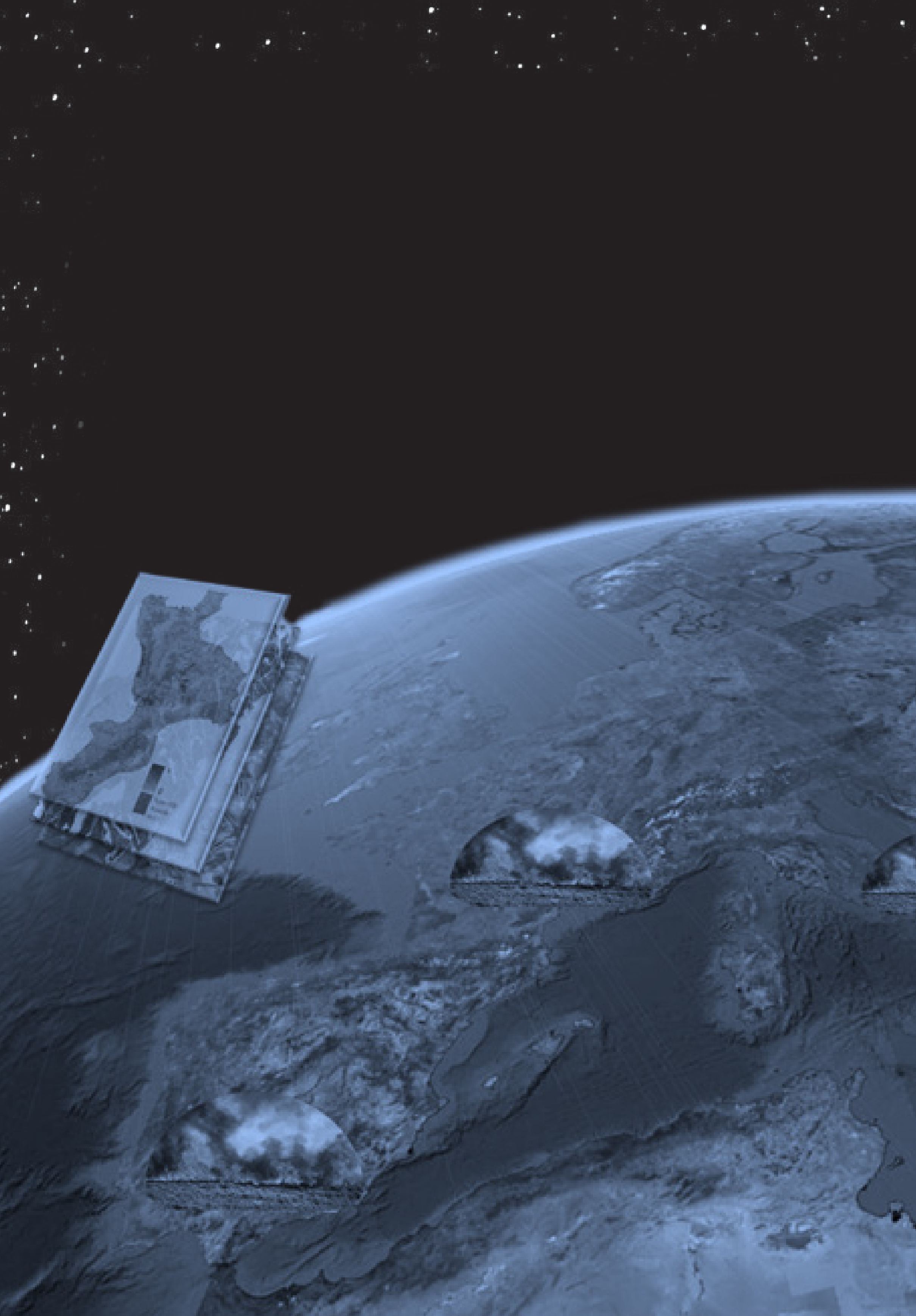
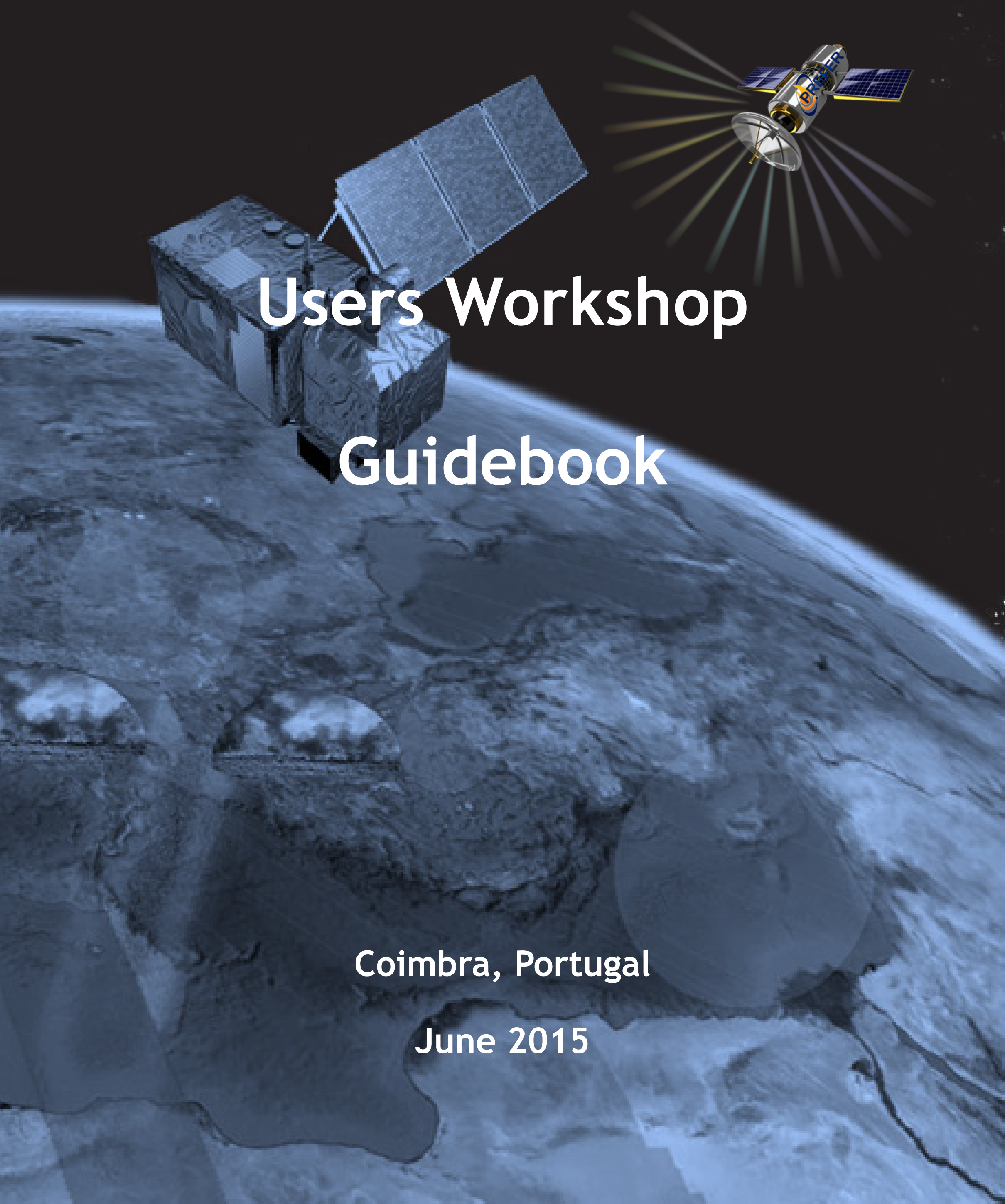


PREFER - Space-based Information Support for Prevention and REcovery of Forest Fires Emergency in the MediteRranean Area



Users Workshop

Guidebook

Coimbra, Portugal

June 2015

Editorial Board

Title: PREFER Users Workshop Guidebook

Editor: University of Coimbra (UCO)

Coordinator: Luciano Lourenço (UCO)

Content edition: Sandra Oliveira (UCO)

Revision: CGS, DIAEE, GMV, IESC, KEMEA, SATWAYS, SERTIT

Layout and cover: Fernando Félix (UCO)

Printing: Simões & Linhares, Lda.

June 2015

Contents

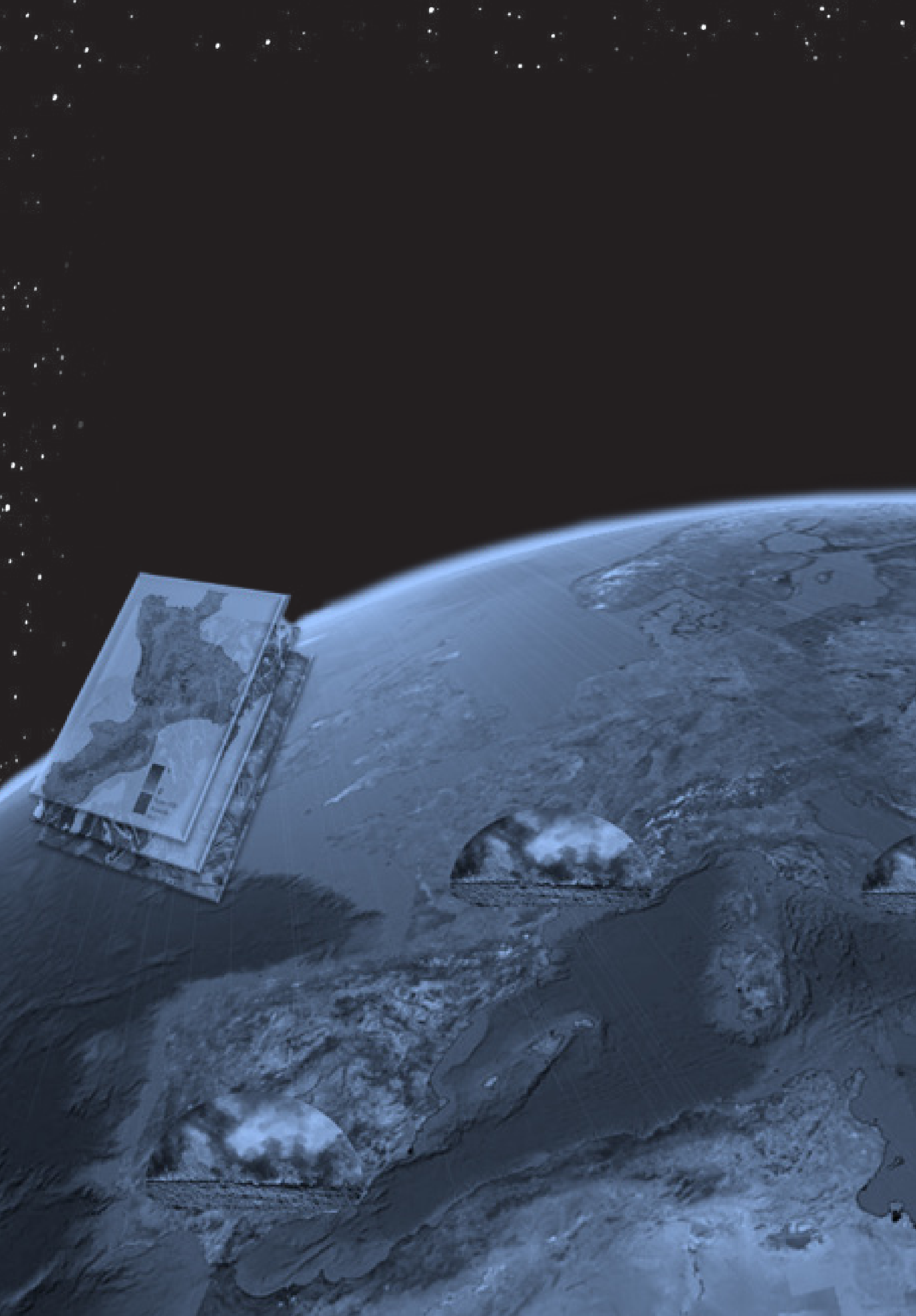
The PREFER project 11
Main characteristics of PREFER 11
PREFER Users 14
The use of remote sensing 15
Areas of Interest (AOI) 19

Service Infrastructure 23
Service Infrastructure Design 25
Web based user interface 27
Mobile user interface 30

Product Portfolio 35
Prevention Phase 37
Fuel Map 39
Daily Fire Hazard Map 47
Seasonal Fire Hazard Map 55
Vulnerability and Economic Value Maps 63
Fire Risk Map 71
Fuel Reduction Map 79
Prescribed Fire Map 87

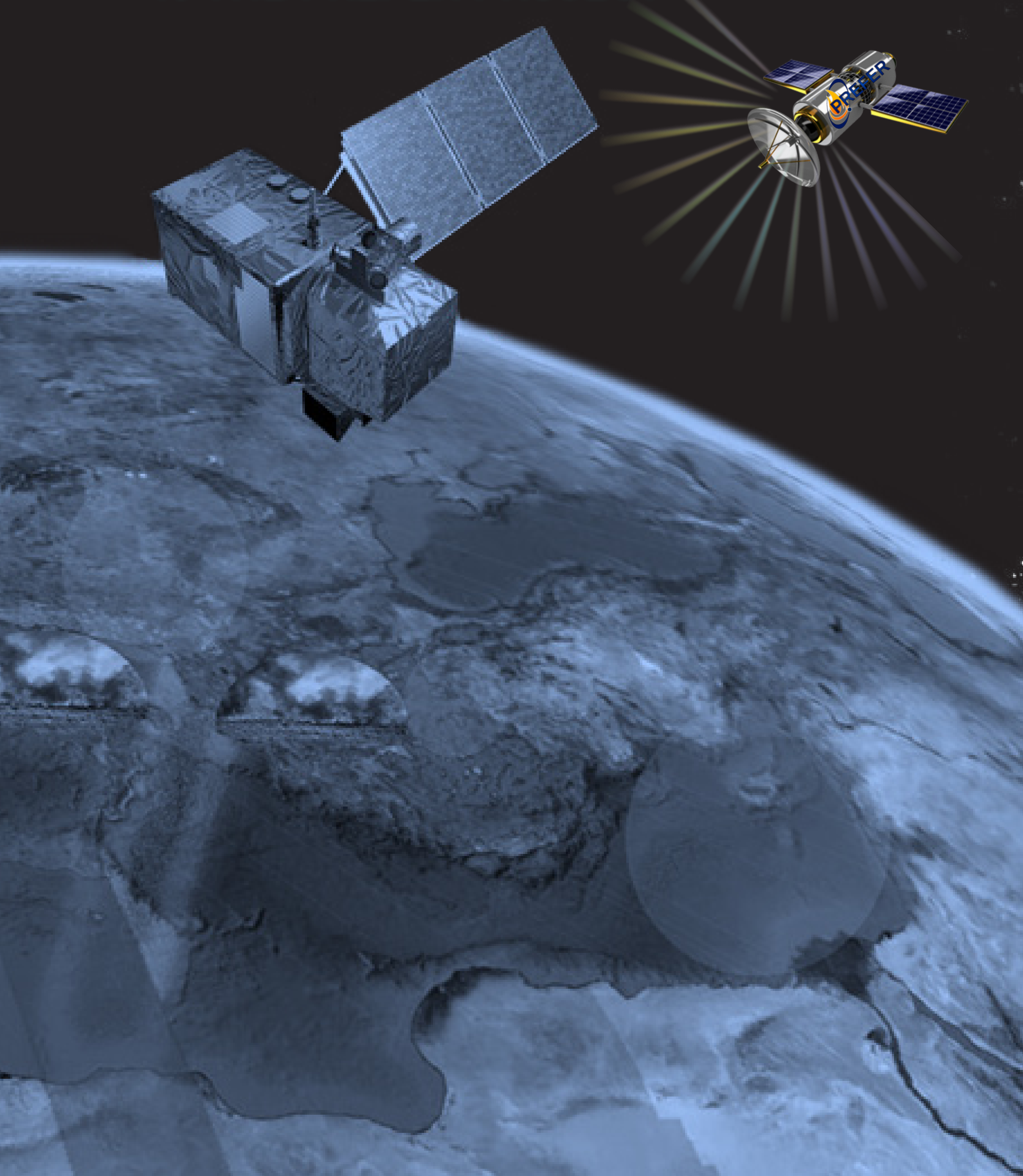
Recovery Phase 95
Post-Fire Vegetation Recovery Map 97
3D Fire Damage Assessment Map 105
Severity Damage Map 113
Burn Scar Maps - HR 121
Burn Scar Maps - SAR 129
Burn Scar Maps - VHR 137

References 145



1. THE PREFER PROJECT

1. THE PREFER PROJECT



Background

PREFER, the acronym for “Space-based Information Support for Prevention and REcovery of Forest Fires Emergency in the MediteRranean Area”, is a project funded under the EU FP7, which started on the 1st December 2012 and has a duration of 3 years.

The main purpose of PREFER is to set up a space-based service infrastructure and up-to-date cartographic products, based on remote sensing data, to support the preparedness, prevention, recovery and reconstruction phases of the Forest Fires emergency cycle in the European Mediterranean Region. This region is particularly affected by uncontrolled forest fires, with negative consequences on ecosystems, such as desertification and soil erosion, as well as on the local economy and, in extreme situations, causing also the loss of human lives.

The PREFER project focuses its activities on the EU Mediterranean Region, namely the five most fire-affected countries in Southern Europe: Greece, France, Italy, Portugal and Spain, which also present the largest fraction of forested areas in Europe (JRC, 2013; World Bank, 2011). In these countries, several conditions overlap that can explain such high fire incidence: the coincidence of the driest with the hottest season and the occurrence of wet and dry weather extremes throughout the year; the coexistence of urban settlements, infrastructure networks and vegetated areas (forest, agricultural and uncultivated areas) in a complex, dense and intimately interconnected patchwork; the diminished control on traditional practices involving fires as an instrument for land management and sanitization and the changes in land use verified in recent decades (Badia *et al.*, 2011; Leone *et al.*, 2003; Moreira *et al.*, 2011; Lampin-Maillet *et al.*, 2011; Pausas, 2004; San-Miguel-Ayanz *et al.*, 2012).

In this region, forest fires are a serious threat and, therefore, the collection of high quality and ample quantity of information, addressing fire knowledge and prevention, is of utmost importance to increase the capacity of societies to deal with fires.

Fire prevention is still the most cost-effective strategy when compared to firefighting and extinguishing that are costly, local, and triggered only in response to already ongoing crises. The PREFER project intends to contribute to responding to such a pragmatic need of Southern Europe’s forests by:

1) Providing timely multi-scale and multi-payload information products based on exploitation of all available space borne sensors;

2) Offering a portfolio of Earth Observation (EO) products focused both on Pre-crisis and Post-crisis forest fire emergency cycle in the EU Mediterranean area;

3) Preparing the exploitation of new space borne sensors available by 2020 and 4) contributing to the definition of User requirements for the new EO missions.

1.1 Main characteristics of PREFER

PREFER is configured as an Industry-driven/Science-controlled initiative, whose priority is the systematic execution of operations regarding the creation and delivery of products. The PREFER consortium is composed of 8 partners from the 5 most fire-affected countries in Southern Europe, among which research institutes and industry (TABLE I).

The PREFER Service portfolio consists of two main services:

- Information Support to Preparedness/Prevention Phase Service (ISP)
- Information Support to Recovery/Reconstruction Phase Service (ISR)

Each of these services is dedicated to the provision of space-based information services and cartographic products (maps) that focus on a particular aspect of the fire cycle, in support to forest fires emergency management in the Mediterranean Area (TABLE II).

TABLE I - Institutions that constitute the PREFER Consortium and their country of origin.

Consortium partners			Country
	Universitá Degli Studi di Roma La Sapienza	DIAEE	Italy
	CGS SPA Compagnia Generale per lo Spazio	GCS	Italy
	GMV Aerospace and Defence S.A.U.	GMV	Spain
	University of Strasbourg	UNISTRA/ SERTIT	France
	Intelligence for Environment & Security	IESC	Italy
	Center for Security Studies	KEMEA	Greece
	SATWAYS Ltd, Satcom & Telematics	SATW	Greece
	University of Coimbra	UCO	Portugal

The key-drivers of PREFER can be summarized in the four main topics below:

SYSTEMATIC FUEL ESTIMATES:

Once ignited, fires are mainly governed by weather parameters (mainly wind), vegetation cover (load, structure and density) and status (moisture content), topography and dead biomass (branches, needles, foliage etc.). In particular, the physical characteristics of forest fuel such as loading (weight per unit area), size (particle diameter) and bulk density (weight per unit volume) of live and dead biomass, contribute to spread, intensity and severity of fires. Robust and timely estimates of available fuel, and of its burning potential, are the key for suitably supporting a pre-event, for the Preparedness-and-Prevention phase, developing an end-to-end service in the PREFER concept.

SYSTEMATIC BURN SCAR MAPPING:

PREFER improves the current, systematic, burnt areas mapping capacity both in terms of area threshold (EFFIS' current thresholds are 40 ha in Rapid Fire and ca.10 ha in Fire Damage assessment mode) and in terms of spatial resolution (currently 250 m in Rapid Fire and 30-50 m in Fire Damage assessment modes, respectively). In turn, systematic mapping at much higher resolution and on a larger quantity of fires, with an improved process automation and a robustness control that are covered within the PREFER project. Further improvement in the Burn Scar mapping capacity had to be focused on areas provided with limited optical visibility because of persistent cloud cover, haze and/or smoke. This call for the development and the demonstration of robust mapping techniques based on X-band (Cosmo-SkyMED, TerraSAR-X) and C-band (Radarsat-2 and the forthcoming ESA Sentinel-1) Synthetic Aperture Radar data, thus projecting ahead, over about 3 to 10 years, the technical sustainability of Remote Sensing operations.

SYSTEMATIC ANALYSIS OF FIRE EFFECTS ON SLOPE STABILITY:

PREFER highlights the transfer of Fire Hazard to Slope Instability Hazard. Rainfall normally absorbed by soils, can run off extremely quickly on impermeable bedrock once soils and vegetation have been charred. Torrential rainfall waters can mobilize large amounts of sand, silt, rocks and remnants of vegetation, bringing to major damage culverts, bridges, roadways and urban areas. Erosion prone areas are linked to many factors including burn severity, slope of the terrain and size of burned drainage basins. The geographic assessment of fire damage in erosion prone slopes is expected to be an added value input to neighbouring Copernicus projects (GEOLAND-2, SAFER, G_MOSAIC and DORIS).

SYSTEMATIC VEGETATION RECOVERY ANALYSIS:
Close monitoring and a quantitative assessment of the vegetation re-growth after depletion by a fire, are essential for the two-fold target of assessing:

(i) the fuel build-up following the restoration of the burned ecosystem, and the changes in fire risk that may derive from this; and

(ii) the reduction of slope instability risk, associated to re-growth of a significant vegetation cover in erosion prone areas. Systematic, quantitative analysis of vegetation re-growth is addressed to the post-fire monitoring of the restoration of wildlife's habitats.

Table II - PREFER Service portfolio.

Service Phase	Product	Description
Preparedness/ Prevention	Fuel Map	Classification map of forest fuel complexes
	Daily Fire Hazard Map	Medium spatial resolution fire danger index, indicating the proneness of a vegetated area to support a fire
	Seasonal Fire Hazard Map	High resolution hazard index with a temporal resolution from 2 to 4 weeks
	Vulnerability & Economical Value Maps	Relative measure of the potential for loss in case a fire occurs, and the estimation of economic losses
	Fire Risk Map	The probability of occurrence of a fire event that can cause losses
	Fuel Reduction Map	Identification of the areas where the prevention procedure based on fuel reduction is advisable
	Prescribed Fire Map	Spatial-temporal map of the areas where it would be useful and safe to apply prescribed fire
Recovery/ Reconstruction	Post-fire Vegetation Recovery Map	Identification of areas previously damaged by fire event where regrowth of vegetation took place
	3D Fire Damage Assessment Map	2D and 3D fire impact monitoring map and soil erosion susceptibility index
	Severity Damage Map	Degree of damage on burned areas
	Burn Scar Map HR Optical	Burn Scar perimeters, at scale 1/25.000-1/50.000
	Burn Scar Map SAR	Burn Scar perimeters, at scale 1/10.000-1/50.000
	Burn Scar Map VHR Optical	Burn Scar perimeters at cadastral scale (1/1.000-1/4.000)

The service infrastructure and the products provided have some particularities, such as:

- The project counts with the participation of end-users from the different countries (Portugal, Spain, Italy, France and Greece), among which civil protection entities, forest services and fire brigades;
- The products are based on a harmonized set of user requirements, defined by the participating users, which provide feedback along the different stages of project development;

- The products requirements also take into account the different legal frameworks existing in the participating countries;
- The products are mainly based on the exploitation of data from the Copernicus space infrastructure;
- The procedure for creation of the products optimizes the integration of different data types from several sources, such as Earth Observation, Digital Terrain Models, socio-economic data, in-situ data and meteorological data;
- The products and services are demonstrated by an interoperable service provision infrastructure (based on OGC/INSPIRE), that will allow easy access to the information;
- The procedure developed to create the products can be applied in the different countries of the Mediterranean Region, in a systematic and sustainable way;
- The products are complementary to the ones provided by the Copernicus Land and Emergency Services and by the EC JRC EFFIS System.

1.2 PREFER Users

The accomplishment of PREFER's objectives is strongly linked to the participation of potential end-users of the products and services provided. During the development of the project, the users contribute to:

- Support the definition of the areas of interest;
- Define the users requirements, to tailor the services and products to their needs;
- Provide in situ data for demonstration and validation;
- Provide a critical evaluation of the products and services;
- Active participation in the training sessions and workshops.

Table III - Users participating in the PREFER project and their country of origin.

Country	User name
France	Office National des Fôrets, Direction Generale Corse (ONF)
	Service Départemental d'Incendie et de Secours de la Haute Corse (SDIS)
Greece	General Secretariat for Civil Protection
	Aristotle University of Thessaloniki
	Balcan Environment Center
	National Centre for Scientific Research Demokritos (NCSRD)
Italy	Corpo Forestale e di Vigilanza Ambientale, Sardinia (CFVA)
	Centro Nazionale di Meteorologia e Climatologia Aeronautica
	Fire Brigades
Portugal	National Authority of Civil Protection (ANPC)
	National Republican Guard, Service of Protection of Nature and the Environment (GNR-SEPNA)
	Institute for Nature Conservation and Forests (ICNF)
Spain	Agencia de Medio Ambiente y Agua de Andalucía

1.3 The use of remote sensing

The services provided by PREFER are primarily based on the use of remote sensing data.

In satellite remote sensing, information about the earth's surface and atmosphere is acquired using sensors mounted on-board satellites orbiting the earth; in comparison to other methods of information gathering, satellite remote sensing provides some advantages:

- Large area coverage;
- Frequent and repetitive coverage of an area of interest;
- Easy data acquisition at different scales and resolutions;
- One single image can be interpreted for different purposes and applications;
- Quantitative measurement of ground features using radiometrically calibrated sensors;
- Provides access to data from areas difficult to access from the ground;
- Semi-automated computerised processing and analysis, although expertise is required;
- Ability to implement a systematic approach;
- Allows for monitoring of dynamic processes.

Remote sensing can, thus, offer useful tools for fire monitoring and damage assessment to support fire management, in a cost-effective way. The PREFER project is inspired in these premises; the systematic carrying out of operations, and the equally systematic creation, update and delivery of products, are a priority, grounded on the exploitation of remote sensing observations.

