Using AWiFS and MODIS data to estimate burnt areas: the case of Galicia forest fires during the 2006 summer season

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Abstract – This paper concerns an estimation of burned areas in Galicia (North-West Spain) due to forest fires occurred mainly during the first fifteen days of August 2006. The study presented herein uses an image from the AWiFS (Advanced Wide Field Sensor) sensor dated on the 21st of August 2006, MODIS (MOderate resolution Imaging Spectrometer) 'hotspot' data for the first twenty days of August as well as ancillary maps and information. The developed methodology, that combines data from both sensors, allowed the production of detailed burned area maps. The later was based on BAI (Burned Area Index) calculation and threshold determination in order to produce burned – unburned maps. Reached results showed that this method would be of great interest at regional to national scales, since it was proved to be quick, accurate and cost-effective.

Keywords: BAI, hotspot, wildfire, Mediterranean basin.

1. INTRODUCTION

Forest fires are a major source of concern both for environmental and safety reasons in many parts of the world, including the Mediterranean States of Southern Europe. This geographical area is characterized by high temperatures and low precipitations during summer, what together with an unusual accumulation of forest fuels due to the abandonment of rural areas, is producing an increase in the area affected by forest fires. Wildfires cause casualties as well as important economic, social and environmental losses. 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 and the global climate of our planet.

The use of traditional methods to map forest fires is expensive and time-consuming. Burned area assessment and mapping using remote sensing observations and algorithms have significant advantages over conventional methodologies, and it is therefore becoming one of the main techniques for such purpose. This is due to the fact that remote sensing estimations are quick, reliable and cost-effective what would allow the establishment of rapid response systems. Besides, these maps could be combined with slope and soil type maps, in order to locate priority intervention areas and plan forest restoration works (González-Alonso *et al*., 2007).

The range of methods dealing with burned mapping using satellite data includes, among others (Koustias *et al*., 1999): (i) thresholding of single bands or indices, (ii) supervised classification of original bands or indices, (iii) unsupervised classification, (iv) multivariate analysis of original bands, (v) spectral unmixing, (vi) time-series analysis, etc. Among the different techniques, a variation of the 'thresholding of single bands or indices' method was chosen to develop the current research.

The work presented herein aims at the estimation and mapping of burned areas in Galicia (North-West Spain) due to forest fires occurred mainly during the first fifteen days of August 2006. For doing so, we used satellite data from the Resourcesat-1 – AWiFS (Advanced Wide Field Sensor) and Terra/Aqua – MODIS (MOderate resolution Imaging Spectrometer) sensors as explained in section 2. The AWiFS post-fire image was used to derive a variation of the BAI (Burned Area Index, Martín *et al*., 2005) index in order to produce a burned – unburned map. MODIS data, that consisted of thermal anomalies or 'hotspots', were used for BAI threshold determination and commission errors removal, as explained in section 3.

2. MATERIAL

The material used for the present work falls into three categories: (i) a post-fire satellite image, (ii) thermal anomalies locations or 'hotspots' and (iii) ancillary maps and information.

We used a post-fire image from the AWiFS sensor onboard Indian satellite Resourcesat-1, dated on the 21st of August 2006, as well as MODIS 'hotspot' data for the first twenty days of August 2006 (see figure 1). 'AWiFS is a unique sensor, providing data of 56m spatial resolution at 5-day intervals' (Kulkarni et al., 2006) in four spectral bands (see table 1). MODIS is a sensor onboard Terra and Aqua NASA satellites with more than 30 channels at variable spatial resolutions (250 to 1000m), two of which are thermal bands (1000m pixel size) used for 'hotspot' location.

MODIS hotspot data, as provided by the MODIS Land Team, consisted of a series of text files (one file per day) with a record per hotspot and with information related to location (latitude and longitude), date, time, confidence level and involved satellite (Terra or Aqua). In particular, and for the first 20 days of August, Galicia region (more than 3 million hectares) accounted for 3340 hotspots.

Ancillary maps and information consisted of: (i) a digital terrain model for AWiFS image pre-processing and (ii) the CORINE Land Cover 2000 coverage (CLC2000) for masking purposes.

