to the duration of the wildfire event, Sentinel 2 images were selected right before and after the event considering the percentage of cloud coverage in the AoI in order to calculate NBR and NDVI indices and provide the delineation and damage grading of the fire extent in Falakro mountain. Imagery collected from the 16th of July for the preprocessing stage and from the 28th for the post processing were found suitable for the analysis, as the percent of cloud coverage was nearly 0% (see Table 5).

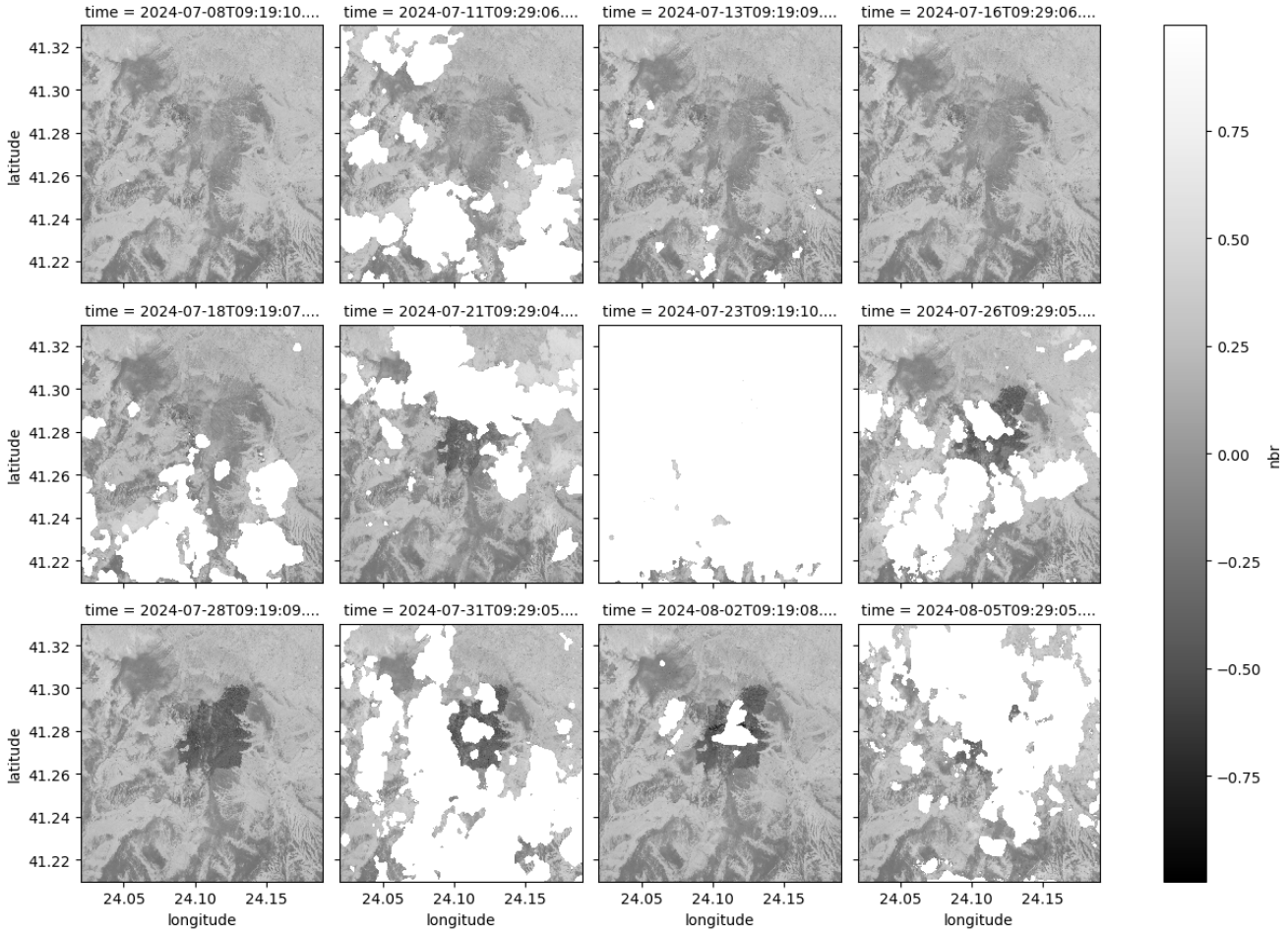

Figure 4: Timeseries of satellite imagery for before, during and after the event indicating the cloud coverage (%) and NBR index.

