# REGIONAL FUEL MAPPING USING AN OBJECT-ORIENTED CLASSIFICATION OF QUICKBIRD IMAGERY

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**Abstract**

The knowledge of fuel load and composition is critical for improving current fire prevention and modeling programs and to alleviate the negative effects of fire on the ecosystem. Commonly, the generation of fuel maps from remote sensing images has been based in the analysis of medium resolution sensors, such as Landsat data. This paper presents a methodology to generate fuel type maps from remote sensing data at a high spatial resolution. The Prometheus system, a fuel type classification adapted to the ecological characteristics of the European Mediterranean basin, was adopted for this study.

Fuel maps were derived from QuickBird imagery. This satellite is the highest-resolution commercial remote sensing satellite now operating, offering multi-spectral and panchromatic imagery ranging from .61 to 2.88 m resolution. The images, dated from July 2002, was located in the NW of Madrid Region. Preprocessing consisted of orthorectificatation using ground control points and resampling of the multi-spectral data to 70 cm-pixels through a resolution merge with the panchromatic data.

With high-resolution imagery, objects of interest are often aggregations of pixels exhibiting a variety of spectral properties. Correct identification of these objects through classification requires explicit consideration of the spatial context of each pixel. We used object-oriented approach as a complement to traditional pixel-based techniques; it allowed explicit consideration of spatial context during the classification process. The first step of this object-oriented analysis was multi-scale image segmentation. In iterative steps, a hierarchical network of image objects was developed. The simultaneous representation of image information on different scales allowed the identification of image objects composed of smaller, co-occurring sub-objects. The accuracy of the Prometheus fuel map created through this approach was assessed through a network of stand surveys. Results were encouraging and suggest that object-oriented classification of high-resolution imagery has the potential to create accurate and highly precise fuel maps.

## Introduction

Mediterranean vegetation is strongly subjected to the risk of wildfires, which can become a major cause of land degradation (Maselli *et al*., 2000). The knowledge of the spatial variations of this risk is essential, therefore, for forest resource management. Modelling is used to develop fire prescriptions, conduct prescribed fire operations, and predict fire behavior. Models are also used to project potential ecosystem changes, and assess risk to life and property (Andrews and Queen, 2001)

Because it is difficult to describe all physical characteristics for all fuels in an area, fuel classes are often created by grouping vegetation types with similar fire behavior characteristics. More specifically, a fuel type has been defined as "an identifiable association of fuel elements of distinctive species, form, size, arrangement, and continuity that will exhibit characteristic fire behavior under defined burning conditions" (Merrill and Alexander 1987). Two well-known fire behavior fuel type systems are the Northern Forest Fire Laboratory (NFFL) system (Albini, 1976) and the Canadian Forest Fire Behavior Prediction (FBP) system (Lawson et al., 1985). Within Europe, the system referred to as "Prometheus" deals with the composition and the sorting of various types of vegetation found in Mediterranean ecosystems (Riaño *et al*., 2002).

In the past, satellite image analysis towards fuel mapping at a local scale was limited by the relatively coarse spatial resolution of the available data sources. With the development of very high resolution sensors, such us QuickBird satellite, the remote sensing potential has been increased. It has become possible to develop local-scale projects, which might be involving for example the wildland-urban interface.

The very high spatial resolution of the advanced sensors increases the spectral within-field variability, in contrast to the integration effect of older ones (Benz *et al*., 2004). In this context, object-oriented constitute a valuable and complementary approach that create regions instead of points or pixels as carriers of features which are then introduced in the classification stage.

The goal of this paper is to evaluate the potential of QuickBird images to discriminate Mediterranean fuel types at a local scale by means of object-oriented analysis.

## Methodology

Data pre-processing:

Object-oriented classification was carried out using ten image layers and one thematic layer.

