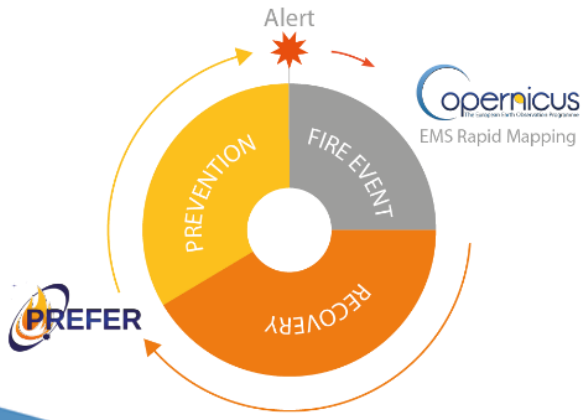
# PREFER

*Space-based Information Support for **P**revention and **RE**covery of Forest **F**ires **E**mergency in the Medite**R**ranean Area*

**G.A. 312931**

## FINAL REPORT

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# 1. INTRODUCTION

This document summarize the results presented during the PREFER Final Meeting and corresponds to the deliverable D61.4 'Project Final Presentation'.

The scope of this deliverable is to provide a description of:

- the project achievements,
- the service availability & exploitation,
- PREFER website,
- further development and future activities.

In particular, the content of this document is partially based on the information provided in the following deliverables:

- Del 42.2 'Demonstration Report';
- Del 42.3 'PREFER Information Support to Preparedness/Prevention phase service - demonstration products';
- Del 42.4 'PREFER Information Support to Recovery/Reconstruction Phase Service - demonstration products';
- Del 43.1 ' User Appreciation Report'.

A specific document is devoted to illustrate the Lessons Learned.

# 2. APPLICABLE AND REFERENCE DOCUMENTS

## 2.1 APPLICABLE DOCUMENTS

| | |
|---|---|
| [AD1] | PREFER Space-based Information Support for Prevention and Recovery of Forest fires Emergency in the Mediterranean Area. Grant agreement no.: 312931. “Description of Work”. |
| [AD2] | PREFER Information Service Product Portfolio Specifications |
| [AD3] | PREFER Information support to preparedness/prevention phase service design report |
| [AD4] | PREFER Information support to recovery/reconstruction phase service design report |
| [AD5] | PREFER Validation Plan |
| [AD6] | PREFER Demonstration Plan |
| [AD7] | PREFER Validation Report |
| [AD8] | PREFER Demonstration Report |
| [AD9] | PREFER Information Support to Preparedness/Prevention phase service - demonstration products |
| [AD10] | PREFER Information Support to Recovery/Reconstruction Phase Service - demonstration products |
| [AD11] | PREFER User Appreciation Report |

# 3. ACRONYMS AND TERMINOLOGY

| | |
|---|---|
| 3DI | 3D Damage Assessment |
| ANPC | National Authority of Civil Protection |
| AOI | Area Of Interest |
| ARPAB | Agenzia Regionale per la Protezione Ambientale della regione Basilicata |
| BAI | Burned Area Index |
| BSHR | Burn Scar High Resolution |
| BSVHR | Burn Scar Very High Resolution |
| CBI | Composite Burned Index |
| CFS | Corpo Forestale dello Stato |
| CFVA | Corpo Forestale e di Vigilanza Ambientale della regione Sardegna |
| CLC | Corine Land Cover |
| DEM | Digital Elevation Model |
| DFHI | Daily Fire Hazard Index |
| dNBR | delta Normalized Burned Ratio |
| DPC | National Department of Civil Protection |
| DSI | Damage Severity Index |
| EC | European Commission |
| EFFIS | European Forest Fire Information System |
| EFI | European Forest Institute |
| EO | Earth Observation |
| FR | Fuel Reduction |
| GIO | GMES Initial Operations |
| GIS | Geographic Information Service |
| GMES | Global Monitoring for Environment and Security |
| GNR | Guard National Republican |
| HR | High Resolution |
| HW | Hardware |
| ICNF | Institute for Nature Conservation and Forests |
| INSPIRE | Infrastructure for Spatial Information in Europe |
| ISP | Information Support to Preparedness/Prevention Phase |
| ISR | Information Support to Recovery/Reconstruction Phase |
| NBR | Normalized Burned Ratio |
| NCSRD | National Centre for Scientific Research Demokritos |
| NDVI | Normalized Difference Vegetation Index |
| NIR | Near-Infrared |
| ONF | Office National de Forest |
| PF | Prescribed Fire |
| PPR | Plans for the Prevention of Natural Hazards Predictable |
| PR | Permanent Reflector |
| RdNBR | delta Normalized Burned Ratio Relative |
| REA | Research Executive Agency |
| RTD | Research and Technological Development |
| RUSLE | Revised Universal Soil Equation |
| SDIS | Service Departemental d'Incendie et de Secours |
| SH | Seasonal Hazard |
| SW | Software |
| SWIR | Short-Wavelength Infrared |
| VHR | Very High Resolution |
| VVFF | Corpo Nazionale dei Vigili del Fuoco |
| WP | Work Package |
| YF | Yearly Fuel |

# 4. PREFER PROJECT ACHIEVEMENTS

## 4.1 PRODUCTS STATUS, MATURITY AND USEFULNESS

PREFER products are based on tools and methodologies resulting from many EO research projects (Table 4.1-1), carried out in international (EC, ESA) and national R&D contests.

*Table 4.1-1: Major international & national projects on wildfires with results considered in the development of PREFER products.*

| Project acronym | Funding | Year concluded | Products retained and improved in PREFER |
|---|---|---|---|
| FIREMONT | USDA | On-going | Correlate ground based vegetation damage level with satellite data based indices. |
| ODS3F | DG ECHO | 2015 | Surveillance camera fire monitoring systems performances |
| ICN-Fires | Institute for Nature Conservation Government. of Portugal | 2014 | Mapping methodology is based on the exploitation of Remote Sensing satellite imagery through automatic classification techniques. |
| ArcFuel | LIFE+ | 2013 | Fuel map computation methodology |
| EUFODOS | EC FP7 | 2013 | Assessment of forest damage. |
| FIRESMART | EC FP7 | 2012 | Identification of obstacles to the effectiveness of forest fire preventive measures, and recommendations to integrate prevention practices in regular forest management plans. |
| SAFER | EC FP7 | 2012 | Public awareness on the potentiality EO satellite images<br>Provide a rapid mapping capacity in response to disastrous events. |
| SIGRI | ASI (IT) | 2012 | Daily hazard index, fuel reduction map, burn scar mapping algorithms. |
| FUELMAP | EC-JRC | 2011 | Fuel types standardization, designing a novel classification approach adapted to the European landscapes |
| MOVE | EC FP7 | 2011 | Methodology for the measurement and assessment of vulnerability to natural hazards in Europe's regions. |
| FIREPARADOX | EC FP6 | 2010 | Definition of new practices and integrated management policies to prevent and fight fires most effectively. |
| RISK-EOS | ESA | 2008 | Example of operational servicing capacity, which benefit of Earth Observation capabilities in combination with other data sources and models for supporting the organizations and institutions mandated for the management of Natural Hazards. |
| ITALSCAR | ESA on behalf of ASI and the Italian Civil Protection | 2001 | Test of Burn Scar (Burned Area) mapping algorithms for incorporation in the national law no. 353/2000 on Forest Fire Fighting |

Table 4.1-2 provides a summary of products delivered during the PREFER demonstration phase. TRL (Technology Readiness Level) is also shown for each product.

Thanks to research activities, and the validation and demonstration most of the PREFER products have reached and eventually exceeded TRL 7.

