Mapping Forest-Fire Damage with Envisat

Federico González-Alonso, S. Merino-de-Miguel, S. García-Gigorro, A. Roldán-Zamarrón & J.M. Cuevas
Remote Sensing Laboratory, INIA, Ministry of Education and Science, Madrid, Spain

Olivier Arino
Data User Programme Manager, ESA Directorate of Earth Observation, ESRIN, Frascati, Italy

Wildfires are a major environmental problem in many parts of the World, including some European countries around the Mediterranean where large forest fires have often spread uncontrollably at frightening rates in recent years. Such fires play a critical role in many aspects of ecosystem functioning, such as biodiversity and hydrology. They can destroy large tracts of the landscape, as well as triggering the release of considerable amounts of the main greenhouse gas carbon dioxide, thereby affecting the global atmospheric chemistry of our planet.

Background

Global studies (e.g. GLOBSCAR) have produced widely differing figures for biomass burning varying, according to the literature, from 200 to 1000 million hectares per year, with Africa the largest contributor. Of the different vegetation types under threat, savannas are by far the most affected. In the European Union region, according to the European Commission, the five Mediterranean States – France, Greece, Italy, Portugal and Spain – suffer burnt areas of between 200 000 and 600 000 hectares per year as a result of the 20 000 to 60 000 forest fires that have occurred annually in the period 1980 to 2003.

Since forest fires are a major source of concern both for environmental and safety reasons, information about them must be available in a timely and harmonized way. Remote sensing from space is

especially suitable for forest-fire-related studies, including those focusing on estimating the degree of damage caused by wildfires as well as mapping the affected areas.

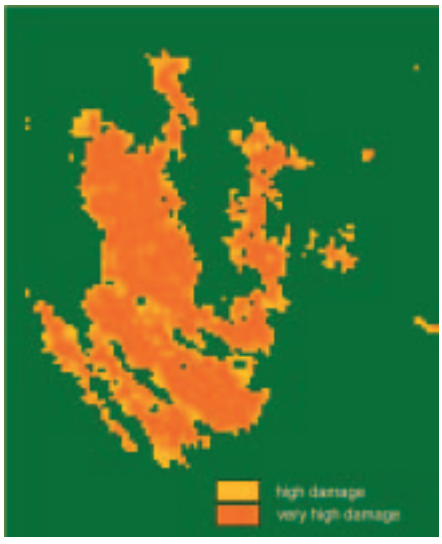
ESA's Envisat environmental satellite, launched in March 2002, is a powerful tool for monitoring the state of our planet and the impact that human activities are having on it. For doing so, it carries ten highly sophisticated instruments, one of which is the Medium Resolution Imaging Spectrometer, better known as 'MERIS', which is providing unique fire-damage information.

Mapping the Level of Damage

The MERIS instrument has shown itself to be an accurate eye in space for estimating the degree of damage caused by forest fires, thanks to its multi-spectral imaging capabilities in the visible and near-infrared regions of the spectrum and its narrow spectral bands. MERIS's imagery has also been used very successfully for estimating the areas affected by particular fires, thanks largely to its improved spatial resolution (300 metres in Full Resolution Mode) compared with other satellite sensors, such as the AVHRR instrument on the NOAA satellite series.

Level-of-damage estimation on the basis of remote sensing from space can also be of considerable help in terms of catastrophe management because it is both time-saving and cost-effective. It can be used for subsidy assignment and for better planning of post-fire restoration actions, allowing more investment to be targeted at the areas that are most badly affected.