All the image layers were derived from QuickBird imagery. This satellite is the highest-resolution commercial remote sensing satellite now operating, offering multi-spectral and panchromatic imagery ranging from .61 to 2.88 m resolution. The images, dated from July 2001, included the municipalities of Galapagar, Colmenarejo, Villanueva del Pardillo and Valdemorillo, located in the NW of

Madrid Region. Preprocessing consisted of orthorectification by Toutin model (PCI, 1999), using ground control points.

The image layers consist of: four multi-spectral bands (Red, Green, Blue, NIR; with 2.88 m resolution); these same bands resampled to 70 cm-pixels through a resolution merge with the panchromatic data; NDVI index, estimated from the 2.88 m resolution bands and resampled afterwards to 70 cm resolution; and a pixel-based supervised classification (ERDAS, 2002) performed on the 70 cm-pixel multi-spectral bands.

The thematic layer delimited areas where there might exist pine trees (affected by reforestation plans in the past)

Prometheus models adoption:

The organization and ordering of classes was determined by the "Prometheus" system. According to this standardization, fuels are divided into 7 types (Giakumakis et al., 2002):

1) Land Fuel (grass cover >50%): This category comprises grasslands consisting of agricultural and herbaceous vegetation.
2) Surface fuels (shrub cover >60%, tree cover <50%): This category comprises grasslands, low-lying shrubs (30-60cm) and a high percentage (30-40%) of herbs. In this category are also included clear-cuts, where slash was not removed.
3) Medium-height shrubs (shrub cover >60%, tree cover <50%): It comprises medium to large-sized shrubs (0.6-2.0 m), as well as young trees resulting from natural regeneration or forestation.
4) Tall shrubs (shrub cover >60%, tree cover <50%): Tall shrubs (between 2.0 and 4.0 m), and regenerating trees.
5) Forest areas with no understory: Tree stands with a clean ground surface (shrub cover <30%). It includes areas where ground fuel was removed either by prescribed burning or by mechanical means.
6) Forest areas with medium understory: Tree stands with medium surface fuels (shrub cover >30%); the base of the canopies is well above the surface fuel layer (>0.5 m). The fuel consists essentially of small shrubs, grass, litter, and duff.
7) Forest areas with high and dense understory: Tree stands with heavy surface fuels (shrub cover >30%) stands with a very dense surface fuel layer and with a very small vertical gap to the canopy base (<0.5 m).

Object oriented classification:

First step of the object-oriented analysis was multi-scale image segmentation. In iterative steps, a 3-leveled hierarchical network of image objects was developed. Level 1 consisted of the pixel-based classification, objects in level 2 were used to improve level 1 weak points, and finally the fuel type classification was developed in level 3, regarding all the information embraced in the previous levels. Objects classified as “urban” in level 3 were not considered for further segmentations.

As we were working with objects, not only the spectral signature but also some spatial characteristics – such as shape, area and neighboring objects – were considered as classification factors. Besides, the simultaneous representation of image information on different scales allowed the propagation of many different kinds of relational information. For example, pixels with reflective properties of trees were assigned the sub-object label of “tree” in level 1 but could be later subsumed either in class objects of “forest” or “grassland” in level 3, depending on the arrangement of neighboring sub-objects.

Along this process, whereas the first steps were more data driven, more knowledge and semantic differentiation were applied in later steps. Thus, classes in level 3 were mainly defined in relation to class-related features (relative area of a certain class in its sub-objects).

## Results and discussion

Pixel-based classification:

The supervised classification arranged pixels according to 11 categories (ground, road, rock, grass, irrigated grass, short grass, Thymus, Retama, shrub, tree, and shadow). The main problems were distinguishing pine trees and shrubs and classifying tracks and urban areas. Also, in some riparian areas trees were classified as irrigated grass. Regardless of these deficiencies, which could be improved in further steps by taking into consideration context parameters, the classification map showed correct and reliable results. A global classification accuracy of 74% was established through a network of 77 stand surveys.