A few products require some additional research effort in order to reach a TRL value suitable for operational applications. However, as users have stressed the need for new product being tested during 2-3 years before

being accepted in their operational procedure, their experience with PREFER products during the demonstration phase is not long enough to make the new products exploited by users.

In the peculiar case of the Vulnerability map and Soil Erosion map products, further research activity is needed in order to improve the definition and the consistency of input parameters needed.

Concerning the 3D Vegetation Volume loss (3Di) index the low TRL value is due to the difficulty to create the index. PREFER's 3Di product is interesting but expensive, with respect to current results, as it requires availability of very high spatial resolution Digital Elevation Model (DEM) and stereoscopic or interferometric pairs to assess the canopy's height. Keeping in due account the severe radar drawbacks in presence of sparse vegetation, referred to below, the detection and measurement of 3D volume losses in dense forest environments with Sentinel-1 worth further investigation.

**a) Validation**

Deliverable D41.2 (PREFER Products Validation report) is devoted to describe the results of the PREFER validation activity. All the products have been subjected to validation by comparing them with similar products provided by users or computed by using different source of data.

However, it should be taken into account that, due to the novelty of some of the PREFER products no comparison is possible for them. This is the case of: Fire Vulnerability map, Fuel reduction map, Prescribed fire maps, Damage Severity map, soil erosion susceptibility map, 3D Volume loss.

In other cases, the comparison could be made with similar information of equivalent or lower quality (e.g. lower spatial resolution). This is the case of: Fuel map, Burned areas, Daily Fire Hazard map.

In the case of Post-fire vegetation recovery maps, validation was performed by checking that areas, previously damaged by fire, were characterized by an increase in GEMI (Global Environment Monitoring Index) vegetation index value (extracted from EO).

The validation based on the comparison with users held information is frequently purely qualitative, due to the poor accuracy of the information available to the users. This is the case of:

- burned areas. The accuracy of GPS measurements depends on the possibility of reaching the burned area with the GPS receiver, and the availability of signals not spoiled by multipath (in case of steep lateral topography, as in canyons) nor severely attenuated or even zeroed by dense canopy (in forests). Furthermore, GPS measured perimeters typically concern small percentages of medium sized fires (a few hectares), whereas very small fires and very large fires are not measured.
- daily fire hazard index. Users often use level of hazard on province (county) scale corresponding to hundreds or thousands of pixels of the PREFER maps.
- burn scar maps based processing SAR images by multi-temporal and contextual algorithms, presented high rates of omission error (with respect to the spaceborne truth constituted by moderate and high resolution multispectral information) and did not pass validation. As best results were obtained over microwave reflecting canopies of densely vegetated, timber tree areas, lack of robustness in scattering coefficients appeared to be associated to eventually inappropriate wavelength-footprint-texture combinations. Failure of to achieve validation explains with (i) the low-to-nil sensitivity of radar backscattering to changes in open areas with little or sparse vegetation, pastures and grassland, prevailing in the areas dealt with, and (ii) the insufficient number and the odd space-time distribution of high resolution (20m) SAR datasets over the test areas. The main drawback of satellite radar assessments stays with the need of independent ancillary information to qualify the type of change detected, a problem usually overcome in multispectral images both in contextual and in multitemporal mode.

Previously, at the end of research activity (Del 32.2, Information Support to Recovery/Reconstruction phase research report), the development of the biomass burning aerosol product was stopped since no user declared

interest in this product. A few users looked eventually interested in CO2 emissions by fires, but this parameter fell out the scope of the fire aerosol emissions product.

Concerning the products validation, exceptions concern:

- The innovative product "Volume loss and Soil erosion" (REC-3DFDA), which was shown to be technically feasible but was demonstrated at high resolution only (Sentinel 2A). Indeed, REC-3DFDA requires availability of high-precision/high-resolution DEMs by stereoscopic or interferometric pairs, and is best exploited with very-high resolution (VHR) post-event satellite images that could not be acquired during PREFER.
- Biomass Burning Aerosols did not raise any valuable interest in the broad target user group of PREFER, composed of Civil Protections (Portugal, Italy and France), Fire brigades (Italy, France, Spain and Greece), Meteorological services (Italy, France and Greece), Environmental agencies (Spain), and applied Research institutes in Forestry and Agronomy, Environmental and Geological Sciences in the five countries. In lack of interested end-users, the product was not further developed.

### b) Demonstration

All products (Table 4.1-2) passing validation entered the demonstration phase. The results of activity are described in deliverables D4.2.2 (Demonstration Report), D4.2.3 (Information Support to Preparedness/Prevention Phase Service - demonstration products) and D4.2.4 (Information Support to Recovery/Reconstruction Phase Service - demonstration products). Products were tested using the online PREFER service and tests were linked to the pilot areas of the project (Table 4.1-3). Testing was performed by members of the UAB (User Advisory Board, Table 4.1.4) starting from the training event organized in Coimbra, Portugal in June 2015.

Tests continued till the end of the fire season (October 2015). The end users were provided with updated information for the areas of interest during the entire demonstration period. Users were supported in testing by the local national PREFER partners.

The demonstration of Prescribed Fire maps will continue until end of March 2016.

Due to data availability restrictions (in particular to the required ancillary data) not all products were available for testing over all the test areas. However all validated PREFER products were tested at least in one pilot area and in cooperation with at least one end user organization.

It has to be mentioned that beyond the product suitability and usefulness to the end users the tests included evaluation of usability of the web-based PREFER service, and the related quality.

*Table 4.1-2: PREFER Products validated and delivered during the demonstration*

| Products | TRL |
|---|---|
| Yearly Fuel Map (YF) | 8 |
| Daily Fire Hazard Index (DFHI) | 8 |
| Yearly Fire Vulnerability Map (SE) | 6 |
| Yearly Risk Map (SR) | 6 |
| Seasonal Fire Hazard Map (SFH) | 8 |
| Fuel Reduction Map (FR) | 8 |
| Prescribed Burning Map (PF) | 8 |
| Burn Scar Map HR (BSHR) | 8 |
| Burn Scar Map VHR Optical (BSVHR) | 8 |
| Post-Fire Vegetation Recovery (PFVGR) | 8 |
| Damage Severity Map (DSI) | 8 |
| 3D Fire Damage Assessment (Volume loss) (3DI) | 4 |

| | |
|---|---|
| Soil Erosion Susceptibility (SESI) | 6 |

Table 4.1-3 synthetically provides, for each of the 5 test areas, the list of products which have been delivered during the demo. Further to the demonstration products being delivered over 2 PREFER's test sites, the 3DFDA product was delivered upon user's request over the Noce River Basin in the Basilicata Region of Italy, and over a Copernicus EMS EMSR127 fire affected AOI in Andalusia, Spain using Sentinel-2 data.