Step 02 || **Data Pre-processing**

This step involves preparing the (acquired) raw satellite data (Level 2A) for analysis and includes the following operations:

- Geometric Correction: Aligning the satellite images to a standard map projection
- Cloud Masking: Identifying and masking clouds and cloud shadows using the Scene Classification band from the Sen2Cor software to ensure analysis focuses only on clear-sky observations

Step 03 || **Creation of Composites**

The creation of a composite image offers a series of advantages such as cloud free images, noise reduction, gap fillings due to anomalies, enhanced detail by combining the best quality pixels and reduced shadow effects. For this scenario, the median composite per band (NIR, SWIR, Red, Green, Blue) were generated. To this direction. the median composite of pre-fire images provides a clear, stable baseline of the area's normal conditions by minimizing transient anomalies like temporary cloud cover or other noise. Similarly, the median composite of post-fire images offers a reliable representation of the changes caused by the wildfire, filtering out short-term variations. This approach enhances the accuracy and reliability of the analysis, helping in effectively assessing and monitoring the wildfire's impact over the specified period).

Step 04 || **Indices Calculations**

Calculation of NDVI and NBR is important in order to assess vegetation health, burns and detect changes, along with dNBR (delta NBR) and dNDVI (delta NDVI) to evaluate the severity of fires and their impact on vegetation.

The **Normalized Difference Vegetation Index (NDVI)** is a widely used remote sensing index that measures and monitors plant health, vegetation cover, and biomass production. NDVI is calculated using the near-infrared (NIR) and red bands of the electromagnetic spectrum, typically captured by satellite or aerial imagery. It is calculated using the following equation:

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

where:

- **NIR (Near-Infrared)**: Reflectance in the near-infrared band.
- **Red**: Reflectance in the red band

The resulting NDVI values range from -1 to +1:

- **-1.0 to 0.0:** Non-vegetated surfaces (e.g. water bodies and bare soil)
- **0.0 to 0.2:** Sparse vegetation or non-vegetated areas
- **0.2 to 0.4**: Low to moderate vegetation cover
- **0.4 to 0.6**: Moderate to dense vegetation cover
- **0.6 to 1**: (Very) Dense vegetation cover

Change in Normalized Vegetation Index - also called Delta Normalized Vegetation Index (dNDVI) - is calculated by subtracting the post-fire NDVI value from the baseline NVDI value as defined in this equation:

$$dNDVI = NDVI_{pre} - NDVI_{POST}$$

The **Normalized Burn Ratio (NBR)** is a key remote sensing index that is commonly used for identifying burned areas and assess burn severity in vegetation following a wildfire. It leverages the differences in the

way healthy green vegetation and burnt vegetation reflect light to detect changes caused by fire. It is calculated using the following equation:

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

where:

- **NIR** (Near-Infrared): Reflectance in the near-infrared region, typically band 8 in Sentinel-2.
- **SWIR** (Short-Wave Infrared): Reflectance in the short-wave infrared region, typically band 12 in Sentinel-2.

As the NIR band is sensitive to healthy vegetation (which strongly reflects NIR light), & the SWIR band is sensitive to moisture content and charred vegetation (which absorbs SWIR light) their combination (NBR) highlights areas affected by fire. NBR returns values between -1 & 1. An interpretation of NBR values is given below:

- **Positive Values:** Indicate healthy, unburned vegetation.
- **Negative Values:** Indicate burned areas with significant loss of vegetation.
- **Zero Value:** Typically represents non-vegetated surfaces, such as bare soil or urban areas

Change in Normalized Burn Ratio - also called Delta Normalized Burn Ratio (dNBR) - is calculated by subtracting the post-fire NBR value from the baseline NBR value as defined in this equation:

$$dNBR = NBR_{pre} - NBR_{POST}$$

This difference highlights the change in vegetation condition due to the fire. Higher dNBR values indicate more severe burns. When assessing burn severity, there are specific ranges of dNBR's values that indicate certain categories of fire's severity. These categories enhance the understanding for the impact of the fire on vegetation and planning restoration efforts accordingly. The common classification ranges for burn severity using dNBR on Sentinel 2 imagery are presented in the table below (Table 7):