Current remote sensing initiatives and satellites for fire management

Several remote sensing satellites are currently available, providing imagery suitable for forest fire research and fire monitoring operations; from land cover/use maps, to burnt area and fire danger estimations, today users can access several global, pan-European products for use in the field of fire preparedness and recovery of the vegetation after fire. Several initiatives also exist to generate Earth Observation data according to predetermined standards and to optimize the access of the users' community to geo-information products derived from remote platforms. Some examples are the Global Fire Monitoring Centre (GFMC, http://www.fire.uni-freiburg.de), the Fire Mapping and Monitoring theme of the GOFC/GOLD (Global Observations of Forest and Land Cover Dynamics, http://gofc-fire.umd.edu), which is a Technical Panel of GTOS (Global Terrestrial Observing System - http://www.fao.org/gtos/index.html), the CEOS (Committee on Earth Observation Satellites) and several missions of NASA (National Aeronautics and Space Administration, http://www.nasa.gov/mission_pages/fires/main/missions/index.html)

The PREFER project is particularly associated with the European Programme Copernicus (http://www.copernicus.eu/), formerly known as GMES (Global Monitoring for Environment and Security). The goal of Copernicus is to develop operational information services on a global scale, using both space- and ground-based monitoring systems, in support of environment and security policy needs. This programme aims at providing an increasingly broad user community with accurate, timely and easily accessible information collected from Earth observing satellites and in-situ sensors, establishing a European capacity for Earth Observation. The Copernicus programme comprises satellite-borne earth observation and in-situ data, and a services component that combines these in order to provide essential information for monitoring the terrestrial environment. Copernicus services address six main thematic areas: **Land, Marine, Atmosphere, Climate Change, Emergency Management and Security**.

The services that are most relevant to PREFER are the **Land and the Emergency Management**. The **Land Monitoring service** (GIO-land) provides land products at various scales (global, pan-European and local) and periodicity. The **Emergency Management service** (GIO-EMS), operational since 2012, provides a rush-mode service and a non-rush mode service. The rush mode refers to on-demand and fast provision of satellite-derived products immediately following an emergency event. These maps are based on satellite data, together with other geospatial data useful for analysing a crisis situation such as aerial imagery, in field measurement and data from global geo-spatial databases. Maps are delivered as fast as possible, typically within 24 hours or less, after the reception of satellite data. The non-rush consists of the on-demand provision of geospatial information supporting emergency management activities not related to the immediate response phase and with a longer delivery time than the products of rush mode. This service addresses prevention, preparedness, disaster risk reduction or recovery phases (product delivery in weeks/months) and provides pre-fire and post-fire maps.

It is a main objective of PREFER to ensure and foster complementarity of the PREFER EO information products portfolio with the EO products delivered by the other on-going Copernicus operational Land and Emergency services. For this reason, PREFER has analysed the synergies between different services and initiatives currently available, as well as the current EO space missions, to identify best suitable EO sensor to exploit by the PREFER service, based on technical performances and cost trade off. Among current missions, the most relevant ones are: MODIS, Landsat 8-OLI, SPOT4 HRVIR-1 &2, SPOT 5 HRGT 1&2 and IRS P6 LISS3, KOMPSAT-2, GeoEye, QuickBird, IKONOS and RapidEye.

Additionally, the future EO space missions, to be launched by 2020, were also examined, to ensure the availability of cost-effective remote sensing data and the long-term sustainability of the project's services, and to identify potential gaps of future missions with respect to PREFER users requirements. As future EO missions are concerned, the analysis paid a special attention to the Copernicus/GMES Sentinels System, where the European Space Agency (ESA) is developing five new missions (Sentinels) specifically for the operational needs of the Copernicus programme.

The Sentinel missions are based on a constellation of two satellites to fulfil revisit and coverage requirements, providing robust datasets for Copernicus Services. These missions, launched since 2013, carry a range of technologies, such as radar and multispectral imaging instruments for land, ocean and atmospheric monitoring:

- Sentinel-1 is a polar-orbiting, all-weather, day-and-night radar imaging mission for land and ocean services. The first Sentinel-1 satellite has been launched on the 3rd April 2014.
- Sentinel-2 is a polar-orbiting, multispectral high-resolution imaging mission for land monitoring providing, for example, imagery of vegetation, soil and water cover, inland waterways and coastal areas. Sentinel-2 will also deliver information for emergency services. The first Sentinel-2 satellite is planned for launch in June 2015.
- Sentinel-3 is polar-orbiting, multi-instrument mission to measure variables such as sea-surface topography, sea- and land-surface temperature, ocean colour and land colour with high-end accuracy and reliability. The first Sentinel-3 satellite was planned for launch late in 2015.
- Sentinel-4 is a payload that will be embarked upon a Meteosat Third Generation-Sounder (MTG-S) satellite in geostationary orbit scheduled to be launched in 2019. Sentinel-4 is dedicated to atmospheric monitoring.
- Sentinel-5 is a payload that will be embarked on a MetOp Second Generation satellite, also known as Post-EPS, to be launched in 2020. Sentinel-5 is dedicated to atmospheric monitoring. Sentinel-5 Precursor satellite mission is planned to launch in 2016, thereby reducing data gaps between Envisat (Sciamachy data in particular) and Sentinel-5. This mission will be dedicated to atmospheric monitoring.

The mission of Sentinel-1 (C-band SAR) is available during the project lifetime, as it has been launched in 2014, and its exploitation within PREFER services is being tested.

The optical very high resolution Pleiades mission, with the first products available in March 2012, are also considered. The Italian Hyperspectral Mission (PRISMA) and the German Hyperspectral Mission (ENMAP), whose launch has been scheduled for 2017-2018, were considered. Also the Eumetsat Post-EPS missions (foreseen by 2020) were analyzed.

Remote sensing fire products – Burnt Area and Hazard Index

Burnt Area is a land cover sub-product of particular interest for wildfire management and several worldwide products exist. The most widely known by the fire end-users is the MODIS burned-area product (500 m resolution) provided by the University of Maryland, who implements an algorithm that accounts for spectral, temporal, and structural changes in the MODIS imagery (Roy *et al*. 2005).

In Europe, MODIS is also the source for the **EFFIS Rapid Damage Assessment** product which provides, twice a day, updated perimeters of burnt areas in Europe for fires of about 40 ha or larger at a resolution of 250 m. Although only a fraction of the total number of fires is mapped by this service, but still the area burned by fires of this size represents about 75% to 80% of the total area burned in EU (http://forest.jrc.ec.europa.eu/activities/forest-fires/rapid-damage-assessment/). This product's resolution is higher than that of Maryland's University and it is in fact used by fire managers, but still its resolution is not optimum to satisfy their accuracy requirements, namely: to detect fires below 10 ha, and 20 m RMS, according to the compilation of users' needs performed within PREFER. However, the above resolution requirement is not met by the production of the *EFFIS Fire Damage Assessment* product, which is computed using IRS data (56 m spatial resolution), or DMC data (32 m), hence allowing for the mapping of fires larger than 10 - 20ha. This product is only available at the end of each fire season, allowing its use for planning and executing the restoration of the vegetation and fire preparedness for the following season.

EFFIS provide also a **fire hazard index** at European level. The differences between EFFIS and PREFER common products are given in the following table:

Table IV - EFFIS vs PREFER products.

Product	EFFIS product characteristics	PREFER product characteristics
Fire Hazard map	Spatial resolution = 10 - 40 km	Spatial resolution = 250 m
Burnt area HR	Spatial resolution > 10 ha	Spatial resolution = 1 ha
Burnt area VHR	N/A	Spatial resolution = 0.25 ha

Since 2012, the Copernicus GIO-EMS service provides European users with a rush-mode service and a non-rush mode service for burnt area mapping. GIO-EMS ensures the coherence with national scale geospatial reference data by accessing these data, and using them in the generation of the pre- and post-fire maps, through an agreement with EuroGeographics (network of mapping agencies, http://www.eurogeographics.org/). Nonetheless, this product is not systematically available for all fires, since prior to its production, the GIO-EMS service needs to be activated by authorized users. Generally, the GIO-EMS service is only triggered for large and dangerous fires, which is not always the case. The PREFER burnt area products (HR/VHR) being a compilation of a season's burn scars of above 10 ha, is innovative as it is intended to provide this at a higher resolution, a resolution more compatible with forest user demands (1/1.000 - 1/25.000 scales).

Characteristics of remote sensing data used in PREFER

The selection of satellite remote sensing data depends on the purpose of the analysis and their application. The main characteristics to consider are:

1) Spatial resolution – the pixel size of satellite images covering the earth surface;

2) Temporal resolution – the revisiting frequency of a satellite sensor for a specific location;

3) Spectral resolution - the number of spectral bands in which the sensor can collect reflected radiance and the position of the bands in the electromagnetic spectrum;

4) Spectral bands - specific frequencies across the electromagnetic spectrum, with different wavelengths;

5) Radiometric resolution – it refers to the number of divisions of bit depth in data collected by a sensor, specifying how well the differences in brightness in an image can be perceived;

6) Swath width - the strip of the Earth's surface from which geographic data are collected by a satellite,;

7) Launch date and availability of archive data.

The spectral bands used within the context of fire preparedness and recovery are:

Blue: mapping water near coasts, differentiating between soil and plants.

Green: shows the green reflectance of healthy vegetation. It is useful for differentiating between types of plants, determining the health of plants, and identifying man-made objects.

Red: discriminating among different kinds of vegetation, mapping soil type boundaries and geological formation boundaries.

Near infrared (NIR): especially responsive to the amount of vegetation biomass present in a scene, useful for crop identification, distinguishing between crops and soil, and delineating bodies of water.

Shortwave infrared (SWIR): sensitive to turgidity (amount of water in plants), is useful in drought studies and plant vigour studies.

Thermal infrared: measures the amount of infrared radiant flux (heat) emitted from surfaces, and thus is useful to assess evapotranspiration rates, and thus to analyze vegetation stress, and measure soil moisture.

SAR: active sensors are shown to be useful when the area under study is frequently cloudy and/or a description of the vegetation structure is needed (SAR and Lidar).

In the context of Copernicus, the European Space Agency has established a set of resolution classes, that have been used to classify the operative sensors with potential for PREFER, as follows:

- HR1 High Resolution 1 where: 4 m <resolution <= 10 m
- HR2 High Resolution 2 where: 10 m <resolution <= 30 m
- VHR1 Very High Resolution 1 where: resolution <= 1 m
- VHR2 Very High Resolution 2 where: 1 m <resolution <= 4 m

1.4 Areas of Interest (AOI)

The target geographic area of the PREFER project is composed by all European territories located in the Mediterranean area and where fire occurrence is particularly relevant. The products and services developed by the project are foreseen to be applicable to any location within this region.

To test and demonstrate the products and services developed, 5 smaller areas were defined within the most-affected countries in Southern Europe; these areas of interest (AOI) were selected based on the interest of the users, the availability of data required for the development of the products and services, the physical and social conditions of these areas and their association with fire occurrence history (fig. 1). The areas of interest in the PREFER project are:

PT – Minho Region, Portugal;

ES – Los Alcornocales, Andalusia, Spain;

FR – Corsica, France;

IT – SW Sardinia, Italy;

GR – Messinia, Peloponnese region, Greece.

Fig. 1- Location of the Areas of Interest (AOI - in red) in the participating countries (in blue). PT–Minho region; ES-Alcornocales, Andalusia; FR–Corsica; IT–SW Sardinia; GR–Messinia, Peloponnese.

Minho region, Portugal

Products tested:
- Fuel map
- Daily Fire Hazard map
- Seasonal Fire Hazard map
- Vulnerability map
- Fire Risk map
- Fuel Reduction map
- Prescribed Fire map
- 3D Fire Damage Assessment Map
- Post-fire Vegetation Recovery map
- Burn Scar maps (HR)

The Minho region covers 24 municipalities and has an area of 4.700 km^2. It has an irregular topography, with altitude ranging between 0-1400 m. It is characterized by a high amount of rainfall, particularly in the areas influenced by the Atlantic Ocean, contributing to the high level of biomass productivity of the region. Species such as the Alvarinho Oaks (*Quercus robur L.*), the Sycamore (*Acer pseudoplatanus L.*), and, most recently, the Maritime Pine (*Pinus pinaster spp.)* and the Eucalyptus (*Eucalyptus globulus*), are present. The eastern side of the region is occupied by the protected area of Peneda-Gerês, whose importance is internationally acknowledged.

The high biomass production, the irregular topographical conditions and the abandonment of the rural area due to recent demographic and social changes (ageing of population and migration to urban centres), favour the occurrence and propagation of forest fires; this high incidence of fires, especially in the inland municipalities, is also due to the presence of human activities (hunting, grazing), different accessibility structures and the availability of prevention and firefighting resources.

Los Alcornocales, Andalusia, Spain

Products tested:
- Fuel map
- Daily Fire Hazard map
- Seasonal Fire Hazard map
- Vulnerability map
- Fire Risk map
- Fuel reduction map
- Prescribed Fire map

The area covers 523 km^2 and encloses two municipalities (Cádiz and Malaga), corresponding to the Natural park of Alcornocales, a protected area. The vegetation corresponds to Mediterranean native forests, with a significant presence of cork oak (*Quercus suber*); other tree species present in the area are *Quercus canariensis*, *Pinus pinea*, *Pinus pinaster* and *Eucaliptus spp*. The altitude in the area ranges between 0-500 m.

The Alcornocales Park is affected by fires and requires a special effort in prevention due to its outstanding ecological value. Fires affecting the park typically originate in the border with urban areas outside the park, particularly in summer season. During the summer season, the Alcornocales Park is normally considered as "very high fire risk area", but at the same time, the cork oaks silviculture counteracts fire risk.

Corsica, France

Products tested:
- Vulnerability map
- 3D Fire Damage Assessment Map
- Burn Scar maps (HR, VHR, SAR)
- Damage Severity Map
- Post-Fire Vegetation Recovery map

The Corsica region, with an area of 8.680 km^2 is composed by 2 departments: Corse-du-Sud and Haute-Corse. Its topography ranges from 0 to 2706 m. Its Mediterranean climate, with typical summer drought, is often tempered by altitude. The vegetation is mainly made up of scrubland in Haute-Corse and forests (pine, beech, chestnut tree, oak…) in Corse-du-Sud. This predominantly rural territory is classified as a French Regional Natural Park, due to its exceptional landscapes, natural habitats and cultural heritage, and benefits from important safeguard measures.

On average, more than 500 fires burn over 1000 ha per year throughout the region. In this context, 360 municipalities are exposed to risk of forest fires, hence prevention and fight against this type of hazard is a major challenge, both to protect the public and to preserve biodiversity.

SW Sardinia, Italy

Products tested:
- Fuel map
- Daily Fire Hazard map
- Seasonal Fire Hazard map
- Vulnerability map
- Fire Risk map
- Fuel Reduction map
- Prescribed Fire map
- Burn Scar maps (HR, VHR, SAR)
- Damage Severity Map
- Post-Fire Vegetation Recovery map

The AOI corresponds to the footprint of a SPOT image and covers about 3000 km^2. The selected area in Sardinia is an important agricultural site but it is mostly important from the ecological point of view, since it hosts several protected areas (Natura2000 areas, parks) and in particular the Monte Arcosu Forest, which is one of the bigger holm oak forest of the Mediterranean region.

The vegetation is characterized by Mediterranean maquis and oak forest (*Quercus ilex* and *Quercus suber*). The altitude in the area ranges between 0-1200 m.

Sardinia is one of the Italian regions more affected by fires. In fact, in 2013, it was the most affected, with 10.588 ha of area burned. The PREFER AOI comprises the provinces of Carbonia Iglesias, and parts of the provinces of Cagliari and Medio-Campidano; it includes protected areas (Monte Arcosu Forest), areas of Community interest and regional parks (Sulcis, Monte Arcu Entu, Linas-Marganai). Forest fires, frequently occurring during summer season, represent the main source of risk for the area which, for this, requires a special effort in prevention and restoration.

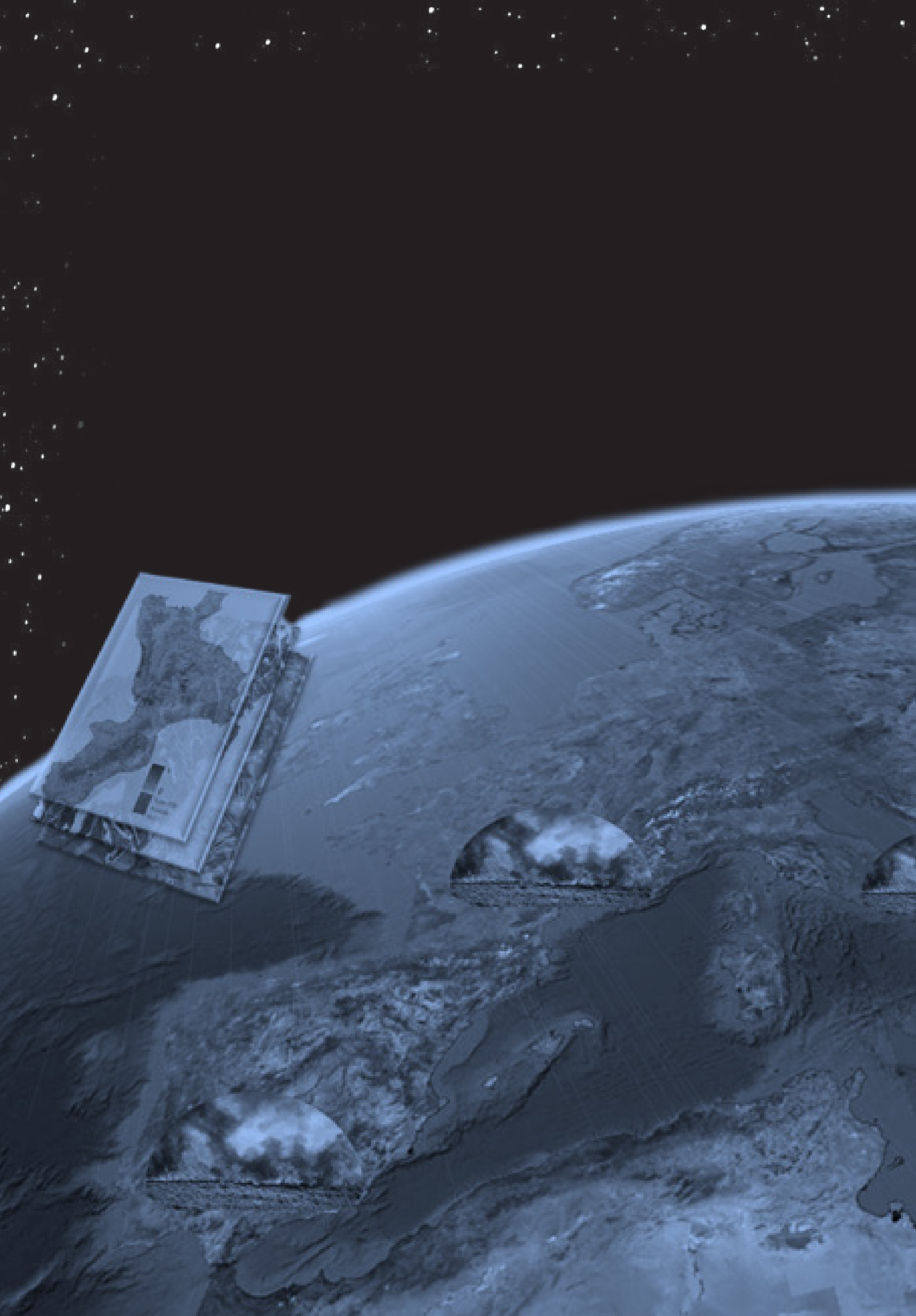
Messinia, Peloponnesus, Greece

Products tested:
- Burn Scar maps (HR, VHR, SAR)
- Damage Severity Map
- Post-Fire Vegetation Recovery map

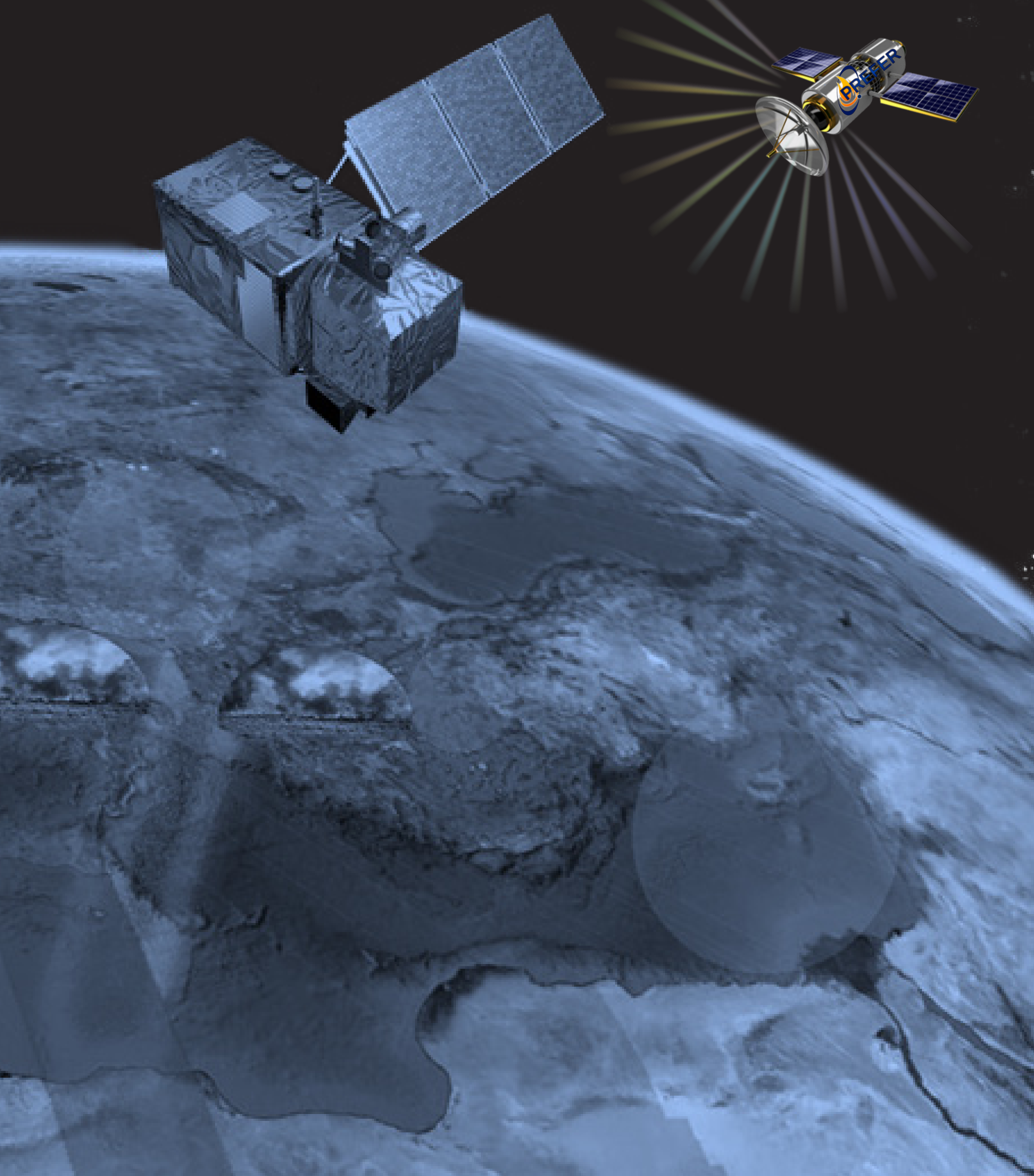
The Greek pilot area is sited in south-west Peloponnesus and spans across five administrative units of Messinia region. It includes 29 Municipalities and hundreds of small villages and communities covering an area of 1.650 km^2. The test area includes Gialova lagoon, Greece's southernmost major wetland surrounded by the natural bay of Voidokilia and featuring a significant sand-dune ecosystem. The natural vegetation covers the rough mountain relief from the sea level up to 1200 m in Mount Taygetos on the east. The flora is rich and diverse, including Greek Firs (*Abies cephalonica*) and Black Pine (*Pinus nigra)* in the woodlands of Mount Taygetos, Aleppo Pine (*Pinus halepensis*) in the coastal forests around Nedas estuary, as well as Mediterranean maquis, such as mastich trees (*Pistacia lentiscus*), strawberry trees (*Arbutus unedo*), spiny brooms (*Calicotome villosa*), oaks (*Quercus spp.*), Juniper trees and Posidonia sea grass.

The area receives increased amount of rainfall compared to Central and Eastern parts of Greece, which leads to high forest biomass production. The climatic conditions of wet spring and prolonged dry summer are favorable to fire ignition. The strong decline of population in the region in recent decades led to the abandonment of agricultural land and to fuel accumulation.

Fires occur often at the mid and low altitudes and the majority of them are linked with human activity, grazing and land use change. Although fires usually burn scrublands and shrubs at the lower altitudes, high forests of firs and black pines have burned at Mount Taygetos during the large fires of 2007.



2. SERVICE INFRASTRUCTURE



Service Infrastructure Design

The PREFER Service Infrastructure is an information system that includes two main sub-systems:

1) Data Processing System, devoted to the generation of PREFER products;

2) Service Provision Infrastructure, which provides a customized WEB access to EO-based information.

The main elements of the two subsystems are presented in fig. 2.

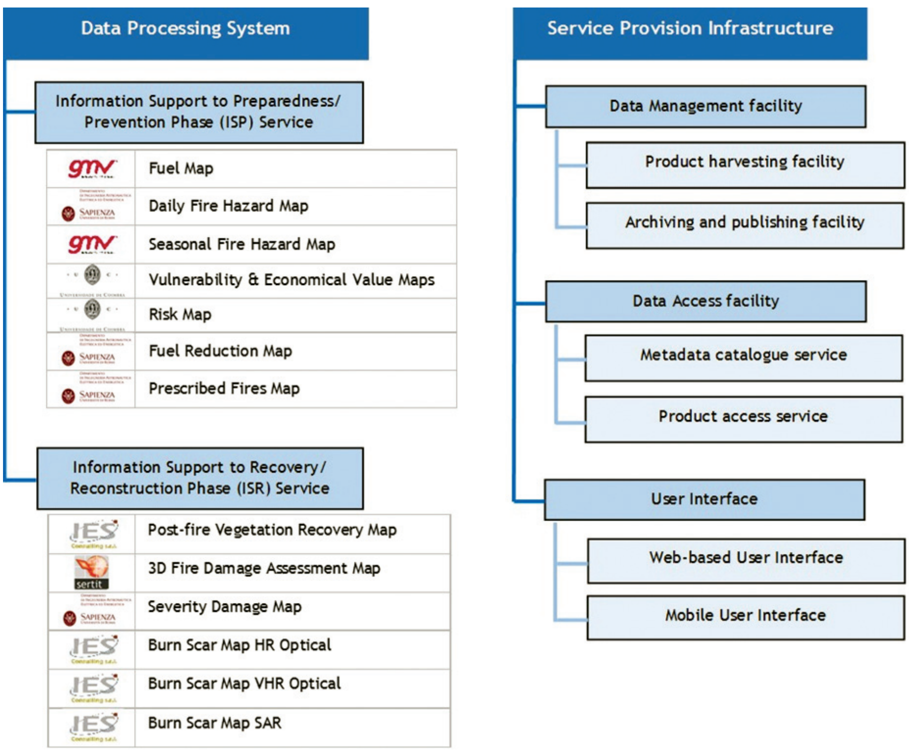


Fig. 2 - Organization of the PREFER Service Infrastructure.

