Copernicus Emergency Management Service
Risk & Recovery Mapping
Tailor-Made Mode (FLEX)

FINAL REPORT

EMSN198: Wildfire delineation and grading in Chios Island, Greece

Framework Contract NUMBER — 945235 – IPR – 2023

Ready to: European Commission - Joint Research Centre

Created by: INDRA SISTEMAS, S. A.
Ctra. Loeches 9, Torrejón de Ardoz, 28850, Madrid
CIF: A-28599033

Team:

Client:
EUROPEAN COMMISSION
JOINT RESEARCH CENTRE

Directorate-
General for Joint Research Centre

European Commission

Issue/Rev.: A/1

Date: 31/07/2024

DOCUMENT CHANGES RECORD

Edit./Rev.	Date	Chapters	Reason for change
A/1	31/07/2024	All	First issue

TABLE OF CONTENT

INDEX OF FIGURES

INDEX OF TABLES

TERMS & ACRONYMS

ACRONYM	Description
AoI	Area of Interest
AU	Authorised User
CCI	Climate Change Initiative
CD	Calendar Day
CEMS	Copernicus Emergency Management Service
LC	Land Cover
CSCDA	Copernicus Space Component Data Access
EFFIS	European Forest Fire Information System
EMSN	Emergency Management Service
EO	Earth Observation
EPSG	European Petroleum Survey Group
EU	End User
FLEX	Tailor-Made Products
FWC	Framework Contract
GDB	Geodatabase
GIS	Geographical Information System
MIRBI	Mid-Infrared Burned Index
NBR	Normalized Burn Ratio
Ha	Hectares
JRC	Joint Research Centre
LULC	Land Use Land Cover
QA	Quality Assurance
QC	Quality Control
RRM	Risk and Recovery Mapping
RTP	Ready to Print
RF	Random Forest
SCL	Scene Classification
sq km	square kilometre
sq m	square metre
SR	Specific Risks
SWIR	Short Short Wave Infrared
TS	Technical Specifications
UTM	Universal Transverse Mercator
VIIRS	Visible Infrared Imaging Radiometer Suite
WD	Working Day

1 INTRODUCTION

This Technical Report presented by Indra responses to the specific tender “EMSN198: Wildfire delineation and grading in Chios Island, Greece” under the Framework Contract NUMBER — 945235 – IPR – 2023 (“Copernicus Emergency Management Service – Risk and Recovery Mapping”).

This request relates to service activation by Natalia Pastroti (General Secretariat for Civil Protection, Greece).

The scope of the service is to support the General Secretariat for Civil Protection of Greece and local authorities (Forest Service, Regional authorities and municipalities) for recovery and restoration planning of the affected area.

1.1 CHARACTERISTICS OF THE SERVICE

The primary objective of this activation is to provide detailed information on the extent and severity of the wildfire within the specified area of interest. The fire was active from July 1st to July 8th, 2024 .To achieve it, data from the Sentinel-2 satellite were used to map the burned areas and assess the fire using specific burn area indices.

1.1.1 AOI

The Area of Interest (AoI) is located on the island of Chios, in eastern Greece, and is very close to neighboring Turkey. The AoI covers an extension of 48.43 sq km and is mostly covered by vegetation. According to the provided data, the majority of the area is covered by bushes (31.23%) and pine forest (46.62%). Other land covers include agricultural areas (8.61%), grasslands (11.35%), barren lands (1.93%), and settlements (0.26%).

The following figure shows AoI where products were generated.

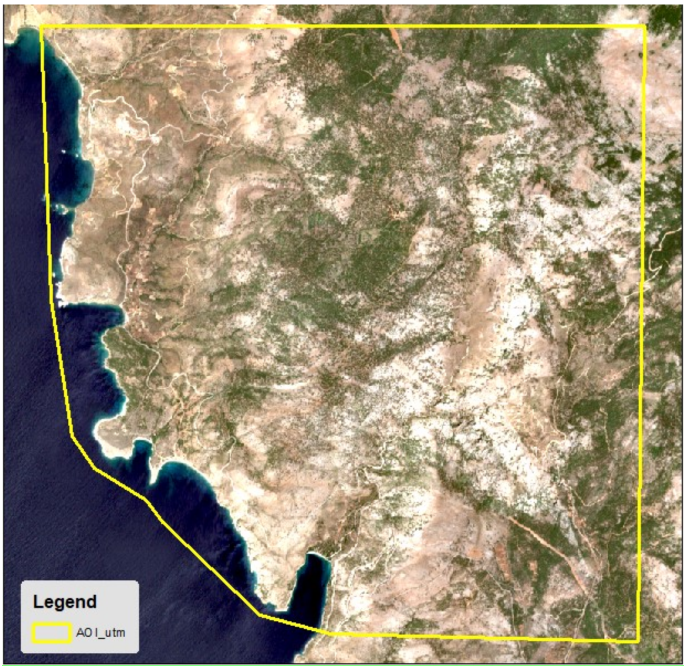

Figure 1-1 Region of interest in the island of Chios

1.1.2 Data sources

All details about the available data sources are further explained at chapter 1.3 Data sources, a section specially dedicated to the in-depth analysis of the available data and the selection of the sources of relevance for the current service.

In summary, main input for burned area delineation and grading is recent Sentinel-2 scenes. Thermal anomalies detected by VIIRS satellite sensor is an additional input. As supporting information to summarize affected areas, pre-existing LULC (Land Use Land Cover) has been implemented.