Table 7: Burnt severity classes

dNBR Range	Burn Severity Class
0.1 < dNBR ≤ 0.27	Low severity
0.27 < dNBR ≤ 0.44	Moderate severity
0.44 < dNBR ≤ 0.66	High severity
dNBR > 0.66	Very high severity

Using both NBR and NDVI for identifying burnt areas is advantageous because each index provides unique information about the landscape, which helps improve the accuracy and reliability of burned area detection. Specifically, NBR is prone to misclassification of other disturbances such as harvesting, urban development, and water bodies as burned areas. This is because these changes can similarly alter the reflectance in the NIR and SWIR bands, leading to similar NBR values as those resulting from burns. At the same time NDVI helps at distinguishing between vegetation loss due to wildfire and other land cover

changes that do not involve vegetation, such as urban development or water bodies. Thus, the combination of the two indices lead to improved detection accuracy and reduction of false positives.

Step 05|| **Delineation of the affected area & Damage Grade assessment**

Lastly, having calculated the dNBR and dNVI, typical thresholding techniques took place for the identification and the classification of the burned areas. The typical thresholds for dNBR can be used for this (Table 7), along with the potential calibrated dNDVI thresholds based on the specific area and vegetation types. The adaption of a logical combination of dNBR and dNDVI results enhances the accuracy of the delineation and reduces possible misclassification errors caused by other disturbances (e.g. harvesting). In addition, the LULC dataset is used to assist interpreting burn severity by providing context about the types of vegetation or land cover that were affected. At the same time, this vector allows the differentiation between natural vegetation and human-modified areas, improving the accuracy of burn severity assessments. Expert photointerpretation of the results was further conducted for the correction of the delineation completeness. The generated grading map was compared against a large set of visually collected sample points over the post-fire image (composite). The samples were representative to the different categories of fire severity classes over the affected area and were used for assessing the mapping accuracy. The comparison of the resulted grading map against the check points allowed the production of the accuracy statistics in the form of Overall Accuracy.

6 RESULTS

6.1 PRODUCT 1 - WILDFIRE DELINEATION AND GRADING

Product 1 involves the delineation and grading of the fire severity. Multispectral Sentinel-2 images with low cloud coverage closest to the date of the fire were used to automatically delineate the perimeter. Subsequently, using the aforementioned thresholding technique of dNBR and dNDVI the burned area has been segmented into four categories based on the damage severity, them being low, moderate, high and very high severity. Results of Product 1 are shown in Figure 5.

