The satellite-based products for supporting prevention and recovery of forest fires in prefer

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ABSTRACT

The PREFER FP7 project aims at responding to major fire prevention needs in Southern Europe. The Mediterranean area is systematically affected by uncontrolled forest fires with large impact on ecosystems, soil erosion, slope instability, desertification trends, and local economies as a whole, with a negative mid-to-long term prospect because of expected climate change. In this scenario, the need to improve the information and the intelligence support to forest fire prevention is widely recognized to be relevant. Fire prevention is still the most cost-effective strategy when compared to fire-fighting 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 spaceborne sensors; 2) offering a portfolio of 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 spaceborne sensors available by 2020 (e.g.: Sentinels) and 4) contributing to the definition of user requirements for the new EO missions.

The paper is devoted to illustrate some of the more significant and innovative products developed by the project.

INTRODUCTION

Because of its overall mild climate, the broad northern Mediterranean Region (including Greece, Italy, France and Portugal, the latter being the westernmost temperate non-Mediterranean areas of Europe) is the region presenting the largest fraction of forested areas in Europe. Portugal, with its 38% of forests, is ranked first, followed by Spain’s 36.41%, Italy’s 30.36%, Greece’s 30.28% and France’s 29.13% (World Bank, 2011). These areas are subject to persistent, high wildfire hazard arising from several causes such as, among others: occurrence of wet and dry weather extremes; diminished control on traditional practices involving fires as an instrument for land management and sanitization; coexistence of urban settlements, infrastructure

networks and vegetated areas (forest, agricultural and uncultivated areas) in a complex, dense and intimately interconnected patchwork.

In general, however, the ignition of wildfires remains basically man-made (either voluntarily or by negligence) in the whole of the area of interest.

In the last decade, France, Greece, Italy, Portugal and Spain recorded a yearly average of about 50,000 fires and about 470,000 burned hectares (JRC Report n.10, Forest Fires in Europe 2009, EUR 24502 EN - 2010). These figures are comparable to figures assessed for the previous decade (European Commission, DG Environment-DG Agriculture-JRC, 2001: Forest Fires in Southern Europe, Vol.1). Therefore, we can note the near-stationary incidence of the phenomenon despite the deployment of newer fire-fighting techniques, larger water-bombing means and the diversification of containment strategies, accompanied by more sophisticated detection, mapping and ICT technologies to address tactical (support to fire-fighting and crisis management) and strategic issues (assessment, intelligence and prevention). As a consequence of this effort in improving the fire-fighting techniques and means, for instance, over 95% of day-time fires hitting the whole Italian territory are extinguished within 3 hours from the first alert – where alerts are typically given within minutes, thanks to the capillary diffusion of mobile phones and to a high density of urban road networks all over the national territory – but expected improvements in the efficiency of fire-fighting will be only fractional. Therefore, we see that fostering a significant improvement in effectiveness and timeliness of prevention measures, is the most suitable way to mitigate efficiently this major environmental threat, and reverse its tendency to grow with time (1). Therefore, the PREFER project is not taking into consideration ‘tactical’ activities spanning over limited temporal horizons but only any efficiency improvement in preventing ignitions and supporting planning and logistics of fire-fighting response, it relies upon an improvement in quality, quantity, scale and timeliness of mapping. The key-drivers of PREFER can be summarized in the four main topics below: systematic fuel estimates, systematic burn scar mapping, systematic analysis of fire effects on slope, systematic fire hazard (daily and bi-weekly) estimate.

PREFER is a project funded under the EU FP7 (G.A. 312931), to be developed in the period 2013-2015. It aims at responding to major fire prevention needs in Southern Europe by extensive exploitation of space-borne sensors. This project intends to contribute to responding to such need by: 1) providing timely multi-scale and multi-payload information products based on exploitation of all available space-borne sensors within the project time frame (the next 4 years); 2) offering a portfolio of 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 (e.g.: Sentinels) and 4) contributing to the definition of user requirements for the new EO missions.