1.2 DELIVERABLES

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

The following tables summarizes **common deliverables**.

1.2.1 Common deliverables

The following table summarize common deliverables provided within the current activation:

Table 1-1. Deliverables overview.

Product	Data type* / Format	Filename	Description	Pixel size - Scale
P01	A	P01_FDG_FireDelineation (EMSN198_FLEX_UTM35N_V01.gdb/Products)	Delineation of the exterior perimeter of the forest fire, excluding unburned enclaves within the interior.	1:50k
P01	A	P01_FDG_FireGrading (EMSN198_FLEX_UTM35N_V01.gdb/Products)	Categorization and delineation of the different (5) levels of fire severity, based on the difference between pre- and post-fire indices.	20 m
P01	EG	EMSN198_FLEX_AOI01_P01_FDG_Statistics.xlsx	Tabular table with statistics for fire severity and lulc categories	NA
P01	.lyr/.sld	Same name as to every relevant layer	Symbology file which store the path to the source dataset. Lyr and sld	NA
All	.xml	Same name as to every relevant layer	Extensible Mark-up Language (.xml) files are provided for each product, vector file and image delivered.	NA
QC files	several	several	Various files format (documents and GIS files) See section 3	NA
All	.docx	EMSN198_Technical_Report_v01.docx	According to description stated in ITT.	NA NA
All	.pptx/pdf	Presentation of the result**		NA

* Type: A: vector polygon; L: vector polyline; P: vector point; R: Raster; EG: excel files.

** To be delivered at a later stage following the supervision of other deliverables and after reaching a consensus with the EU on the content to be presented.

1.3 DATA SOURCES

For the purpose of this activation, two data sources are required. All relevant details are provided in the following section.

1.3.1 Imagery

The table shows the Sentinel-2 images that were used to delineate the burned area and grade the fire (P01). Thermal anomalies detected by VIIRS satellite sensor is an additional input.

Table 1-2. List of EO data used

Filename	Cloud cover	Acq. Date (yyyy/mm/dd)	Tile	Sensor	Product	Sensor type	Orbit Number
S2A_MSIL2A_20240625T085601_N0510_R007_T35SMC_20240625T133401	1.8%	2024/06/25	T35SMC	Sentinel-2A	L2A	Optical	007
S2B_MSIL2A_20240630T085559_N0510_R007_T35SMC_20240630T105345	2.8%	2024/06/30	T35SMC	Sentinel-2B	L2A	Optical	007
S2B_MSIL2A_20240710T085559_N0510_R007_T35SMC_20240710T122920	2.3%	2024/07/10	T35SMC	S2B	L2A	Optical	007
S2A_MSIL2A_20240715T085601_N0510_R007_T35SMC_20240715T134059	3.4%	2024/07/15	T35SMC	S2A	L2A	Optical	007

1.3.2 Ancillary datasets

The following table summarizes ancillary geospatial data for this activation.

Table 1-3. List of ancillary datasets.

Data input	Provider	Scale/ Resolution	Use
Land-Use Land-Cover	Authorised User	1:50,000-1:100,000	Supporting tabular data
VIIRS Active Fire and Thermal Anomalies product (VNP14IMGTDL)	Fire Information for Resource Management System (FIRMS)	375 m	Inputs for P01

2 RESULT ANALYSIS

The objective of this activation is to generate a product (P01) that delineates the perimeter of the wildfire that occurred on the island of Chios and calculates its severity using multispectral satellite images. The following figure summarizes the procedure used for generating the required products:

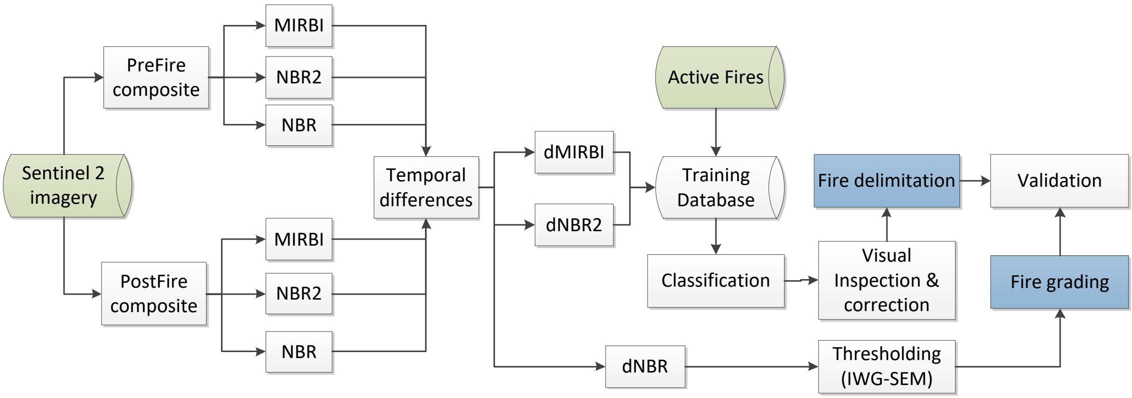

Figure 2-1 Activation workflow

2.1 PRODUCT 1: WILDFIRE DELINEATION AND GRADING

2.1.1 Description

Product 1 involves the delineation and grading of the fire severity. Multispectral Sentinel-2 images closest to the date of the fire were used to automatically delineate the perimeter. Subsequently, using the IWG-SEM methodology[1], the burned area has been segmented based on the damage severity.