*Table 4.1-3: List of the PREFER products delivered during the demonstration phase for each test area.*

| Test Areas | | Preparedness/Prevention Service | Recovery/Reconstruction Service |
|---|---|---|---|
| Minho region (PT) | | Fuel Map<br>Daily Fire Hazard Index<br>Fire Vulnerability Map<br>Seasonal Risk Map<br>Seasonal Fire Hazard Map<br>Fuel Reduction Map<br>Prescribed Burning Map | Burn Scar Map HR<br>Burn Scar Map VHR Optical<br>Post-Fire Vegetation Recovery<br>Damage Severity Map<br>Soil Erosion Susceptibility (SESI) |
| Andalucia region (SP) | | Fuel Map<br>Daily Fire Hazard Index<br>Fire Vulnerability Map<br>Seasonal Risk Map<br>Seasonal Fire Hazard Map<br>Fuel Reduction Map<br>Prescribed Burning Map | Soil Erosion Susceptibility (SESI) |
| Sardinia region (IT) | | Fuel Map<br>Daily Fire Hazard Index<br>Fire Vulnerability Map<br>Seasonal Risk Map<br>Seasonal Fire Hazard Map<br>Fuel Reduction Map<br>Prescribed Burning Map | Burn Scar Map HR<br>Burn Scar Map VHR Optical<br>Post-Fire Vegetation Recovery<br>Damage Severity Map<br>3D Fire Damage Assessment Map and Soil Erosion Susceptibility (SESI) (on an area in Basilicata region) |
| Peloponnesous Region (GR) | | Daily Fire Hazard Index | Burn Scar Map HR<br>Burn Scar Map VHR Optical<br>Post-Fire Vegetation Recovery<br>Damage Severity Map |
| Corsica region (FR) | | Daily Fire Hazard Index | Burn Scar Map HR<br>Burn Scar Map VHR Optical<br>Post-Fire Vegetation Recovery<br>Damage Severity Map |

Table 4.1-4 below provides the list of users involved in the product demonstration. Representatives of the same institutions were involved in the training session organized in Athens (February 2015) and in Coimbra (June 2015).

*Table 4.1-4: List of institutions involved in the PREFER demonstration activity and the corresponding products of interest.*

| Institution name | Country | Products evaluated (see Table 4.1-1) |
|---|---|---|
| Basilicata Region Civil Protection | Italy | SESI, SE |
| Sardinia region Civil Protection | Italy | YF, DFHI, SE, SESI |
| National Republican Guard (GNR) | Portugal | DFHI, SE |
| National Authority of Civil Protection (ANPC) | Portugal | DFHI, BSHR, PFVGR |
| Institute for Nature Conservation and Forests (ICNF) | Portugal | FR, PF, PFVGR |
| Agencia de Medioambiente y Aqua de Andalucia | Spain | YF, DFHI, BSHR, SESI |
| Aristotle University of Thessaloniki | Greece | YF, BSHR, DFHI |
| Balcan Environment Center | Greece | YF, SE, SR, DFHI, BSHR |
| NCSRD | Greece | YF, SE, SR, BSHR, DFHI |
| SIDS2B | France | YF, SE, SR, SFH, DFHI, SESI, DSI |

Fig. 4.1-1, shows the distribution, between the different test areas, of the total number of products delivered during the demonstration activity. The larger number of products for the recovery phase computed for the Portugal with respect to the other test sites, is due to the large number of fire events occurred in 2015 in the Minho region. This resulted in releasing a larger number of damage severity maps. Indeed, one DSI (and BSI and DNBR) map is provided for each single fire having burned an area larger than 10 hectares.

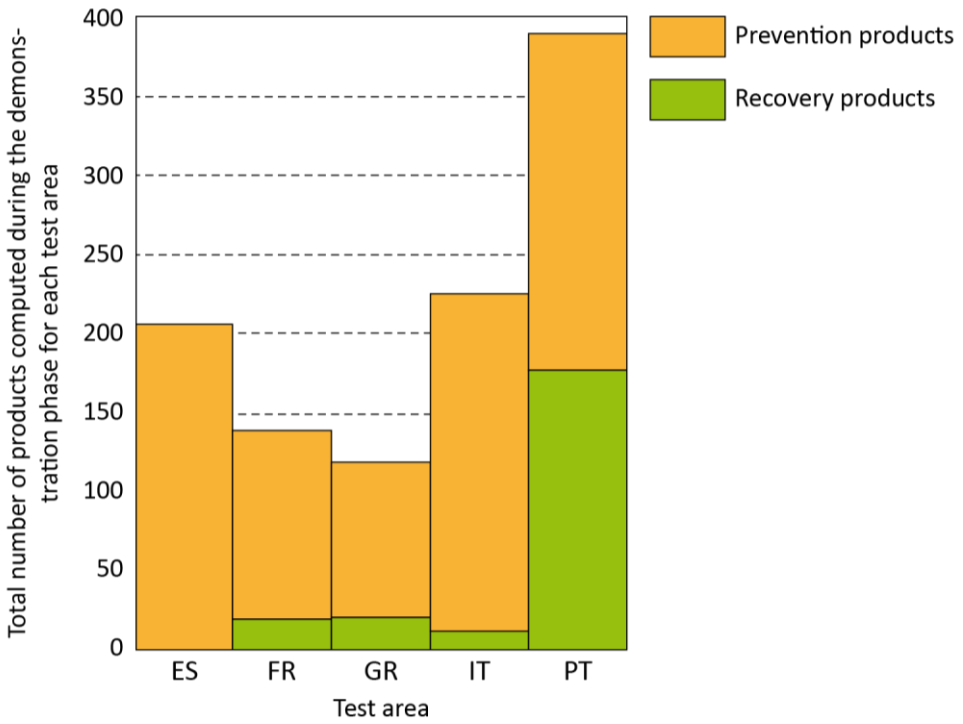



*Figure 4.1-1: Number of the products computed during the demonstration activity for each test area, for the two PREFER Services.*

Table 4.1-5 shows the amount of satellite images used during the validation and demonstration activities.

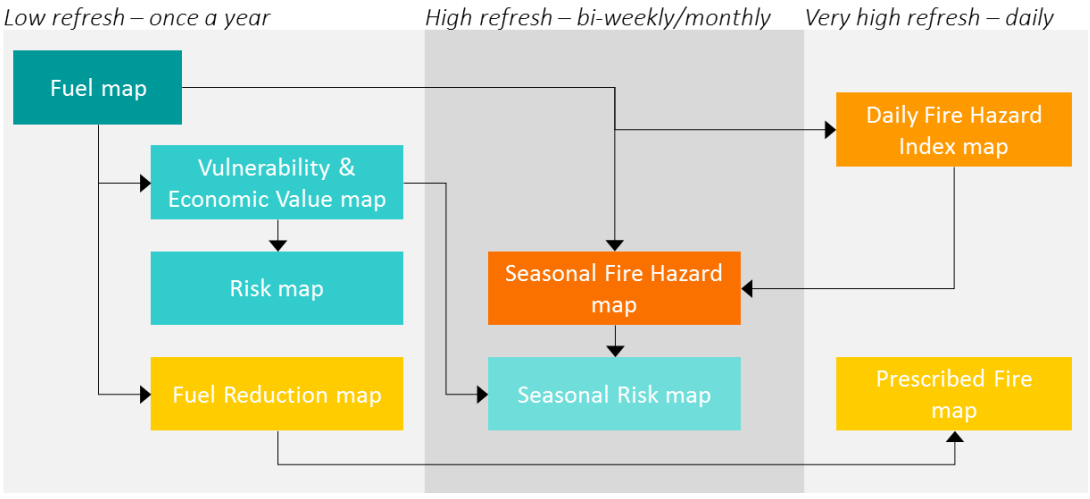
*Table 4.1-5: List of images used in the validation and demonstration phases.*

| Dataset Title | Images |
|---|---|
| Archive_rush_Optical_HR1 | Rapid-Eye (2) |
| Archive_standard_Optical_HR1 | Rapid-Eye (89), SPOT 5 (12) |
| Archive_standard_Optical_VHR1 | Pleiades (7) |
| Archive_standard_Optical_VHR2 | Kompsat-2 (14) |
| Archive_standard_SAR_VHR2 | CSK (4) |
| New acquisition_standard_Optical_HR1 | SPOT 5 + Rapid-Eye (63) |
| New acquisition_standard_Optical_VHR1 | Pleiades + WorldView-2 + GeoEye (9) |
| New acquisition_standard_Optical_VHR2 | Kompsat-2 (5) |
| New acquisition_standard_SAR_VHR2 | CSK (26) |
| Archive_standard_Optical_HR2 | Landsat (150), SPOT 4 (11) |
| MODIS | ~820 |

The final synthetic comment on each PREFER product are given below. Before proceeding, it is worth recalling that the PREFER products are intimately inter-linked as depicted in Fig. 4.1-2. Indeed, all products related to the:

- prevention/preparedness phase take the Fuel Map product as an input;
- recovery phase take Burn Scar vectors (Burned areas) as an input.