PREFER will set up a regional service, able to process and distribute the information to end users, developed and maintained by a regional R&D cluster of core users, industries and research institutes. Through the exploitation of the synoptic character of spaceborne EO data, the regional service is intended to stimulate further the coordination between countries on forest fires prevention in the EU Mediterranean region.

**METHODS**

The PREFER Service portfolio consists of two main services (see Table 1): Information Support to Preparedness/Prevention Phase (ISP) Service, and Information Support to Recovery/Reconstruction Phase (ISR) Service.

Hereafter the peculiarities of such information services:

- They will be based on a harmonized set of user requirements, defined by the different users from Portugal, Spain, Italy, France and Greece, also taking into account the different legal frameworks existing in such countries.
They will be as general as possible to be usable in the different countries of the Mediterranean Region.

They will be demonstrated by an interoperable service provision infrastructure (based on OGC / INSPIRE), that will allow easy access to the information.

They will be complementary to the products provided by the GMES Land and Emergency services of the GMES Initial Operations.

They will be complementary to the products provided by the EC JRC (Joint Research Centre) EFFIS (European Forest Fires Information System).

They will be based on the exploitation of the data from the GMES space infrastructure.

They will optimise integration of different data: EO, Digital Terrain Models, socio-economic data, in-situ data, and meteorological data.

The PREFER consortium has the ambitious objective to start up the formation of a cluster of research institutes, industries and SMEs focused on the provision of space-based information services and products in support to Forest Fires emergency management in the Mediterranean Area (Fig. 1).

Figure 1 - In gray the countries where the PREFER project partners are located and in red the project test areas.

Table 1. List of products to be developed in the framework of the PREFER project.

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<th>Service: Information Support to Preparedness/Prevention Phase</th>
<th>Service: Information Support to Recovery/Reconstruction Phase</th>
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<td>Post-fire Vegetation Recovery Map</td>
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**Seasonal Fuel Map**

Traditionally, the purpose of classifying forest fuels is to enable planning specialists to identify the inherent potential for fire problems on the forest and agricultural lands under his/her jurisdiction (2).

The first approaches to classify forest fuels were based on identifying the dominant cover types - grass, brush or timber (3). These gradually evolved into descriptions more specifically related to...
problems of fire control. By the 1930s the concept of cover type turned into the concept of fuel type. Fuel descriptions intended to classify forest fuels according to their potential rate of spread and so (4) used four classes for classifying the rate of spread. In the 70’s, following the wide acceptance of the surface fire behaviour model of Rothermel (5), a quantitative description of the fuel parameters was established as a standard. Seeking for an easier way of inventorying the forest fuels, Albini (6) created a group of 13 standardized fuel models in the US. This set of models is widely known as the NFFL (National Forest Fire Laboratory) models or Anderson’s models, which classify fuels according to the strata responsible for fire propagation in four groups: grass, shrubs, forest litter, and logging slash (6, 7). More recently Scott and Burgan (8) expanded the original 13 NFFL models to a new set of 40 standard fire behaviour fuel models.

In 2008 the JRC implemented the FUELMAP project (JRC-ITT/RFQ Reference 2008/S 116-153998) which provides a first approach of standardized forest fuel typology and a draft map of the distribution of forest types in EU (FUELMAP project, 2011). The IES of the JRC elaborated further and revised the forest fuel types proposed in FUELMAP and defined a new typology of forest fuels in Europe. FUELMAP responded to the need of developing a new fuel classification system, suitable to European environments, with a common standard methodology. FUELMAP was used as a background material in a subsequent LIFE+ project: ARCFUEL.

PREFER intends to calibrate ARCFUEL methodology and FUELMAP project forest fuels classification over a number of AOIs in the Mediterranean area. In fact, the FUELMAP classification follows a hierarchical scheme, specifically thought to be completed or refined at its more precise level, without losing the capacity for fuel type mapping and analysis at European scale. This lies on the assumption that the development and use of site-specific fuel classification systems can solve the uncertainties associated to the assumption of pre-existing fuel models to a given area, due to the mismatches between vegetation types.