2.1.2 Product access

The delivered Product 1 is composed of 2 data layers (P01_FDG_FireDelineation and P01_FDG_FireGrading). Layers are delivered within an ESRI file geodatabase, named EMSN198_FLEX_UTM35N_V01.gdb. Attribution of these data layers are detailed on the next table:

Table 2-1. P01_REF: fields and attributes within data layer.

GDB Fields				Products	
Field Name	Alias	Data Type	Description	P01_FDG_Fire Delineation	P01_FDG_Fire Grading
area_ha	Burnt Area (ha)	Float	Burned area	X	
area_ha	Area hectares	Float	Area in hectares of each severity category in the layer		X
damage_grade	Damage Grade	Text (254)	Fire Severity Grade. Categories from Unburned to High severity		X

[1] https://www.un-spider.org/sites/default/files/IWG_SEM__Guidelines_Fire_chapter_SERTIT_1_0.pdf

2.1.3 Methodology

2.1.3.1 Fire delineation

First, a composite of Sentinel-2 images was created. The goal was to eliminate pixels that may contain clouds or atmospheric noise, resulting in a completely cloud-free product for the study area. To achieve this, Scene Classification (SCL) masks generated during the atmospheric correction of Sentinel images were used. Pixels meeting the following criteria were be removed:

Table 2-2 Pixels Removed Based on the Sentinel-2 SCL Layer

SCL Layer Value	Description	Action
0	No data available	Removed
1	Saturated or defective pixels	Removed
2	Dark area pixels	Removed
3	Cloud shadows	Removed
6	Water	Removed
8	Medium probability clouds	Removed (5-pixel dilation)
9	High probability clouds	Removed (5-pixel dilation)
10	Thin cirrus clouds	Removed (5-pixel dilation)
11	Snow	Removed

After analyzing the Sentinel-2 SCL masks (Figure 2-2), it was determined that the best images for generating the burned area perimeter are from the dates 2024/06/30 and 2024/07/10. Both images provide complete coverage free of clouds, shadows, and potential noise, ensuring an accurate calculation of the burned area.

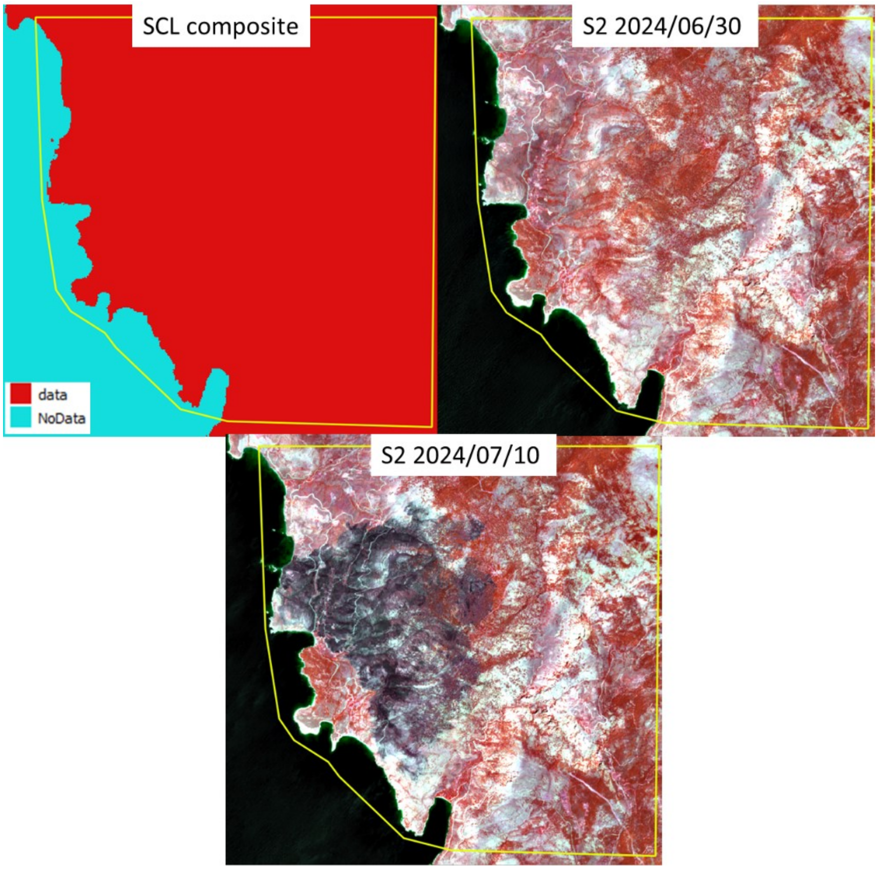

Figure 2-2 Temporal composite of Sentinel-2 SCL layers (top left), RGB-infrared composition of the pre-fire situation (top right), and post-fire situation (bottom)

Furthermore, to ensure comprehensive temporal coverage of the disaster, the images preceding and following the selected composites were thoroughly examined (Figure 2-3). Through the photointerpretation of RGB compositions with infrared, potential reactivations of the fire were investigated. This analysis determined that there were no significant changes in the fire distribution, confirming that the previously generated composite is optimal for delineating the burned area perimeter and estimating fire severity. The only change observed between the two post-fire images, taken five days apart, was a slight decrease in the carbon signal left by the fire. This analysis ensure that the selected images are as near as possible to the start or end of the fire, minimizing information loss.