**Prevention/Preparedness Phase**




**Recovery Phase**

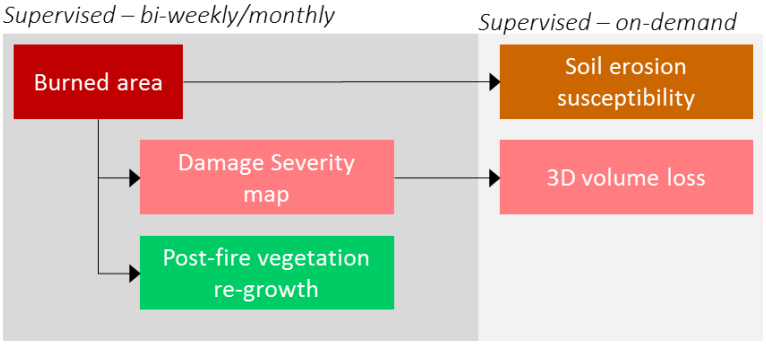



*Figure 4.1-2: Flow and inter-links of the PREFER products.*

## Fuel map

The validation and demonstration of the PRE-SF product was carried out during spring and summer 2015 (May to October) over three test sites, Italy (Sardinia), Portugal (Minho) and Spain (Cádiz). Based on the extent of the area of interest, Landsat -8 and RapidEye images were used. This product was evaluated by the Environment and Spatial Planning of the Andalusia Regional Government.

Synthetically:

- the Fuel Map has been developed following an adaptation of the method set by the JRC's ArcFuel project the coarse scale and the intended use of the product;
- the identified Fuel Types should be considered as the starting point for the development of further improved products, thanks to the incorporation of Copernicus Sentinel-2 satellites' extended capacity into the processing chain;
- additional work shall be carried out in order to assess the quantitative properties of fuel types. In the present version, however, the fuel type characteristics are based on JRC fuel type definition;
- the development of fully operational fuel maps, capable to be ingested by for example fire behavior modelling software at finer scales, may consider the reference fuel classification scheme should be closely focused on the intended local application.

## Daily Fire Hazard Map

The validation and demonstration of the PRE-DFH product was carried out during the 2015 (January to October) over the 5 test sites of the PREFER project. From the demonstration activity we can conclude that:

- during the 4+ months covered by demonstration between June 24th and October 31st maps were unavailable during 2 days only, and because of external reasons (unavailability of Meteo-data provided by the Air Force);
- as indicated by the Sardinia Regional Civil Protection, the index proved capable of capturing the temporal and spatial distribution of fire hazard in about 80% of cases;
- the definition of thresholds used to identify the different hazard levels seems appropriate, if compared with the number of pixels associated to each class and the corresponding maps provided by EFFIS.

## Seasonal Fire Hazard Map

This innovative index, was designed to take advantage of the increased need of speed in the availability of fire occurrences information by local authorities or the availability of hot spots information based on satellite images. Along with meteorological data, it highlights the characteristics of the actual with respect to the previous fire season, under the **human and climatic behavior** standpoints.

The map, computed bi-weekly, displays the spatial evolution of fire hazard with respect to onset of the fire season, that is the starting season fire hazard map based on historical data.

This information is considered by Users potentially effective to relocate human resources and extinguishing means over the territory in view of potentially impending emergency peaks.

The product was considered interesting by the Andalusia Medio-Ambiente Agency and the Sardinia Regional Civil Protection.

## Yearly Vulnerability & Economic Value map

The Vulnerability map were evaluated by Basilicata Regional Civil Protection and the Portuguese National Civil Protection. The production of vulnerability maps depends on the availability of appropriate input data for the assessment of each component, which varies by country and/or by region. Whenever possible, worldwide or European datasets were used, to ensure the consistency of the procedure throughout the whole study area.

Thanks to the request by newly added Basilicata user it was possible to demonstrate the map in an additional area to the initial five test areas:

- the procedure developed (stepwise approach) was easily ported onto the new test area, with only a few adjustments required. Required data on the "coping capacity" were not available and complete during the demonstration period, thus demonstration focused on the exposure and sensitivity components. This activity also confirmed that the procedure may apply satisfactory to different geographic areas, provided that sufficient and reliable data are available.
- even though some data are missing - as it has occurred with the coping capacity data as above - the other components of vulnerability can still be computed, and prove useful for the users.
- although vulnerability map is provided once a year, before the start of the main fire season, it can be updated every 6 months, considering the seasonal changes of fuel. The other variables (population, protected areas, roads and buildings, coping capacity data) can be updated according to the availability of new data.
- the economic value maps present only the monetary value of some of the elements exposed for which reliable economic data exist. Similar as for the other components, the processing chain includes the possibility to integrate additional or better data as they become available.
- the vulnerability maps can be further improved by incorporating in the definition of vulnerability the socio-economic and cultural dimensions (primarily non-spatial data), as requested by some users.

### Seasonal Risk map

The map was considered simple and totally dependent on the quality of the input maps (vulnerability and hazard). If the input layers are consistent, the risk map interpretation should be reliable. The updated risk maps for the AOI of Italy and Portugal made in early September 2015 show no significant changes confirming the consistency and the reliability of the product. However, this maps, **originally designed to be computed twice** during the fire season could be more effective in representing the evolution of the risk during the season **should be computed with higher frequency**, in particular, with the same frequency of the seasonal fire hazard maps, that is every 2 weeks.

### Fuel Reduction map

The Fuel reduction maps were validated considering the areas affected by fire events in the years not considered for computing the map. Most fires (84%) occurred in the areas defined at **moderate or high level of priority**. Based on fire behaviour simulation it was also possible to demonstrate that this product can spatialize the fire hazard and give the possibility to mitigate the fire effects, if fuel load reduction is applied.

Using same meteorological data as in the daily fire hazard index, it would also be possible constraining the expected spatial distribution of Rate of Spread (ROS) and Flame Length (FL) daily, as suggested by the Fire Brigade (SDIS-2B) of Corsica.

### Prescribed Fire map

The demonstration activity showed that:

- the automatic procedure, implemented to generate the product, is robust enough. In fact, during the 157 days of the partial demonstration period (1st of October 2015 – 5th of March 2016) the percentage of the produced maps is about 83% (as a consequence of the on-time unavailability of meteo-data).

Portugal is the only country, of those involved in the PREFER Project, that exploits the prescribed burning technique to reduce the fuel load as a prevention method to mitigate fire hazard.

The Instituto da Conservação da Natureza e das Florestas, provided the polygons where the prescribed burning were performed in 2014 and 2015. Such polygons fit very well the GeoSpatial Hazard classes described by the FR

map, as over than 97% of these polygons are classified as high or very high levels. The comparison of the date of the prescribed burning action performed on the field was with the weather conditions predicted by the PF maps provide good results. In particular:

- the 12th of January, both polygons lie in the areas predicted by the PF map;
- the 28th of January, the five available polygons intersect or lie in the areas predicted by the PF map.

**According to the ICNF, Prescribed Fire maps will be essential** for planning fuel load reduction over areas larger than currently done. In fact, the current application of prescribed fires on small areas does not look effective in reducing the incidence of fires in Portugal.