2.1. Data Processing System

The data processing system is composed of different modules, one per each product provided by the consortium. Each module is distributed along the network and operated at partner premises, i.e., each product is originally developed by the responsible partner and, subsequently, transferred to a common server.

2.2. Service Provision Infrastructure

The service provision infrastructure is composed of three main elements: Data Management facility, Data Access facility and User Interface.

2.2.1 Data Management facility

This module handles the new products available in the input repository. The Product Harvesting Facility regularly checks the availability of new PREFER products (generated by the data processing system) in the input repositories, verifies the validity of the files and activates the archiving and publishing module.

2.2.2 Data Access Facility

This module carries out the PREFER product archiving and publication of OGC services. The metadata catalogue is in charge of metadata generation and publications, implementing a metadata catalogue compliant to the CS-W standard. In addition, it provides discovery capabilities to the User Interface. The Product Access Services SW module contains all the services that provide PREFER products to the users, in particular download functionality, by getting products from the Archive, and product browsing through OGC services (WMS, WFS and WCS). It also includes functionalities that enable the download of native/scientific product format.

2.2.3 User interface

This module is responsible of the interaction of PREFER service infrastructure with the Users, providing access to archived and published products and to the metadata catalogue.

Two types of user interfaces are implemented:

a) Web based user interface;

b) Mobile user interface.

The Web user interface is mainly composed by a Web Application, using standard technologies such as HTML/CSS/AJAX. The Web Application runs on the Application Web Server environment that implements standard HTTP/HTTPS protocols and is visible on the Internet.

The mobile user interface is available as an application (“App”) on the main mobile device software platforms: it uses specific functionalities available on mobile device (i.e. widgets), but communicates with the system (Application Web Server) using the same standard protocols (HTTP/HTTPS).

Both User Interfaces require user authentication; for this scope, a User Database is foreseen. The Interfaces provide to the users the abilities to search products in the Metadata Catalogue, through a Catalogue Connector, that creates standard CS-W queries on the base of user selections. The products are displayed on an interactive map that allows zooming, panning and layers overlay.

The products layers are retrieved by the virtual map using WMS protocol, from the service implemented in Product Access Service module.

How to access the Service Infrastructure and Products

a) Web based user interface

1. Access the web interface through the link:

   http://prefer.cgspace.it

2. Login by means of User Name and Password:

   Username: **prefer**

   Password: **prefer_demo**

Fig. 3 - Web based user interface.

3. After user login, the PREFER Web user Interface shows the virtual map, centered on the European area.

4. Click on Products Catalogue and browse by selecting specific filters:

   - Product type, grouped by the data processing subsystem;

   - Date range (from – to);

   - Area of interest (Italy, Spain, France, Greece, Portugal).

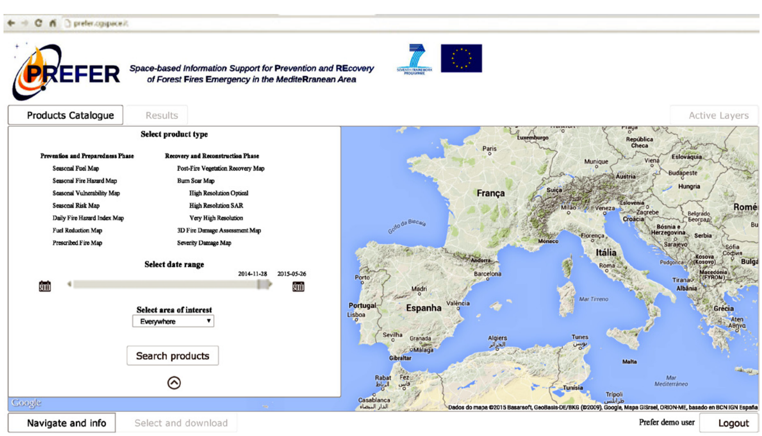


Fig. 4 - Main view of the PREFER Web and Products Catalogue.

5. Click on “Search products” to start browsing the catalogue.

6. When the search operation ends, the list of products matching filters criteria is shown.

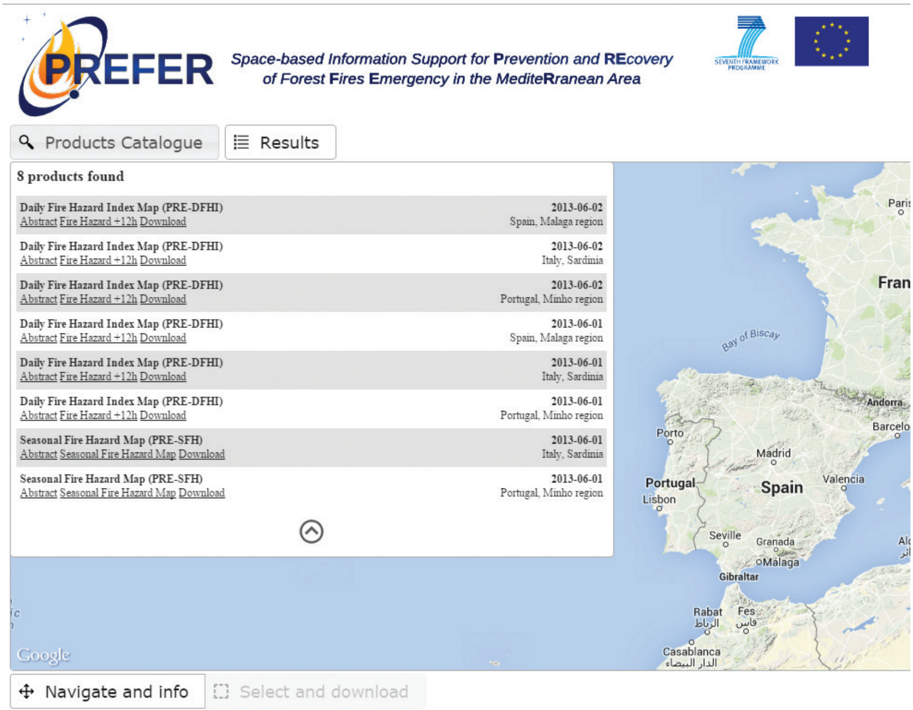


Fig. 5 – Products Catalogue (different search criteria and the results of the filters).

7. Explore the functionalities of the web service; for each product the user can do several actions:

   - Display abstract of the product (popup dialog is shown);
   - Download the product (native format): the download will start immediately;
   - Add the layers associated to each product to the virtual map;
   - Visualize metadata related to the product (popup dialog is shown);
   - Active layers: displays the list of layers currently available on the virtual map;
   - Navigate and info: allows the browsing of the virtual map and the ability to query layers by selecting a feature on the map;
   - Select and download: allows the user to select a part (region) of layer on the map and download it through standard protocols and format.

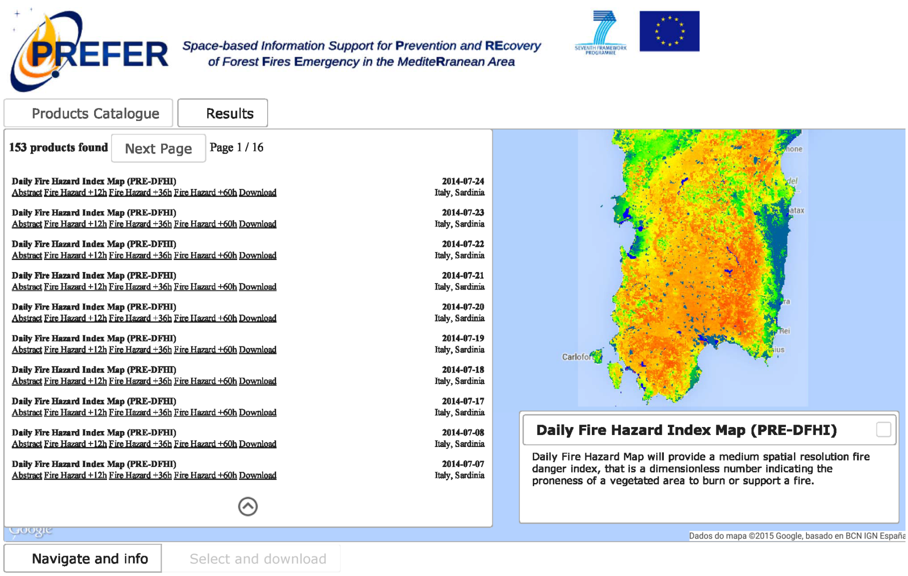


Fig. 6 – Results of the search with filters and display of the products abstract.

8. Logout: disconnects the user from the web interface.

b) Mobile user interface

The Mobile User Interface is accessible via the PREFER Mobile which is an Android based mobile application (Android 4 or above). When launched, the PREFER Mobile user interface shows a map view, centered in Europe.

1. Download the app to access the mobile interface through the link: www.satways.net/prefer/prefer-mobile.apk

2. Users are able to move and zoom in/out the map with the following gestures on their touchscreen device:
   - To move the map, drag the map with your finger.
   - To zoom in, double-tap a location with one finger or touch an area with two fingers at once and spread them apart. Or press the zoom in button that appears on the map.
   - To zoom out, touch once with two fingers or touch an area with two fingers and pinch them together. Or press the zoom out button that appears on the map.

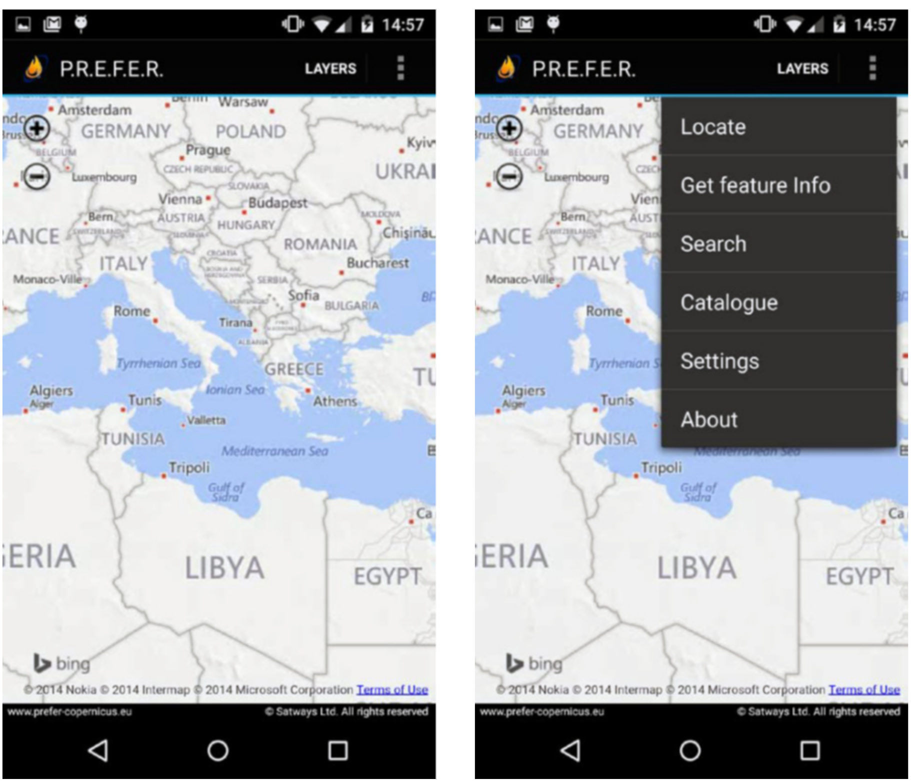


Fig. 7 - Initial view of the mobile application and options menu.

3. From the top right button menu the application provides the following functionalities:

- Locate
- Layers (always appears on the bar)
- Catalogue
- Search
- Get feature Info
- E/O Products
- About
- Settings

a) Locate Menu Option

The Menu option “Locate” centers and controls the zoom level of the map according to the user’s mobile device location. This function is enabled only if the Location option has been configured in the Android settings. Upon menu selection an icon appears on the top right of the map. If the user clicks this button the map will be centered and zoomed to the mobile’s location.

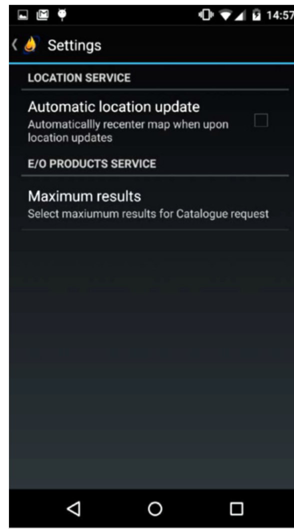


Fig. 8 - Settings menu options.

b) Settings Menu Option

Via the Settings menu options a user can configure to automatically update the map when the user’s location is changed. In this way the map is refreshed automatically. With the second option “Maximum the user can limit the number of results of the Catalogue requests.

c) Layers Menu Option

The Layer menu option displays the Layer Selection view. This view enlists map layers and their visibility with a checkbox. The layers are separated into:

- Base Layers
- Loaded layers

The Base layers are predefined imagery layers that appear below any loaded layer. The user is able to choose only one the layers from the list. These are:

- Bing Road
- OpenStreetMap
- Bing Aerial
- Bing Aerial + Labels - by selecting the option “Bing Aerial + Labels” the map displays aerial imagery with labels from BingMaps.

Fig. 9 - Display of base layers with Bing Aerial + Labels options.

The "Loaded layers" section lists the PREFER layers that have been selected from the Catalogue search results (see Catalogue Menu Option).

For each layer (base and loaded) there are options to control their transparency by clicking the name of the layer while for the loaded layers there is the option to show/hide its legend

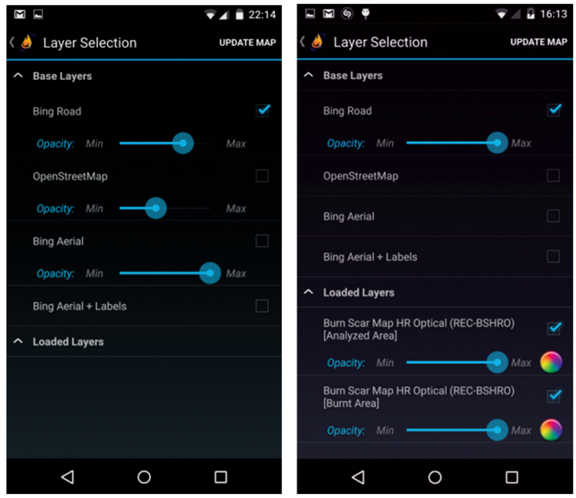


Fig. 10 - Transparency and legend layer controls.

d) Catalogue Menu Option

This option enables the connection to the PREFER service infrastructure and the query and fetch of PREFER products. From the user interface the user is able to choose the area, product types and time period. Available areas appear on the combo box from the following predefined list (where PREFER products are currently available):

- Minho
- Malaga or Huelva
- Corsica
- Sardinia
- Peloponnese

Upon selection of the Choose Product combo box, the list of available products appears. The user can choose a product type by clicking the respective option. Next, the user can choose the time period using the start and end date buttons and press the Go button.

The Catalogue request results are then depicted according to the request parameters imposed by the user selections.

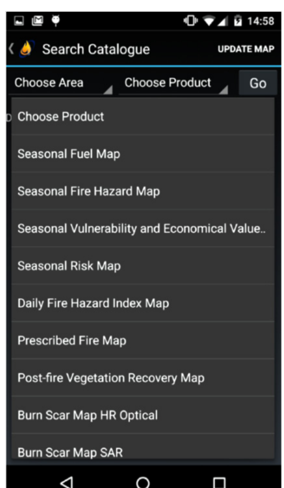


Fig. 11 - Product types selection.

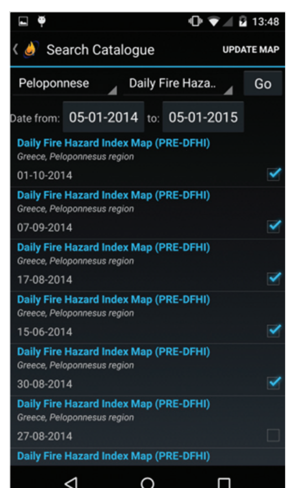


Fig.12 - Catalogue results.

By clicking the checkbox next to each product, a set of layers is loaded into the map.

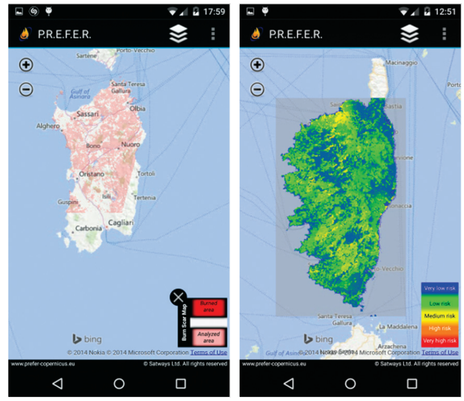


Fig.13 - Product layers and legends depicted on the map.

e) Search Menu Option

This option provides places and points of interest (POI) search functionality. In the respective text field one can enter a place or point of interest and press the search button. The results of this operation are depicted in a list below. The results can be more than one at any time. By pressing the Go button the map is centered and zoomed to the place/POI location.

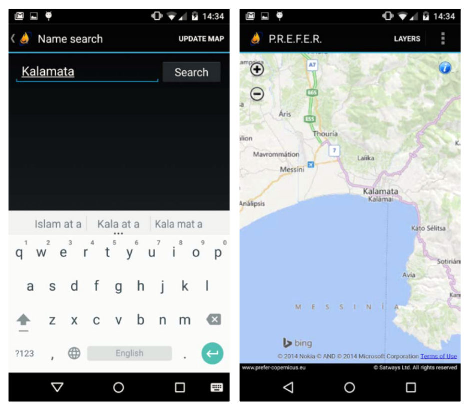


Fig. 14 - Search menu options and selection of a point of interest.

f) Get Feature Info Menu Option

Finally the Get Feature Info menu option provides the ability to query the values of a WMS imagery layer. When this option is selected an information button appears in the top right area of the map. In order to query a layer the user must click this button and then to click in a location of map where a PREFER product layer is visible. The server response provides the result of the query.

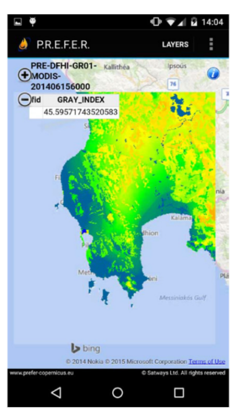
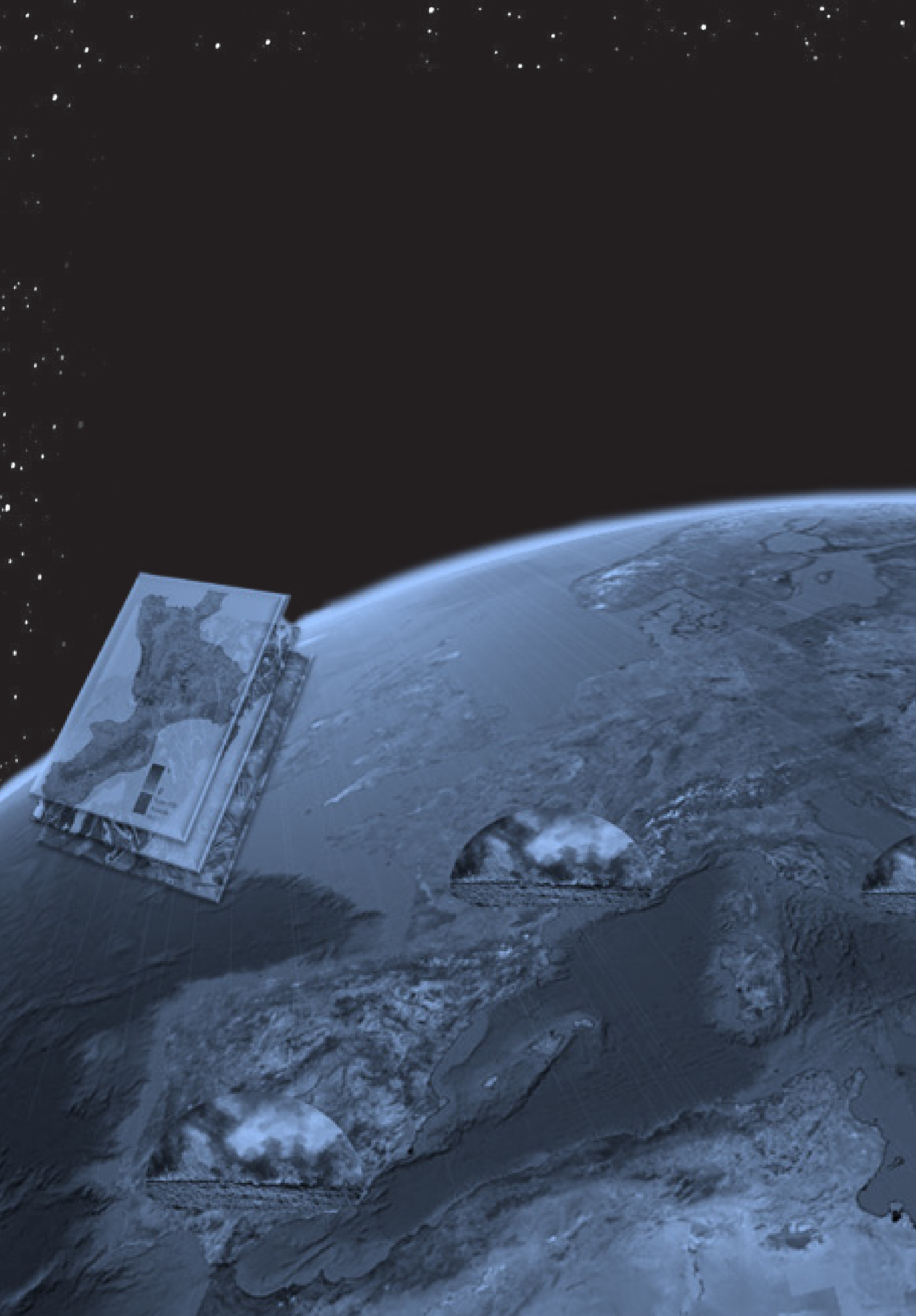
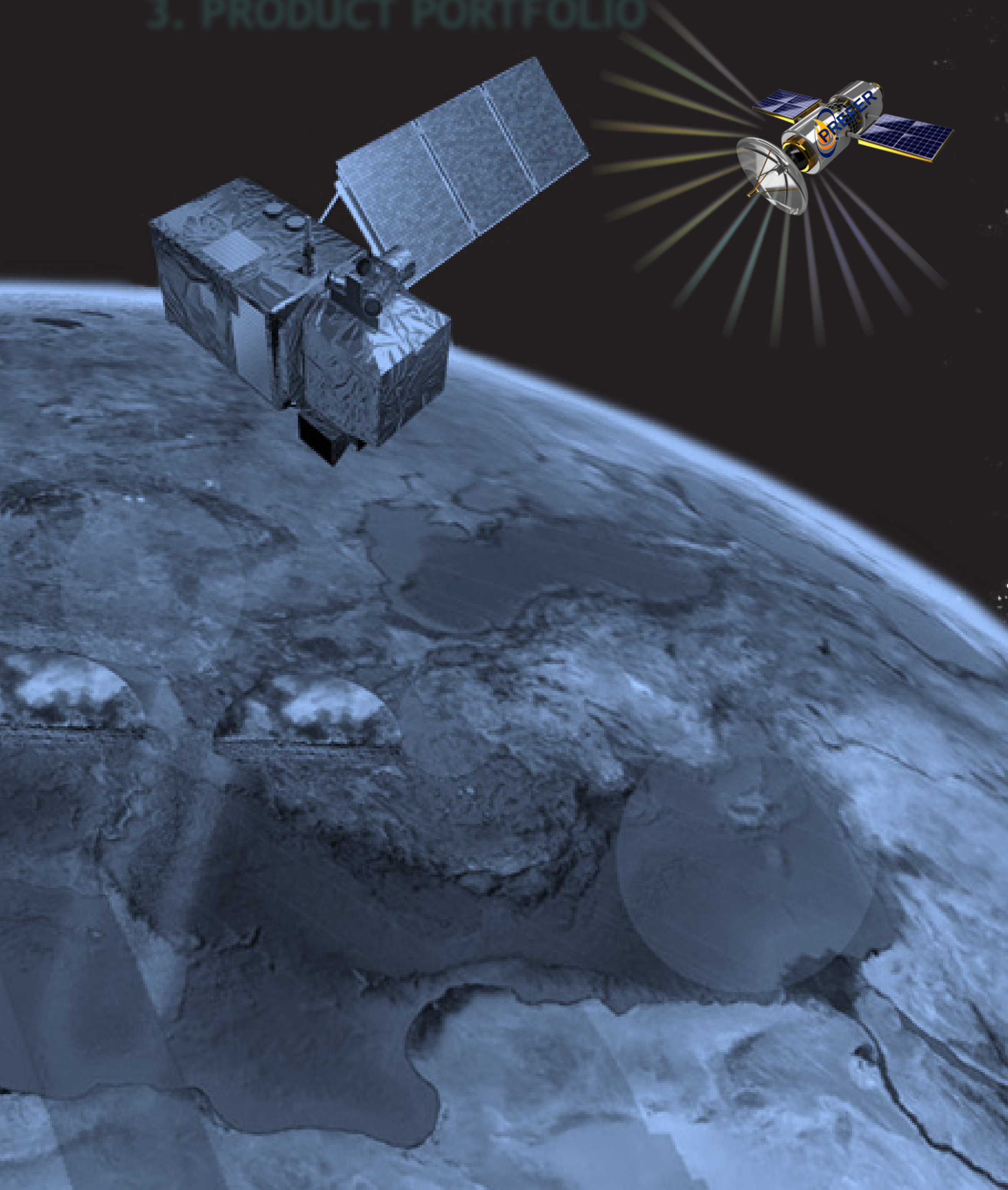
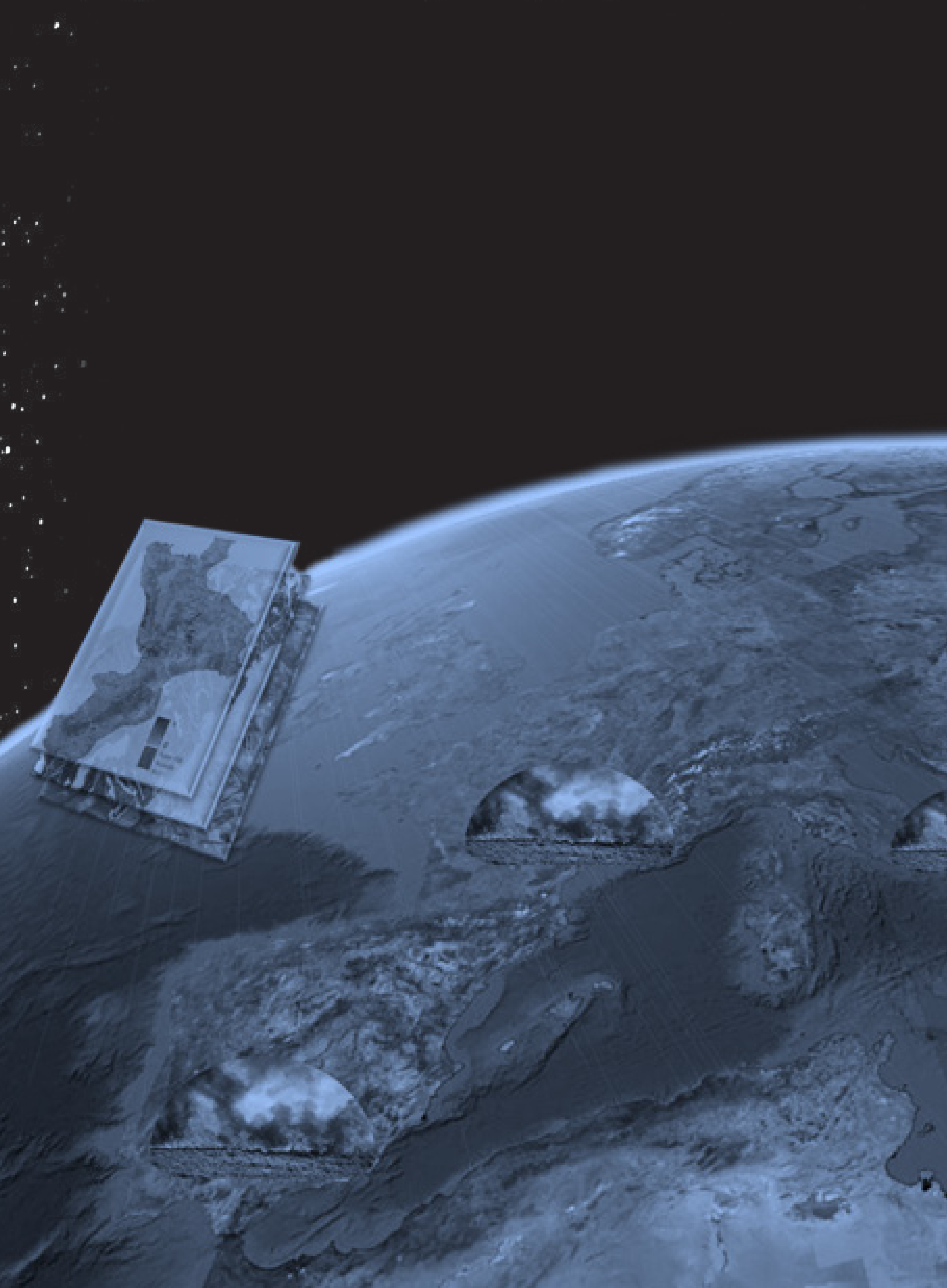


Fig. 15 - Get feature info result.