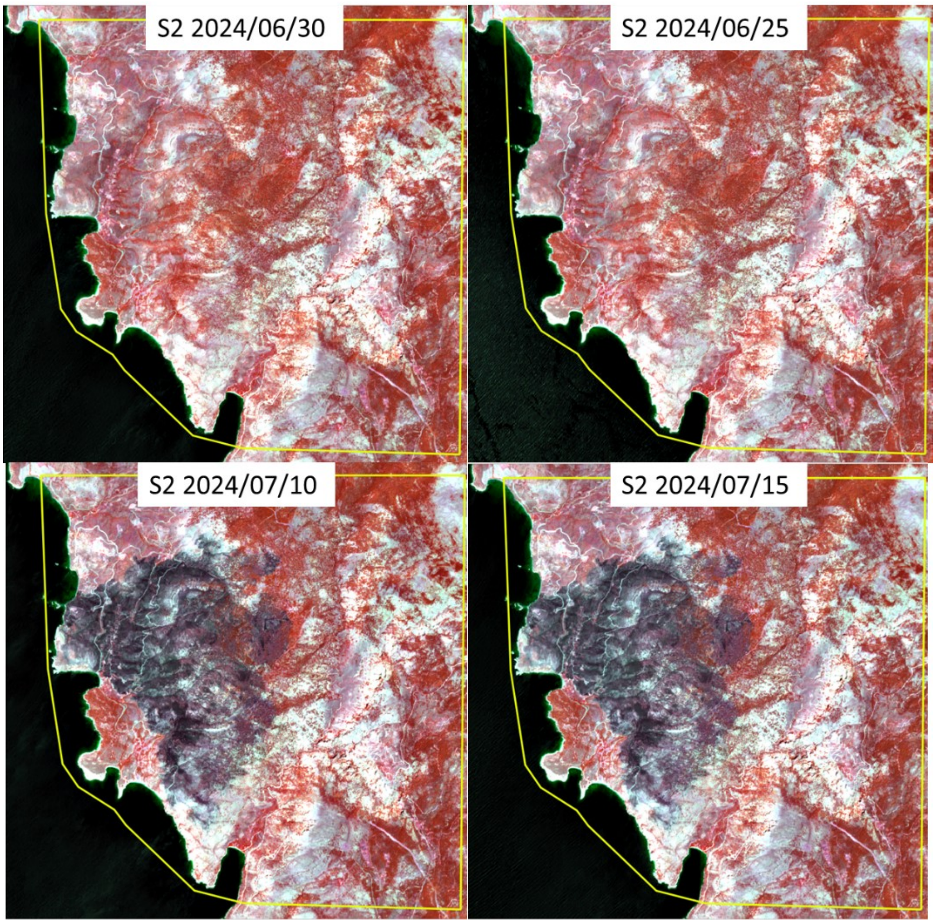

Figure 2-3 RGB-infrared composition of pre-fire (top row) and post-fire (bottom row) conditions

For the detection of the burned area, an automatic classification algorithm based on non-parametric classifiers was used. First, the burn area indices NBR2 and MIRBI (Mid-Infrared Burned Index) were calculated for pre- and post-fire images. The NBR2 and MIRBI spectral index equation is as follows:

$$NBR2 = \frac{\rho_{SWIRS} - \rho_{SWIRL}}{\rho_{SWIRS} + \rho_{SWIRL}}$$

$$MIRBI = \left(10 \cdot \rho_{SWIRL} - 9.8 \cdot \rho_{SWIRS} + 2\right)$$

Where:

- ρ_{SWIRS} = Short Short Wave Infrared Short reflectance (B11 band divided by 10000 in the case of Sentinel 2)
- ρ_{SWIRL} = Short Wave Infrared Long reflectance (B12 band divided by 10000 in the case of Sentinel 2)

The MIRBI and the NBR2 both represent the relationship between two very important spectral spaces for burned signal detection: Long SWIR (Sentinel 2 band 12) and Short SWIR (Sentinel 2 band B11). These two spectral indices were selected because they have the highest separability, in the spectral analysis carried out during the development of the Sentinel-2 burned area algorithm and product for the FireCCI [2](Climate Change Initiative) project.

[2] https://climate.esa.int/en/projects/fire/

Secondly, the temporal differences of both indices (dNBR2 and dMIRBI) were calculated. This information was crossed with the active fire detections from VIIRS (Visible Infrared Imaging Radiometer Suite - VNP14IMGTDL_NRT). The combined data from these three products formed the basis for training the classifier (**¡Error! No se encuentra el origen de la referencia.**).