### Burned areas

Before PREFER this product had been successfully tested and validated only over (almost) the whole of Italy. In the framework of PREFER the algorithm has been generalized with targeting worldwide application. These products have been tested and validated on three test areas and demonstrated on four Mediterranean countries. The main results based on the statistical analysis of the burned areas (BS) detected for the year 2015 over the four test areas of France, Greece, Italy and Portugal can be summarized as follows:

- the product provides for immediate availability of quantitative burn scars. At the end of the fire season, this turns into quantitative figures of total burned areas and their distribution among different vegetation classes;
- the Portuguese user has shown - in a particular case where Copernicus-EMS was activated soon after the event in 2015 - that the PREFER results were obtained with significant advance and comparable quality;
- at present, the computational procedure is partially supervised. To become unsupervised, it will require quantitative initial information on the fire, which can be obtained either by satellite-based hot spot detection (on an EO-only configuration) or by ground-based fire services (in collaborative, compound EO-ground configuration).

### Post-fire Vegetation Recovery

The procedure to compute this product is mature and both users and the SAB suggested to improve the information content of the product. Indeed, the regeneration of vegetation is currently represented by a binary indicator, pointing to whether or not re-growth of vegetation has occurred for each analyzed pixels, without quantifying the level of re-growth. **For this product to become better suited to the user's needs, it was asked to include the following attributes:** pre-fire vegetation class, fuel content, fire date and damage severity, along with additional quantification by differential burnt/unburnt analysis in the same vegetation class.

This matter requires thoughtful revisit as the demand for the above parameters may not account for constraining differences in scale (product vs. land cover).

### Damage Severity indices (DSI, BSI, DNBR)

This product, use as input the burned areas described above and for all the fires larger than10 ha compute the level of damage by downloading automatically pre- and post-event Landsat8 images. During the validation and demonstration phases:

- the procedure which automatically downloads the burned areas (BSHR), then retrieves the information on the Landsat8 images needed to compute the indices, requested twice the intervention of the operator due to a failure in the internet connection at the DIAEE. This could be considered a good demonstration of the robustness and reliability of the implemented processing chain;
- the three indices provide very similar results, even if DSI slightly overestimate the vegetation damage;

- users have demonstrated, through their replies to three different questionnaires, a general high interest for this product but have not used it. This demonstrate that users are keen to trust and accept products that are already familiar to them in context of their daily operational activity and are more reluctant to new and innovative products and procedures. It has to be mentioned that this fact varies from country to country in the EU, even in consequence of the national/regional legislation and the presence of an entity committed to carry out the activity possibly supported by such product.

### 3D Damage Assessment (Volume loss and soil erosion susceptibility)

At the beginning of PREFER these products started their life at a very low Technological Readiness Level. Through state of the art analysis, methodological testing in different environments (including input layer availability) and finally production in the demonstration phase the products have evolved to become more robust, standardised. Moreover the products have migrated from a default status of VHR to HR products.

Furthermore, during the lifetime of PREFER their production has been facilitated by the appearance of RUSLE factors elaborated on a European scale in 2014 and 2015 and distributed via the JRC's European Soil Data Centre (ESAC). Through the availability of these factors and the access to Sentinel-2 data these products can now be elaborated in a matter of hours rather than days incorporating more RUSLE factors than previously. The availability of a better and high quality European-wide DEM would be a further improvement. The SESI (Soil Erosion Susceptibility Index) could now be made available during and/or very soon after a fire with the aim of monitoring an area's soil vulnerability to erosion and conversely vegetation recovery over time. This information could help in understanding the persistence or not of soil erosion risks. The product name remains as an "indicator".

3D volume loss indicators remain difficult to produce and will remain an axis of R&D in SERTIT into the near future developing the integration of new 3D data sources. Those 3Di products already elaborated are interesting but are expensive to produce, given results to date.

The SESI was highly appreciated by the Basilicata Region of Italy Civil Protection Office.

## 4.2 SERVICE AVAILABILITY & EXPLOITATION

Upon completion of PREFER, we can state that the project has achieved its main objectives, which were the "design, development, validation and demonstration of an “End-To-End“ Information System able to exploit the raw data from current Earth Observation satellites instruments to provide reliable information services for supporting prevention/preparedness and recovery phases of the Forest Fires emergency cycle in the EU Mediterranean Region".

It should be stressed that the PREFER system is an “operational system”, in the straightforward significance that it was given at the beginning of the work: a system able to process and to provide satellite based information timely, appropriately and directly to the applicant end user, according to the requirements, the specifications, and the validation outcomes of the latter.

Considering that, - on one hand - within the large product portfolio of PREFER there are products more or less mature, and more or less attractive for the individual Users and - on the other - Users can be more or less interested in individual products, and more or less prone or capable to introduce them in their daily work, it is worth stating that changing the way of working of the Users would be unrealistic goal to achieve. Overall, the PREFER “operation” is completed upon delivery of information, and once the User has been trained enough to be able to exploit it properly.

The PREFER Consortium is now highly motivated to pursue the objective of continuing the PREFER service delivery to users beyond the project's expired timeframe, and the exploitation of project intermediates (maps or data developed or retrieved for obtaining the final products) or final results is in the target of all participating teams.

Therefore, PREFER Consortium will undertake initiatives for commercializing the project results demonstrating to potential clients that:

- the products provided by the project are innovative and advanced with respect to the State-of-Art;
- scalable solutions customized to special user needs are possible;
- the information offered is cost-effective;
- the service provision infrastructure is user-friendly and flexible.

The main obstacles to give PREFER’s operations appropriate continuity beyond the end of the project remain:

- ⇨ the time required – measurable in years rather than months – to introduce changes in the procedures of qualified public users, but mainly
- ⇨ the difficulty the interested Users incur to pay or to retrieve economic support for ordering such products/services after their reliability is proven.

Aiming to keep the PREFER system alive and operational, the Consortium should agree on bearing the costs associated to demonstration(s) much longer lasting than the PREFER demonstration phase.

As illustrated in Tables 4.2-1 and 4.2-2 below, the effort in human resources and data costs needed to compute each product greatly varies as a function of refresh frequency, level of automation and type of satellite images needed. However, stretching the time of non-profitable operations beyond accountable sustainability is unachievable for the industrial component of the Consortium, which is a balanced merge of research centers/universities and private companies.

Being aware that most of users and (intended) potential customers are Institutions involved in the management of forest fires, and accounting for the possibility that some of the PREFER products may have impact on the Citizens’ security, **a subset of the product portfolio** - scaled upon the sustainable processing and computational effort - **will be released also during the 2016 fire season.**

*Table 4.1-1: List of images needed for generating the PREFER products.*

| Product | N. of Images/year | Needed images for a region like Sardinia |
|---|---|---|
| Yearly Fuel map | 4/1/42 | Landsat8 (4), Sentinel-2 (1) and RapidEye (42) |
| Daily Fire Hazard Map | 130 | MODIS images (1 - 2) |
| Seasonal Fire Hazard Map | 8 | Hot spot MODIS (1) |
| Vulnerability & Economic value map | **36** | **Spot (Necessary if needed layers are not available)** |
| Fire Risk map | -- | Based on PREFER products |
| Fuel Reduction Map | -- | No satellite images requested |
| Prescribed Fire Map | **4** | **VHR images in rush mode (1), not mandatory** |
| | | |
| Post-Fire Vegetation Recovery | 8 or 2 | Landsat8 (4), Sentinel-2 (1) |
| High Resolution Burn Scar | 36 or 9 | Landsat8 (4), Sentinel-2 (1) |
| Very High Resolution Burn Scar | **On demand** | **Quickbird, Ikonos, WorldView (1)** |
| Damage Severity Map | 36 or 9 | Landsat8 (4), Sentinel-2 (1) |
| 3D damage assessment – Soil Erosion | **On demand** | **Sentinel 2, Rapid Eye** |
| 3D damage assessment – Volume burned | **On demand** | **Stereo or interferometric pairs (Pleiades, Tandem-X) and Sentinel-1 (interfer) plus Sentinel-2 (impact) combinations. Could become a regular service.** |