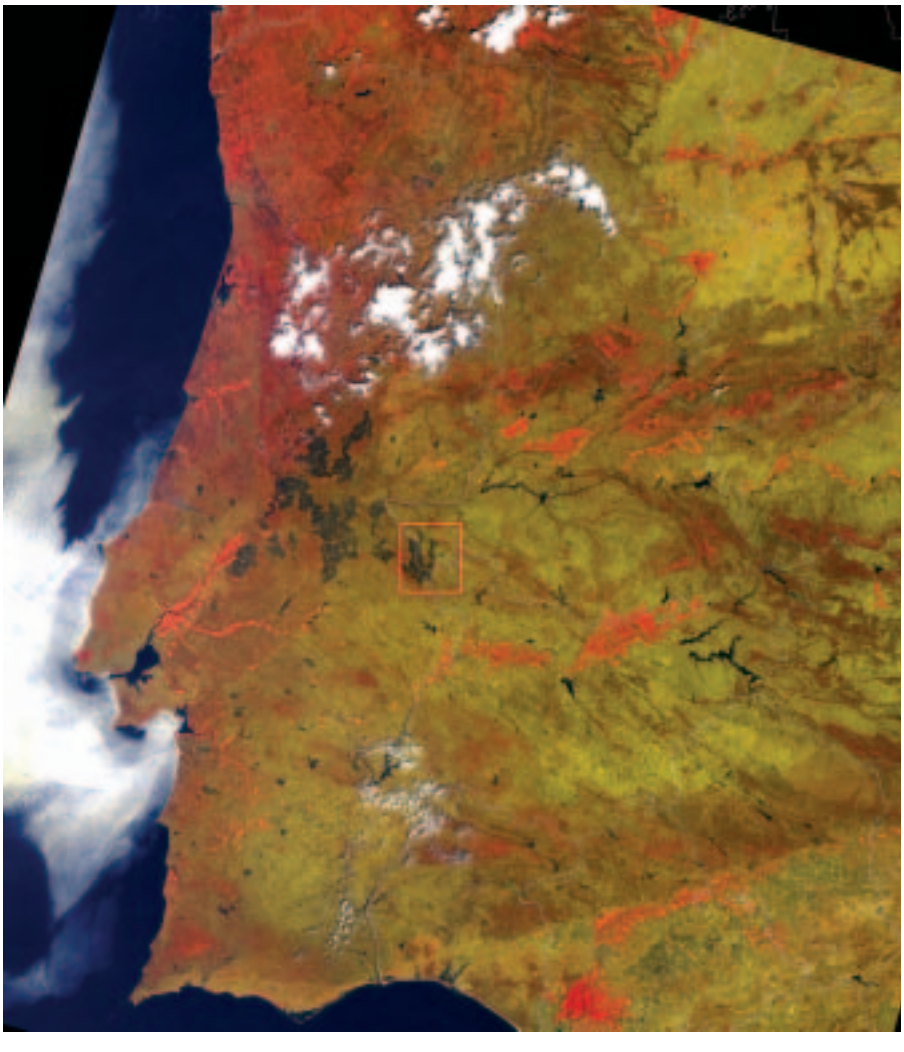
Information about forest fires is also of strategic value for protocol implementation and treaty verification. The Kyoto Protocol strives to reduce carbon-dioxide and other greenhouse-gas emissions by an average of 5% of 1990 levels, and wilderness fires are an important contributor of carbon dioxide to the atmosphere. On a global scale, land-use changes are considered one of the main sources of this gas, deliberate burning being one of the most common means of transforming forest into agricultural land, especially in the tropics.



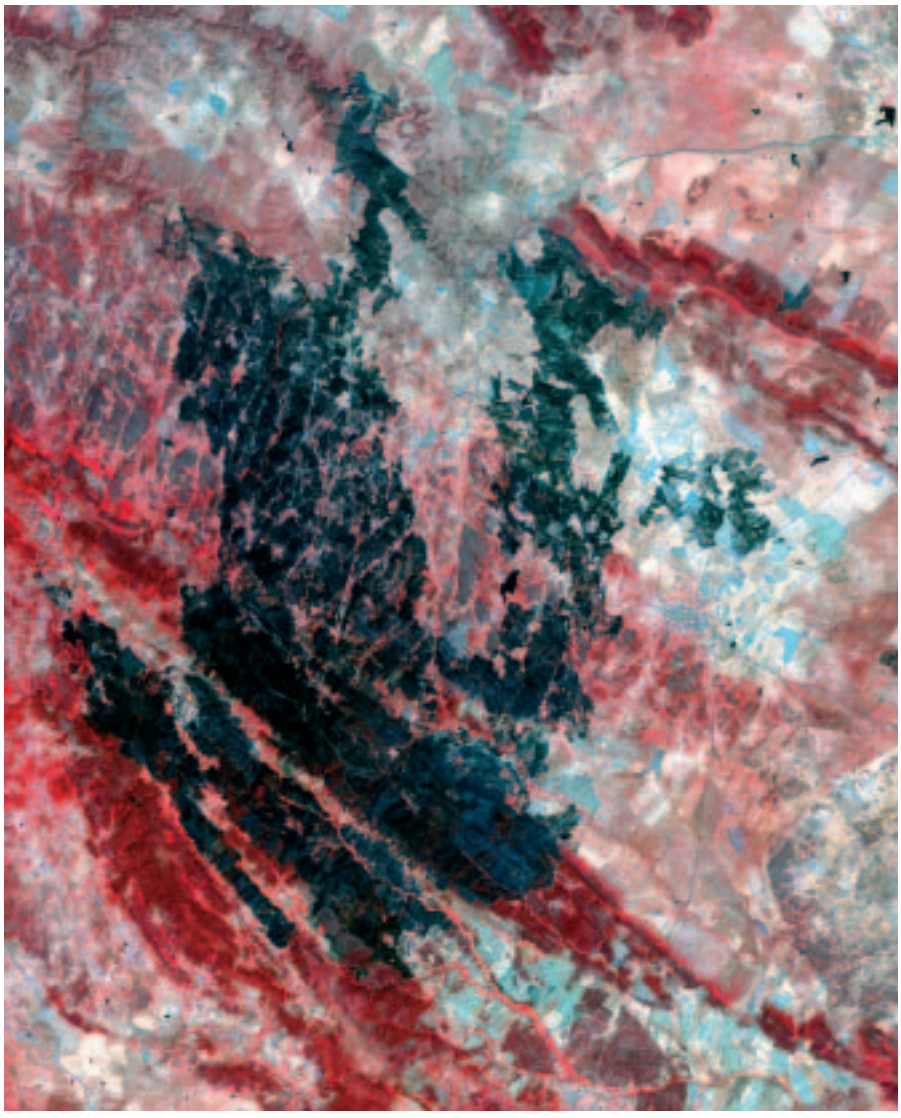
Level-of-damage estimates obtained by MERIS image processing

