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SENTINEL-2A red-edge spectral indices suitability for discriminating burn severity

Alfonso Fernández-Manso[a], Oscar Fernández-Manso[b], Carmen Quintano[c,d,*]

[a] Agrarian Science and Engineering Department, University of León, Spain
[b] Civil Protection Agency, Castilla y León Government, Valladolid, Spain
[c] Electronic Technology Department, University of Valladolid, Spain
[d] Sustainable Forest Management Research Institute, University of Valladolid-Spanish National Institute for Agricultural and Food Research and Technology, Spain

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ABSTRACT

Fires are a problematic and recurrent issue in Mediterranean ecosystems. Accurate discrimination between burn severity levels is essential for the rehabilitation planning of burned areas. Sentinel-2A MultiSpectral Instrument (MSI) record data in three red-edge wavelengths, spectral domain especially useful on agriculture and vegetation applications. Our objective is to find out whether Sentinel-2A MSI red-edge wavelengths are suitable for burn severity discrimination. As study area, we used the 2015 Sierra Gata wildfire (Spain) that burned approximately 80 km^2. A Copernicus Emergency Management Service (EMS)-grading map with four burn severity levels was considered as reference truth. Cox and Snell, Nagelkerke and McFadde pseudo-R^2 statistics obtained by Multinomial Logistic Regression showed the superiority of red-edge spectral indices (particularly, Modified Simple Ratio Red-edge, Chlorophyll Index Red-edge, Normalized Difference Vegetation Index Red-edge) over conventional spectral indices. Fisher's Least Significant Difference test confirmed that Sentinel-2A MSI red-edge spectral indices are adequate to discriminate four burn severity levels.

1. Introduction

Remote sensing techniques have proven their usefulness to accurately estimate fire-affected areas and burn severity (Chuvieco, 2009). In this context, the Europe's Copernicus environmental monitoring programme Sentinel-2 gives continuity to the multispectral high-resolution optical observations over global terrestrial surfaces provided by the European Space Agency (ESA) through the SPOT series of satellites (Fletcher, 2012). Sentinel-2A, the first of the two-satellite Sentinel-2 mission, was launched on 23 June, 2015; Sentinel-2B will be launched in 2016. Some scientific journals had special issues dedicated to Sentinel-2 (e.g. Berger and Aschbacher, 2012), and many papers have proven the utility of Sentinel-2A data on different research lines (e.g. van der Werff and van der Meer, 2015; van der Meer et al., 2014).

Fires consume vegetation, destroy chlorophyll, alter soil moisture and leave bare soil. The chlorophyll decrease lead to changes in the visible, the red-edge and the near-infrared (NIR) wavelengths (Escuin et al., 2008). Most studies involving burn severity and remotely sensed data are based on red, NIR and shortwave infrared (SWIR) spectral regions (Chuvieco, 2009). Few works have, however, related the red-edge spectral domain with burn severity, mainly due to the low availability of red-edge remote sensed data of an acceptable spatial resolution. Chuvieco et al. (2006) stated that standard indices based on red and NIR bands (as Normalized Difference Vegetation Index, NDVI) increase its correlation to burn severity when using the upper part of the red band (red-edge). Korets et al. (2010) showed that red-edge based indices (indicators of chlorophyll content) are useful for quantifying and mapping forest damage due to fires in Siberia.

The MultiSpectral Instrument (MSI) onboard Sentinel-2A records data in the vegetation red-edge spectral domain, that is one of the best remote sensing based descriptors of chlorophyll content (Curran et al., 1990), providing an opportunity to assess red-edge spectral indices for burn severity discrimination. Thus, our work aims to find out whether Sentinel-2A MSI data is suitable to quantify burn severity in Mediterranean forest ecosystems. Particularly, our goal is to evaluate the potential of their red-edge spectral bands and to determine which Sentinel-based red-edge spectral indices

* Corresponding author at: Electronic Technology Department, University of Valladolid, Spain.
E-mail address: menchu@tele.uva.es (C. Quintano).