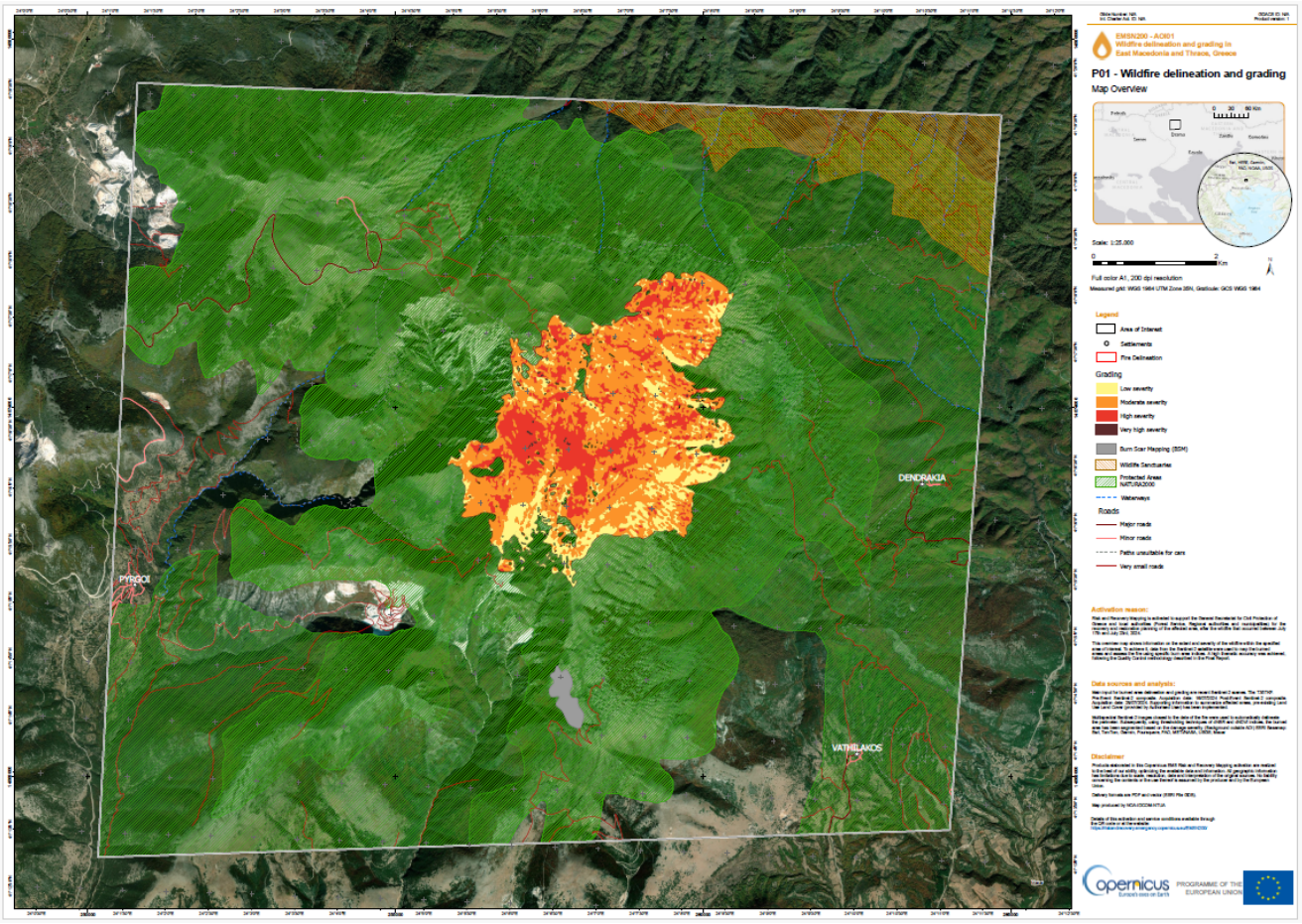

Figure 5: Map with the extent of the wildfire in Falakro, Greece and the damage grade of the burned area.

2.1.2 Product access

The delivered Product 1 is composed of 3 data layers (P01_WDG_FireDelineation, P01_WDG_FireGrading and P01_WDG_FireGradingRaster). Layers are delivered within an ESRI file geodatabase, named EMSN200_FLEX_UTM35N.gdb in EPSG: 32635 (UTM35N, WGS84) and with their required symbology layers in both lyrx and sld format. This geodatabase contains:

- A georeferenced raster layer classifying the burn severity into four categories based on dNBR, dNDVI indices.

- Two vector data, one delineating the affected area and one demonstrating the damage grade after the wildfire event with associated statistics for land cover categories, e.g., Barren lands, Juniper tree, Agriculture crops, Oak, Bushes, Chestnut tree, Grasslands, alpine plants, Settlements, Beech tree, Black pine.

Furthermore, attribution of these data layers are detailed on the next table:

GDB Fields				Products	
Field Name	**Alias**	**Data Type**	**Description**	**P01_WDG_Fire_ Delineation**	**P01_WDG_Fire_G rading**
area_ha	Area (ha)	Double	Burned area in hectares	X	
area_ha	Area (ha)	Double	Area in hectares of each severity category in the layer		X
Grading	Grading	Text	Fire Severity Grade. Categories from Low to Very High Severity		X
VEG_TYPE	Land Use	Text	Categories of Land Use – Land Cover (LULC)		X

In total, 1308 hectares have burned in the study area. The most affected type of vegetation is grasslands/alpine plants, accounting for 94.6% of the total, followed by beech trees with only 4%, as shown in Figure 6 and Table 8 below. On the other hand, the least affected areas are bushes, black pine and barren grasslands, which represent the rest 1.4 % of the study area.