**Seasonal Risk Map**

Risk is commonly defined as:

\[
\text{Risk} = \text{Hazard} \times (\text{Vulnerability} \times \text{Economic\_Value})
\]

(1)

Vulnerability, in a general sense, means the potential for loss (9). The concept of vulnerability has evolved towards a more broadening approach (10), thus integrating multiple components (exposure, susceptibility, coping and adaptive capacity) and embracing different thematic areas (physical, social, economic, environmental or institutional). Despite the differences in the precise definition of vulnerability, it is rather well established that it relates to the degree of loss that can be expected in case of a hazard, which in turn can affect different types of assets, either biophysical or anthropogenic (11, 12). In this sense, the assessment of vulnerability should integrate, on one hand, the different dimensions of the environment and of the society where losses could occur; on the other hand, vulnerability also encompasses the capacity of the natural and human systems to absorb expected changes and recover from the potential losses, thus the ability for coping and recovering should also be considered (13, 14, 15).

An approach directly related to wildland fires vulnerability was recently developed under the supervision of the JRC. Between 2010 and 2012, a project was established with the purpose to assess wildland fire vulnerability at the European level and create a tool for a quick estimation of approximate post-fire damages (16). Wildland fire vulnerability was defined as a measure of potential socio-economic damage caused by a fire in a specific area, and it was estimated, generally, as the cost of restoring the previous land cover after a potential fire. A restoration cost was established for each land cover class at country level, based on the Corine Land Cover, and an average restoration time was assigned according to the recovery capacity of the land cover. As a conservative approach, the standard economic formula for discounting future benefits was applied, which includes fire damage value (€/ha), damage level, restoration cost (€/ha), the discount rate and the restoration period (year).
This approach of vulnerability was limited to land cover, however it had the advantage of attributing an economic value to the damages, which is a useful measure to integrate in vulnerability assessment.

The definition of the concept behind the products we are developing is crucial to understand its application and value. The vulnerability approach within the PREFER Project intends to be comprehensive and holistic, combining indicators that represent exposure, sensitivity and resilience (capacity to anticipate and respond, or coping capacity overall), as well as the characteristics of the hazard. Additionally, the economic value of the vulnerable elements will be provided, as an expression of the importance of the element and/or the costs of protecting or restoring it.

**Daily Fire Hazard Map (DFHI)**

Briefly, as shown in the past by the JRC (17) to which the European Commission, has committed the task to develop and implement a method for assessing the fire risk at European scale, there are a number of dynamic indices (compiled daily). In particular, the JRC has identified 7 and until a few years ago, the prediction was made by that organization on the basis of these 7 different risk indices (6 of which represent the evolution of other indices developed for national applications, and are substantially meteorological indices), by using data from meteorological stations interpolated on a 50 km grid, weather forecast by Meteofrance and satellite data. These latter were used for the calculation of one of the seven indices. The 7 indices mentioned above are: Portuguese Index, ICONA Method, Drouet-Sol Numeric Risk, Italian Risk index. Canadian Fire Weather Index, BEHAVE Model, Fire Potential Index (FPI).

Only the last one, namely the FPI, involves the use of satellite images in the assessment process. For this reason, in addition to the utility demonstrated in its applications in the United States, this index was adopted in the past as part of the project SIGRI (18).

Currently, the fire risk maps provided by the module EFFRFS (European Forest Fire Risk Forecasting System) of EFFIS (European Forest Fires Information System) are based on the Canadian index (CFWI). This index provides both the daily value of the expected value for a few days. The spatial resolution of 10 km of this index is suited to continental coverage. The index adopted as part of SIGRI, is an evolution of the Fire Potential Index (FPI), which was introduced in 1998 in the United States (19). The DFHI adopted in PREFER represents a further development of the previous one applied in SIGRI by DIAEE (18).

**Prescribed Fires Map**

In the history of the land use in Europe the fire has been an important tool to modify the environment, for example, to expand agricultural lands in the Mediterranean regions. The pastoral use of the fire has continued until present and together with other traditional cultivation systems have shaped the Mediterranean landscapes. However, during the second half of the 20th century, in some countries, the fire culture was lost, in particular in Northern and Central Europe (20). With regard to prescribed fire practices, in the 1980s in the southern European countries began the first applications for the fire hazard reduction.