*Table 4.2-2: List of PREFER products according with their refresh rate.*

| Delivery Frequency | Product (*format*) |
|---|---|
| Annual | - Annual Fuel Map (*raster*)<br>- Vulnerability & Economical Value Map (*raster*)<br>- Fuel Reduction Map (*raster*) |
| Twice a year | - Post-fire Vegetation Recovery Map (vector) |
| Bi-weekly-monthly | - Seasonal Fire Hazard Map (*raster*)<br>- Seasonal Risk Map (*raster*)<br>- High Resolution Burn Scar Map (*vector*)<br>- Damage Severity Map (*raster*) |
| Daily | - Daily Fire Hazard Index Map (during summer season) (*raster*)<br>- Prescribed Fire Map (during autumn-winter season) (*raster*) |
| On demand | - Very High Resolution burn scar map (*vector*)<br>- 3D Fire Damage Assessment Map (SESI = Soil Erosion Susceptibility, 3DI = Volume Loss Indicator) (*raster*) |

Aiming to ensure continued product computation and delivery, the Consortium plans to consider potential cooperation with JRC and the relevant EFFIS services.

*Table 4.3-3: List of the potential users of PREFER products.*

| Frequency | Prevention Products | Potential user |
|---|---|---|
| Products computed once a year | Fuel maps;<br>Vulnerability & Economic value maps;<br>Risk Map;<br>Fuel Reduction map. | - National/Regional Civil Protection;<br>- Insurance Companies;<br>- Forest Corps;<br>- Forestry and Agronomy Universities/Institutes;<br>- Environmental managers; |
| Products computed bi-week - monthly: | Seasonal Fire Hazard maps;<br>Seasonal Risk Maps; | - Civil Protection;<br>- Forest Corps;<br>- Fire Brigade;<br>- Disaster managers;<br>- Environmental managers; |
| Products computed daily | Daily Fire Hazard Index maps;<br>Prescribed fire maps | - Fire Brigade;<br>- Regional Civil Protection;<br>- Forest Corps;<br>- Landowners;<br>- Farming;<br>- Meteo services;<br>- Transports and viability;<br>- Local Municipalities;<br>- Citizens (as drivers, tourists, hikers, etc.);<br>- Disaster managers; |
| **Frequency** | **Recovery Products** | **Potential user** |
| Products computed bi-week - monthly | Post-fire re-grow<br>Burned areas<br>Damage Severity maps | - Forestry and Agronomy/ Environmental & Geological Universities/Institutes;<br>- Forest Corps;<br>- Environmental managers;<br>- Insurance Companies; |
| Products computed on-demand | 3D damage assessment<br>Very High resolution burned areas | - Forestry & Agronomy/ Environmental & Geological Universities/Institutes;<br>- Land Registers;<br>- Transports and viability;<br>- Forest Corps;<br>- Environmental managers;<br>- Insurance Companies. |

The PREFER product portfolio as expected addresses a wide range of users in the public and private sectors, as follows:

The **public sector** is the primary user segment concerning PREFER products, including:

- ⇨ Civil Protection Authorities (at all levels: national, regional, local),
- ⇨ Governments (at all levels),
- ⇨ Fire Services (Forest Corps, Fire Brigade),
- ⇨ Forestry Management Services,
- ⇨ Meteorological services,
- ⇨ Environmental Agencies,
- ⇨ Universities/Institutes (Forestry & Agronomy/ Environmental and Geological).

Information conveyed by these products serves the security of citizens and of the protection of the territory against forest fire hazards.

The **private sector** represents the secondary user's segment for PREFER products, including:

- ⇨ insurance companies,
- ⇨ infrastructures and transport companies whose business can be jeopardized by wildfires (railways, motorways, energy grids, oil & gas),
- ⇨ forest and agriculture federations and industry,
- ⇨ tourism and travel industry.

It is worth stressing further that, although the private sector has already been proposed EO-based products similar to those of PREFER, most potential customers are still reluctant in introducing the use of EO products in their usual working practices, and several years are considered as necessary to introduce such a change in the private sector.

The demand for wildfire management products is very high, given the magnitude of the wildfire issues in Europe at various degrees depending on countries and regions. However:

- ⇨ the actual addressable demand - users that are ready to pay for the services - is limited and scattered;
- ⇨ the capability of EFFIS of addressing this demand are limited by the absence of up-to-date products at high spatial resolution which can better address users' needs at regional and local scales.

In relation to Copernicus EMS core services, we may note that PREFER's products are:

- ⇨ complementary to the Copernicus EMS Rapid Mapping in terms of Early Warning and thorough, widespread burn scar (fire delineation) mapping and
- ⇨ complementary to Copernicus EMS Risk & Recovery with the potential of providing relevant risk data related to potential fire hazards and exposure plus recovery mapping more or less systematically depending on the product over large areas relating to burn scars, fire severity, potential soil erosion and landslide risks.

The project exploitation plan includes the potential impact of exploiting its products within this core service. Overall, we think that PREFER has the potential of covering fires more systematically than most EO based fire information services to date.

PREFER entering into a fully operational mode can happen via different operating models or scenarios. Among them, two possibilities, of product generation prevail:

- ⇨ on already established areas (at predefined temporal intervals);
- ⇨ upon user's requests on specific areas (on demand).

Furthermore, Public-Private Partnerships will be investigated considering that:

- the Service Providers of PREFER get market access in exchange of a commitment to maintain the products. In particular both the RTD centers and the industry can exploit the products and deliver added value services increasing the effectiveness of wildfire management in all its phases (prevention, tactical, recovery);
- the European Commission and the JRC are empowering capacity of the Copernicus EMS EFFIS and stimulate the EO market to reach out to new segments for further growth;
- the users can rely on a wide range of wildfire products delivered through downstream services by Copernicus.

The **project strategy** to continue to generate and deliver the products and supporting the users in the effort to integrate the products into their flow of work will be twofold:

- firstly, the Consortium will continue to elaborate and submit project proposals in response to International calls covering the broad "Fires" subject;
- secondly, the PREFER project partners will continue to cooperate with local users to keep them interested in testing and adopting the existing and improved PREFER products. This approach has already been implemented by GMV which has signed a MoU with Regional Ministry of Environment and Territory and the Environment and Water Agency of the Andalusia to continue testing some PREFER products (involving a number of partners, SERTIT, GMV, UNIR1); whereas UNIR1 will continue cooperating with the Sardinia Civil Protection providing them with the Daily Fire Hazard index for the time needed up to final adoption.

The exploitation strategy foresees that products can be bought by each User through an **annual subscription** related to a region (Area of Interest) having the typical size of a PREFER demonstration area. In the table below the tentative prices of annual subscription for most of PREFER products are reported. The service subscription includes the Mobile App, the access to the web Interface and the access to the WMS service.

*Table 4.4-4: PREFER products pricing list.*

| Product Type | Number of products per year per AOI | Annual subscription price (€/year) |
|---|---|---|
| Fuel Map ( first map) | 1 | 2200 |
| Fuel Map ( update) | 1 | 3400 |
| Seasonal Fire Hazard Map | 6 | 2350 |
| Seasonal Vulnerability & Economical Value Map | 1 | TBD |
| Seasonal Risk Map | 6 | TBD |
| Daily Fire Hazard Index Map | 4 months / daily during summer + 1 fuel map | € 12.600 |
| Prescribed Fire Map | 4 months / daily during winter | € 9.200 |
| Post-fire Vegetation Recovery Map | 2 | € 12.700 |
| Burn Scar Map HR | 3 | € 17.400 |
| Burn Scar Map VHR | 1 | € 9.200 |
| 3D Fire Damage Assessment Map | On request | € 13.500 |
| Damage Severity Map | 3 | € 4.200 |
| SESI (Soil Erosion Susceptibility Index) | 1 | € 5.300 |
| Fuel reduction map | 1 | € 4.000 |

PREFER results are expected to be beneficial in numerous ways to the whole Consortium and to individual partners.