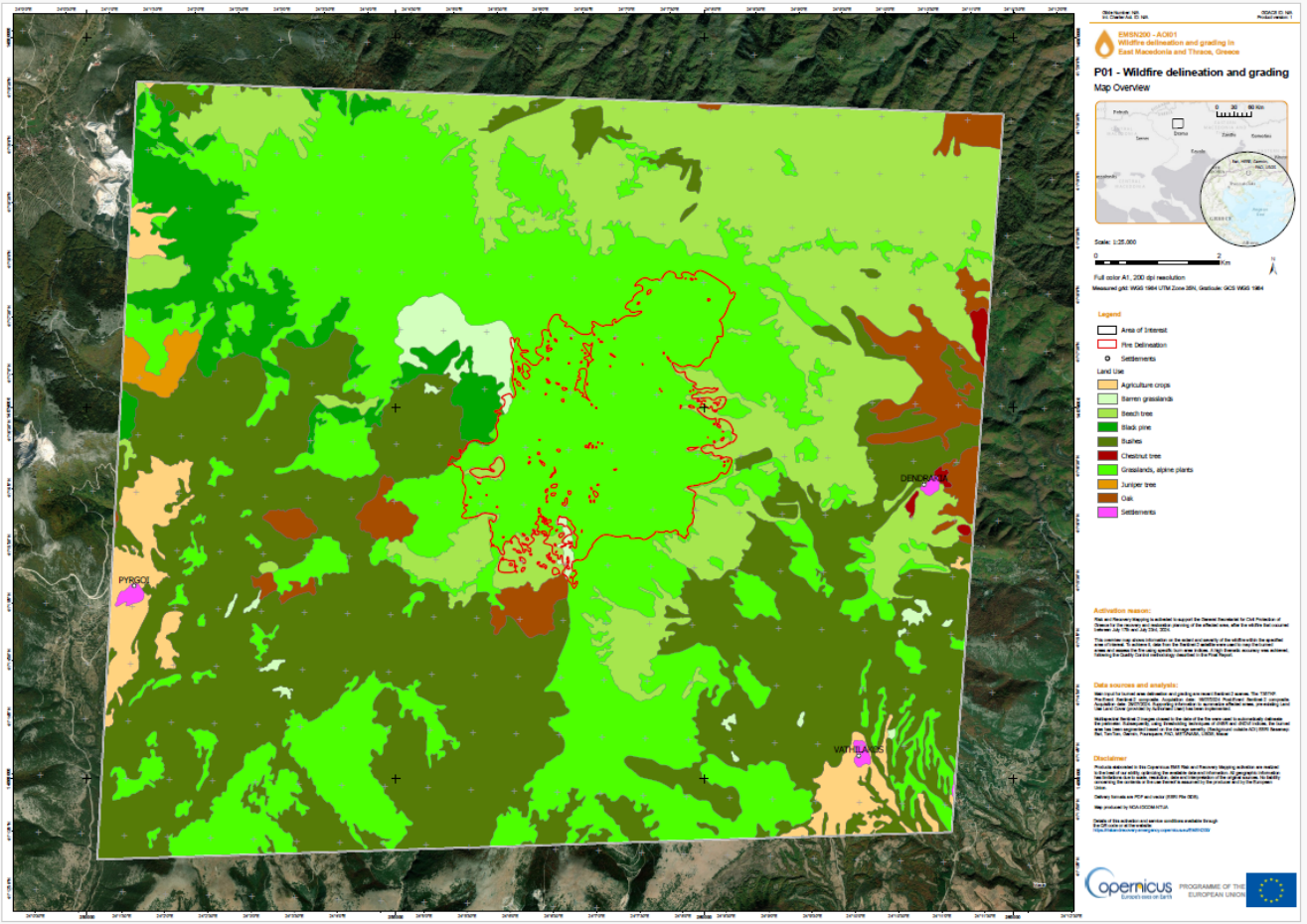

Figure 6: Map with the extent of the wildfire in Falakro, Greece and the affected LULC of the burned area (red boundary).