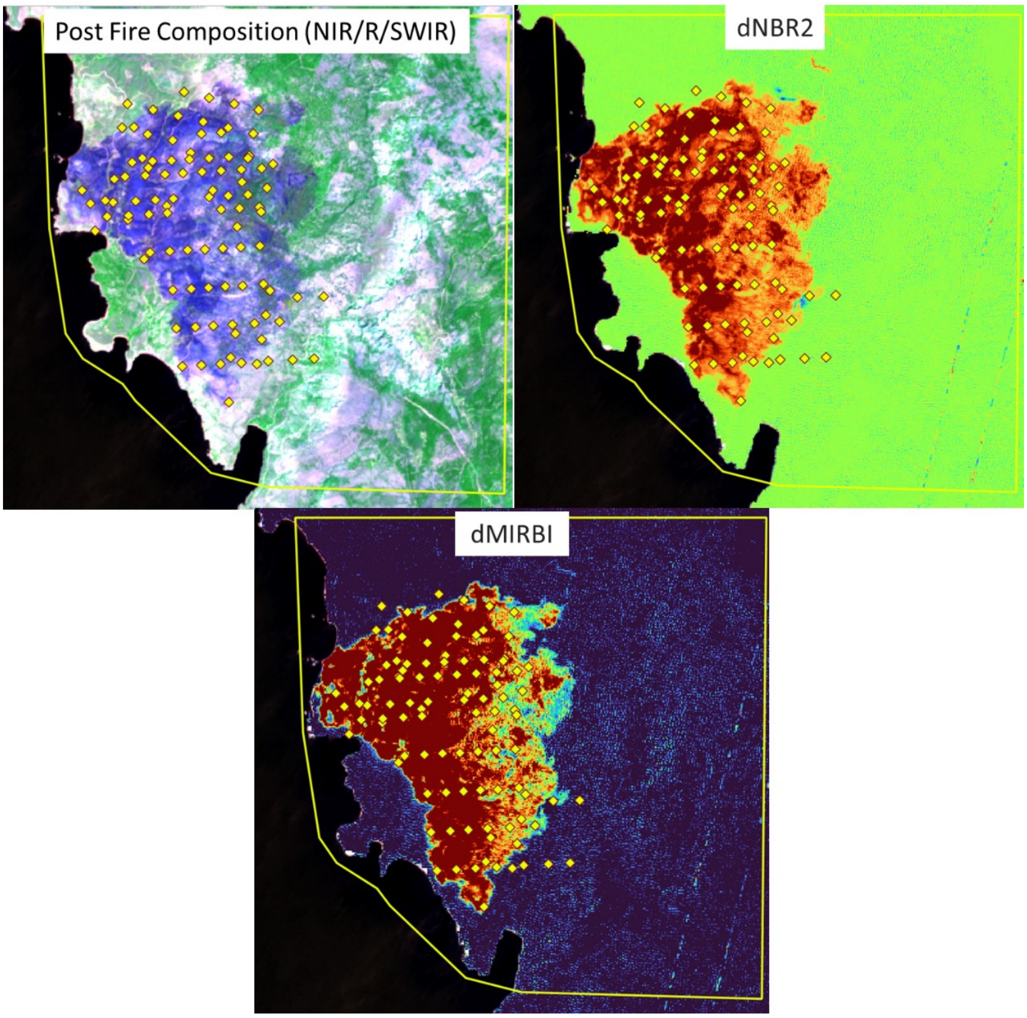

Figure 2-4 RGB composition with infrared and SWIR (top left), temporal difference of NBR (top right), and temporal difference of MIRBI (bottom).

The VNP14IMGTDL_NRT dataset is based on the VIIRS instrument, which provides data with a nominal resolution of 375 meters. The VNP14IMGTDL data offer excellent detection capabilities for small-area fires and improved mapping of large fire perimeters. Consequently, this data is well-suited for fire management and fire mapping applications[3].

Training data was selected from pixels with a negative dNBR2 (NBR2_post – NBR2_pre) that intersect with active fire detections within a radius of 375 meters. These data were used to train a model based on the Random Forest (RF) algorithm to generalize the classification across the entire study area, utilizing dNBR2 and dMIRBI as explanatory variables. RF[4] is one of the most frequently used algorithms for the classification of satellite images[5] and burned areas[6]. Its ability to integrate data from different scales and sources, coupled with its robustness to noise and non-normal distributions, makes it highly effective for many satellite image

[3] Lizundia-Loiola, J., Franquesa, M., Khairoun, A., & Chuvieco, E. (2022). Global burned area mapping from Sentinel-3 Synergy and VIIRS active fires. Remote Sensing of Environment, 282, 113298.

[4] Breiman, L. (2001). Random forests. Machine learning, 45, 5-32.

[5] Belgiu, M., & Drăguţ, L. (2016). Random forest in remote sensing: A review of applications and future directions. ISPRS journal of photogrammetry and remote sensing, 114, 24-31.

[6] Ramo, R., García, M., Rodríguez, D., & Chuvieco, E. (2018). A data mining approach for global burned area mapping. International journal of applied earth observation and geoinformation, 73, 39-51.

applications. This versatility and reliability are the reasons for its widespread adoption in remote sensing and environmental monitoring. The trained model enabled accurate and efficient mapping of the burned areas, providing valuable information for assessing fire impact and guiding recovery efforts.

The trained model was be applied to the ROI to produce a binary layer indicating burned and unburned areas. This layer was then vectorized. Finally, using false-color infrared RGB compositions from 10-meter Sentinel-2 images, photointerpretation was conducted to correct any errors, improve the perimeter, and generate the final deliverable.

The fire perimeter was intersected with the provided land cover data to quantify the areas affected by the fire for each type of land cover. The results were presented in a detailed table (see section 2.1.4), showing the different land use categories and the extent of each that was impacted by the fire.