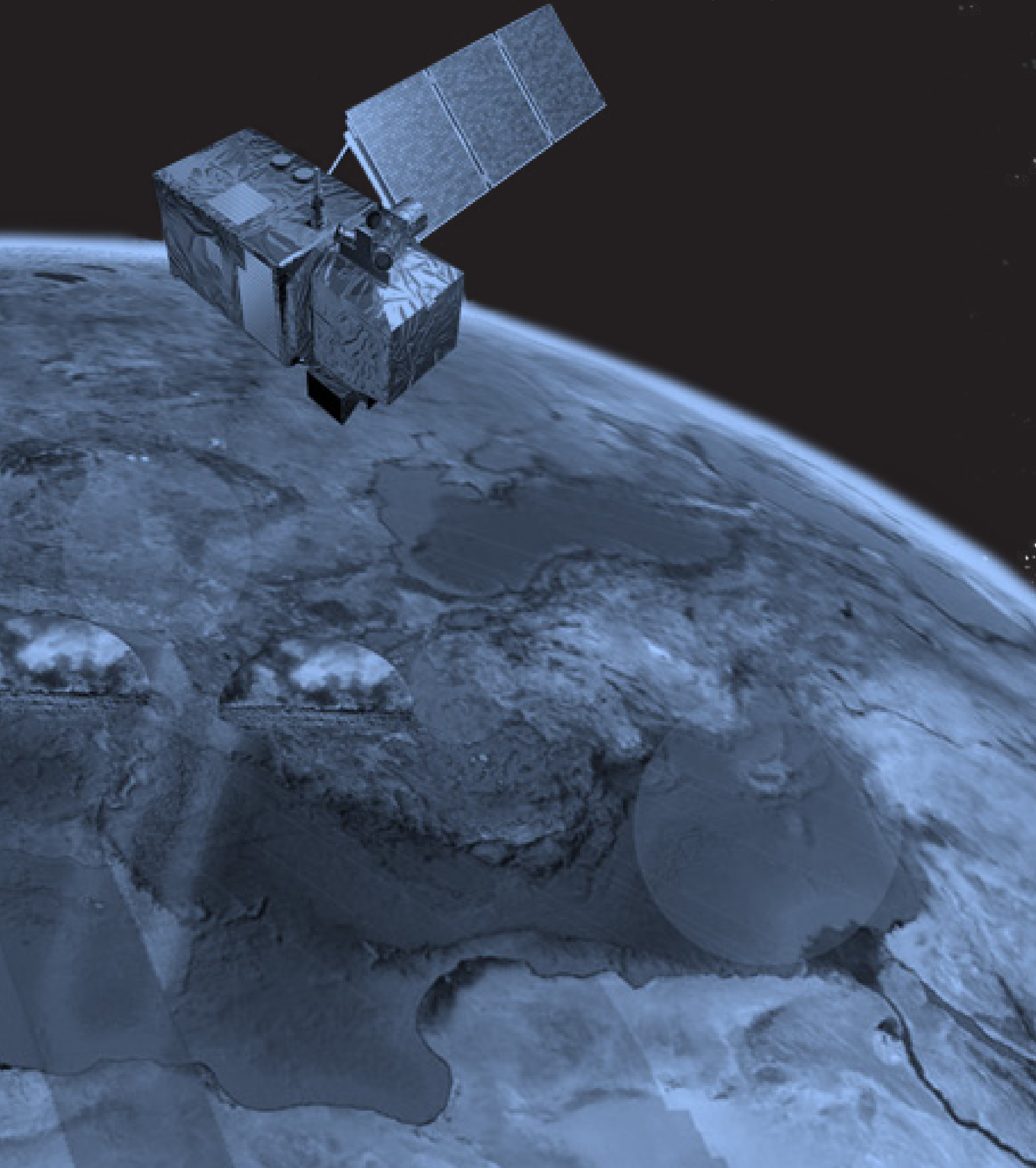


3. PRODUCT PORTFOLIO





3.1. Information Support to Preparedness/ Prevention Phase Service (ISP)



Fuel Map

Fuel Map (PRE-SF)

Definition

Classification map of forest fuel complexes, according to the assessed capacity to support fire occurrence and contribute to fire potential.

Background

Forest fuels can be defined as an identifiable association of fuel elements of distinctive species, form, size arrangement and continuity that will exhibit particular fire behaviour, under defined burning (meteorological) conditions.

The fuel types mapping method implemented in PREFER combines GIS-based methods with remote sensing–based methods, aiming at capturing with remote sensing those aspects of vegetation not usually mapped, as well as those dynamic aspects, not usually updated. It evolves from the results of previous projects, namely FUELMAP and ArcFUEL, providing two main innovations:

- "Seasonality"

  Fuel types maps will be derived yearly, in order to account for modifications in the vegetation classes.

- "Re-scalation"

  The procedure to jump from the high resolution scale fuel map to a medium resolution fuel map using VIIRS data will be defined in the Spanish test site. VIIRS is conceived as the NASA's Terra/Aqua MODIS continuity instrument. This product is cardinal to Andalusian users who are using MODIS to produce their own fuel maps.

In addition, it assigns physical parameters to the derived fuel-oriented vegetation, required for fire risk and behaviour modelling, prescribed fires and vulnerability modelling.

Output

The forest fuel type product depicts forest fuel complexes in the AOI's and classifies them according to the assessed capacity of these complexes to support fire occurrence and contribute to fire potential. The fuel types are presented in categories, according to specific characteristics such as vegetation density and arrangement, as listed in TABLE V (next page).

Association with other products

Daily Fire Hazard Map, Seasonal Fire Hazard Map, Vulnerability Map, Fire Risk Map, Fuel Reduction Map, Prescribed Fire Map

Table V - Fuel categories.

Vegetation complex	Type	Density/Arrangement
Forest	Broadleaved deciduous	dense
	Broadleaved deciduous	open
	Broadleaved deciduous	scrub
	Broadleaved evergreen	dense
	Broadleaved evergreen	open
	Broadleaved evergreen	scrub
	Coniferous evergreen	dense
	Coniferous evergreen	open
	Coniferous evergreen	scrub
	Mixed deciduous	dense
	Mixed deciduous	open
	Mixed deciduous	scrub
	Mixed evergreen	dense
	Mixed evergreen	open
	Mixed evergreen	scrub
Shrubs	Small to medium-sized woody plants. They have shorter height than trees	
Grasses	Herbaceous plants with narrow leaves growing from the base	
Agroforestry	It is a combination of trees or shrubs and crops or pastureland, for example, Mediterranean dehesas	
Non wildland fuels	Growing areas and other no wild vegetation	
Reeds	Perennial flood-tolerant grasses (*Phragmites spp.*). Different response to fire regarding the other grasses	
Azonic fuels	This category included any course or area associated with water such as salines, rivers or marshes	
Burnt areas	The burned areas during the fire season	
No fuels	Artificial areas related with human activities: transportation networks, industries and urban areas	

Technical Specifications

Field of Application	Prevention phase, regional scale
AOI	PT, ES, IT
Geographic projection / Reference system	GCS_ETRS_1989, Datum D_ETRS_1989
Spatial Resolution / Scale	1:25.000, 5 m resolution, MMU ≤ 0.5 ha 1:75.000, 15 m resolution, MMU ≤ 2 ha
Coverage / Area	Minimum area covered by a product: 500 km^2
Output data format	Raster: Geotiff (*.tif) Vector: Shapefile (*.dbf, *.prj, *.shp, *.shx, *.shi)
Refresh rate	Once a year (before the main fire season)
Naming convention	PRE-SF-<AOI>-<Instrument>-<Date>.<ext> Where: • PRE-SF: is the product id • <AOI> (Area of interest): is a code identifying the area of interest • <Instrument>: is a code specifying the EO data exploited for the product generation • <Date>: Product reference date, format YYYYMMDD (UTC) • <ext>: extension

Data

EO Data	¤ Two optical EO data (initial and final season) characterized by a pixel size from 5 m to 30 m (higher and lower resolutions allowed - Landsat5/8; RapidEye) ¤ Ideally one image acquired between March/April and another one between August/September
Other data	¤ JRC Forest Cover map (http://forest.jrc.ec.europa.eu/activities/forest-mapping/) ¤ Land Use Land Cover Maps: AOI ES ¤ The SIOSE map 2005 of the Junta de Andalucía - REDIAM ¤ The National Forest Map 2005 of the Ministry of Environment ¤ The National Forest Inventory (IFN3) 2006 of the Ministry of Environment AOI IT ¤ Land Use Land Cover Map of the Autonomous Region of Sardinia 2008 ¤ High Resolution SAR-derived DEM, Autonomous Region of Sardinia AOI PT ¤ The Portuguese LULC Map of Continental Portugal for 2007 (COS'2007)

Processing

1. Download source imagery;
2. Satellite imagery have been pre-processed for atmospheric correction (to remove the interference of the atmosphere) and for geometrical correction;
3. Crop the images on the area of interest;
4. GIS operations: extract the main fuel classes from the specific LULC for each AOI;
5. Process the images:
    a. AOI ES:
        - Supervised classification to obtain forest and no forest classes;
        - Supervised classification to obtain shrub and grass classes;

    b. AOI IT and AOI PT:
        - Computing the Normalized Difference Vegetation Index (NDVI) (t0 and t1) and the difference (NDVIt0 – NDVIt1), Unsupervised classification taking into account both NDVI and the difference between them to obtain deciduous and evergreen forest classes;
        - Supervised classification to obtain shrub and grass classes;
6. GIS operations: Combine the classes produced by the processing of the images (step 5) and the rest of the classes (step 4);
7. Classify the JRC Forest Cover map into three density levels;
8. Classify the forest classes using the density map (f);
9. Add ecoregion attributes;
10. Add fuel physical parameters:

    The assignment of the fuel physical parameters to the derived fuel-oriented vegetation classes is the last step of the methodology to build the fuel type map. These physical parameters were retrieved from the JRC pan-European fuel type map resulting from FUELMAP project (JRC-ITT/RFQ Reference 2008/S 116-153998) following a sound and common method for the entire European landscapes. Based on this correspondence, the following fuel parameters are assigned to PREFER's Seasonal Fuel Type: fuel load (t/ha) in diameter classes, surface are/volume ratio (m^2/m^3), fuel depth (cm), heat content (kJ/kg) and extinction moisture (%).

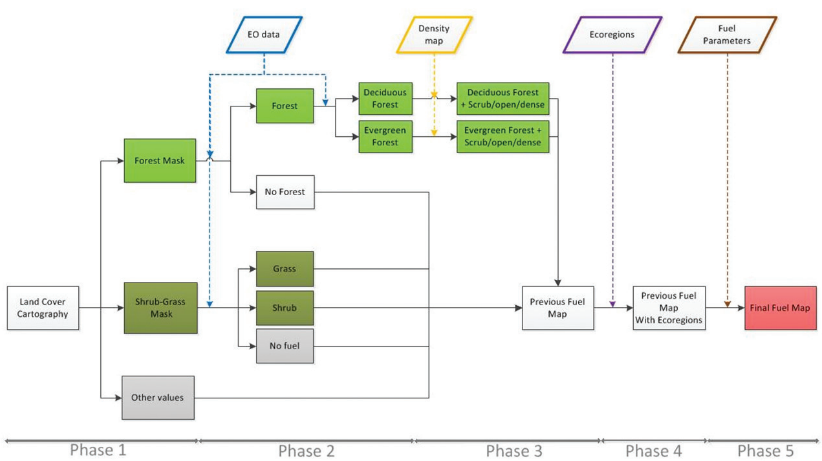


Fig. 16 – Workflow of the development of the Fuel Map.

Product examples

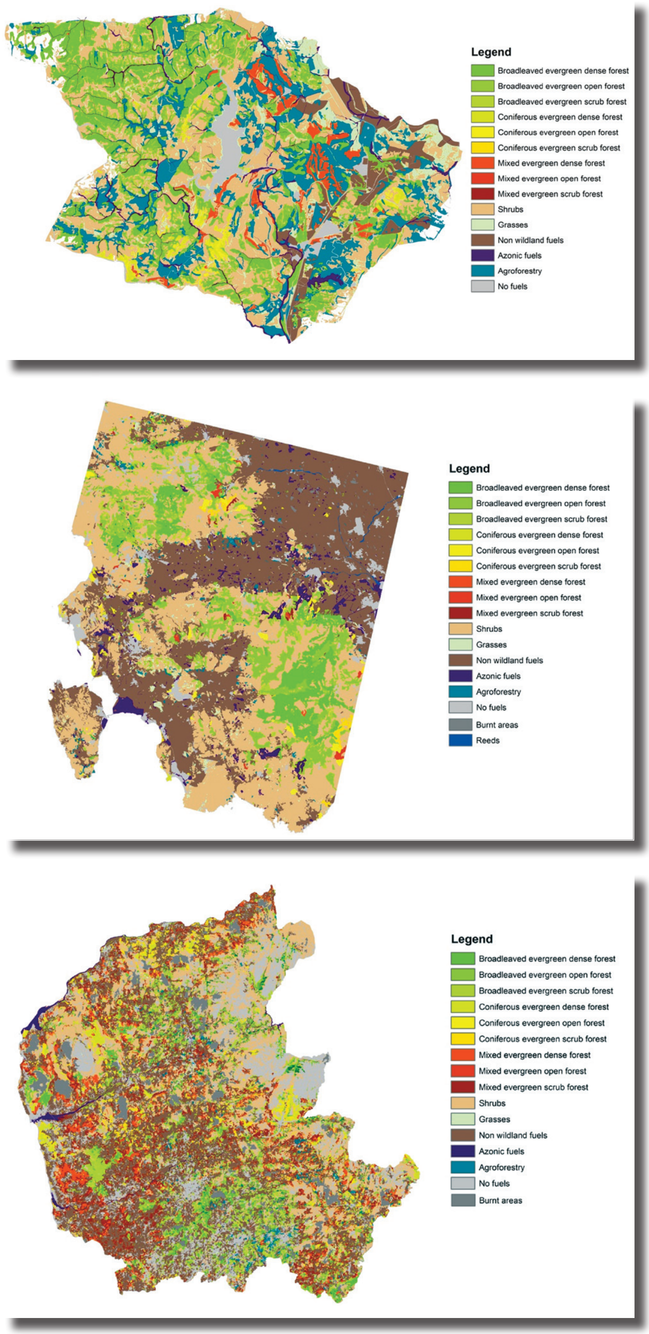


Fig. 17 - Fuel Map - Product examples for the AOI of Spain (top), Italy (middle) and Portugal (bottom).

Daily Fire Hazard Index Map

Daily Fire Hazard Index Map (PRE-DFHI)

Definition

The Daily Fire Hazard Map provides a medium spatial resolution fire danger index, through a dimensionless number indicating the proneness of a vegetated area to burn or support a fire.

Background

This product is based on the observation that there is a tight relationship between the fire and the characteristics of the fuel (vegetation type, density, humidity content), of the topography (slope, altitude, solar aspect angle) and the meteorological conditions (rainfall, wind direction and speed, air humidity, surface and air temperature). These parameters directly impact the proneness of a given area to the fire ignition and propagation.

In the Mediterranean area, more than 90% of the ignitions are due to human actions, either intentional or accidental, and as such unpredictable. Notwithstanding, since the values of fuel, topography and meteorological conditions can be measured, the behaviour of the fire, in case an ignition occurs, can be foreseen when such parameters are known.

Output

The map represents an index containing values from low hazard (0) to very high hazard (100).

Every day three maps are produced for the area of interest providing the fire hazard for the present day and the two following days.

Association with other products

Fuel Map, Seasonal Fire Hazard Map, Fire Risk Map

Technical Specifications

Field of Application	Prevention phase, regional/national scale
AOI	PT, ES, IT
Geographic projection/ Reference system	Lat, Long WGS84
Spatial Resolution/Scale	250 m
Coverage / Area	N/A
Output data format	Raster: Geotiff (*.tif)
Refresh rate	Daily during the summer season (June – October)
Naming convention	PRE-DFHI-<AOI>-<Instrument>-<Date&Time>.<ext> Where: • PRE-DFHI: is the product id • <AOI> (Area of interest): is a code identifying the area of interest • <Instrument>: is a code specifying the EO data exploited for the product generation • <Date&Time>: Product reference date, format YYYYMMDDhhmm (UTC) • <ext>: extension

Data

EO Data	• MODIS images of the present or previous day; Optical EO data MR2 and LR multispectral images • MR2: MODIS on board of Terra and Aqua satellite (RED and VNIR channels at 250 m and BLU and SWIR channels at 500 m); • LR: MODIS on board of Terra and Aqua satellite (BLU and SWIR channels at 500 m)
Other data	¤ Meteorological data (at this time, provided by the Dept. of Meteorology of the Italian Air Force) - meteo data forecast produced at 06:00 of the present day for the following 72 hours; ¤ Digital Elevation Models of AOI's; ¤ The most updated Land Cover map; ¤ The most updated fuel map, provided by GMV. ¤ From these data, several maps are computed: • Maps of NDVImin and NDVImax (minimum and maximum absolute values of NDVI computed on the last 5 years of MODIS images for each pixel of the AOI) • Maps of EWTmin and EWTmax (minimum and maximum absolute values of EWT computed on the last 5 years of MODIS images for each pixel of the AOI)

Processing

Satellite images data pre-processing:

1. Download the MODIS image of the day;
2. Crop the MODIS images on the area of interest;
3. Cloud mask;
4. Compute the NDVI;
5. Compute the EWT.

Meteo Data Pre-Processing

1. Download the meteo data of the day;
2. Crop the meteo data on the area of interest;
3. Extract air temperature and humidity corresponding to 12:00, 36:00 and 60 forecast hours, that means, time 12:00 of present day, time 12:00 of the following day and time 12:00 of the second following day;
4. Geo-reference meteo data in geographic coordinates.

Data Processing

1. Computing the Relative Greenness (exploiting NDVI extracted by MODIS imagery);
2. Computing the reference evapotranspiration (ET0, by using meteo data and DTM);
3. Computing fine fuel equivalent moisture content (emc, by using meteo data);
4. Computing the DFHI.

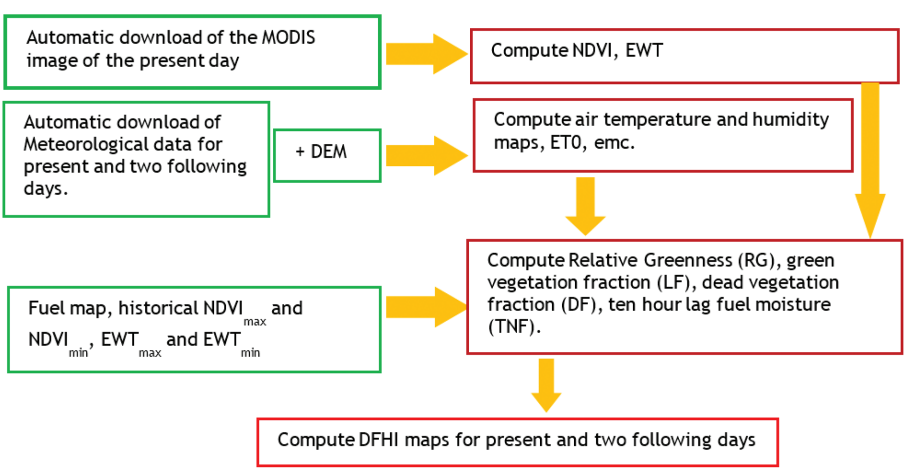


Fig. 18 - Workflow of the development of the Daily Fire Hazard Index map.

Product examples

Example of daily hazard index map computed for the Sardinia region. The maps produced on the 7th August 2014 depict the situation for that day and provides the prediction of the fire hazard for the next two days (8th and 9th of August 2014).

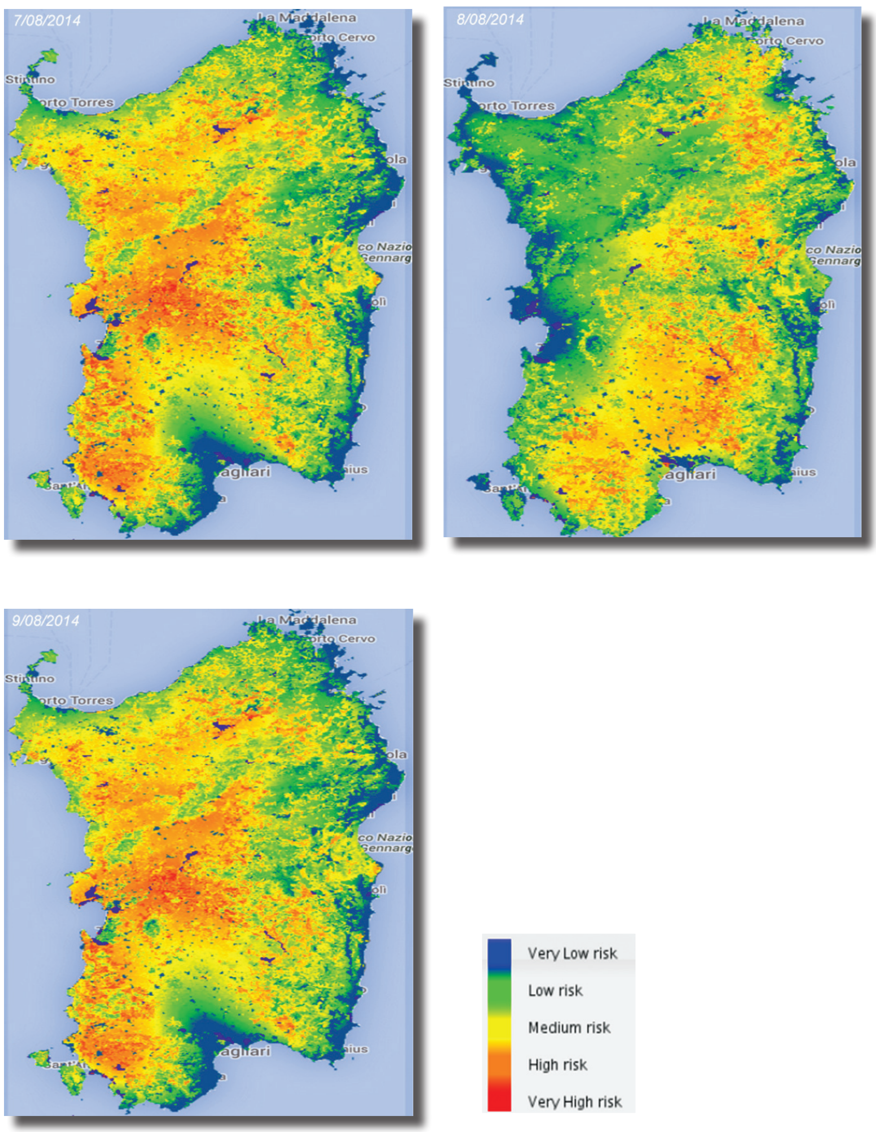


Fig. 19 - Daily fire hazard index map - Product example for the AOI of Italy.

Seasonal Fire Hazard Map

Seasonal Fire Hazard Map (PRE-SFH)

Definition

The Seasonal Fire Hazard Map provides a high resolution hazard index with a temporal resolution from 2 up to 4 weeks (updated during the fire season).

Background

The seasonal fire hazard index has the objective to combine the human and meteorological factors developing a new index able to describe as best as possible the factors that may determine the onset and the spread of a fire. It has been developed to show the fire hazard on a long time scale (bi-weekly or monthly), being based on several factors. On one hand, the natural factors, distinguishable in static (fuel map, slope, aspect, climatic zone) and dynamic (NDVI, meteo data, updated fuel map with burned areas, DFHI); on the other hand, human factors, distinguishable in static (urban areas, roads, fire statistics, cultural factor) and dynamic (current season fire statistics).

The natural factors take into account the morphological characteristics (slope, aspect) and the vegetation stress (DFHI averaged on 14 days, DFHIav)).

The human factors consider the accessibility factor, the cultural factor and the seasonal factor. The accessibility factor evaluates the number of people that could access the zone, more people can access more is the probability to have an accidental fire. The cultural factor is based on the fire occurrences for the last 5 - 10 years, it models the security of a place. Seasonal factor is based on the current season fires trend with respect to the 5 previous years, which is evaluated by satellite systems, such as FIRMS or real time ground data provided by fire fighters and on the current meteorological conditions accounted through the DFHI averaged on 2 weeks.

Output

The seasonal fire hazard map results from the computation of a series of HTC (Homogeneous Territorial Classes), which were defined based on topographic (elevation, slope and aspect) and environmental (fuel and climate) characteristics on which the fire occurrences of the last 5 - 10 years are superimposed. Therefore, it provides a map of the fire ignition probability. The map is represented in level of hazard ranging from 0 (null/lower hazard) up to 5 (higher hazard).