Individually, National Research Institutes (UNIR1, UCO, SERTIT) will benefit from scientific and technological advancements. From a scientific point of view, the ability to process large amount of multispectral and SAR EO data, covering different scales and areas and/or long time periods, will provide scientists with unique opportunities to investigate wildfire phenomena with potential hazardous consequences. In particular:

- UNIR1 has developed automated procedure allowing to handle large amount of images (SEVIRI, MODIS, Landsat-8) for real-time processing aiming at change detection analysis, medium resolution fire hazard index computation, Hot Spot detection. The knowledge acquired in the field through the applied research activity has also a significant impact on the content of the courses taught at the university.
- UCO has developed an operational procedure in order to automatize the whole process of data analysis and creation of maps of vulnerability and economic value, to facilitate the transfer of knowledge and the

development of the products in a timely manner. With this efficient and sustainable service, specifications and procedures can be applied to other areas in Mediterranean Europe and for different timeframes, according to the requirements of potential users. The knowledge acquired in the field through the applied research activity (combination of different datasets and variables, obtained from diverse sources and at different scales and/or formats, definition of processing chain for data analysis in order to ensure the consistency of the products) has significant impact on the content of the courses taught at the university.

- SERTIT as a self-financing university service will develop and cooperate in developing and exploiting more operational product work-flows for mapping fires, their consequences and impacts to expand the Copernicus EFFIS portfolio. Also SERTIT will investigate how to exploit the systematic burn scar and severity mapping in Copernicus EMS Rapid Mapping on one hand and soil erosion and 3D impact assessment products within Risk & Recovery on the other.

KEMEA, as a partner involved in security policy related to natural hazard emergency management will evaluate in cooperation with relevant organizations how to take-up the PREFER products and services for fire management in Greece. Forest fire management is performed by the services of the Greek Ministry of Interior (MoI) and therefore KEMEA may facilitate discussions and planning and furthermore will be able to document any relative future policy or decision of the Ministry. The scientific advancements on the products design, the identification of the users' requirements for introducing such products into users' operational practices through the development of standard operating procedures and the validation of the products and services will strengthen the role of KEMEA as a consulting organization to the Greek MoI.

The Industry (CGS, GMV) and SMEs (IESC, STW) benefit in different ways from participating in the project, and from its outcomes.

- CGS, having as core business the development of small, low cost commercial satellites for earth observation applications for disaster management (including innovative Cubesat Constellations) will benefit from the experience gained in the design and development of the PREFER service provision infrastructure and from the direct interaction with the end users involved in the project. This experience will be exploited in the company strategies in view of the future spacecraft missions.
- GMV specialized in the processing and analysis of EO imagery for multiple purposes, will benefit from the possibility to expand their advanced capability to process Sentinel data, adding services & products to their portfolio. This will strengthen the European leadership of GMV as advanced EO-based products and service providers. They will both benefit chiefly from experience gained in design of the overall system supporting the products portfolio prototype. Particularly, in the case of GMV, the refinement of the technical & methodological approaches along with the progress towards more operative products will consolidate its position as service provider of satellite data value added products in the field of forestry.
- STW as an SME that is developing Command and Control applications for first responders will be able to enhance its product portfolio with forest fires related products that will act as decision support tools helping first responders taking the right decisions the right time. Such tools provide market differentiation features to the existing STW products.
- IESC, by exploiting its patented techniques will be able to further develop new algorithms and new products, offering a larger portfolio of high added value products, validated and characterized by TLR levels higher than 7. IESC will be able to provide customers with a set of crucial information to assess the fire damages on vegetation and to follow-up the ecosystem regeneration of burnt biomes. This will expand the EFFIS products and services portfolio, enlarging the number and types of potential users in Europe.

## 4.3 PREFER WEBSITE

All the material published throughout the PREFER project classified at PU (public) dissemination level will be made available without restriction on the PREFER website (www.prefer-copernicus.eu).

The website will be maintained and updated **up to end 2016**.

Products delivered through the project geoserver at the address **http://prefer.cgspace.it/main/login** will be accessible to authorized users provided with credentials.

To obtain the credentials the interested user is addressed to: *ltampellini@cgspace.it* or *mvimercati@cgspace.it*.

The SAB comment concerning the possibility to allow a bi-directional Provider-Users interaction during the operations is potentially groundbreaking as it could allow the continuous validation of products and the improvement of the service infrastructure at once. This possibility could be further improved by developing the smartphone app created by SATWAYS, with the possibility of uploading messages or data (photos, videos, etc.) to the PREFER web server. However, this idea calls for the significant increase in the project service infrastructure dimension, which would be realistic only if the Consortium will be able to find fresh funding by national and/or international sources.

## 4.4 FURTHER DEVELOPMENTS AND FUTURE ACTIVITIES

PREFER aims at advancing the operational capabilities of Copernicus-EFFIS by integrating State-of-Art technologies and products developed by previous FP7 projects, supporting the prevention and recovery phases of the forest fires management.

In particular, the integration of the PREFER products, will allow EFFIS to scale up its current capabilities in forecasting and monitoring of wildfires to different scales, i.e. local, regional and national scale in order to:

- satisfy the needs of local institutions like regional Civil Protection and Forest Corps, National Fire Corps, Regional and local Fire Brigades;
- strengthen trans-regional or trans-national cooperation in forest fire management and forest protecting by providing standardized and systematically updated information at best refresh rates;
- increase the accuracy of the post-fire-season statistical information at local/regional/national scale.
- allow users to know, test and validate the products provided by the project and, when convinced, adopt such products in their own operational procedures, through Copernicus-EFFIS;
- improve the accuracy of their own hazard, risk and vulnerability maps with the objective to reduce the costs of fire management activities;
- stimulate the adoption of satellite based products in fire management;
- stimulate the development of new products based on satellite images and ground-based information.

Herein for each PREFER product is suggested the future activity, possibly within a H2020 project framework, which could be carried out to improve the products or incorporate the use of the Sentinel satellite series imagery (Table 4.4-1).

## Expected evolution of products for prevention/preparedness

### Yearly Fuel Map

Despite of the maturity this product attained in PREFER project, there is still scope for improvement:

- First, in what it refers to better assignment of physical characteristics of the described fuel types. To this purpose the potential contribution of more detailed standard classification schemes, such as the 40 fuel models classification by Scott and Burgan (Scott, Joe H.; Burgan, Robert E. 2005: http://www.treesearch.fs.fed.us/pubs/9521), where distinct distributions of fuel loading found among surface fuel components, size classes, and fuel types are described, will be assessed.
- In addition PREFER is an opportunity to optimize the generation of fuel maps to serve EFFIS. This means that, in comparison with PREFER, the fuel map product will be up-scaled and computed over larger pilot areas. Sentinel-2 potential advantages, and its complementarity with other satellites (e.g. Landsat 8) will be tested to this aim.

### Daily fire hazard and Seasonal fire hazard mapping

Both products have been validated and released systematically during summer 2015. They could be further improved by:

- expanding the area covered by each map. In particular, the possibility to compute both maps at national level will be explored. The main limit could be represented by the computation time needed to compile such maps on a country level scale;
- evaluating the use of Sentinel-3 images, beside of MODIS;
- continuing to provide maps to the users, aimed to provide them with the appropriate continuity and time to have them accepted into the standard operational procedures.