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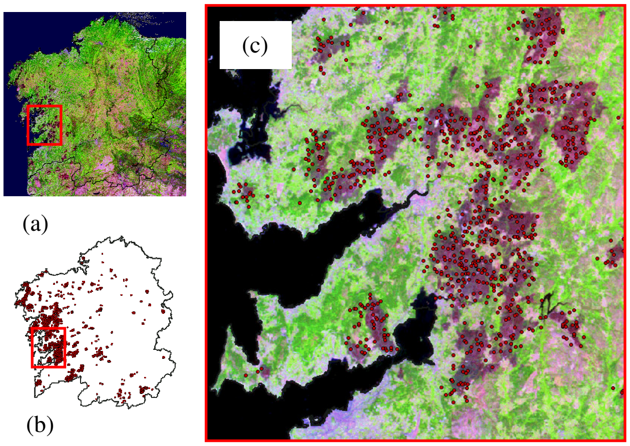

Figure 1. (a) AWiFS post-fire image (dated 21st August 2006, RGB composition: 543), (b) MODIS hotspots (dated 1st to 20th August 2006), (c) most burned areas (darker) presented MODIS hotspots.

Table 1. AWiFS sensor characteristics (NIR: near-infrared; SWIR: shortwave-infrared)

	B2 (green)	B3 (red)	B4 (NIR)	B5 (SWIR)
Spatial resolution	56m	56m	56m	56m
Swath-width	740km	740km	740km	740km
Temporal resolution (days)	2-5	2-5	2-5	2-5
Spectral resolution (nm)	520-590	620-680	770-860	1550-1700

3. METHODS

3.1. AWiFS image pre-processing

Radiometric and geometric corrections were performed on the AWiFS image in order to prepare it for further processing. Radiometric correction consisted of sensor calibration (conversion of digital numbers into radiance values) and reflectance estimation. At present, no atmospheric correction was performed. Resulting 'top-of-atmosphere' reflectance images were ortho-rectified using a digital elevation model (25m spatial resolution) for external calibration, and the corresponding 'geometrical calibration files' (also known as 'RPC' files) for internal calibration. Image pre-processing was carried out using ENVI 4.2 software.

3.2. Burned area mapping

Burned area estimation and mapping consisted of the following steps: (i) BAI calculation, (ii) BAI threshold determination (burned – unburned), (iii) CLC2000 mask application and (iv) hotspots analysis for final burned area map production. Image and data processing was carried out using ENVI 4.2 and ArcView 3.2 software packages.

The Burned Area Index (BAI) was specifically defined to discriminate fire-affected areas. 'This index is computed from the spectral distance from each pixel to a reference spectral point, where recently burned areas tend to converge' (Chuvieco *et al.*, 2002). The BAI index has the following expression:

$$BAI = 1/((\rho c_{nir} - \rho_{nir})^2 + (\rho c_{swir} - \rho_{swir})^2) \quad (1)$$

where ρc_{nir} = near-infrared reference reflectance
ρ_{nir} = near-infrared pixel reflectance
ρc_{swir} = shortwave-infrared reference reflectance
ρ_{swir} = shortwave-infrared pixel reflectance

Values of reference reflectances were based on the analysis of burned pixels as extracted from the AWiFS post-fire involved bands. More than 150 training areas were digitalized using both original bands and spectral indices (NDVI – Normalized Difference Vegetation Index and NBR – Normalized Burn Ratio Index) in order to extract reliable burned pixels statistics. In particular, we defined reference reflectance in the NIR (ρc_{nir}) as the 'ρ_{nir} value for 5% accumulated probability' and reference reflectance in the SWIR (ρc_{swir}) as the 'ρ_{swir} value for 95% accumulated probability'.

BAI threshold determination was based on the analysis of the best correlation between 'burned area' and 'number of MODIS hotspots' for different grid sizes (1, 2, 3 and 4km). 'Burned area' was established keeping only those polygons containing at least one hotspot. BAI threshold values considered were: 80, 83, 85, 90, 95 and 100. Best results (in terms of coefficient of determination) were found for a BAI threshold value of 90 for all grid sizes, as shown in figure 2 and table 2. The application of such threshold resulted in a burned – unburned image.

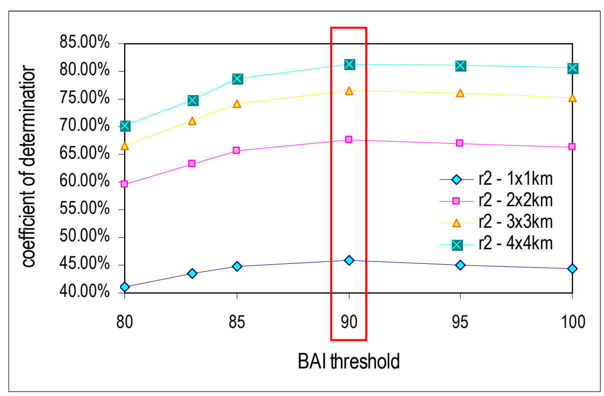

Figure 2. Coefficients of determination between 'burned area' and 'number of hotspots' for different BAI threshold values