Association with other products

Fuel Map, Daily Fire Hazard Map, Fire Risk Map

Technical Specifications

Field of Application	Prevention phase, regional scale
AOI	PT, ES, IT
Geographic projection/ Reference system	GCS_ETRS_1989, Datum D_ETRS_1989
Spatial Resolution / Scale	250 m
Coverage / Area	N/A
Output data format	Raster: Geotiff (*.tif)
Refresh rate	Temporal resolution from 2 up to 4 weeks (updated during the main fire season (June-October)
Naming convention	PRE-SFH-<AOI>-<Instrument>-<Date>.<ext> Where: • PRE-SFH: is the product id • <AOI> (Area of interest): is a code identifying the area of interest • <Instrument>: is a code specifying the EO data exploited for the product generation • <Date>: Product reference date, format YYYYMMDD (UTC) • <ext>: extension

Data

EO Data	N/A
Other data	¤ Daily Fire Hazard Index (DFHI) (DIAEE) ¤ Fuel Map (GMV) ¤ Elevation AOI IT and AOI PT: ASTER – DEM (1°x1° ASTER GDEM files) AOI ES: MDT05 PNOA ¤ Burned areas: • AOI IT: Burned areas sourced by DIAEE • AOI PT: Burned areas from Institute for Nature Conservation and Forests (ICNF), Available at http://www.icnf.pt/portal/florestas/dfci/inc/info-geo • AOI ES: Occurrences of fires sourced by Junta de Andalucía ¤ Climatic zones: • AOI IT: climatic map sourced by DIAEE • AOI PT: climatic map by Rivas-Martínez (2007), Available at http://home.isa.utl.pt/~tmh/aboutme/Informacao_bioclimatologica.html • AOI ES: not applicable, as the Spanish AOI falls into a single climatic zone

Processing

1. Input acquisition (Downloading or by users);
2. Crop the DEM files, the burned areas and the climatic zones on the area of interest; for Spain, conversion of occurrences of fires (in tables with coordinates) into points;
3. Compute aspect and slope from the DEM file; reclassify elevation, aspect and slope into some specific classes;
4. Generate Homogeneous Territorial Classes (HTC) combining the Seasonal Fuel classes, the elevation classes, the slope classes, the aspect classes and the climatic zones;
5. Generate the Fire Ignition Probability (FIP) combining the HTCs and burnt areas and/or ignition points at the starting of the fire season;
6. The FIP classes are reclassified in a scale from 0 (null) to 5 (high) according to the probability that a fire occurs in a given HTC;
7. Update the FIP every two weeks during the fire season using the new fires occur in those weeks.

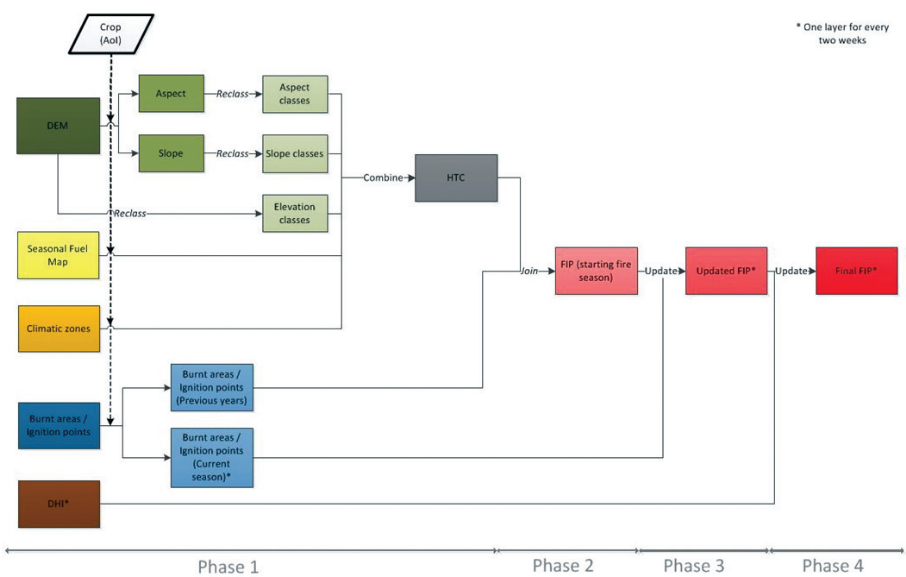
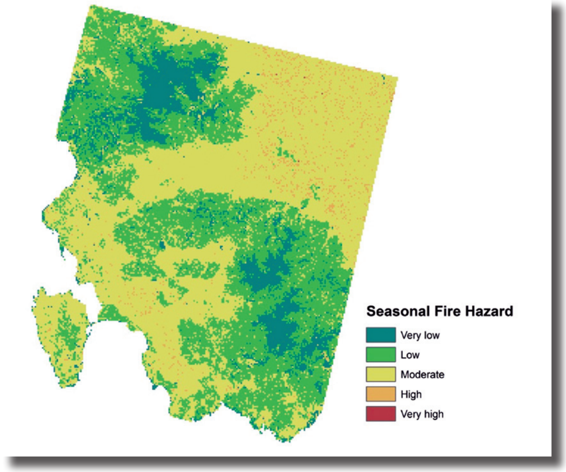
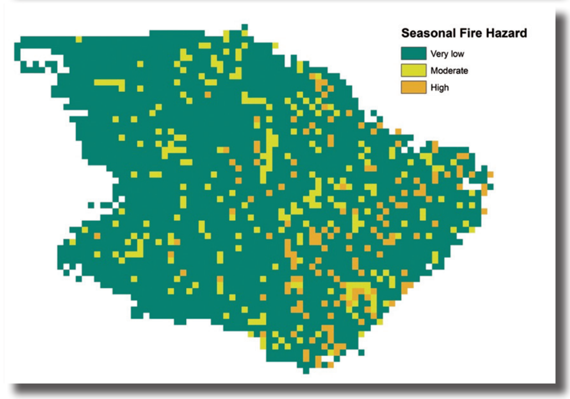


Fig. 20 - Workflow of the development of the Seasonal Fire Hazard Map.

Product examples





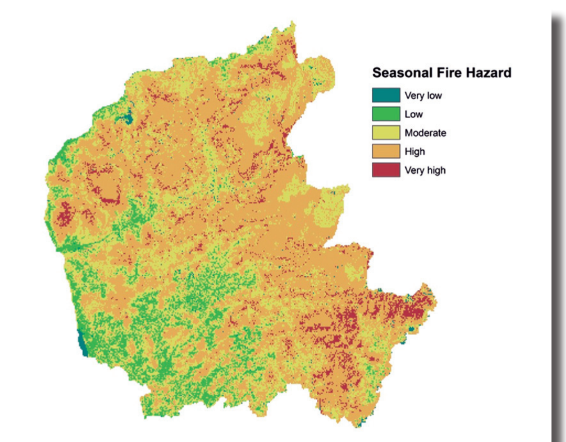


Fig. 21 – Seasonal fire hazard index map - Product examples for the AOI of Italy (top), Spain (middle) and Portugal (bottom).

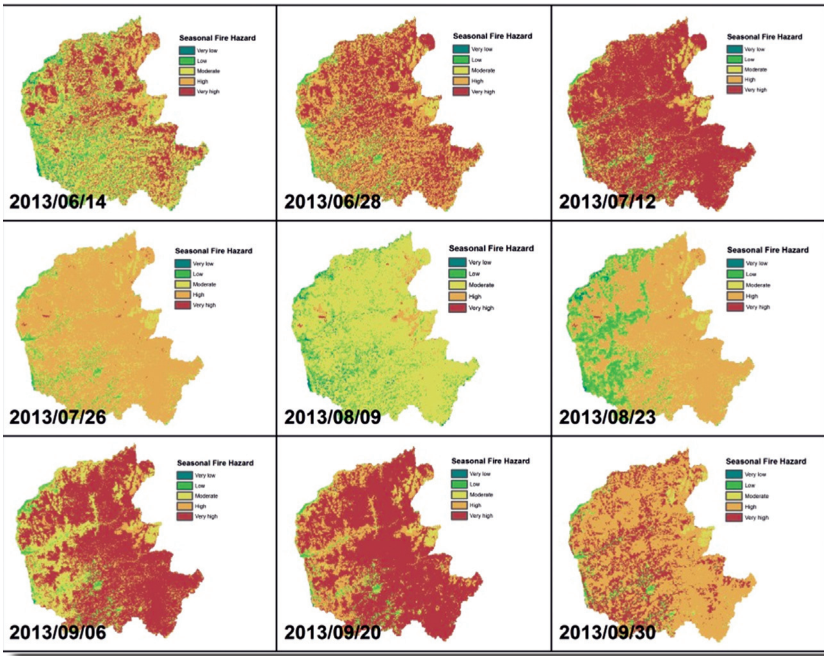


Fig. 22 - Seasonal fire hazard index map. Time series. AOI of Portugal.

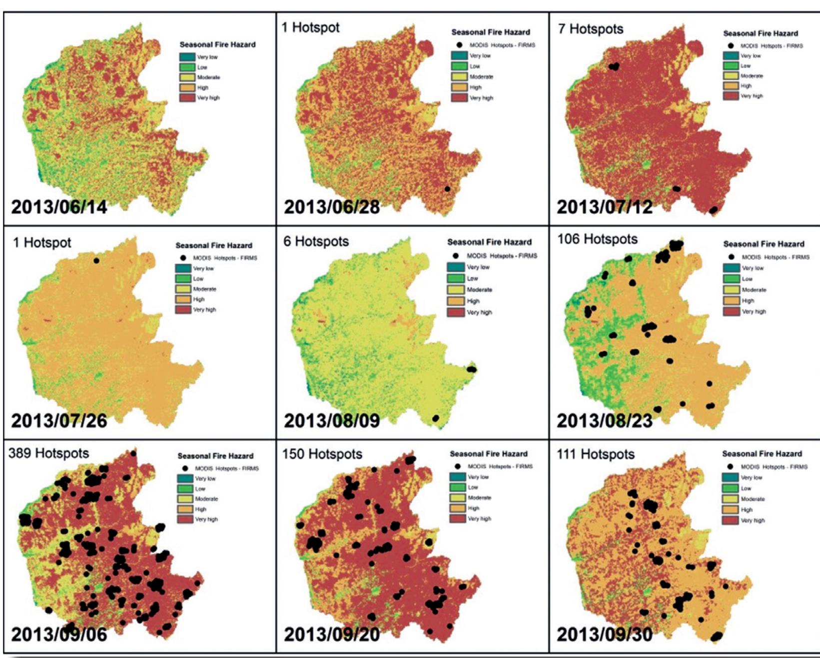


Fig. 23 - Seasonal fire hazard index map. Time series - MODIS Hotspots. AOI of Portugal.

Vulnerability Map and Economic Value Map

Vulnerability Map (PRE-SE) and Economic Value Map

Definition

The vulnerability map provides a relative measure of the potential for loss in case a fire occurs, taking into account the level of exposure and sensitivity to fire of the elements present in an area, as well as the coping capacity of the community.

The economic value map provides a measure of the economic losses potentially occurring in case of fire, based on the monetary value of the elements exposed.

Background

In a general sense, vulnerability means the potential for loss, which can affect different types of elements, either biophysical or anthropogenic (Birkmann *et al.*, 2013; Cutter *et al.*, 2008; Cutter, 2011). This potential for loss or damages results from the combination of physical, social, economic and environmental conditions that increase the susceptibility of a community or element to the impact of hazards (UNISDR, 2009).

The vulnerability approach applied in PREFER is comprehensive, combining variables that reflect multiple dimensions. It results from the combination of three different components: exposure, sensitivity and coping capacity. Exposure represents the presence of people, property, systems, or other elements in hazard zones that are, for that reason, subject to potential losses. Sensitivity represents the conditions that influence the predisposition of the exposed elements to suffer a certain level and extension of damages; it is related to their susceptibility level and degree of protection. Coping capacity is related to the circumstances that reduce or amplify the ability of the elements to respond and recover from the impacts of a hazard (resilience), including prevention and firefighting measures.

The economic dimension of vulnerability is represented separately, in the economic value map, which reflects the monetary value of specific exposed elements; hitherto, reliable economic data could only be obtained for the restoration costs of land cover and the price of housing. Human lives, for what they represent, are not translated into a monetary value; the ecological value of vegetation and ecosystems could not be assessed, due to lack of data.

Output

This product provides two separate maps: vulnerability and economic value. The vulnerability map identifies the areas with higher likelihood to suffer losses in case a forest fire occurs. The intermediate indices that compose vulnerability (exposure, sensitivity and coping capacity) are computed separately. These indices are calculated from the analysis of a set of variables and normalized to a common scale (0 to 1), with 1 representing the maximum level of the component found in the area of interest. These indices are, subsequently, combined and the vulnerability classes are calculated, with 1 representing the lowest vulnerability class and 5 the maximum level of vulnerability in the area assessed.

The economic value map represents, in a monetary unit, an estimation of the potential costs of these damages, in relation to the importance of the exposed elements, the costs associated with their protection or the application of coping measures.

Association with other products

Fuel Map, Seasonal Fire Hazard Map, Fire Risk Map

Technical Specifications

Field of Application	Prevention phase, regional/national scale
AOI	PT, ES, IT
Geographic projection/ Reference system	GCS_ETRS_1989, Datum D_ETRS_1989
Spatial Resolution / Scale	100 m 1:25.000
Coverage / Area	N/A
Output data format	Raster: Geotiff (*.tif) Vector: Shapefile (*.dbf, *.prj, *.shp, *.shx, *.shi)
Refresh rate	Once a year: before the start of the main fire season (May)
Naming convention	PRE-SE-<AOI>-<Variable>-<Instrument>-<Date>.<ext> Where: • PRE-SE: is the product id • <AOI> (Area of interest): is a code identifying the area of interest • <Variable>: is a code of a list specifying the variables integrated for the product generation, according to data availability for the AOI • <Instrument>: is a code specifying the EO data exploited for the product Generation. <NOSAT> means no direct satellite images were used • <Date>: Product reference date, format YYYYMMDD (UTC) • <ext>: extension

Data

EO Data	N/A
Other data	Vulnerability Map ¤ Population density (latest Census); ¤ Fuel map (GMV); ¤ Buildings location (cartographic sources); ¤ Roads network (cartographic sources); ¤ Protected areas map (protectedplanet.net; EEA (natura2000); national/regional cartographic sources); ¤ Firefighting statistics (national/regional entities); ¤ Prevention measures data (national/regional entities). Land cover map ¤ Land cover map (Corine Land Cover, EEA) ¤ Statistical data on costs of land cover recovery (JRC) ¤ Housing/buildings map (national/regional cartographic sources) ¤ Statistical data on price of housing (national/regional statistics)

Processing

Pre-Processing of variables

1. Transform statistical or cartographical data to a numerical scale, by calculation densities (population, roads, buildings), proportions (fuel, protected areas) or ratios (firefighting, fuel reduction measures);

2. Transpose statistical or cartographical data to 1 ha scale, by intersecting the base grid (1 ha) with each layer and calculating the weighted mean of the values, when required;

3. Normalize all the variables into a common scale (0-1).

Data Processing

This function, based on a procedure developed in a GIS environment, is in charge of:

1. Computing the exposure index, by integrating the selected variables and applying the processing algorithm (variable weighting and addition);
2. Computing the sensitivity index, by integrating the selected variables and applying the processing algorithm (variable weighting and addition);
3. Computing the coping capacity index, by integrating the selected variables and applying the processing algorithm (variable weighting and addition);
4. Computing the vulnerability index, by combining the three intermediate indexes according to the weighting defined;
5. Classifying the values of the vulnerability index in 5 pre-defined classes;
6. Computing the economic value index, by integrating the selected variables and applying the processing algorithm (addition of monetary values);
7. Creating the corresponding maps at 1 ha, as required.

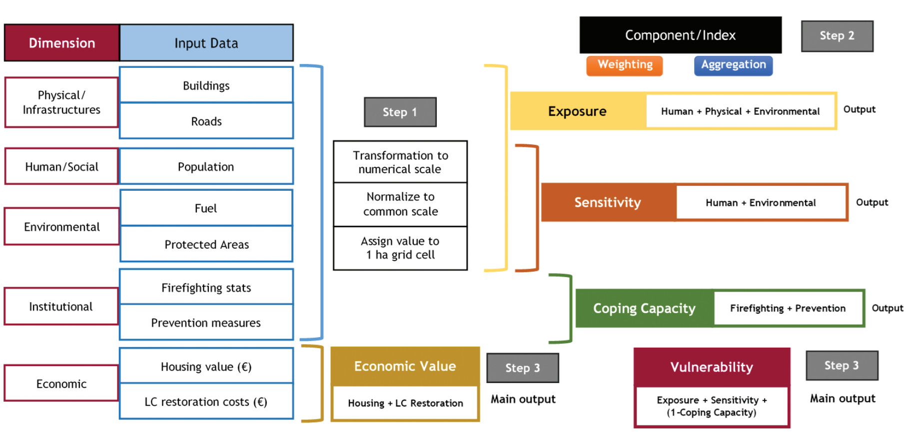
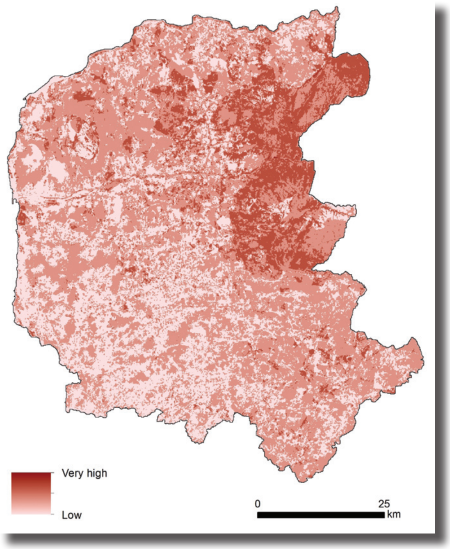


Fig. 24 – Workflow of the development of the Vulnerability Map and Economic Value Map.

Product examples



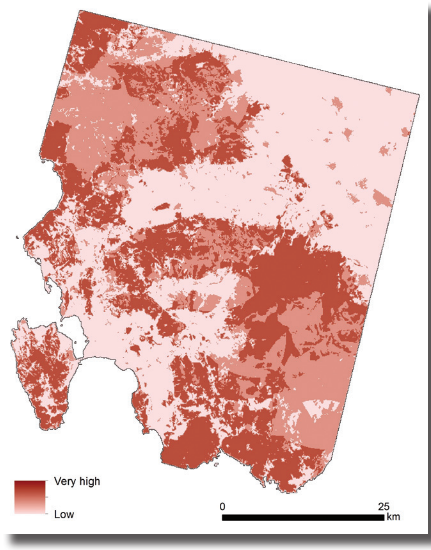


Fig. 25 – Vulnerability map - Product examples for the AOI of Portugal (left) and the AOI of Italy (right).

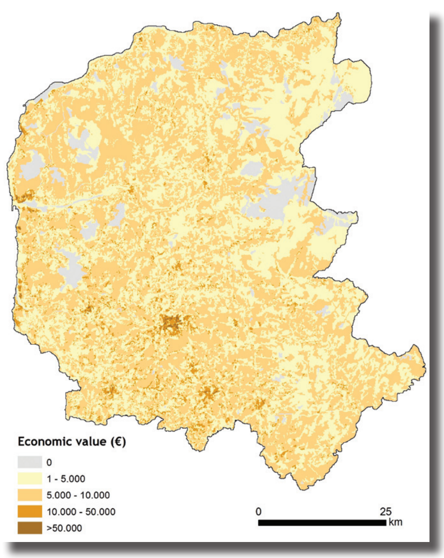


Fig. 26 – Economic value map - Product example for the AOI of Portugal.

Fire Risk Map

Fire Risk Map (PRE-SR)

Definition

The probability of occurrence of a fire event that can cause losses. It results from the combination of fire hazard (the probability of fire occurrence) with vulnerability (the potential for loss).

Background

Fire risk assessment is a valuable tool for fire managers and policy-makers, since it contributes to the improvement of forest fire prevention systems.

The PREFER project follows a long-term risk assessment, related to structural factors which remain relatively stable during at least one fire season. It is usually intended to determine the most fire-prone areas based on their intrinsic conditions, and provides indications of the stable conditions which favour fire occurrence. The assessment of structural fire risk is an important input for forest fire defence plans, contributing to a better allocation of resources prior to the beginning of the fire season.

Output

The purpose of the risk map is the identification of areas where the likelihood of occurrence of a fire that may cause losses is high. It assesses the probability of fire occurrence with regards to the potential for losses.

The risk map results from the combination of two other PREFER products:

- Seasonal fire hazard map (represents the likelihood that a fire may occur)
- Vulnerability map (represents the potential for losses)

Both the hazard and the vulnerability maps are presented in 5 classes. The multiplication of the value (1 to 5) of the classes, according to pre-defined criteria, results in a risk scale, as follows: Class 1 represents the lowest risk, as a combination of low hazard and low vulnerability, and class 5 shows the maximum level of risk in the area assessed.

		Vulnerability				
Hazard	*Classes*	**1**	**2**	**3**	**4**	**5**
	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5

Legend
Low risk
Moderate Risk
High Risk
Very High Risk
Maximum Risk

Fig. 27 – Classification of fire risk.

Association with other products

Fuel Map, Seasonal Fire Hazard Map, Vulnerability Map

Technical Specifications

Field of Application	Prevention phase, regional/national scale
AOI	PT, ES, IT
Geographic projection/ Reference system	GCS_ETRS_1989, Datum D_ETRS_1989
Spatial Resolution / Scale	100 m 1:25.000
Coverage / Area	N/A
Output data format	Raster: Geotiff (*.tif) Vector: Shapefile (*.dbf, *.prj, *.shp, *.shx, *.shi)
Refresh rate	Once a year: before the start of the main fire season (May)
Naming convention	PRE-SR-<AOI>-Date>.<ext> Where: • PRE-SR: is the product id • <AOI> (Area of interest): is a code identifying the area of interest • <Date>: Product reference date, format YYYYMMDD (UTC) • <ext>: extension

Data

EO Data	N/A
Other data	▫ Vulnerability map (UCO) ▫ Seasonal Fire Hazard map (GMV)

Processing

1. Check projection of maps and re-project as required;
2. Downscale values of Seasonal Fire Hazard map to 100 m resolution;
3. Aggregate the Seasonal Fire Hazard map with the Vulnerability map, by multiplying the values of the classes (1 to 5) of both layers;
4. Classify the resulting values in the 5-classes scheme of fire risk;
5. Create the corresponding Fire Risk map.

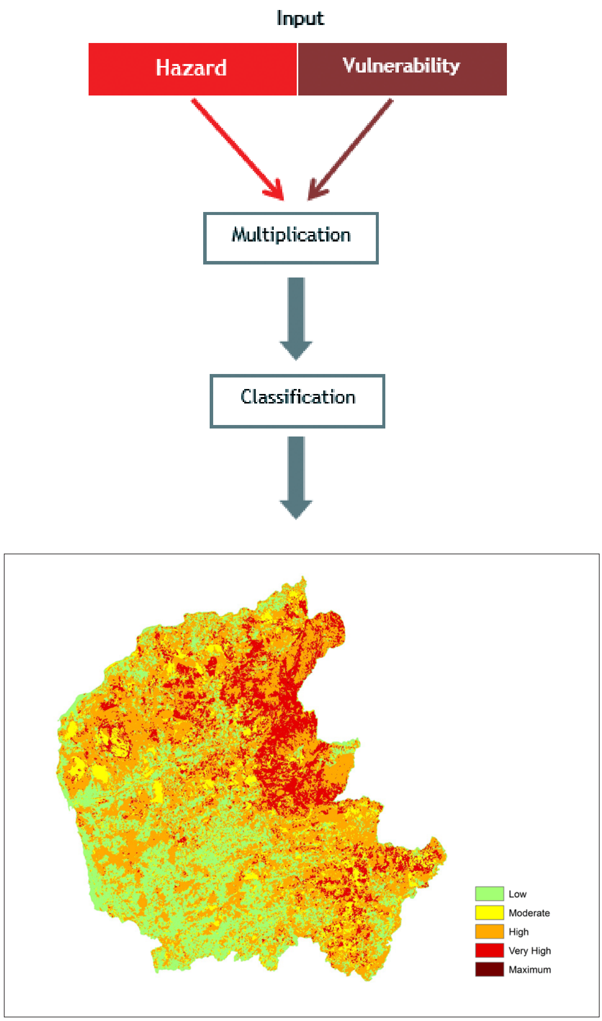


Fig. 28 - Workflow of the development of the Fire Risk Map.

Product examples

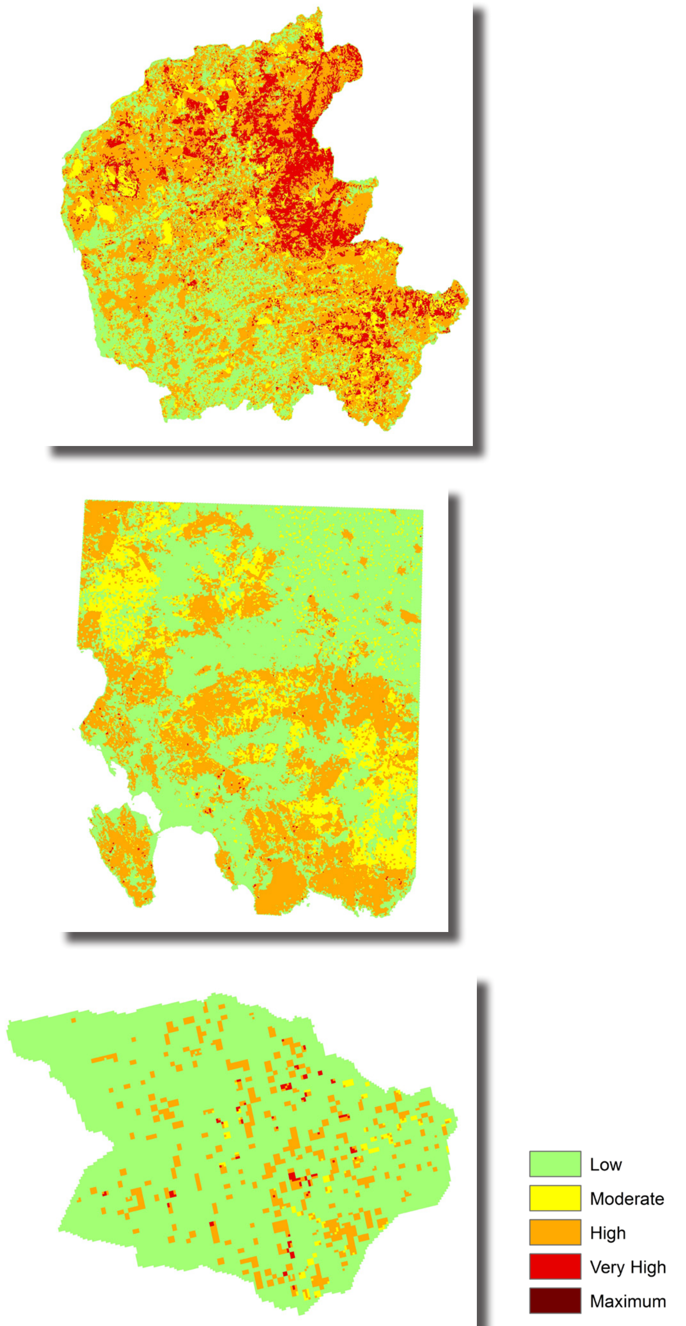


Fig. 29 - Fire Risk map - Product examples for the AOI of Portugal (top), Italy (middle) and Spain (bottom).

Fuel Reduction Map

Fuel Reduction Map (PRE-FR)

Definition

This map identifies the areas where the prevention procedure based on fuel reduction is advisable.

Background

Regardless of the recognition that most fires are human-caused in Southern Europe, and thus awareness activities are required in this regard, it is known that particular environmental and meteo-climatic conditions may favour the spread of fire to other areas away from the ignition point.

The main idea that has inspired this activity consists in defining the factors which favour fire spread and, consequently, in identifying the territorial units which have a higher probability of being affected by a fire. That is, the computation of a fire propagation probability (FPP) in the study area from which to extrapolate the territorial units with greater proneness to be affected by fires and, thus, on which to plan an appropriate programme for reducing the fuel load in order to mitigate the effects of a potential fire.

The methodology takes into account, first of all, geo-spatial elements, that is, all those factors related to the territory that may affect the onset and the fire spread.