FAO provides the following definition of the prescribed fire: “Prescribed Burning (PB) represents the controlled application of fire to vegetation under specific environmental conditions to attain planned resource management objectives”. PB is one of the most versatile and cost effective land management tools primarily used to reduce dangerous fuel accumulations, thus providing increased protection to people, their homes and the forest.

However, the use of PB is a well established practice in US whereas in Europe it is still a disputed matter and generally not permitted.

The most important EU project on the analysis of the PB has been Fire Paradox (21). The overall objective was the creation of the scientific and technical basis towards integrated fire management practices and policies in Europe. However, the main limitation of Fire Paradox approach is the
“time factor”, that is, the lack of information on the temporal window most convenient to perform the PB. This topic represents the main improvement to be made by PREFER for the wild fire prevention based on the prescribed fire: developing a dynamic product, easily updatable, to predict the right time and the secure way to employ the PB in the areas of Interest.

**Optical and radar Burn Scar Map**

Several approaches for burned land assessment are currently adopted by National Forest Services. They largely depend on the available technology and the scale of measurement. Traditionally, field observation has been the basis of fire statistics, since forest fire extinction services were obliged to fill out a report on each large event. For small fires, the assessment was done with lower accuracy. In any case, field methods are costly and time consuming. Its feasibility to be included in an operational national burnt land-mapping project is based on a dense network of human workload. Other than this difficulty, field reports are not always very precise cartographically, and they do not consider different levels of vegetation damage.

<table>
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<th>Table 2. Techniques for burned area mapping</th>
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<td>Field work</td>
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<tr>
<td>Accuracy</td>
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<tr>
<td>Cost</td>
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<tr>
<td>Time</td>
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<tr>
<td>Coverage</td>
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<td>GIS connection</td>
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The use of remote sensing methods provides an alternative to field survey and GPS techniques. The use of b/w, colour or infrared aerial photography in a scale ranging from 1:5,000 to 1:50,000, provides information in relatively high measurement and observational scales, which, it should be mentioned, is not free of errors. Aerial photography was employed to map fire damages and to estimate forest losses due to fire and diseases some decades ago. Although aerial photography offers the possibility to cover larger geographical areas than the human-made measurements and to process the data and extract the desired information with a lower cost, its potentials to be included in an operational burnt land mapping system still remains limited. Satellite remote sensing offers an alternative to aerial photography, providing periodic spectral data from different spectral regions that can be related to burnt areas.

**Damage Severity Map**

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.

<table>
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<th>Table 3. CBI damage severity levels.</th>
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<tr>
<td>CBI Burn Severity Scale</td>
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<td>No effect</td>
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In particular, a series of field-based indices have been introduced (CBI, Composite Burn Index; GeoCBI, Geometrically Structured CBI) (22, 23, 24) which were correlated to spectral indices based on multi-spectral images. In fact, the CBI index is based on a visual assessment of the quantity of fuel consumed and the degree of soil charring (25) whereas the GeoCBI represents a modified CBI where the fraction of vegetation coverage (FCOV) is introduced as a weighting factor (23) and both of them are correlated with quantitative indices like the NBR (Normalized Burn Ratio) (26), the DNBR (differential NBR) (27) or the RdNBR (Relative delta Normalized Burn Ratio) (28). Such information can be useful to define the recovery priorities and the type of intervention on the interest areas in addition at allowing a more accurate estimate of the combustion efficiency (BE, Burning Efficiency). Recent studies have proposed the use of radiative transfer models (RTM) to simulate the continuous range of measured severity levels of the damage using the CBI (23). The radiative transfer models can simulate the spectral signatures of a set of input parameters, of both leaf and canopy. In direct mode simulation, the RTM is used to analyze the effects of characteristics of the plant on the spectral reflectance, while the spectra in the reverse (from remote sensing data) are used as input to estimate some of these parameters. In the framework of the PREFER project we aim at developing a damage severity index (BSI and DSI) that, starting from the experience gained so far in the FIREMON project (29), is capable of evaluating the damage severity in burned areas by high resolution multispectral satellites images.