Table 8: Burned Area in hectares and percent by vegetation type.

Vegetation Type	Area (ha)	Percentage (%)
Grasslands, alpine plants	1237,074	94,60%
Bushes	1,772	0,14%
Beech tree	51,774	3,96%
Black pine	2,316	0,18%
Oak	0,030	0,00%
Barren grasslands	14,755	1,13%
Total	1307,721	100,00%

In terms of fire severity, only a small portion has been classified as very high severity, representing 0.15% of the burned area. Within this category, the most affected type of vegetation has been grasslands/alpine plants and beech trees. The 27.33% of the burned area has been classified as high severity, where most of the affected vegetation in that class belongs to grasslands/alpine plants. More than half of the area has been classified as moderate severity (52.60%), where more than 90% of the vegetation consists of grasslands/alpine plants. Lastly, the 19.92% has been classified as low severity as the fire spread more superficially through the vegetation.

Table 9: Burned Area in hectares and percent by severity category and vegetation type.

Fire Severity Class	Affected Area / %	Vegetation Type	Area (ha)
Low severity	260,47 (19,92%)	Barren grasslands	6,74
		Beech tree	26,02
		Black pine	0,28
		Bushes	1,07
		Grasslands, alpine plants	226,33
		Oak	0,03
Moderate severity	687,91 (52,60%)	Barren grasslands	7,23
		Beech tree	20,47
		Black pine	1,85
		Bushes	0,70
		Grasslands, alpine plants	657,66
High severity	357,48 (27,33%)	Barren grasslands	0,79
		Beech tree	5,19
		Black pine	0,19
		Grasslands, alpine plants	351,31
Very high severity	1,96 (0,15%)	Grasslands, alpine plants	1,86
		Beech tree	0,10

7 INTERNAL QUALITY CONTROL

7.1 PRODUCT 1 - WILDFIRE DELINEATION AND GRADING

7.1.1 METHODOLOGY APPLIED

To ensure the high quality of our delivered products, comprehensive quality control methods were employed. These methods focused on the accuracy of burnt area boundary delineation and the assessment of damage grading categories.

Burnt Area Delineation:

For evaluating the correctness of the burnt area boundaries, 68 sampling points along the boundary were randomly selected (Figure 7). These points were assessed by experts through cross-referencing with the dNBR, dNDVI and Land Use/Land Cover maps.

Damage Grading Assessment:

To evaluate the damage grading categories, 68 sampling polygons, each measuring 374m x 374m, were randomly selected (Figure 7). These polygons represent 5% of the total area of interest. The accuracy of the burn severity classification was validated by experts through cross-referencing with dNBR, dNDVI, and Land Use/Land Cover maps.