Four types of factors were taken into account, grouped as follows:

- Topographic factor: altitude, slope, aspect;
- Environmental factor: fuel type, climate;
- Factor depending on the land use: natural parks, forests, roads, urban areas, agricultural areas;
- Factor dependent on the fires incidence: burned areas in the last five years (or longer).

The techniques for the reduction of the fuel load can be included in all those practices used on the field for reducing the excessive and dangerous accumulation of natural fuel. These include:

- Prescribed fire: deliberate use of fire in a given area and well defined environmental conditions;
- Mechanical treatments: modification, manual or mechanical removal of natural fuels, such as cutting, crushing, stacking;
- Other treatments: application of herbicides, introduction of biological controls, pasturage.

Output

The Fuel Reduction Map provides a spatial map of the areas where it would be useful to apply the fuel reduction practice, measured in m^2, in order to decrease the fire hazard and the potential fire spread.

The thematic values of the Fuel Reduction Map indicate the priority classes in terms of prevention purpose. The values range from low priority (1) to high priority (5) to reduce the fuel load. Values 0 correspond to areas not considered in the analysis (azonic fuel, no-fuel, urban areas, etc.).

Association with other products

Fuel Map, Daily Fire Hazard Map, Prescribed Fire Map, Burn Scars HR Optical, SAR and VHR Optical Maps

Technical Specifications

Field of Application	Prevention phase, regional/national scale
AOI	PT, ES, IT
Geographic projection/ Reference system	GCS_ETRS_1989, Datum D_ETRS_1989
Spatial Resolution / Scale	Scale : 1/10.000-1/25.000 Horizontal accuracy: 5-20 m
Coverage / Area	Portugal test site: 4925 km^2 Spain test site: 179 km^2 Italian test sites: 3445 km^2
Output data format	Raster: Geotiff (*.tif)
Refresh rate	Once a year at the end of summer season.
Naming convention	PRE-FR-<AOI>-<NOSAT>-<Procdate&time>.<ext> Where: • PRE-FR: is the product id • <AOI> (Area of interest): is a code identifying the area of interest (PT for Portugal, SP for Spain and IT for Italy) • <NOSAT>: explains that no satellite data have been used to compute this product • <Procdate&time>: elaboration date and time, format YYMMDDhhmm. • <ext>: extension

Data

EO Data	▫ Landsat ▫ Sentinel 2
Other data	▫ Burn Scars at scale 1/10.000-1/50.000 extracted from High Resolution Optical and SAR EO data (related to fire events occurring before the acquisition date of the reference image) (IESC) ▫ Fuel map (GMV) ▫ Geographic vector layers ▫ CORINE land cover ▫ DEM/DTM ▫ Climate map ▫ Phytoclimatic map ▫ Roads network ▫ Past years archived fire events (Series of 5 years or higher of Burned Areas polygons)

Processing

1. Computing the slope, aspect and elevation by using the DTM;
2. Classifying the topographic (slope, aspect, elevation) and the environmental (climate, fuel) parameters in predefined ranges;
3. Computing the Homogenous Territorial Classes (HTC);
4. Computing the Geospatial Hazard (GH) index by calculating the fire propagation probability for the HTC;
5. Creating the protection buffer zones around the vulnerable areas, by using the vector layers of the Urban Areas, Woodland and Roads;
6. Intersecting the Geospatial Hazard with the buffer zones.

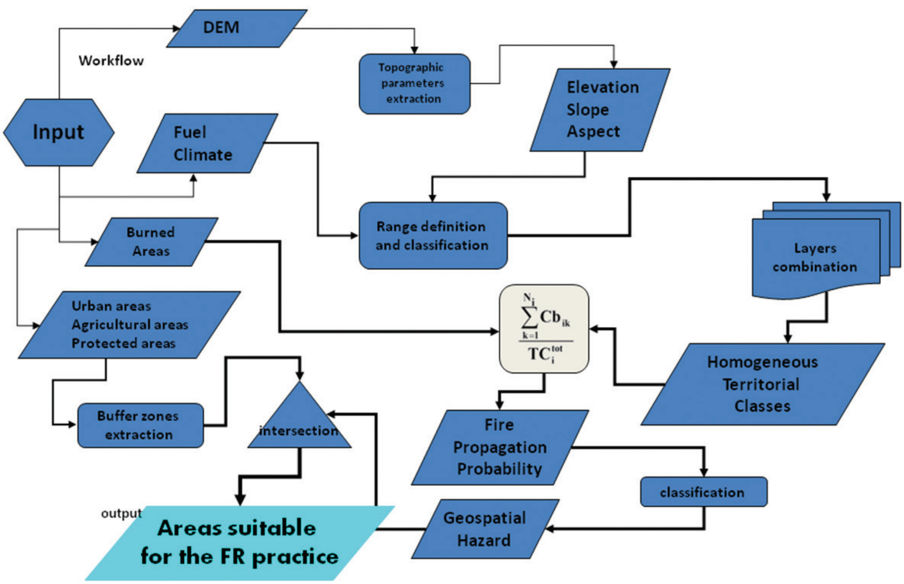


Fig. 30 - Workflow of the development of the Fuel Reduction Map.

Product examples

Fig. 31 – Fuel Reduction Map - Product example in the AOI of Italy.
Orange areas represent the interface zones where it could be useful to apply a vegetation fuel reduction practice for decreasing the fire hazard and/or the fire impact.

Prescribed Fire Map

Prescribed Fire Map (PRE-PF)

Definition

This product provides a spatial-temporal map of the location of the areas where it would be useful and safe to apply the prescribed fire practice.

Background

This product builds from the Geospatial analysis of the Fuel Reduction Map (see previous product), adding a time module.

The fuel load reduction can be obtained by means of several techniques, among which the practice of Prescribed Burning (PB). If the legal framework allows it, the PB can only be applied under certain environmental conditions, in order to operate on the field in safe conditions and achieve the fuel reduction through a controlled low intensity fire. To attain this purpose, specific conditions related to ranges of meteorological variables, among which wind speed, air temperature, relative humidity, number of days without rain and moisture content of fine fuels, have to be met. In the document “Handbook to Plan and Use Prescribed Burning in Europe” [Fernandes & Loureiro, 2010], published in the framework of the FIRE PARADOX project, combustion time windows and environmental conditions to plan a PB intervention on the field were defined and are applied in this module.

The analysis of the time factor provides the prediction of “when” the optimum for the application of the PB occurs. In other words, when the conditions expressed by the meteorological variables (prescription items) will be satisfied, together with the geospatial conditions described for the fuel reduction map. For this purpose, it is necessary to use a short/medium-term forecasting model (3-7 days) of the meteorological variables involved.

Output

The Prescribed Fire Map provides a spatial-temporal map of the areas where it would be useful to apply the prescribed fire practice. This product has to be integrated with the map obtained from the geo-spatial module. In fact, only after the overlapping and the intersection between time module and geo-spatial module, it is possible to get the full information about where and when to plan a PB intervention. The final products are a set of forecasting map obtained by the intersection between the thematic map of the priority classes of intervention (as the Fuel reduction map) and the daily masks containing only the area where the climate conditions for the prescribed fire practice are satisfied.

The output is a daily forecast map of the areas where all the conditions are met, to support the identification of the areas where and when the “prescribed fires” prevention procedure is applicable in a secure way.

Association with other products

Fuel Map, Daily Fire Hazard Map, Fuel Reduction Map, Burn Scars HR Optical, SAR and VHR Optical Maps

Technical Specifications

Field of Application	Prevention phase, regional/national scale
AOI	PT, ES, IT
Geographic projection/ Reference system	GCS_ETRS_1989, Datum D_ETRS_1989
Spatial Resolution / Scale	Scale: 1/10.000-1/25.000 Horizontal accuracy: 5-20 m
Coverage / Area	Portugal test site: 4925 km^2 Spain test site: 179 km^2 Italian test sites: 3445 km^2
Output data format	Raster: Geotiff (*.tif) Vector: Shapefile (*.dbf, *.prj, *.shp, *.shx, *.shi)
Refresh rate	Daily during the winter season (November - March)
Naming convention	PRE-PF-<AOI>-<METEO>-<Procdate&time>.<ext> Where: • PRE-PF: is the product id • <AOI> (Area of interest): is a code identifying the area of interest (PT for Portugal, SP for Spain and IT for Italy) • <METEO>: indicates that the product is based on the weather forecast provided by the Dept. of Meteorology of the Italian Air Force • <Procdate&time>: date and time to which the forecast refers, format YYMMDDhhmm (UTC). • <ext>: extension.

Data

EO Data	▫ Landsat ▫ Sentinel 2
Other data	▫ Burn Scars at scale 1/10.000-1/50.000 extracted from High Resolution ▫ Optical and SAR EO data (related to fire events occurring before the acquisition date of the reference image) (IESC) ▫ Fuel map (GMV) ▫ Geographic vector layers ▫ CORINE land cover ▫ DEM/DTM ▫ Climate map ▫ Phytoclimatic map ▫ Roads network ▫ Past years archived fire events (Series of 5 years or higher of Burned Areas polygons)

Processing

Meteo Data Pre-Processing

1. Download the meteo data of the day;
2. Crop the meteo data on the area of interest;
3. Extract air temperature, relative humidity, wind speed and total precipitation corresponding to 12:00, 36:00, 60:00 forecast hours, that means, time 12:00 of present day, time 12:00 of the following day and time 12:00 of the second following day;
4. Geo-reference meteo data in geographic coordinates.

Assessment Of The Suitable Areas (Where To Apply Pf)

1. Computing the slope, aspect and elevation by using the DTM;
2. Classifying the topographic (slope, aspect, elevation) and the environmental (climate, fuel) parameters in predefined ranges;
3. Computing the Homogenous Territorial Classes (HTC);
4. Computing the Geospatial Hazard (GH) index by calculating the fire propagation probability for the HTC;
5. Creating the protection buffer zones around the vulnerable areas, by using the vector layers of the Urban Areas, Woodland, Parks and Protected areas, Roads;
6. Intersecting Geospatial Hazard and buffer zones.

Assessment Of The Suitable Date (When To Apply Pf)

1. Computing the range values of Temperature, Humidity, Wind and Total precipitation required for the application of the prescribed fire;
2. Computing daily masks where the prescribed fire conditions are satisfied.

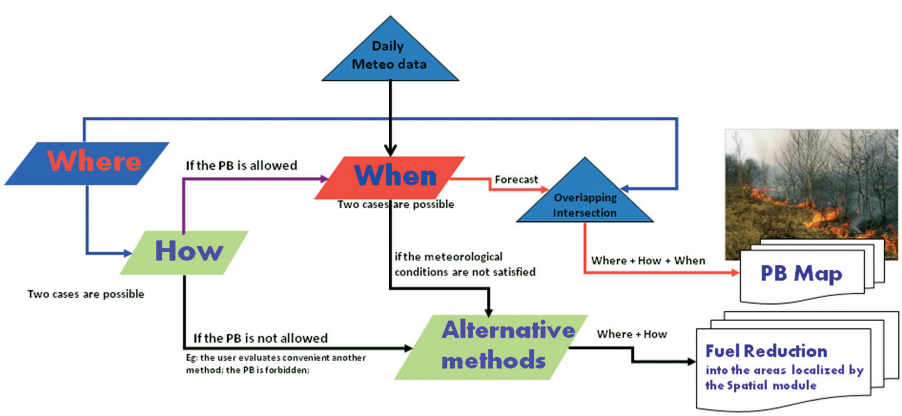


Fig. 32 - Workflow of the procedure to assess when the Prescribed Fire would be possible.

Product examples

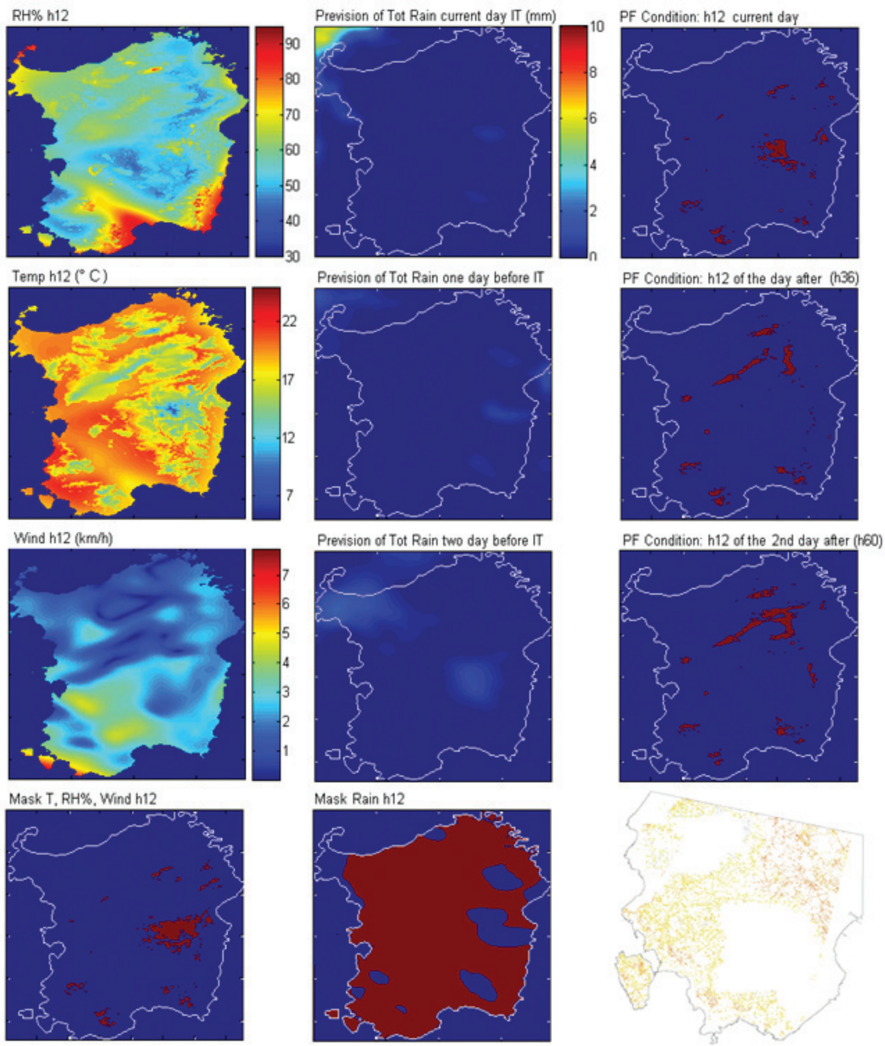
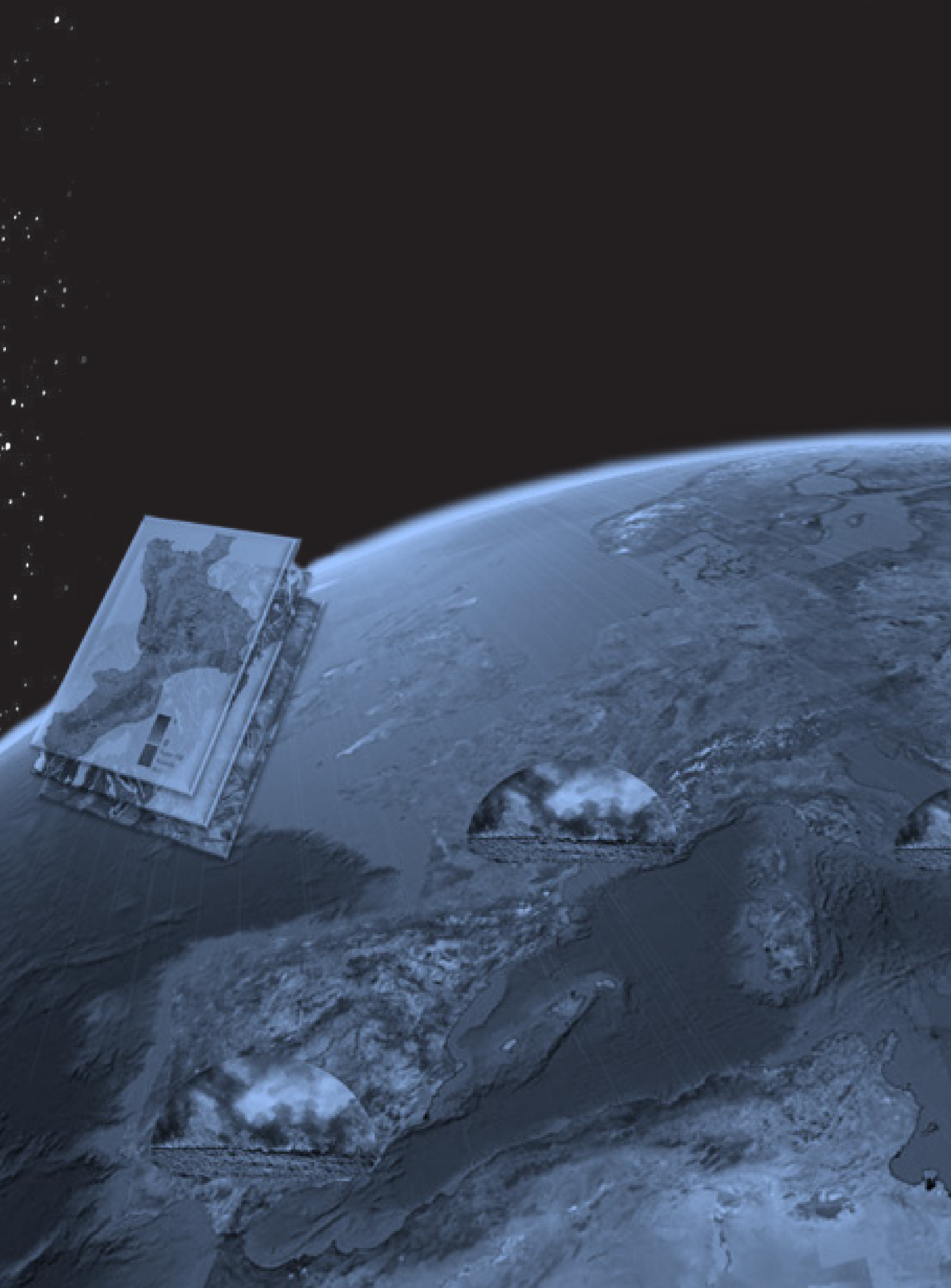
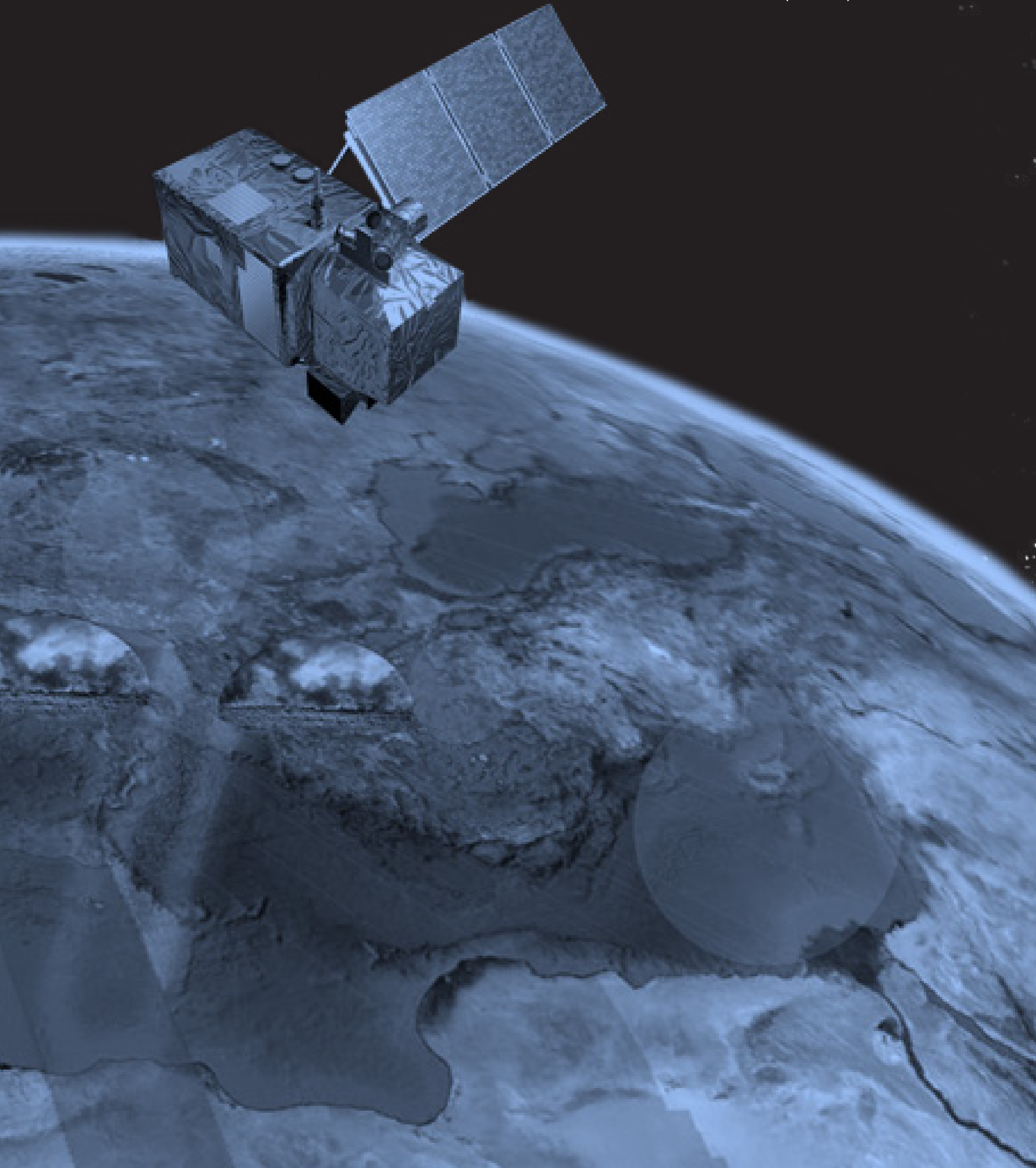


Fig. 33 - Prescribed Fire Map - Product example for the AOI of Italy.



3.2. Information Support to Recovery/ Reconstruction Phase Service (ISR)



Post-Fire Vegetation Recovery Map

Post-Fire Vegetation Recovery Map (REC-PFVGR)

Definition

The purpose of this product is the identification of areas previously damaged by fire event where regrowth of vegetation took place. It estimates the recovery capacity of vegetation in fire affected areas.

Background

Remote sensing data has been used to assess post-fire dynamics. Changes in reflectance values caused by the disappearance of charcoal-ash remains, the increase of vegetation cover and the subsequent decrease of bare soil caused by the recovery process are targets for remote sensing. Increases in infrared reflectance and consequent decreases in red and blue wavelengths (caused by increases in chlorophyll) are registered. Some authors argue that following fire, there is an increase in homogeneity (Chuvieco, 1996) as a consequence of the destruction of vegetation. Lloret *et al*. (2002) observed an increase of patch density and a decrease of patch size in burned areas due to different post-fire vegetation succession phases coexisting in the same area. Pérez-Cabello *et al*. (2005) found a high increase in diversity values caused by the different vegetation responses of plant communities, of charred and burnt vegetation remains and post-fire charcoal-ash. The increase in diversity values following a fire is inversely proportionate to pre-fire diversity values.

Regeneration measurements through vegetation indices must be carried out by considering unburned control points, in order to discriminate variation due to climatologic conditions, phonological seasonal variations, hydric vegetation stress and/or acquisition parameters of satellite images (atmospheric conditions, sun elevation, radiometer type) (Riano *et al*., 2002; Fraser *et al*., 2000, Balzter *et al*., 2008, Diaz-Delgado *et al*. 2002; Diaz-Delgado *et al*. 2003; van Leeuwen *et al*. 2010).

In the framework of this project, the vegetation recovery identification is conducted through multi-temporal and multispectral analysis of High Resolution Optical EO data (reference image and final image). The regeneration of vegetation is represented by a logic 0/1 indicating if re-growth of vegetation has occurred or not for each of the analysed pixels, without quantifying the growth of vegetation.

Output

This product results in a vector of polygons representing the presence of vegetation cover on areas previously burned. The algorithm for the determination of post-fire vegetation recovery is based on a multi-temporal analysis of the spectral behavior in NIR and SWIR channels, considering both the change in reflectance in the individual channels of observation and in some channel ratios.

Association with other products

Burn Scars HR Optical, SAR and VHR Optical Maps

Technical Specifications

Field of Application	Recovery phase, regional/national scale
AOI	FR, IT, GR
Geographic projection/ Reference system	UTM WGS84 Zone 32N for French and Italian test sites, zone 34N for Greek test site
Spatial Resolution / Scale	Scale : 1/25.000-1/50.000 Horizontal accuracy : 30-50 m Minimum detected area: 1 hectare
Coverage / Area	Minimum area covered by a product: 3600 km^2
Output data format	Vector: Shapefile (*.dbf, *.prj, *.shp, *.shx, *.shi)
Refresh rate	Twice a year: April/May and August/September
Naming convention	REC-PFVGR-<AOI>-<DateStart><Sat>-<DataStop><Sat>-<Procdate&time>.<ext> Where: • REC-PFVGR: is the product id • <AOI> (Area of interest): is a code identifying the area of interest (FR for France, GR for Greece and IT for Italy). • <DateStart>: reference image date, format YYMMDD • <DateStop>: final image date, format YYMMDD • <Sat>:satellite type of the initial and final optical data (L5 for Landsat 5 and L8 for Landsat 8, S4 for Spot4 and S5 for Spot5, T2 for Sentinel2, R6 for Resourcesat-1 and R7 per Resourcesat-2) • <Procdate&time>: elaboration date and time, format YYMMDDhhmm • <ext>: extension

Data

EO Data	¤ Two optical EO data (reference and final EO data) characterized by a pixel size from 10 m to 30 m, one acquired between April/May and one between August/September.
Other data	¤ Burn Scars at scale 1/10.000-1/50.000 extracted from High Resolution Optical and SAR EO data (related to fire events occurring before the acquisition date of the reference image) (IESC)

Processing

HR Optical Data Pre-Processing

1. Ortho rectify the data
2. Digitize the vector of clouds related shadows of input image

HR Optical Data Processing

1. Resize of the input images in terms of pixel size and geographic coverage
2. Radiometric processing
3. Cloud and shadows mask
4. Change detection-multitemporal analysis:

   Selection of pixels of PREFER products “Burn Scar HR optical” and “Burn Scar SAR” (scale 1/10.000-1/50.000) presenting an increase in biomass content and/or chlorophyll absorption (compared to PRs variation) from image N-1 and the image N. The identification of areas subject to increase of vegetation cover and/or biomass is carried out only for the portion of land not covered by clouds in both the initial and final images.