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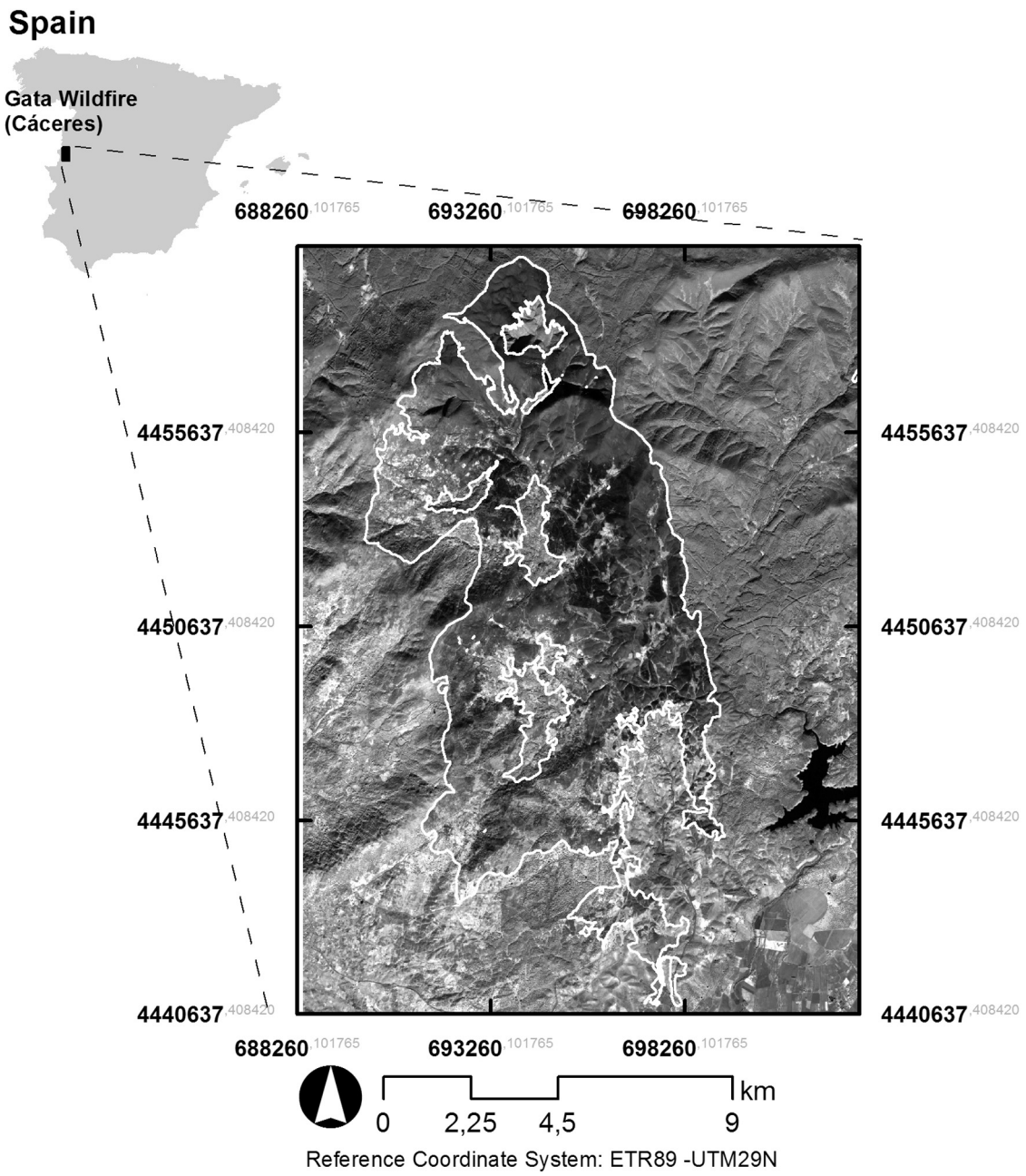

Fig. 1. Location of study area. Copernicus EMS-based burned area perimeter (white line) overlapping a Sentinel-2A MSI red-edge 1 spectral band (B5) image.

are more adequate to discriminate burn severity levels. This study is the first work that relates Sentinel-2A MSI images with burn severity.

2. Materials

The study area is located in Sierra de Gata (central-western Spain) where a wildfire happened from 6 to 11 August, 2015 burning 79.50 km^2 according to the Copernicus European program (Fig. 1). Affected vegetation was mainly a combination of shrubland and forest dominated by *Pinus pinaster* Ait. and *Quercus pyrenaica* Wild.

A Sentinel-2A MSI image (processing level 1C) acquired on 29 November, 2015 was downloaded from the ESA Sentinels Scientific Data Hub. The processing level 1C includes radiometric and geometric corrections with sub-pixel accuracy (ESA, 2015).

A Copernicus EMS-grading map (ID: EMSR132) was considered as reference truth. The map displays four levels of burn severity: destroyed area (level 3); highly damaged area (level 2), moderately damaged area (level 1); and negligible to slight damaged area (level 0). It was based on Pléiades-1A/1B data (acquired on 15 August, 2015) visual interpretation and validated by field plots with an estimated overall accuracy over 85%.

3. Method

The Sentinel-2A MSI bands were scaled to surface reflectance by a Dark Object Subtraction (DOS) based atmospheric correction (Chavez, 1996). Its spatial resolution was homogenized to 10 m using nearest neighbour resampling. Next, red-edge spectral indices were computed. We based our selection on the works about simulated Sentinel-2 data of Hill (2013) and Segl et al. (2015) and