2.1.3.2 Fire grading

The method used to estimate the fire grading is widely used and well described in the IWG-SEM[7] guidelines and is the same one used in the European Forest Fire Information System (EFFIS). It is based on the temporal difference of the NBR applied to Sentinel-2 imagery. **The NBR applied here differs from the one used in fire delineation by replacing one SWIR channel with the NIR**:

$$NBR = \frac{\rho_{NIR} - \rho_{SWIRL}}{\rho_{NIR} + \rho_{SWIRL}}$$

Where:

- ρ_{NIR} = Short Short Wave Infrared Short reflectance (B8A band divided by 10000 in the case of Sentinel 2)
- ρ_{SWIRL} = Short Wave Infrared Long reflectance (B12 band divided by 10000 in the case of Sentinel 2)

This index is computed for the pre-fire and post-fire composites generated in the previous section, with a resolution of 20 meters. The dNBR is obtained by calculating the difference between the NBR values of the pre-fire and post-fire composites. Lastly, the dNBR values are categorized based on the severity thresholds established by Key & Benson (2006) [8]:

Table 2-3 US EFFIS dNBR fire severity classification

Class	dNBR range
Unburned or Regrowth	< 0.1
Low severity	0.1 – 0.27
Moderate low severity	0.27 – 0.44
Moderate high severity	0.44 – 0.66
High severity	>=0.66

Finally, using the provided land cover data, the fire grading results were be overlaid with the land cover categories to determine the amount of affected area in each land use category. This information is presented in tabular format to facilitate analysis and understanding in the next section.

2.1.4 Description of the results

The attached map (figure Figure 2-5) provides a comprehensive visualization of the burned area perimeter and the varying degrees of fire severity on the island of Chios. This analysis, derived from multispectral Sentinel-2 satellite imagery, offers critical insights into the extent and impact of the recent wildfire.

[7] https://www.un-spider.org/sites/default/files/IWG_SEM__Guidelines_Fire_chapter_SERTIT_1_0.pdf

[8] Key, C.H., Benson, N.C., 2006. Landscape Assessment (LA). In: Lutes, D.C., Keane, R.E., Caratti, J.F., Key, C.H., Benson, N.C., Sutherland, S., Gangi, L.J. (Eds.), FIREMON: Fire Effects Monitoring and Inventory System,

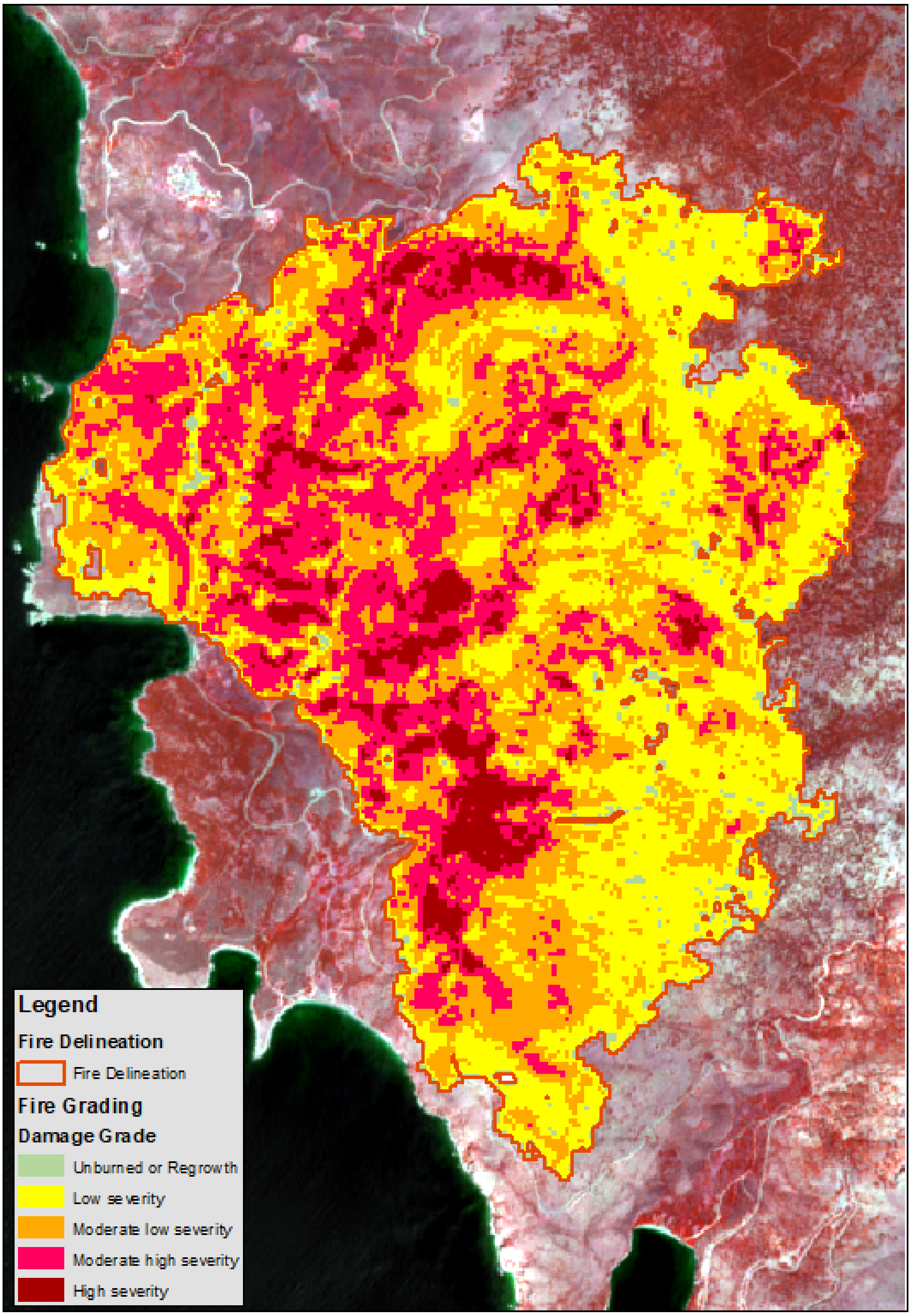

Figure 2-5 P01 Fire delineation and grading

In total, 1123.29 hectares have burned in the study area (Table 2-4). The most affected type of vegetation is pine forest, accounting for 50% of the total, followed by bushes with 37%. Both of these vegetation classes accumulate the most biomass. On the other hand, the least affected areas are agricultural lands and grasslands, which represent 20% of the study area.