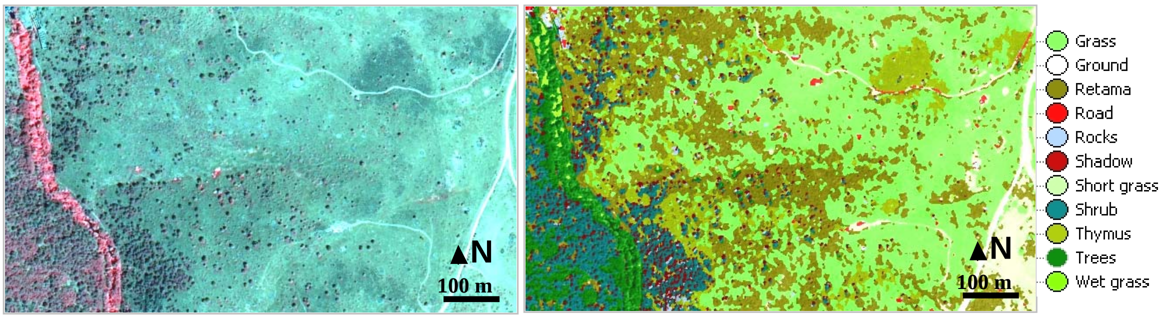


Figure 1. Pixel-based supervised classification

Object-based classification

After developing a hierarchical network, context information worked successfully for classifying urban areas, riparian forests, pine-reforested areas, roads and tracks. Best features for distinguishing urban areas, tracks and roads were “area”, “area of neighbouring objects” and “length/wide”. Relative area of shadows resulted suitable for delimiting tall shrubs and trees.

Fuel type map precision increased significantly after carrying out context analysis. Six of the seven Prometheus fuel types were found and accurately assigned in level 3. Fuel type 6 was not found within the study area. Best improvement was obtained when classifying "urban areas" and "bare soil" (that included roads and tracks). It was necessary to employ a thematic layer delimiting pine reforestations in order to distinguish fuel types 5 and 7.

One problem encountered when working with object-oriented analysis is the amount of time spent in the segmentation process. Nevertheless, it is clearly a tool that is due to receive more research attention and increasing application.

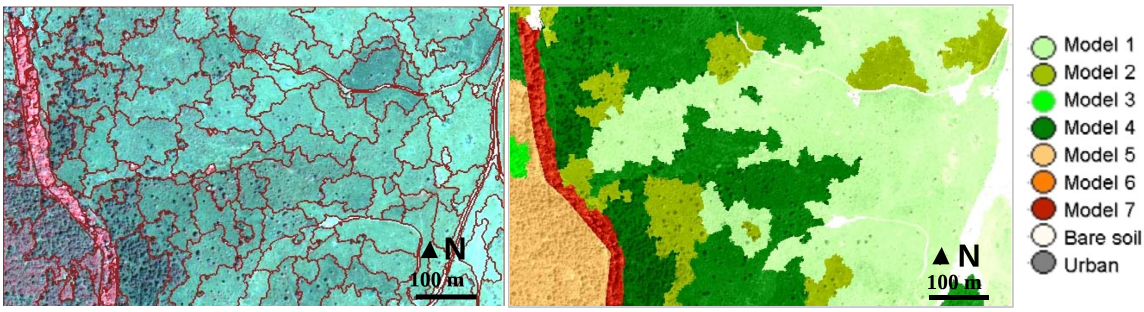


Figure 2. Fuel map obtained with object-oriented classification

## Conclusions

The main conclusions of the presented work are:

- An accurate methodology for local fuel type mapping based on the Prometheus fuel type classification system was created.
- Traditional multi-spectral classification methods on pixel basis by themselves were not suitable for high resolution imagery classification, but provided a useful input for a object-oriented classification.
- Being able to work on different scales is a crucial aspect when local fuel types mapping, since they are described in terms of relative covers.
- Based upon this research, future work is encouraged for the analysis of very high resolution imagery in order to map fuel types at a local scale. Research should be directed to avoiding misclassification of forested fuel types.

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