Table 2. Coefficients of determination between 'burned area' and 'number of hotspots' for different BAI threshold values

BAI	r^2 - 1x1km	r^2 - 2x2km	r^2 - 3x3km	r^2 - 4x4km
80	41.16%	59.63%	66.62%	70.22%
83	43.38%	63.25%	71.04%	74.81%
85	44.85%	65.69%	74.02%	78.63%
90	45.80%	67.71%	76.58%	81.33%
95	45.07%	67.02%	76.18%	80.98%
100	44.29%	66.37%	75.24%	80.61%

In order to improve our burned – unburned map, a CLC2000 mask was applied to it. A reliable burned area map would never include water bodies, urban or un-vegetated areas, thus we used CLC2000 information to get rid of them. Improved burned – unburned map was then converted to vector format.

Resulting polygon layer was then overlaid over an AWiFS RGB composition in order to check omission and commission errors. Galicia region is as large as 3 million hectares and it accounts for a wide range of ecosystems from the Atlantic to the Mediterranean areas (West to East and North to South). It resulted in an 'excellent delineation' of burned patches in the West part of Galicia and a 'considerably number of commission errors' in the South – East area (see figure 3). As shown in figure 1, most burned areas (that appear darker throughout the AWiFS scene) presented MODIS hotspots, therefore it was decided to use the latter to get rid of clearly unburned polygons (commission errors) as well as small polygons (the result is shown in figure 4). Finally, a visual analysis of the image was carried out in order to recover some of polygons that, being clearly burned, had been eliminated for not containing hotspots (the result is shown in figure 5).

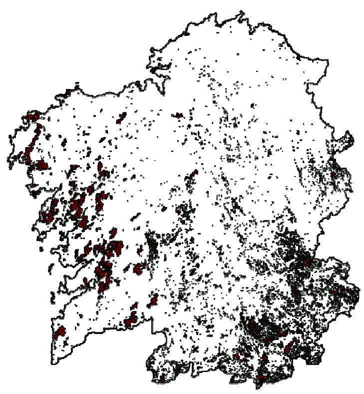

Figure 3. Patches of BAI greater than 90 (vector format)

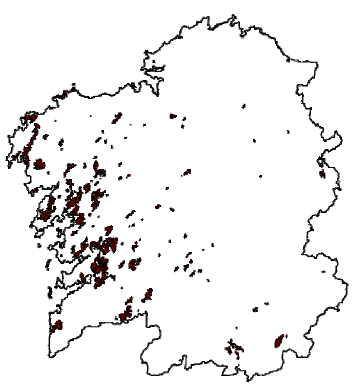

Figure 4. Patches of BAI greater than 90 and containing at least one hotspot (vector format)

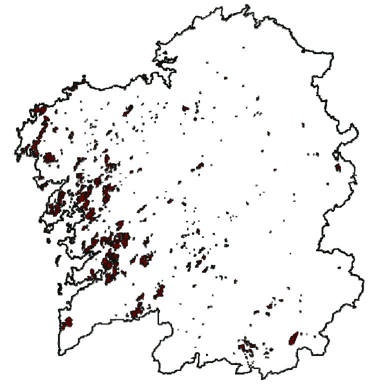

Figure 5. Burned area map: (i) patches of BAI greater than 90 and containing at least one hotspot and (ii) manually recovered polygons

4. RESULTS

Figure 5 shows burned area map for the Galicia region (North-West Spain) for the 2006 summer season until the 21st of August. The resulting affected area was 93,261 hectares, more than 3% of Galician territory. Although no validation using external data (field data, GPS perimeters, etc) was carried out, visual analysis of the resulting map was quite satisfactory.

Nevertheless, reach results agree with data from the Ministry of Environment (Ministerio de Medio Ambiente, 2006) that give us figures of 92,941 hectares burned area for the Galicia region until the 1st of October 2006. According to the Galician authorities (Xunta de Galicia, 2007), the resulting affected area for the whole year was 93,887 hectares.

5. CONCLUSIONS

Burned area estimation and mapping using Resourcesat-1 – AwiFS and Terra/Aqua – MODIS data has produced quick and reliable results. The use of BAI index (calculated using AWiFS data) in combination with hotspot information (calculated using MODIS thermal bands) has resulted in a particularly interesting methodology since: (i) pre-processing and processing of data is rapid, (ii) no field data is needed, (iii) no much human-based decision is required (objective method) and (iv) it has been successfully applied at regional scale (Galicia, 3 million hectares).

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