Table 2-4 Burned Area by Land Cover Class

Vegetation Type	Area (ha)	%
Barren lands	2.39	0.21
Grasslands	38.51	3.43
Agricultural areas	102.05	9.08
Bushes	426.74	37.99
Pine forest	553.59	49.28
Total	1123.29	100.00

In terms of fire severity, only a small portion has been classified as high severity, representing 6.4% of the burned area (Table 2-5). Within this category, the most affected type of vegetation has been bushes. More than half of the area has been classified as moderate severity (58.49%), where 88% of the vegetation consists of pine and bushes. One third of the perimeter has been classified as low severity. In these areas, the fire has not consumed as much biomass and has passed more superficially through the vegetation, affecting the tree canopies to a lesser extent.

Table 2-5 Burned Area by Land Cover Class and Severity Range

Fire Severity Class	Affected area / %	Vegetation Type	Area (ha)
Unburned or Regrowth	37.61 (3.35%)	Barren lands	0.43
		Agricultural areas	0.85
		Bushes	11.09
		Grasslands	4.06
		Pine forest	21.18
Low severity	356.82 (31.77%)	Barren lands	1.33
		Agricultural areas	9.61
		Bushes	92.00
		Grasslands	20.72
		Pine forest	233.16
Moderate low severity	379.46 (33.78%)	Barren lands	0.63
		Agricultural areas	34.94
		Bushes	142.12
		Grasslands	8.05
		Pine forest	193.71
Moderate high severity	277.52 (24.71%)	Agricultural areas	46.58
		Bushes	138.16
		Grasslands	3.26
		Pine forest	89.53
High severity	71.88 (6.4%)	Agricultural areas	10.07
		Bushes	43.38
		Grasslands	2.42
		Pine forest	16.01

3 QUALITY CONTROL

Specific quality targets for the requested products and control measures for ensuring the high quality of all the deliveries are provided as follows. Subsequently, specific quality targets and controls (QC) for the requested products are outlined. These quality targets are conducted considering the positional accuracy, thematic accuracy, consistency, and readability, when applicable, among others. It ensured that the instructions and requirements provided in the Online Manual for Risk and Recovery Mapping are met.

The QC controls were conducted automatically (when feasible), with subsequent manual verification by a technician to ensure accuracy and reliability. The automated quality controls are designed to assess various aspects of the product, and the technician's involvement serves as a final check to confirm the validity of the results. This two-tiered approach aims to uphold the integrity of the product by combining the efficiency of automated processes with the precision of human oversight.

3.1 PRODUCT 1: WILDFIRE DELINEATION AND GRADING

The following table (Table 3-1) shows the control elements verified for the two deliverables of the activation: fire delineation and fire grading. It is important to note that the dNBR (fire grading), being a spectral index derived from Sentinel-2 images, does not have a specific validation protocol. Therefore, its verification were carried out through the checks listed in the provided table. On the other hand, a specific validation has been performed for the fire delineation, which is detailed in the following section (3.1.1).

Table 3-1. QC checks for P01.

QC check	Description	Compliant	
		Fire delineation	Fire Grading
P01-QC1	**Check file naming convention and folder structure:** Manually verify it, ensuring it aligns with the instructions provided in the Online Manual for Risk and Recovery Mapping.	✓	✓
P01-QC2	**Check data format and type:** Manually verify the data format and type of the output file, ensuring it aligns with the expected format based on the tender specification.	✓	✓
P01-QC3	**Check NoData value:** Automated assessment of the NoData value in the output file to ensure it adheres to the designated value and doesn't compromise the integrity of the results.	✓	✓
P01-QC4	**Check pixel size:** Automated verification of the pixel size in the output GeoTIFF file, ensuring consistency with the specified dimensions for accurate spatial representation.	✓	✓
P01-QC5	**Check extension and reference system:** Automatic validation of the file extension and reference system, confirming they match the predetermined standards to maintain geospatial accuracy.	✓	✓
P01-QC6	**Color Ramp Consistency Check:** Verify that the color ramp used in the output file accurately represents the different fire severity levels or fire delineation classes.	✓	✓
P01-QC7	**Result Consistency and Spatial Distribution Verification:** Manual inspection to ensure the consistency and appropriate spatial distribution of the results, confirming alignment with expected fire severity ranges or burned categories.	✓	✓
P01-QC8	**Temporal Consistency Check:** Ensure that the pre-fire and post-fire composite images used for generating the burned area indices are temporally consistent and that there are no temporal anomalies that could affect the fire severity analysis.	✓	✓
P01-QC9	**Cloud and Shadow Masking Verification:** Verify that cloud and shadow masks have been correctly applied and that no cloud or shadow artifacts are present in the Sentinel imagery.	✓	✓
P01-QC10	**Severity Threshold Verification:** Ensure that the thresholds used to classify fire severity levels (i.e., low, medium, high) are correctly applied and correspond to the thresholds defined by Key & Benson (2006) or other relevant standards.	NA	✓

3.1.1 Fire delineation

In addition to the verifications from the Table 3-1, a specific validation for the burned area was done. First, a layer of ground control points distributed over the AOI was used (Figure 3-1). A total of 282 points were generated over the AOI using stratified random sampling, with strata defined as burned and unburned areas from P01. For each of these points, the value of the fire perimeter classification was extracted.