Regarding the definition of damage severity, we consider the internationally recognized one, which provides 4 classes of damage (see Table 3) (30).

3D Damage Assessment

Post-fire soil erosion is a major risk to forest habitats given the long term often permanent damage that ensues, as soil regeneration occurs over geological time-scales, serious erosion is generally considered irreversible (31).

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) (32).

Using an appropriate soil erosion model, areas at risk can be estimated and can provide information about current erosion and 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, a 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 Universal Soil Loss Equation (USLE) is an empirical equation designed for the computation of average soil loss in agricultural fields. This equation was developed for detachment capacity limited erosion in fields with negligible curvature and no deposition and represents soil loss averaged over time and total area.

Within the Geoland2 project a soil erosion model called the “G2 model for erosion” that works on a local to regional scale has been developed. This model could be called a Revised USLE model as it is founded to a large extent on the USLE. The formula of the G2 erosion model is:

\[ E = (R/V) \times (S/(T/I)) \]  

where

E: erosion (t/ha)
R: rainfall erosivity (original USLE formulas or alternatives developed by G2 or other authors)
V: vegetation retention (developed by G2 using BIOPAR and land use/management databases, e.g. CORINE)
S: soil erodibility (original USLE formulas or USLE modified by JRC)

T: topographic influence (USLE modifications, 1996; simulation of original USLE conditions)

I: slope intercept (developed by G2 using satellite data; corrective to T)

The G2 model uses harmonized standard input data from European and global databases, such as the LUCAS soil database, the European Soil Database (ESDB), the Topsoil Organic Carbon (TOC), BioPar products of Geoland2, Image 2006 imagery, CORINE LC, Landsat TM, the ASTER DEM datasets, and other large public datasets. As a data-oriented model, the cartographic scale of a G2 implementation is determined by the spatial resolution of the input data (Panagos et al. 2014).

In order to develop the 3D Fire Damage Assessment Map product in the framework of the PREFER project, the implementation of the RUSLE model - as it seemed both accepted and accessible, will be investigated.

The development of such product requires the computation of VHR DEM based on optical (Pléiades) or radar (Tandem-X, Cosmo SkyMed) data. The 3D fire damage assessment product aims at adding a very high resolution 3D component to fire damage assessment, at indicating where volumes have reduced and, then, using this 3D digital elevation model information plus land-cover/land-use and ancillary soil geo-information, at indicating where soil erosion vulnerability exists.

![Figure 3. An example of the PREFER product burn scar at scale 1/25000. The product (violet areas) is compared with the ground measurements provided by CFVA, the regional Forest Corps of the Sardinia region, (red polygons) and the polygons provided by JRC (blue lines).](image)

RESULTS

Let us describe in this paragraph some of the PREFER products among those that are, at present, at the most advanced stage of development, namely: burn scar map, damage severity map. Figure 3 provides a preliminary example of one of the products which will be developed in the project. In particular, it shows the accuracy in the estimate of the burned areas reachable by using a suitable algorithm applied on high spatial resolution satellite images.

Figure 4 shows an example of a damage severity map computed by using a couple of multispectral images (OLI/Landsat8) of a SIC (Site of Community Interest) area, in Sardinia, affected by a fire. The grade of damage is computed by using the DNBR, introduced above and defined as:

\[
DNBR = NBR_{\text{pre--fire}} - NBR_{\text{post--fire}} \quad NBR = \frac{NIR - SWIR^2}{NIR + SWIR^2}
\]
Near infrared band uniquely decreases after fire, and short wave infrared band reflectance exhibits the greatest magnitude and variation of change compared to other bands, as it increases the most after fire. The difference between NIR (Near Infrared band) and SWIR2 (Short Wave Infrared at 2 \( \mu \text{m} \) band), then, provides good statistical leverage for measuring fire effects. This relationship led to formulating the NBR (Normalized Burned Ratio), which is the foundation of techniques for estimating the damage. Since NBR incorporates the bands most sensitive to fire effects, we hypothesize that the change in NBR is correlated to the ecological change caused by the fire, which is the burn severity. Unburned areas have Delta NBR (DNBR) values near zero. The recent burned areas generally are showed as lighter, more highly positive values, with the range of brightness corresponding to a range of severity. Lightest areas would be judged to be more severely burned than others. Theoretically, DNBR can range between \(-2\) and \(+2\), but in reality it is rare for valid data to vary much beyond \(-0.55\) to \(+1\).