The preliminary results of space-based level-of-damage and burnt-area-assessment studies for the fires that occurred at the border between Portugal and Spain during the first days of August 2003 are already very interesting. It was a particularly dramatic summer in terms of forest fires for much of Southern Europe, and especially Portugal where almost 8% of the wooded area was mapped as burnt at the end of the dry season. In Spain and Portugal alone, the total area razed during 2003 was more than 450 000 hectares.

The study area known as Valencia de Alcántara, delineated on the accompanying MERIS image, is where all of the analyses were carried out. Some image-processing analysis based on linear unmixing algorithms was performed on a



The fire-scarred landscape of Central Portugal and Spain, as seen by Envisat on 8 August 2003, with the Valencia de Alcántara fire outlined in red (MERIS instrument RGB image: 12,9,1 composite)



The scars from the Valencia de Alcántara fire as recorded by SPOT-5's HRG1 instrument on 21 August 2003

post-fire sub-scene of the MERIS image and on a post-fire SPOT-5 image (dated 21 August 2003). The latter is a four-band image with a 10 metre spatial resolution. Two of the spectral bands are located in the visible, the third in the near-infrared and the fourth in the shortwave-infrared region.

The algorithms applied resulted in a fire level-of-damage estimate that was reclassified into two degrees of damage ('high' and 'very high') in order to achieve a better understanding of the problem and for further statistical analysis. Because of its higher spatial resolution and particular spectral capabilities, the SPOT-5 image could be used as the 'ground truth' for evaluating the MERIS-derived estimates of the two parameters of interest, namely level of damage and area affected. The affected area was evaluated with the MERIS data to have 4350 hectares in the 'high damage' category, and 19 050 hectares in the 'very high damage' category.

The information provided by satellite was completed with data from two field trips. The first was made just a few weeks after the fire had been extinguished (September 2003), and the second during the next growing season (June 2004).

A part of the Valencia de Alcántara landscape, with different types of trees having been affected to different degrees

Ground data from the September field trip confirmed the high degree of devastation caused by fire. During the June 2004 trip, clearing-up work could be seen in the ravaged areas, as well as evident signs of the vegetation recovering in various places. Photographs of several locations were linked to GPS points, and subsequently to MERIS and SPOT-5 images, which confirmed a high degree of correlation between the level of damage as evaluated from satellite sensors and what was seen on the ground.

MERIS-derived level-of-damage information was also compared with information on forested land-cover classes as derived from the Spanish National Forest Map (cartography scale 1:50.000). The objective here was to check to what extent the degree of damage was related to a particular type of forest or tree species. The first analysis revealed that there was indeed a link between the forest type and the degree to which the land cover was affected, with most types of trees seemingly affected by wildfire in a characteristic manner. This tendency might be peculiar to this site and might be different in other areas. In particular, our detailed statistical analysis showed that forests dominated by holm oak *(Quercus ilex)* were the most fire-resistant, while those dominated by sessile oak *(Quercus pyrenaica)*, pine *(Pinus pinaster)* and chestnut *(Castanea sativa)* trees were the least resistant. The areas where the cork tree *(Quercus suber)* was the dominant species tended to show an intermediate level of damage.

Conclusion

The results achieved so far show that MERIS-based estimates of wildfire damage over forested areas can be extremely useful not only in establishing the scale of the damage, but also for the subsequent forest renewal projects and for subsidy management. MERIS data can also be used to good effect for future forestry planning activities, since more fire-resistant types of trees - as established by this or similar studies - should be proposed for new plantations in vulnerable areas.

Acknowledgements

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