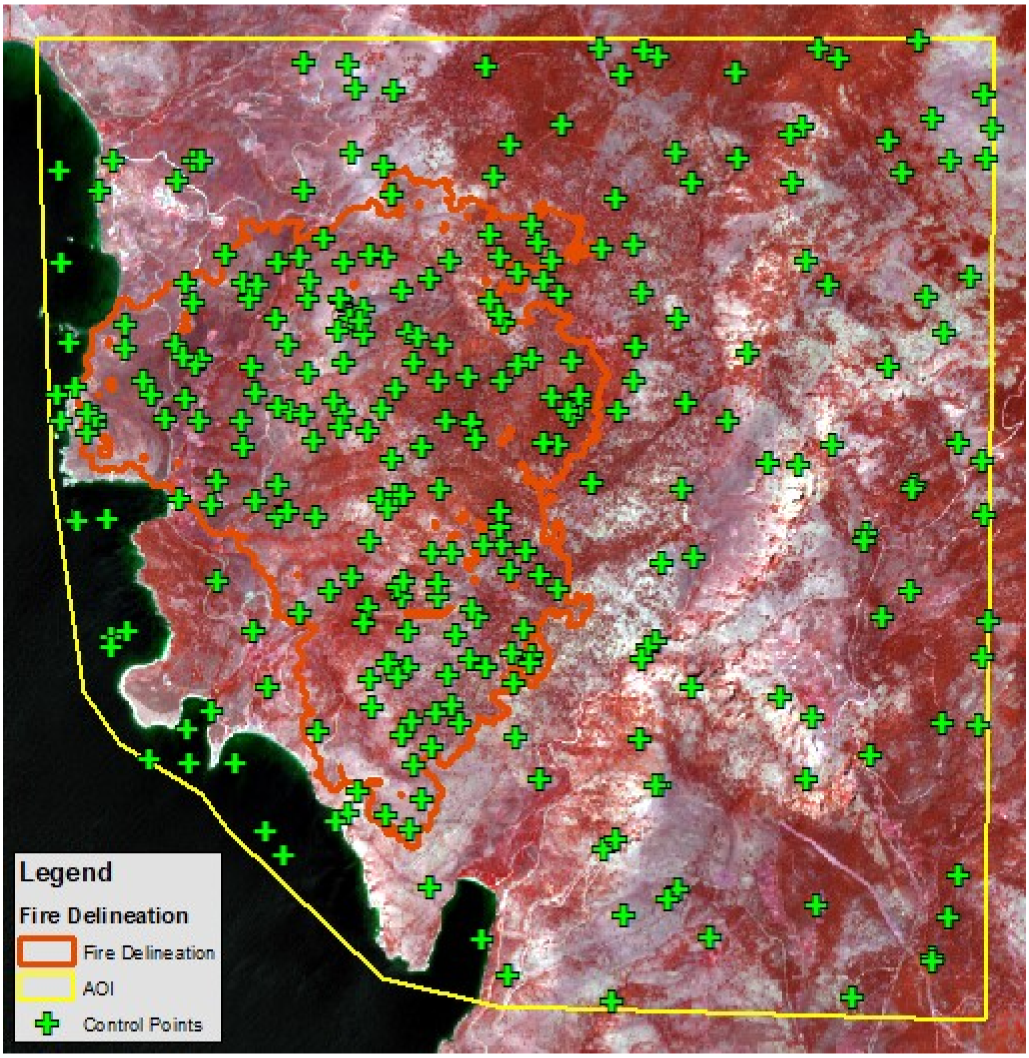

Figure 3-1 Location of the control points

Subsequently, each point was individually analyzed by an independent interpreter using photointerpretation of RGB compositions from the 20 and 10-meter Sentinel-2 images to determine whether the location of the point was burned or not. This analysis was conducted at a scale of 1:1500, allowing for the examination of each point and its surrounding context within a total area of 19 hectares per point. Overall, this means that more than 6% of the ROI was reviewed, ensuring a representative and robust sample for the validation of the burned perimeter.

Based on this verification, a confusion matrix was generated (Table 3-2). The accuracy estimation of the burned area was conducted using the Dice Coefficient[9], a statistical measure that evaluates the similarity between two sets of data. In the context of burned area validation, the Dice Coefficient compares the overlap between the burned areas identified in the cartography and the burned areas verified through photointerpretation.

Table 3-2 Confusion Matrix for Burned Perimeter Validation

	Reference		
Prediction	Burned	Unburned	Row Total
Burned	150	1	151
Unburned	0	131	131
Col.Total	150	132	282

[9] Padilla, M., Stehman, S. V., Ramo, R., Corti, D., Hantson, S., Oliva, P., ... & Chuvieco, E. (2015). Comparing the accuracies of remote sensing global burned area products using stratified random sampling and estimation. Remote sensing of environment, 160, 114-121.

The obtained Dice Coefficient was 99.66%, indicating a high concordance between the generated mapping and the photointerpretation of the RGB compositions. Additionally, the commission error of the product, which represents the areas incorrectly classified as burned, was only 0.66%. No omission errors were observed, meaning that all genuinely burned areas were correctly identified.

Ctra. de Loeches 9

28850 Torrejón de Ardoz

Madrid, España

T +34 916271000