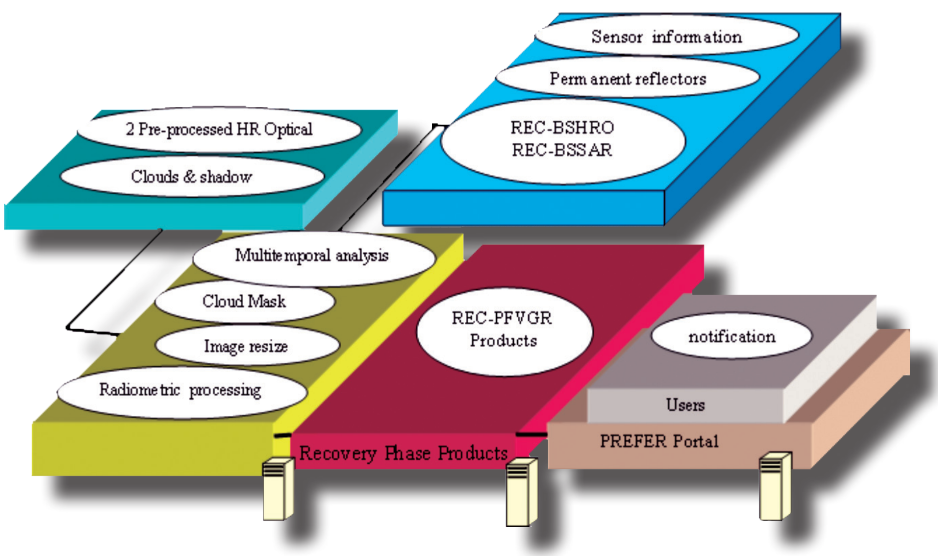
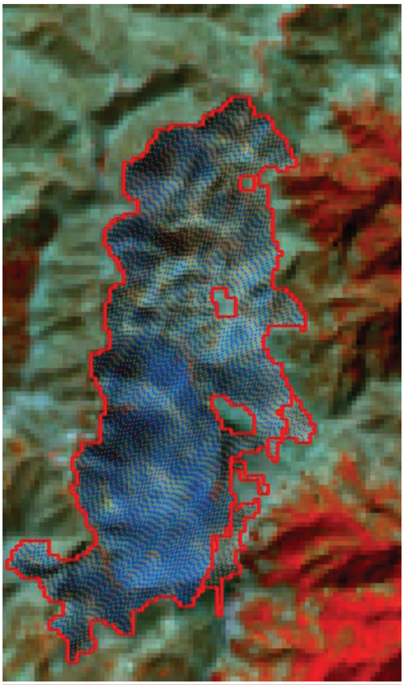


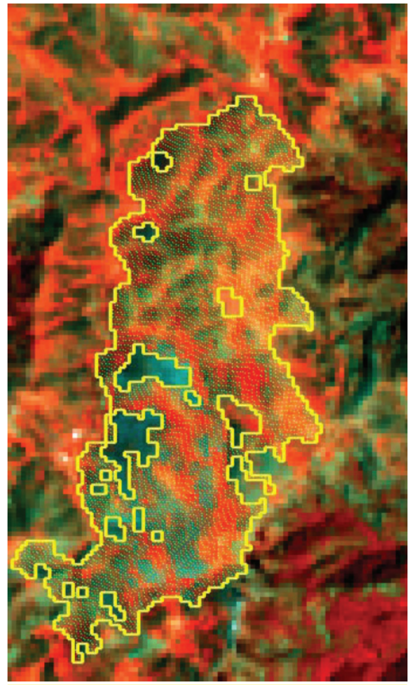
Fig. 34 - Workflow of the procedure for post-fire vegetation recovery map.

Product examples

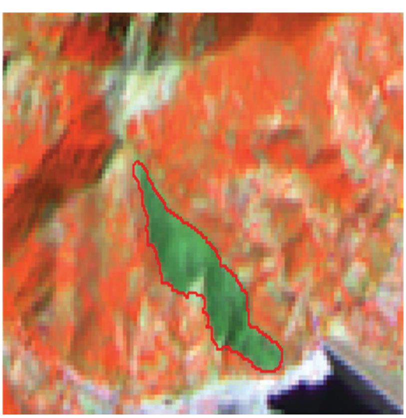
Example of partial recovery.



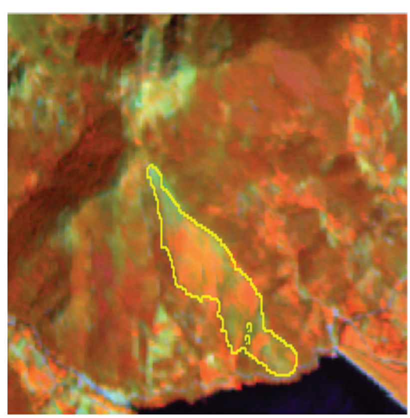
BSHRO Burn Scar (inred) overlaid on Landsat acquired on 20130927



PFVGR (Yellow) overlaid on Landsat acquired on 20140509



Buen Scar between 20120716 - 20120828
overlaid on SPOT 4 - 20120916



Post-Fire vegetation (20120916 - 20130418
overlaid on SPOTS - 20130418

Fig. 35 - Post-Fire Vegetation Recovery map - product examples.

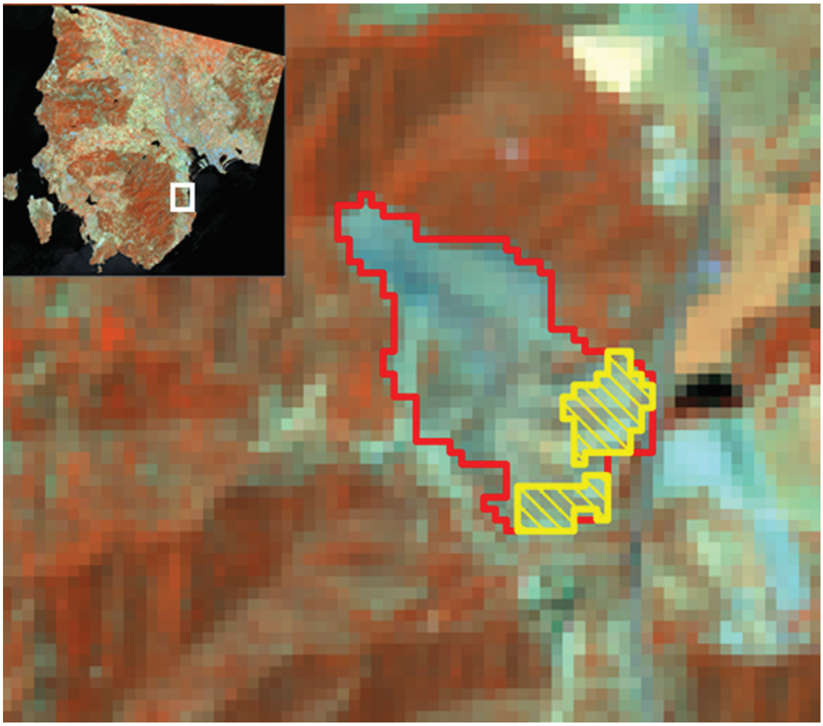


Fig. 36 - Post-Fire Vegetation Recovery map – product example in the AOI of Italy.

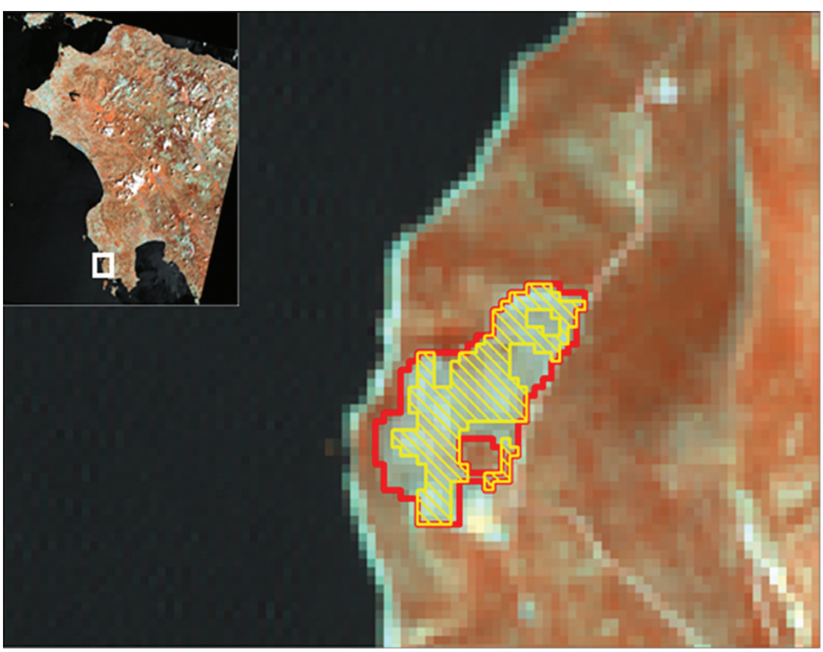


Fig. 37 - Post-Fire Vegetation Recovery map – product example in the AOI of Greece.

3D Fire Damage Assessment Map

3D Fire Damage Assessment Map (REC-3DFDA)

Definition

This product provides 2D and 3D fire impact monitoring maps, as well as a soil erosion susceptibility index, to highlight areas prone to soil erosion and increased risk of flash flooding and debris.

Background

The main motivation for this product is to exploit the benefits of remote sensing data, injecting the third dimension into fire damage assessment. For this purpose, stereoscopy is applied, defined as the use of images to produce a 3D visual model with characteristics analogous to that of actual features viewed using true binocular vision.

Additionally, soil erosion indicators are provided, considering that post-fire soil erosion is a major risk to forest habitats, given the long term often permanent damage that ensue. The Mediterranean region is particularly prone to post-fire water erosion due to its physical factors: climate with long dry summer periods often interspersed with fire events, followed by heavy autumnal downpours and topography (often steep) [Gitas *et al*, 2009].

Using an appropriate soil erosion model, areas at risk can be estimated and can provide information about current erosion, its trends and allow scenario analysis. The integration of existing soil erosion models, field data and data provided by remote sensing technologies, through the use of geographic information systems (GIS), appears to be a lively field of R&D activity. Moreover, higher soil erosion risk can be linked to a number of factors such as steep slopes, climate characteristics, inappropriate land use, land cover patterns (e.g. sparse vegetation) and ecological disasters (e.g. forest fires).

The objectives of this product are:

- To provide 2D and 3D information about the damage caused by forest fires, in order to highlight areas prone to soil erosion;
- To include volumetric indicators about the burnt areas;
- To see the burnt area evolution over time.

Output

The 3D fire damage assessment product aims to add a very high resolution 3D component to fire damage assessment, indicate where volumes have reduced and, then, using this 3D digital elevation model information plus land-cover/land-use and ancillary soil geo-information to indicate where soil erosion vulnerability exists.

The soil erosion susceptibility will be described through indicator(s) based on soil erosion model of the Universal Soil Loss Equation (USLE) family (RUSLE, G2).

Association with other products

Post-Fire Vegetation Recovery Map, Burn scars HR Optical, SAR and VHR Optical Maps

Technical Specifications

Field of Application	Recovery phase, regional/national scale Forest management, post-fire rehabilitation and risk analysis
AOI	FR, IT
Geographic projection/ Reference system	Lambert RGF93 (EPSG: 2154) for France and WGS 84 / UTM Zone 32N (EPSG:32632) if requested WGS 84 / UTM Zone 32N (EPSG: 32632) for Italy (Sardinia)
Spatial Resolution / Scale	1-20 m 1:2.000 to 1:100.000
Coverage / Area	VHR-1: Maximum 400 km^2 for each test site (20 km x 20 km) HR: Maximum 3600 km^2 for each test site (60 km x 60 km)
Output data format	Raster: Geotiff (*.tif) Vector: ArcGIS shape file (*.dbf, *.prj, *.shp, *.shx) Kml. The *prj file specifies the coordinate reference system.
Refresh rate	Twice a year: April/May and August/September
Naming convention	REC-3DFDA-<Type>-<AOI>-<Date>.<ext> Where: • REC-3DFDA: is the product id • <Type>: sub-product type (2D impact, 3D impact, SESI) • <CSCDA Resolution Class> • <AOI> (Area of interest): is a code identifying the area of interest • <Date>: image date, format YYYYMMDD (UTC) • <ext>: extension

Data

EO Data	▫ DSM (Digital Surface Model): optical EO data VHR1 and HR1 multispectral and or panchromatic stereo-pair images acquired at least after fire and preferably before ▫ Thematic image analysis: VHR1 and HR1 multispectral images acquired before and after fire (e.g. SPOT4/5, Pleiades HR, Worldview2/3…)
Other data	▫ At least 1 Pre-processed VHR DSM ▫ 2 Pre-processed HR/VHR Optical data ▫ K-factor (European Soil Database-JRC) ▫ Rainfall (Worldclim©) or national rainfall database

Processing

Optical Data Pre-Processing

1. Ortho-rectify data
2. Radiometric processing: Exo-atmospheric correction algorithm
3. VHR image pan-sharpening using high performance pan-sharpening software modules
4. DSM is generated through panchromatic stereo-pairs using a customized algorithm

Optical Data Processing

SESI: Soil Erosion Susceptibility Index

This product is obtained through applying a RUSLE based model which is a combination of 4 parameters:

a) C-factor: an indication of vegetation land cover:

   1. NDVI calculation from optical multispectral data
   2. Conversion into C factor through algorithm

b) K-factor concerns a soil's erodibility, it is obtained from the European soil database, JRC (500 m pixel size).

   3. This file is resampled to the same resolution as the other input files and clipped to the burn scar footprint.

c) R factor concerns rainfall intensity. (Can be replaced with a more precise data source if available).

   4. This data is resampled to the same resolution as the other input files and clipped to the burn scar footprint and the R algorithm is then applied.

d) LS factor concerns slope and slope length

   5. This factor is derived from the DSM by applying LS factor equation
   6. Combine the factors to generate Soil index susceptibility

2Di-3Di: 2D and 3D impact, indication of volume losses

1. Map forestry in burn scar area from reference optical images through vegetation indexes and multispectral analysis
2. Eliminate non burnt forestry vegetation from forestry layer
3. Tree heights are extracted from DSM change detection or from using contextual analysis to estimate pre-fire tree heights from reference images and the DSM
4. If necessary apply tree heights estimation into post-fire DSM to produce a simulated pre-fire DSM
5. Apply a density calculation to obtain volume loss indicator

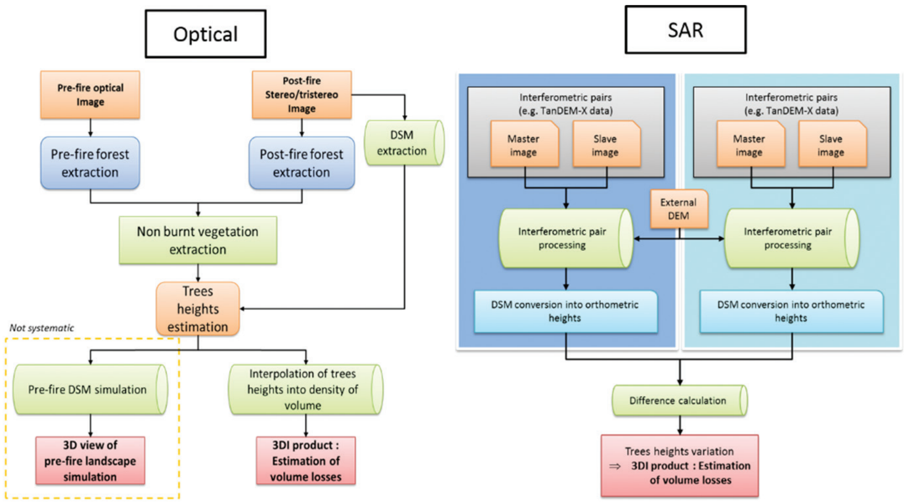


Fig. 38 - Workflow of the development of the 3D Fire Damage Assessment Map.

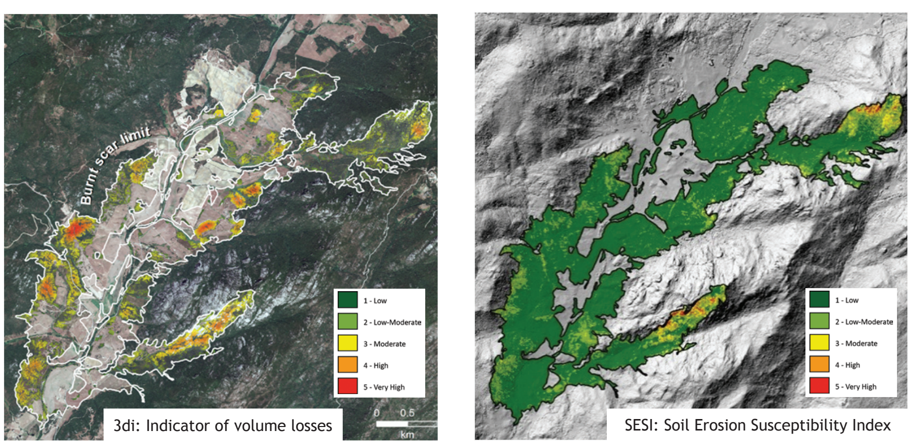


Fig. 39 - 3D Fire damage product examples for the AOI of France.

3Di : Indicator of volume losses (derived from VHR optical data, volume data are estimated through a VHR digital surface model).

SESI : Soil Erosion Susceptibility Index (SESI).

These samples are derived from a Pléiades VHR1 stereo-pair acquired the 30th of June 2013 over the PREFER Corsica site in the area of Sartene.

Damage Severity Map (REC-DS)

Damage Severity Map (REC-DS)

Definition

This map represents the degree of damage on burned areas.

Background

The purpose of this product is the assessment of damage severity in areas previously damaged by fire event. It provides information status of the vegetation after the burning event for planning the recovery phase.

Studies on the possibility of using satellite images for estimating the damage caused on the vegetation by fire, have been carried out in the last years by using images acquired from high spatial resolution multispectral sensors like LANDSAT/TM, ETM+ and OLI. Basically, these involve defining indices that allow determining, using post-event and pre-event images, fire impact on vegetation distinguishing as accurately as possible, between different levels of damage.

Within the PREFER project, the comprehensive approach to monitor burn severity on the landscape is composed of four interrelated elements:

a. The definition of severity;

Burn severity is defined as the degree of environmental change caused by fire, or how much fire has affected the ecological community. It is the result after the fact, and it represents the spatial variation of those effects. Fire intensity is the driver for burn severity, but that relationship is not necessarily constant, different ecological systems show varying degrees of sensitivity to fire. Severity is a measure of gradient of change.

b. The algorithm for burn severity extraction;

It is based on the outcomes of the project FIREMON. The assessment of the damage severity is based on the identification of a relationship between DNBR (Delta Normalized Burn Ratio) and ground based visual estimate of the damage in the field.

c. The field measures to calibrate and/or validate remote sensing results;

d. The implementation of a support chain which delivers the product to users.

Output

The damage severity assessment is conducted through multi-temporal and multispectral analysis of two Landsat 8 (pre and post fire-event images). The algorithm for the determination of post-fire damage severity is based on a multi-temporal analysis of vegetation spectral index. The Damage Severity Index (DSI) production is based on a full automatic tool denominated Damage Severity Index Processor (DSIP). The damage severity is represented by a scale of damage from 0 to 5 indicating the degree of damage.

Association with other products

Post-Fire Vegetation Recovery Map, Burn Scar HR Optical

Technical Specifications

Field of Application	Recovery phase, regional scale
AOI	FR, IT, GR
Geographic projection/ Reference system	Lat, Long WGS84
Spatial Resolution / Scale	30 m
Coverage / Area	N/A
Output data format	Raster: Geotiff (*.tif)
Refresh rate	Every 2 weeks
Naming convention	REC-DS-<AOI>-<Date>.<ext> Where: • REC-DS: is the product id • <AOI> (Area of interest): is a code identifying the area of interest • <Date>: image date, format YYYYMMDD (UTC) • <ext>: extension

Data

EO Data	▫ Landsat8 images, pre and post fire event
Other data	▫ Burn scar map HR optical PREFER product

Processing

Images pre-processing

1. Calibration: convert DN to reflectance;
2. Radiometric Normalization: performs radiometric normalization of a couple of OLI imagery;
3. Cloud Mask: Apply the cloud mask to the images;
4. Crop: Crops the images in the burned areas.

DSI Calculation

1. Band extraction: extracts the bands required for DSI calculation;

   The procedure is used to derive "at satellite" reflectance for each Landsat scene.
2. Index calculation: computes the DSI;
   - Computing NBR for each Landsat scene
   - Computing DNBR from the pair of NBR datasets
3. Damage Classification: converts the DSI in Damage levels - Interpreting results of DNBR:
   - No Damage (DNBR<0.1): the area is indistinguishable from pre-fire conditions;
   - Low Damage (0.1<DNBR<0.5): little change in cover and mortality of structurally vegetation;
   - Medium Damage (0.5<DNBR<0.8): mixture of effects ranging in the pixel from low to high change;
   - High Damage (DNBR>0.8): Vegetation has high to complete mortality.

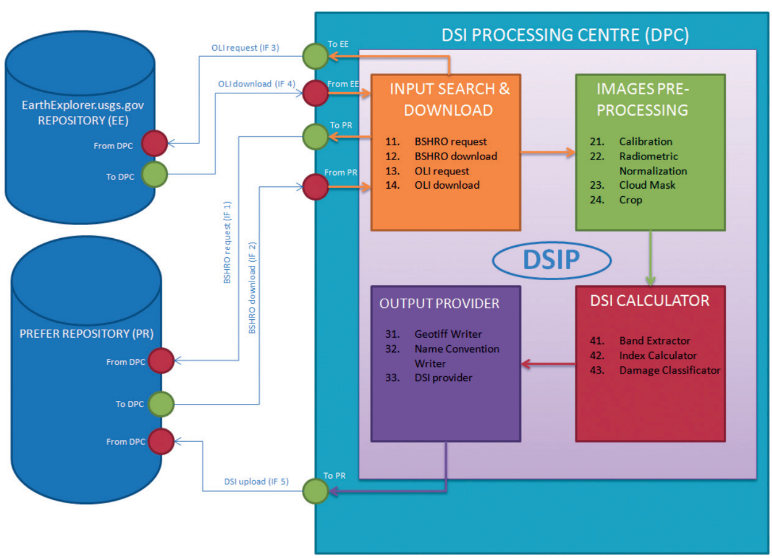


Fig. 40 - Workflow of the development of the Damage Severity Map.

Product examples

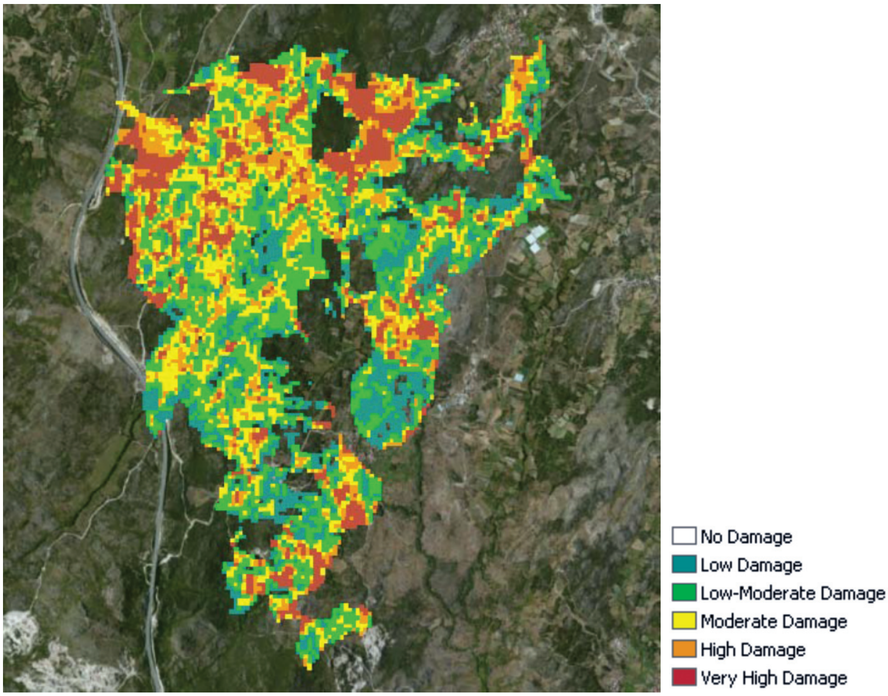


Fig. 41 – Damage Severity Map – product example in the AOI of Greece.

The fire in the example occurred in Greece during summer 2014. Before fire event, the burned area comprised several types of vegetation (grassland, farmland, scrubland, trees). The DSI takes into account the pre-fire vegetation in order to assess damage severity, therefore the highest values of damage correspond to pre-fire wooded areas completely burned, and lowest values of damage correspond to slightly damaged areas or to damaged areas sparsely vegetated before fire.

Burn Scar Maps

High Resolution Optical

Burn Scar Maps – High Resolution Optical (REC-BSHRO)

Definition

Burn Scar perimeters, at scale 1/25.000-1/50.000, obtained through multi-temporal and multispectral analysis of High Resolution Optical EO data.

Background

The most effective, passive remote-sensing methods for detecting and mapping Burn Scars on high resolution data (10-30 m, scale 1/25.000-1/50.000) rely upon the observation in near-infrared (NIR) and short-wavelength infrared (SWIR) bands.

This product development is based on a code that runs a multi-temporal process, based on dynamic spectral behaviour of all classes of land in the electromagnetic windows VIS, NIR and SWIR. Single channel reflectance and Simple Ratio (SR) variations in bispectral spaces VIS/NIR and NIR/SWIR are used in the multitemporal analysis and in the contextual analysis of the multispectral image acquired after fire events.

The method used to separate the variations due to intrinsic reflectance of the vegetation from the variations due to other factors (sensor type, acquisition parameters, atmospheric conditions, etc..) that influence the reflectance to the satellite, is to identify characteristics " pseudo -invariant " to be considered as "targets of reference" or "PR-Permanent Reflectors" in the adjustment of the cross-reflectance in different images. The identification of characteristics of "pseudo-invariant" requires a careful analysis of a large set of optical data.

Output

Vector of Polygons representing the perimeter of the areas damaged by fire events during a time interval. This time interval corresponds to the temporal period between the acquisition dates of the pair of satellite images involved in the multi-temporal analysis.

The mapping of the burn scars from optical data is performed only on the Corine Land Cover (CLC) classes 22 (permanent crops), 244 (agro-forestry areas), 31 (forests), 32 (Scrub and/or herbaceous vegetation associations), 333 (Sparsely vegetated areas).

Association with other products

Post-Fire Vegetation Recovery Map, Damage Severity Map, 3D Fire Damage Assessment Map, Burn Scars SAR, VHR Optical Maps

Technical Specifications

Field of Application	Recovery phase, regional/national scale
AOI	FR, GR, IT, PT
Geographic projection/ Reference system	UTM WGS84 Zone 32N for French and Italian test sites, zone 34N for Greek test site and zone 29N for Portuguese test site
Spatial Resolution / Scale	Scale : 1/25.000-1/50.000 Horizontal accuracy : 30-50 m Minimum detected area: 1 hectare
Coverage / Area	Minimum area covered by a product: 3600 km^2
Output data format	Vector: ArcGIS shape file (*.dbf, *.prj, *.shp, *.shx)
Refresh rate	Three times between April and September
Naming convention	REC-BSHRO-<AOI>-<DateStart><Sat>-<DataStop><Sat>-<Procdate&time>.<ext> Where: • REC-BSHRO: is the product id • <AOI> (Area of interest): is a code identifying the area of interest (FR for France, GR for Greece and IT for Italy). • <DateStart>: reference image date, format YYMMDD • <DateStop>: final image date, format YYMMDD • <Sat>: satellite type of the initial and final optical data (L5 for Landsat 5 and L8 for Landsat 8, S4 for Spot4 and S5 for Spot5, T2 per Sentinel2, R6 per Resourcesat-1 and R7 per Resourcesat-2). • <Procdate&time>: elaboration date and time, format YYMMDDhhmm. • <ext>: extension

Data

EO Data	¤ Two optical EO data (initial and final EO data) characterized by a pixel size from 10 m to 30 m
Other data	¤ Corine Land Cover 2006 (FR, IT, PT) or 2000 (GR)

Processing

Images pre-processing

1. Ortho rectify the data;
2. Digitize the vector of clouds related shadows of input image.

Data Processing

This function processes a pair of Pre-processed HR Optical data exploiting the MyMe software tool:

1. Resize of the input images in terms of pixel size and geographic coverage;
2. Radiometric processing;
3. Cloud and shadows mask;
4. Change detection-multitemporal analysis: Pixels presenting a decrease in biomass content and chlorophyll absorption (compared to PRs variation) from the image N-1 and the image N, are selected. The identification of areas subject to reduction of vegetation cover and/or biomass is carried out only for the portion of land not covered by clouds in both the initial and final images;
5. Contextual analysis: On the image N, pixels selected in the previous step and located in correspondence to Land Cover Corine 22 (permanent crops), 244 (agro-forestry areas), 31 (forests), 32 (Scrub and/or herbaceous vegetation associations), 333 (Sparsely vegetated areas are analyzed. Pixels characterized by reflectance values in one or more channels of observation and in one or more channel combination, lower than the average values calculated for the set of pseudo -invariant pixels or Permanent Reflector (PR), and are considered to have undergone fire damages.