### Seasonal Exposure (Vulnerability & Economical Value) Mapping and Seasonal Risk Mapping

The process to compute these products, is running in partly supervised mode, as it requires supervised assessment and pre-processing before the map-making computing procedure runs automatically. The procedure can be customized according to the users' request. The complete processing chain was tested over Basilicata and Corsica with data provided by the users. These products could be ranked at TRL 5. Therefore some effort will be devoted to:

- raise the TRL of these products to 7 or more;
- analyse with users which socio-economical aspects worth being introduced in the computation of the product;
- demonstrate the sustainability of increasing the dimension of the area covered by the products.

### Fuel Reduction mapping and Prescribed Fires mapping

The reliability of the processing chain in charge of the production of these two products has been demonstrated during the validation and demonstration phases of the PREFER project. These products have been computed on three test areas (Andalucia, Sardinia, Minho). Therefore, further effort will be devoted to:

- increase the TRL of these products by providing them to the users during the next year for future inclusion in the standard operating procedure;
- enlarge the area covered by these maps;
- develop a new product based on the fuel map and weather conditions which provides, daily, a spatialized information on the fire Rate of Spread (ROS).
- add further information - like expected emissions in atmosphere - to quantify the environmental consequence of the use of the prescribed fire practice.

## Evolution of products for recovery/damage assessment

### Burn Scars mapping

The evolution of this product will consist in:

- providing the product to the users to allow them to evaluate the cost-benefit of adopting such information to assess the characteristics and amount of the burned areas during and at the end of the fire season;
- integrating Sentinel-2 data into the processing chains;
- analysing the feasibility of the product up-scaling (input availability, computation time, etc.).

### Post-fire vegetation recovery

This product is based on post-fire vegetation recovery, product developed, demonstrated and validated in the framework of the FP7 PREFER project. The evolution of this product will consist in:

- R&D activity for a quantitative assessment of the vegetation regeneration (identification of pre-fire vegetation class, fuel content, fire date and damage severity, quantifying the vegetation recovery phenomena using vegetation index or by comparison with unburned control point located in the same pre-fire vegetation class, etc.);
- analysis of product upscaling feasibility (input availability, computation time, refresh frequency, etc.);
- use of Sentinel-2 images in input to the elaboration process.

### 3D Fire Damage Assessment Map

Both SESI and 3Di have been computed on three different test areas, demonstrating their usefulness. Therefore, further effort will be devoted to:

- increase the TRL of these products by providing them to the users in order to give them the needed time to include these new information in their normal operational procedure;
- enlarge the area covered by these maps.
- further develop of the soil erosion susceptibility index with emphasis on updating the RUSLE mapping by:
    - ⇨ using Sentinel 2 (10 - 20 m) data;
    - ⇨ using and adapting JRC's RUSLE factors (R and K) with respect their resolution;
    - ⇨ generate RUSLE LS factor from EU DEM and/or SRTM models. Perhaps integrate Sentinel-1 DEM at 20m resolution if results are satisfactory;
    - ⇨ explore SESI change detection in order to enhance final products;
    - ⇨ aim to offer a product option that is robust and easily, rapidly produced with a TRL of 7 perhaps integrating many JRC RUSLE factors except C and perhaps LS (vegetation cover) while also offering ad hoc VHR products.
- develop a landslide susceptibility index for fire affected areas taking Burnt Area and Severity Damage products into account;
- 3D Damage Assessment Indicators: evaluate the feasibility, sustainability and cost-benefit of computing a volume loss index through:
    - ⇨ investigating the possibility to highlight 3D volume losses with S-1 pre- and post-fire pairs,
    - ⇨ using Severity Damage Map for volume loss correlation,
    - ⇨ investigating the integration of CORINE LAND core service High Resolution Forestry Layers into damage assessment mapping.

**Severity damage map**

Main expected innovation on the current product are:

- damage assessment maps by introducing the estimate of the amount of emission in the atmosphere due to burned biomass;
- feasibility of fire damage severity all over European countries and large areas (from local to regional and national scale);
- use of Sentinel-2 images in the computation of the level of damage, and
- provision of product to Users during the fire season, aimed to validate it and stimulate the users' interest;
- integrating Sentinel-2 images in the computation of the level of damage.

*Table 4.4-1: PREFER Products evolution for exploiting Sentinel imagery*

| Products | EO image current version | EO image new version |
|---|---|---|
| Yearly Fuel Map (YF) | Landsat8 | Sentinel-2 |
| Daily Fire Hazard Index (DFHI) | MODIS | Sentinel-3 |
| Yearly Fire Vulnerability Map (SE) | N/A | N/A |
| Yearly Risk Map (SR) | N/A | N/A |
| Seasonal Fire Hazard Map (SFH) | MODIS | Sentinel-3 |
| Fuel Reduction Map (FR) | N/A | N/A |
| Prescribed Burning Map (PF) | N/A | N/A |
| Burn Scar Map HR (BSHR) | Landsat8 | Sentinel-2 |
| Burn Scar Map VHR Optical (BSVHR) | N/A | N/A |
| Post-Fire Vegetation Recovery (PFVGR) | Landsat8 | Sentinel-2 |
| Damage Severity Map (DSI) | Landsat8 | Sentinel-2 |
| 3D Fire Damage Assessment (Volume loss) (3DI) | Optical or SAR Images pair | Sentinel-1 |
| Soil Erosion Susceptibility (SESI) | Optical data for vegetation cover & DEM | Sentinel-1 & 2 |

# 5. CONCLUSIONS

1) According to the feedbacks received by the community of stakeholders and PREFER potential customers the ensemble of products delivered by the project is fully eligible for providing geographical-synoptical information support to the forest fire management community.

2) As far as the two core groups of PREFER products - "Prevention/Preparedness" and "Recovery/Restoration" - are concerned, a qualitative evaluation of the users' appreciation points to the first group to be more relevant, probably because prevention and preparation activities prevail in the PREFER user community. With the exception of burned area maps, conversely, post-fire management spatial themes are unfamiliar to the PREFER stakeholders involved in the demonstration phase. Better characteristics of PREFER-released products with respect to their standard products (e.g. better spatial resolution) are not sufficient to overcome observed reluctances in changing or implementing the Users' standard procedures.

3) According to detailed feedbacks following the demonstration, **Forest fuel, daily Fire Hazard, Burn Scars, 3D fire damage** and **Fire Risk maps** were the highly successful products of the PREFER's portfolio, requested and exploited by the majority of qualified end Users.

4) With minor exceptions, all PREFER products were demonstrated in a pre-operational environment, showing that the **multi-product processing chain is mature and robust enough to compute and deliver with appropriate refresh frequency and fully satisfactory timeliness**. The possibility to improve products, to provide the service continuously while facing costs for computing some of the PREFER products depends on the products, its level of automation, the refresh frequency the status of the partner (private, public, commercial, research);

5) The PREFER ties with the User Community have improved throughout the project, becoming strong and even more promising in a few cases. Most partners established and keep, individually, close links with fire management authorities in Mediterranean countries other than the five collaborating in PREFER, will also provide support to PREFER service during the period it will continue be operating beyond the official end of the project. However operating normally the PREFER service in the future would need financial support that national public services seemed not be able to ensure. For instance, one Spanish and Italian partners from the project consortium have developed formal cooperation and close contact with end user organizations from their respective countries regarding the perspective of the PREFER service. Therefore, PREFER perspective shall be considered viable only if linked with support of the Copernicus Program that will help testing and validating the fire management mapping products developed by the PREFER consortium.