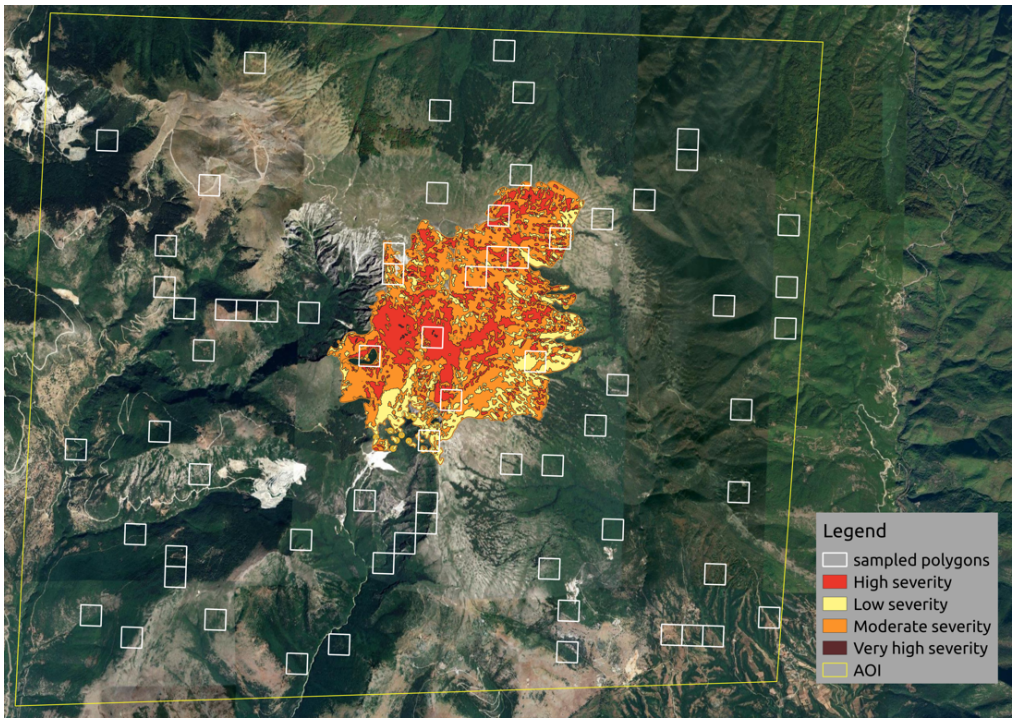

Figure 7: Sampling polygons of the damage grading product

7.1.2 QUALITY RESULTS

The results of the quality control are presented below.

Burned Area Delineation

Concerning the burned area delineation the average distance between the control points and the points indicated by the experts is well below the Sentinel's pixel size (10 m) which is also the threshold that was set in the proposal. More specifically, the average distance of the 68 sampled points was 5.49 meters, where the majority of them are below 5 meters (Figure 8).

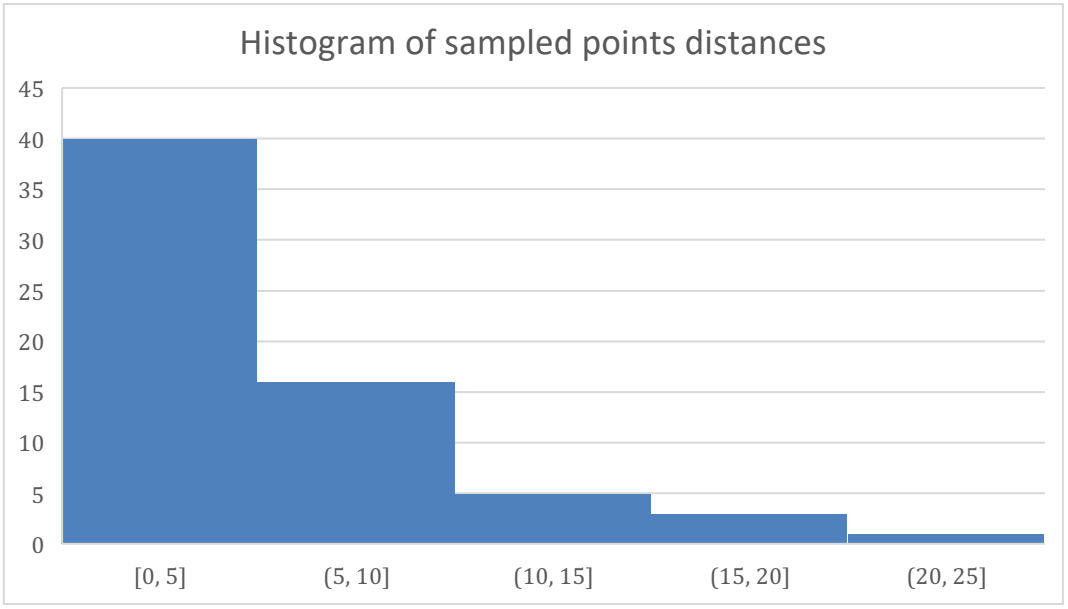

Figure 8: Histogram of distances between sampled points on the burned area boundary and points derived through photointerpretation.

Damage Grading Categories

The overall accuracy of the damage grading categories is 87%, surpassing the desired accuracy threshold. Detailed information about the grading categories is presented in the following Table 10.

Table 10: Accuracy details of the damage grading categories.

Grading Code	Mapped Area (ha)	Expert's area (ha)	Common areas (%)
Very high severity	0.4054	0.5555	0.729792979
High severity	40.5321	39.4198	0.972557553
Moderate severity	72.9449	77.3317	0.94327294
Low severiry	27.896	24.3145	0.871612418