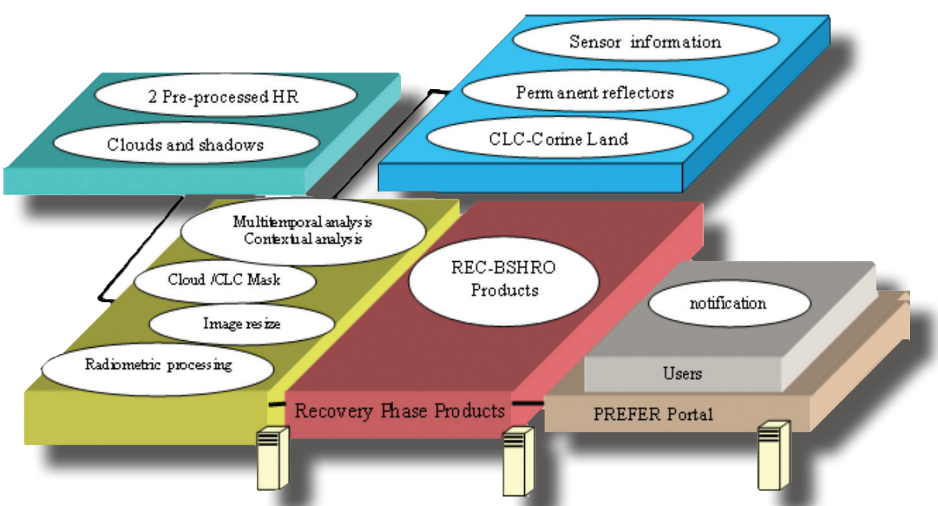


Fig. 42 - Workflow of the development of the Burn Scar High Resolution Optical Map.

Product examples

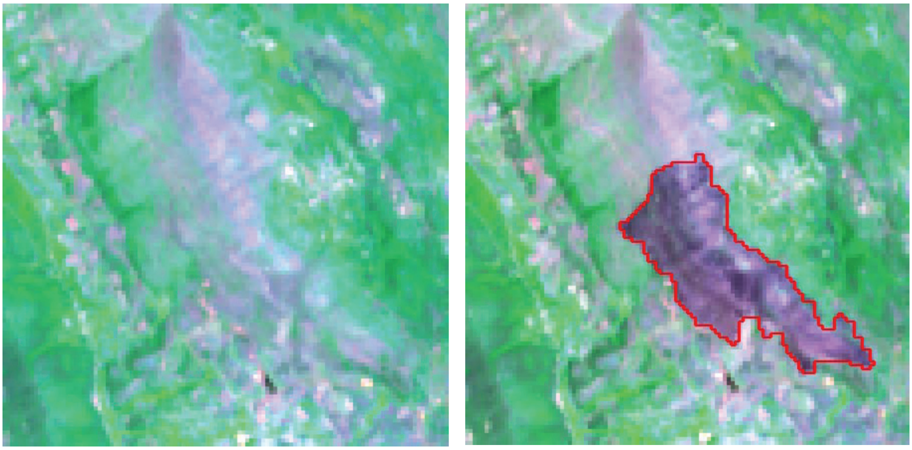


Fig. 43 - Burn Scar High Resolution Optical Map – product example in the AOI of Greece.

On the left, Landsat 8 20140627. On the right, Burn Scar map example overlaid on Landsat8 20140713

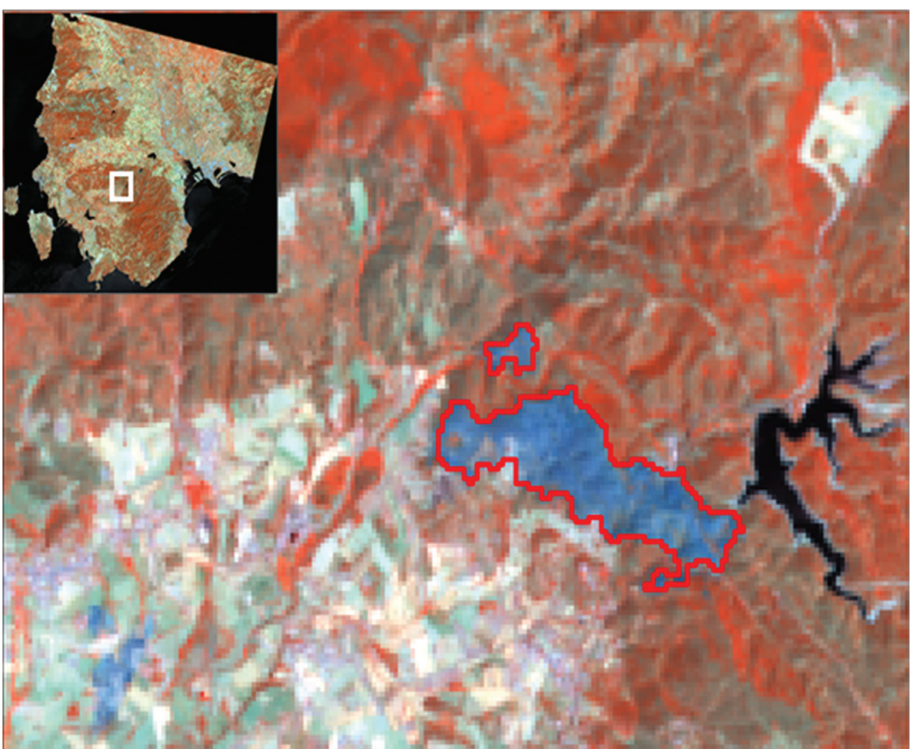


Fig. 44 - Burn Scar High Resolution Optical Map – product example in the AOI of Italy.

Burn Scar Maps

High Resolution SAR

Burn Scar Maps – High Resolution SAR (REC-BSSAR)

Definition

Burn Scar perimeters, at scale 1/10.000-1/50.000, obtained through multi-temporal analysis of High Resolution SAR (Synthetic Aperture Radar) EO data.

Background

The major changes induced by fire on the value of the Radar section on the exposed surface are closely related with the values of soil moisture. Indeed fires, altering the structure and the areal density and volume of the vegetable surfaces, locally determine an increase of the amount of energy reflected from the ground at the expense of that reflected by tree structures. In dry weather conditions, the removal of vegetation cover results in a decrease of the relative humidity in the more superficial layers of soil: therefore, the backscattering coefficient can decrease by up to 4-6 dB observed in the literature, and may increase result of increased soil moisture (rainfall). It was found that under dry conditions, the discrimination is more accurate if you look at the average of the values of the backscattering coefficient, while in wet conditions the standard deviation is a better indicator of the vegetation.

Output

Vector of Polygons representing the perimeter of the areas damaged by fire events during a time interval. This time interval corresponds to the temporal period between the acquisition dates of the pair of satellite images involved in the multi-temporal analysis.

The mapping of the burn scars from SAR data is performed only on the Corine Land Cover (CLC) classes 244 (agro-forestry areas), 31 (forests), 32 (Scrub and/or herbaceous vegetation associations).

The procedural approach provides a preliminary mapping of areas of shadow and layover, necessary for the sake of exclusion from further analysis. This approach is based on the variations of the backscattering coefficient.

Association with other products

Post-Fire Vegetation Recovery Map, Damage Severity Map, 3D Fire Damage Assessment Map, Burn Scars HR Optical, VHR Optical Maps

Technical Specifications

Field of Application	Recovery phase, regional/national scale
AOI	FR, IT, GR
Geographic projection/ Reference system	UTM WGS84 Zone 32N for French and Italian test sites, zone 34N for Greek test site
Spatial Resolution / Scale	Scale : 1/10.000-1/50.000 Horizontal accuracy : 10-50 m Minimum detected area: 1 hectare
Coverage / Area	Minimum area covered by a product: 1600 km^2
Output data format	Vector: ArcGIS shape file (*.dbf, *.prj, *.shp, *.shx)
Refresh rate	Twice between June and September
Naming convention	REC-BSSAR-<AOI>-<DateStart><Sat>-<DataStop><Sat>-<Procdate&time>.<ext> Where: • REC-BSSAR: is the product id • <AOI> (Area of interest): is a code identifying the area of interest (FR for France, GR for Greece and IT for Italy).4 • <DateStart>: reference image date, format YYMMDD • <DateStop>: final image date, format YYMMDD • <Sat>:satellite type of the initial and final data (CH for CSK Stripmap HIMAGE, CW for CSK Scansar Wide Region and T1 for Sentinel-1). • <Procdate&time>: elaboration date and time, format YYMMDDhhmm • <ext>: extension

Data

EO Data	◽ A pair of SAR EO Data is needed as input of the elaboration process.
Other data	◽ Corine Land Cover 2006 (FR, IT) or 2000 (GR) ◽ DEM (Digital Elevation Model)

Processing

Images pre-processing

SAR data are pre-processed using SARSCAPE/ENVI/IDL functions for:

1. Multilooking to obtain approximately squared pixels considering the ground range resolution and the pixel spacing in azimuth;
2. Coregistration of dataset;
3. De Grandi multi-temporal Filtering to balance differences in reflectivity between images at different times;
4. Geometric and radiometric calibration of the backscatter values are necessary for intercomparison of radar images acquired with different sensors, or even of images obtained by the same sensor if acquired in different modes or processed with different processors;
5. Extraction of layover-shadowing layer in order to avoid the analysis on areas where strong are the geometric distortions typical of radar images.

Data Processing

This function processes a pair of Pre-processed SAR data exploiting the MyMe software tool:

1. Change detection-multitemporal analysis: : Pixels presenting an increase in backscattering value (compared to PRs variation) from the image N-1 and the image N, are selected. The identification of areas subject to reduction of vegetation cover and/or biomass is carried out only for the portion of land not affected by layover and/or shadowing geometric distortions typical of radar images;
2. Contextual analysis: On the image N, pixels selected in the previous step and located in correspondence to Land Cover Corine 244 (agro-forestry areas), 31 (forests) and 32 (Scrub and/or herbaceous vegetation associations). Pixels characterized by backscattering value lower than the average calculated for the set of pseudo-invariant pixels are considered to have undergone fire damages.

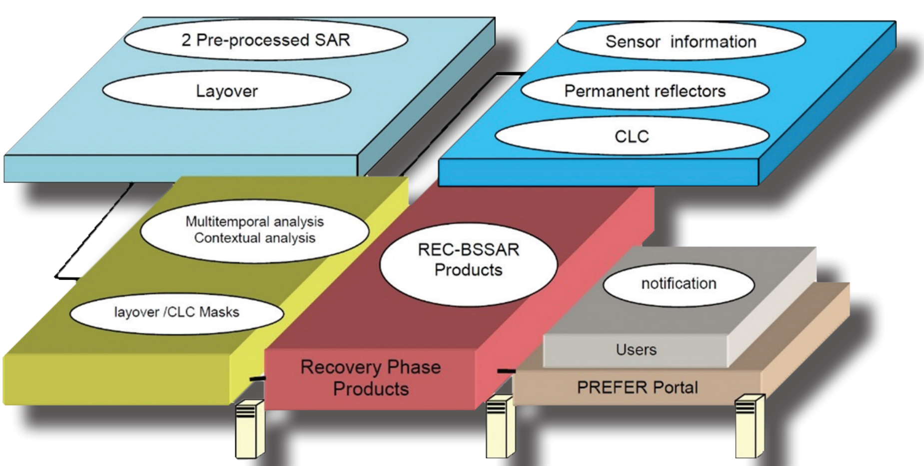


Fig. 45 - Workflow of the development of the Burn Scar High Resolution SAR Map.

Product examples

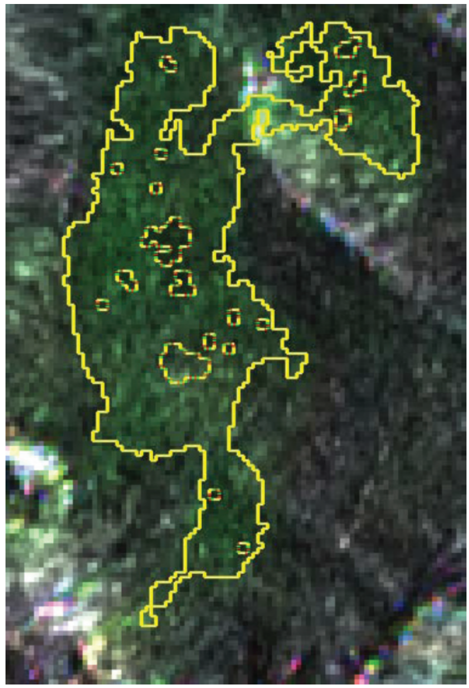
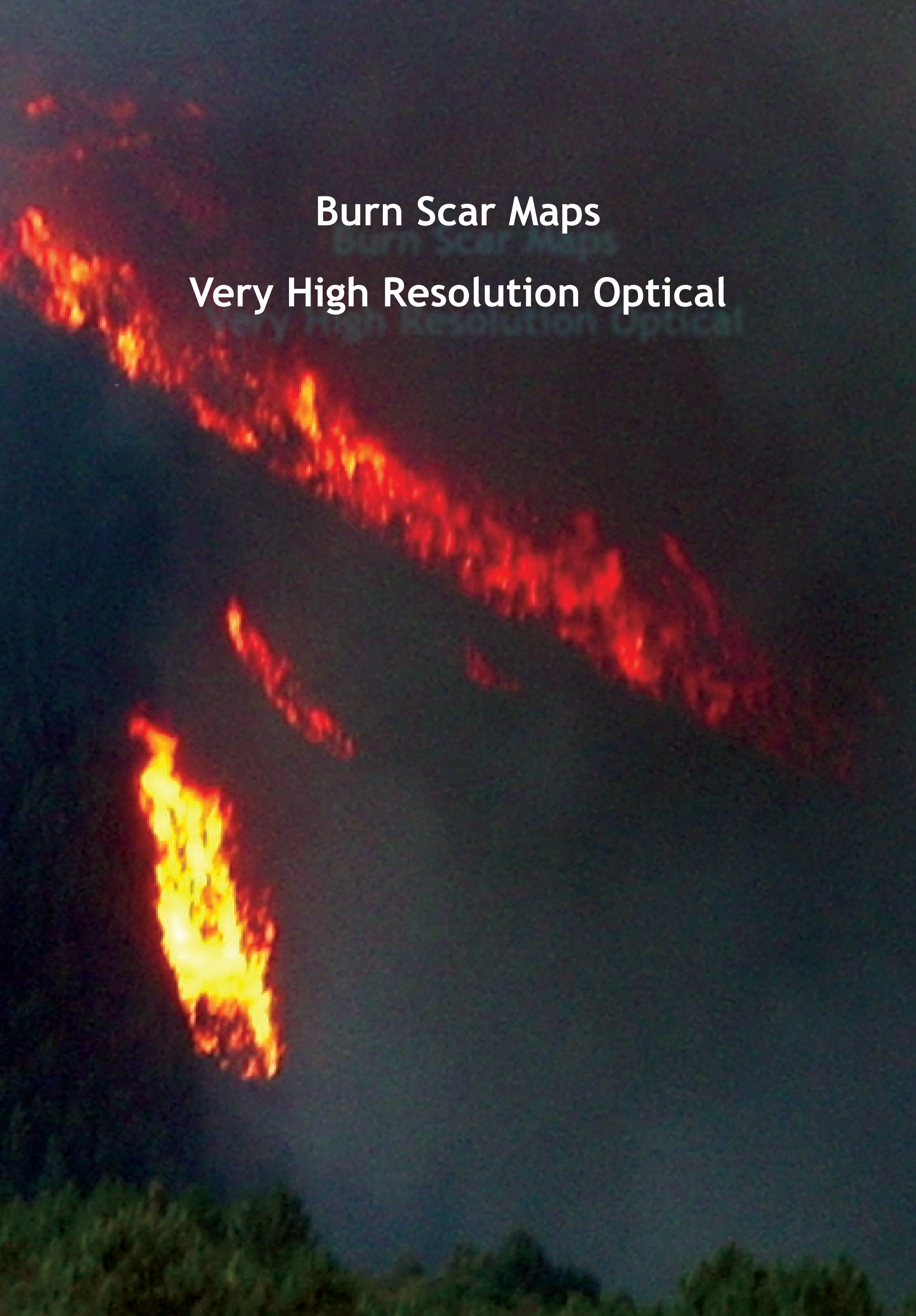


Fig. 46 - Burn Scar High Resolution SAR Map – product example in the AOI of Italy.

In Yellow, an example of Burn Scar map obtained through multi-temporal analysis of Cosmo-Skymed Himage data acquired on 20130802 and 20130903, overlaid on a false color composite RGB =20130802-20130903-20130714.

Burn Scar Maps

Very High Resolution Optical



Burn Scar Maps – Very High Resolution Optical (REC-BSVRO)

Definition

Burn Scar perimeters at cadastral scale (1/1.000-1/4.000) obtained through contextual analysis of Very High Spatial Resolution Optical EO data.

Background

The purpose of this product is to define at cadastral scale contour and extent (1/2.000) of the areas damaged by fire in some sensitive places.

The precise information is of extreme importance in sites particularly sensitive to fire, in terms of vegetation and fauna (natural park, protected areas, Natura 2000 sites), concentration of people (urban areas, particularly schools and hospitals), high cost infrastructure (airports, ports, railway, highway) and in sites characterized by a high probability of fire spread or a high flammability (chemical, container port sites).

The algorithm provides for the return of the polygons of the areas damaged by fire on Visible-NIR multispectral images with very high resolution (QuickBird, IKONOS, KOMPSAT2, GeoEye-1, WoldView and Pleiades) first extension to ‘ V -NIR multispectral information (resolution better than 4 meters , the nominal operating 1:5.000 scale), with subsequent extension of the sequential panchromatic data and improvement of the nominal scale until it reaches the cadastral scale (1:2.000).

The algorithm is based on the contextual analysis of a multi spectral image at very high resolution. The pixels with low amount of biomass and/or ground cover and / or with the presence of ash are characterized by reflectance values in one or more channels of observation and in one or more channel combination, lower than the average values calculated for the set of pseudo-invariant pixels or Permanent Reflector (PR) and are considered as areas affected by fire.

Output

Vector of Polygons representing the perimeter of the burn scars. The mapping of the Very High Resolution burn scars is performed only on the Corine Land Cover (CLC) classes 22 (permanent crops), 244 (agro-forestry areas), 31 (forests), 32 (Scrub and/or herbaceous vegetation associations), 333 (Sparsely vegetated areas) and on geographical regions characterised by a shaded relief value lower than 0.25.

Association with other products

Post-Fire Vegetation Recovery Map, Damage Severity Map, 3D Fire Damage Assessment Map, Burn Scars HR Optical, SAR Maps

Technical Specifications

Field of Application	Recovery phase, regional/national scale
AOI	FR, IT, GR
Geographic projection/ Reference system	UTM WGS84 Zone 32N for French and Italian test sites, zone 34N for Greek test site
Spatial Resolution / Scale	Scale : 1/1.000-1/4.000 Horizontal accuracy : 10 m Minimum detected area: 0.25 hectare
Coverage / Area	Minimum area covered by a product: 25 km^2
Output data format	Vector: ArcGIS shape file (*.dbf, *.prj, *.shp, *.shx)
Refresh rate	On time after fire event
Naming convention	REC-BSVRO-<AOI>-<DateAndTime><Sat>-<Procdate&time>.<ext> Where: • REC- BSVRO: is the product id • <AOI> (Area of interest): is a code identifying the area of interest • <DateAndTime> image date and time, format YYMMDDhhmm (UTC) • <Sat> satellite type (IK for IKONOS, K2 for KOMPSAT2, W2 for WorldView-2, PL for Pleiade, GE for GeoEye and QB for Quickbird) • <Procdate&time>: elaboration date and time, format YYMMDDhhmm • <ext>: extension

Data

EO Data	¤ One very high resolution optical EO data (pixel size between 1-4 m)
Other data	¤ Corine Land Cover 2006 (FR, IT) or 2000 (GR)

Processing

Images pre-processing

1. Ortho rectify the data;
2. Digitize the vector of clouds and related shadows;
3. Extract shaded relief from DEM.

Data Processing

This function processes a Pre-processed VHR Optical data exploiting the MyMe software tool:

1. Radiometric processing;
2. Contextual analysis of MS data:

   Pixels located in correspondence to Land Cover Corine 22 (permanent crops), 244 (agroforestry areas), 31 (forests), 32 (Scrub and/or herbaceous vegetation associations), 333 (Sparsely Vegetated areas, characterized by reflectance values in one or more channels of observation and in one or more channel combination, lower than the average values calculated for the set of pseudo -invariant pixels or Permanent Reflector (PR), are considered as burn scar candidates;

3. Contextual analysis of PAN data (if available):

   On panchromatic image, pixels located on vegetation types 22 (permanent crops), 244 (agroforestry areas), 31 (forests), 32 (Scrub and/or herbaceous vegetation associations), 333 (Sparsely vegetated areas, presenting reflectance value lower than the average value calculated for the set of PR, are tagged as burn scar candidates;

4. Merge of MS and PAN results - Pixels selected in 2) and 3) are taken as burn scars.

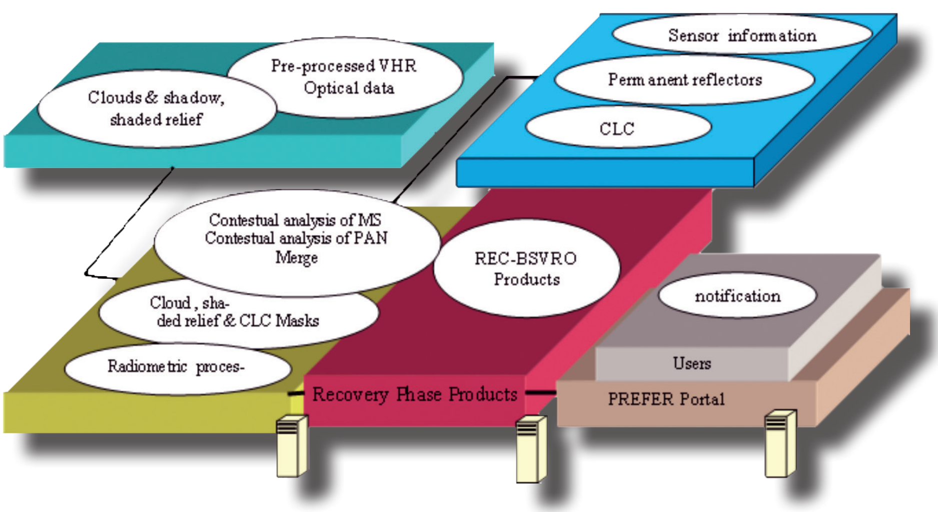
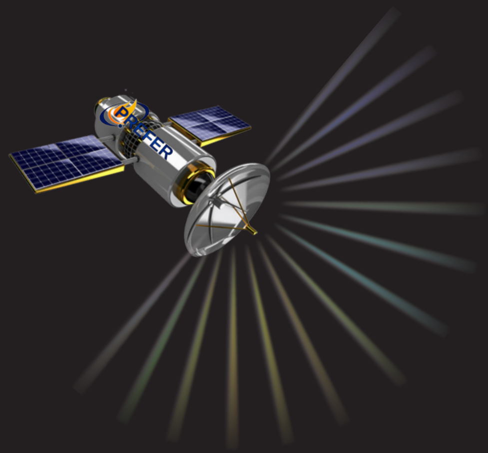


Fig. 47 - Workflow of the development of the Burn Scar Very High Resolution Optical Map.

Product examples

Fig. 48 - Burn Scar Very High Resolution Optical Map – product example in the AOI of Greece.

An example of Burn Scar Map VHR Optical extracted through contextual analysis of very high spatial resolution Kompsat-2 image, represented in white.


PREFER

References

Badia, Anna *et al.* (2011) - Identifying dynamics of fire ignition probabilities in two representative Mediterranean Wildland Urban Interface areas. *Applied Geography* 31, 930-940

Birkmann, J., Cardona, O. D., Carreño, M. L., Barbat, A. H., Pelling, M., Schneiderbauer, S., Keiler, M., Alexander, D., Zeil, P., Welle, T. (2013). Framing vulnerability, risk and societal responses: the MOVE framework. *Natural Hazards*, 67(2), 193-211.

Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., & Webb, J. (2008). A place-based model for understanding community resilience to natural disasters. *Global environmental change*, 18(4), 598-606

Cutter, SL (2011). A ciencia da vulnerabilidade: modelos, métodos e indicadores. Revista Crítica de Ciências Sociais [online] 93, Junho 2011: 59-69. Available from http://rccs.revues.org/165?lang=en

Fernandes & Loureiro, 2010. Handbook to plan and use prescribed burning in Europe. Available at http://www.fireparadox.org/handbook_prescribed_burning_europe.php

JRC, Joint Research Centre (2013) – "Forest Fires in Europe, Middle East and North Africa 2012." *Joint report of JRC and Directorate-General Environment*. Report EUR 26048 EN. Available at http://forest.jrc.ec.europa.eu/effis/reports/annual-fire-reports/

Lampin-Maillet, Corinne *et al.* (2011) - Land cover analysis in wildland-urban interfaces according to wildfire risk: a case study in the South of France. *Forest Ecology and Management* 261, 2200-2213

Leone, Vittorio *et al.* (2003) - The human factor in fire danger assessment. In: Chuvieco, Emilio (ed.), Wildland Fire Danger Estimation and Mapping: The Role of Remote Sensing Data, *World Sci.*, Hackensack, N.J., pp. 143-196.

Moreira, Francisco *et al.* (2011) - Landscape-wildfire interactions in southern Europe: Implications for landscape management. *Journal of environmental management* 92 (10), 2389-2402

Pausas, Juli (2004) - Changes in fire and climate in the eastern Iberian Peninsula (Mediterranean basin). *Climatic change* 63 (3), 337-350

Roy, D. P., Jin, Y., Lewis, P. E., & Justice, C. O. (2005). Prototyping a global algorithm for systematic fire-affected area mapping using MODIS time series data. R*emote sensing of environment*, 97(2), 137-162.

San-Miguel-Ayanz *et al.* (2012) - Land Cover Change and Fire Regime in the European Mediterranean Region. In Moreira, Francisco *et al.* (eds.) P*ost-Fire Management and Restoration of Southern European Forests*, Springer Netherlands, 21-43

WORLD BANK (2012). World Development Indicators 2011. World Bank Publications. Available at http://siteresources. worldbank.org/DATASTATISTICS/Resources/ wdi_ebook.pdf.