Figure 4. An example of the PREFER product Damage Severity map, obtained by applying a well known DNBR index (left) and the new BSI (center) and DSI indices to a couple (pre and post-event) of OLI images of a burned area (Golfo degli Aranci, Sardinia).

Up to now, the assessment of the damage severity is based on the identification of a relationship between DNBR and ground based visual estimate of the damaged (e.g.: CBI). We have applied it in the Mediterranean area (Fig. 4) and the results obtained by this method are quite good. Since the burn severity is an aggregate of many variables, the best way to assess it is by taking into account several vegetation parameters estimable by remote sensing data. Our idea consists in computing several indices, each one capable to assess different characteristics of the vegetation and possibly capable to evaluate the fire effect on it, and then build a map based on these indices.

The indices chosen for “like Landsat” images are:

\[
\text{NBR} = \frac{\text{NIR} - \text{SWIR2}}{\text{NIR} + \text{SWIR2}} \\
\text{NDII} = \frac{\text{NIR} - \text{SWIR1}}{\text{NIR} + \text{SWIR1}} \\
\text{NDVI} = \frac{\text{NIR} - \text{RED}}{\text{NIR} + \text{RED}}
\]

where SWIR1 is the band at 1.6 \( \mu \text{m} \). These indices were combined in a unique index named Burn Severity Index (BSI):

\[
\text{BSI} = \frac{(\text{DNDVI} + \text{DNDII} + \text{DNBR})}{3}
\]

where DNDVI, DNDII and DNBR are the differences between the pre-fire and post-fire indices.

Some studies, however, showed that DNBR tends to saturate, and this forces to define only 3 classes of damage, with high difficulty in finding the threshold between medium and high damage level. Therefore, we define an optimized version of NBR called Modified Normalized Burn Ratio (MNBR) defined as follows:

$$MNBR = \frac{NIR - \frac{1}{\text{swir}_2}}{(0.7-NIR)^2+\text{swir}_2^2} \quad (6)$$

Finally the index for the optimal measure of the damage severity, called Damage Severity Index, is:

$$DSI = MNBR_{\text{pre}} - MNBR_{\text{post}} \quad (7)$$

Through the above procedure, we have created an index (DSI) that is theoretically optimized to detect changes due to the burning in a pixel.

In Fig. 4 the comparison between DBNR, BSI and DSI is shown. We can see as DSI values, at least in this case, are better connected to photos taken in the field and the damage assessed by using very high spatial resolution satellite image.

CONCLUSIONS

The FP7 PREFER project objectives originate from the circumstance that, notwithstanding the improvements in the efficiency of the fire fighting, the phenomenon is not showing any tendency to decrease. Therefore, the European Commission has recently adopted a Communication on the prevention of natural and man-made disasters that focuses on the concept that a common approach is more effective than separate national approaches: for example, developing knowledge, linking actors and policies, and efficient targeting of community funds to prevention. In fact, the prevention is still the most cost-effective strategy, when compared to fire fighting and suppression, able to efficiently mitigate this major environment threat. PREFER intends to contribute at responding to such a pragmatic need of southern Europe's forests by: providing timely information products based on the exploitation of all available spacecraft sensors, offering a portfolio of products focused on pre- and post-crisis forest fire emergency, suitable for the users in the different countries of the European Mediterranean area.

Therefore, PREFER will set up a regional service, able to process and distribute the information to end users. The service will be ready for operational deployment at the end of the project, as a new powerful tool at the disposal of the authorities in charge of forest fire management in the Mediterranean area.

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REFERENCES


