TOWARDS MONITORING POST-FIRE VEGETATION COVER DYNAMICS IN THE MEDITERRANEAN WITH THE USE OF OBJECT-BASED IMAGE ANALYSIS OF LANDSAT IMAGES

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ABSTRACT

Up to date information on vegetation cover is essential to assess daily fire potential danger. Since satellite sensors are able to cover wide areas at a high frequency and are also able to provide information about non-visible spectral regions, they represent a very valuable tool for monitoring vegetation recovery and vegetation succession after fire. The aim of this work was to develop a model for an operational monitoring of vegetation cover dynamics in fire-prone Mediterranean ecosystem with the use of multi-temporal Landsat images. The specific objectives were 1) to map the extent of burned areas, and 2) to monitor post-fire vegetation recovery within the fire affected areas. The work involved the development of an Object-Based Image Analysis (OBIA) model with the use of multi-temporal Landsat images covering North-Lebanon. In this approach, instead of processing all areas of an image with the same algorithms, a differentiated procedure would be more appropriate. The results of the classification showed the extent of burned areas (objects classified as burned) in one specific year. Subsequently, pixels located within objects previously classified as burned areas were monitored 16 years and 20 years of the fire events. It was found that the developed approach was flexible enough to be employed for a continuous monitoring of post-fire vegetation dynamics. In future work, it will be possible to 1) narrow the monitoring down to a yearly basis by importing multi-temporal satellite data acquired on every year after the fire event, and 2) assess the accuracy of the results by conducting field visits.

INTRODUCTION

Fire is an integral part of many ecosystems, including those of the Mediterranean (1). Wildfires create deep and rapid changes in the structure of vegetation cover and functioning of natural ecosystems. Research studies have shown that severe fires can be a driving force in landscape homogenization and that burned areas in which flammable shrublands expand can have higher probabilities of reburning than neighboring unburned areas (2). In some areas the effect of fire is able to modify permanently the vegetation cover. Therefore, monitoring and assessing the impact of post-fire effects (forest regeneration and vegetation recovery) and succession dynamics in the long term is important to address fire prevention activities and establish post-fire resource management plans (3).

Traditional methods of recording post-fire impact on vegetation include extensive field work or observations from an airborne platform (4). As fire sizes increase and time becomes a constraining factor, traditional methods have become costly and labor-intensive. Long-term monitoring is often required in order to evaluate the resilience of the different ecosystems towards forest fires (5).

In comparison with extensive and labor-intensive field campaigns, remote sensing offers a time- and cost-effective alternative for mapping post-fire vegetation over large areas (6). Accordingly, satellite sensors, which are able to cover wide areas at a high frequency and provide information about non-visible spectral regions, represent a very valuable tool for monitoring forest regeneration and vegetation recovery after fire (7,8). In addition, satellite remote sensing has provided an opportunity to evaluate patterns of forest regeneration and vegetation recovery after wildfire.

Both supervised (9,10,11) and unsupervised (12) techniques have been applied in monitoring post-fire effect on vegetation. A major problem associated with pixel-based classifications is the occurrence of salt-and-pepper artifacts, among others. As a solution, object-based classification schemes include both spectral and contextual information (13) and have the potential of overcoming some of the problems that are related to a pixel-based classification.

The aim of this work was to develop a model for an operational monitoring of vegetation cover dynamics in fire-prone Mediterranean ecosystem with the use of multi-temporal Landsat images. The specific objectives were:

1. to map the extent of burned areas; and
2. to monitor post-fire vegetation recovery within burned areas.

It is expected that spatial information on post-fire vegetation cover dynamics would influence wildfire risk assessment in Lebanon. Most recently, an Italian system for wildfire risk forecasting (14) has been installed at the Lebanese Civil Defense Headquarter. The system provides daily forecasts on next-days potential wild fire risk all over the Lebanese territory. Accordingly, this research has a future potential in feeding into this system continuous spatial information in relation to burned areas and post-fire vegetation cover dynamics.

STUDY AREA AND DATASET DESCRIPTION

The study area is the forested landscape of North-Lebanon (Figure 1). A prominent characteristic of vegetation communities and landscape structure in Lebanon is the high diversity and heterogeneity, in terms of the spatial distribution and arrangement of the abiotic, biotic, floristic and ecological components. In general, the landscape in Lebanon is composed of a mixture of large, small, distinct and indistinct patches of vegetation cover. The Landsat data comprised one MSS image acquired on 15-9-1972, one TM image acquired on 28-9-1986, one TM image acquired on 19-11-2002, and one TM image acquired on 3-12-2010.

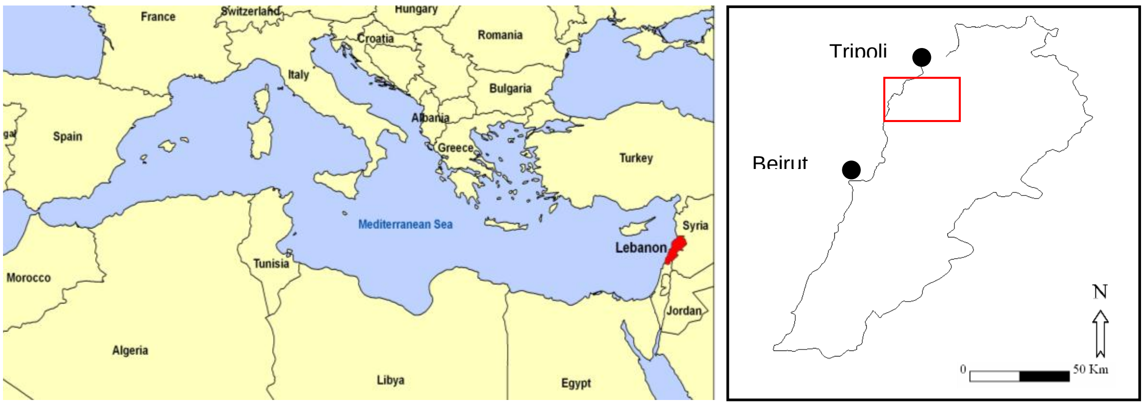

Figure 1: Location of Lebanon in red (left), and the study area of North-Lebanon (right).

METHODS

The work involved the development of an Object-Based Image Analysis (OBIA) model with the use of multi-temporal Landsat images covering North-Lebanon.

The strategy before classifying fire affected areas and monitoring post-fire vegetation recovery was to create a four-level graded scale of segmentation. Thus, larger objects (regarded as super-objects) would provide information for smaller objects at lower levels. After segmentation, the different levels of segmentation were classified using both spectral (e.g. NDVI) and contextual information (e.g. relationship to super-objects).

More specifically, the following classes were created at the different levels (Figure 2). The classes “vegetation L4” and “no vegetation L4” were classified using the 1972 image (level 4). The classes “vegetation L3”, “burned L3”, and “other L3” were classified using the 1986 image (level 3). The classes “recovery L2”, “other vegetation L2”, “unrecovered L2” and “other L2” were classified using the 2002 image (level 2). Finally, the classes “new recovery L1”, “ongoing recovery L1”, “other vegetation L1”, “unrecovered L1” and “other L1” were classified using the 2010 image (level 1). Each class of a classification scheme formulated in the object-oriented approach contained a class description. Each class description consisted of a set of fuzzy expressions (a fuzzy rule) allowing the evaluation of specific features for classification.

In addition, every image object in the class hierarchy is networked in a manner that each image object “knows” its context – which its neighbors are, which levels and objects (super-objects) are above it and which are below it (sub-objects). No image object may have more than one super-object, but it can have multiple sub-objects.

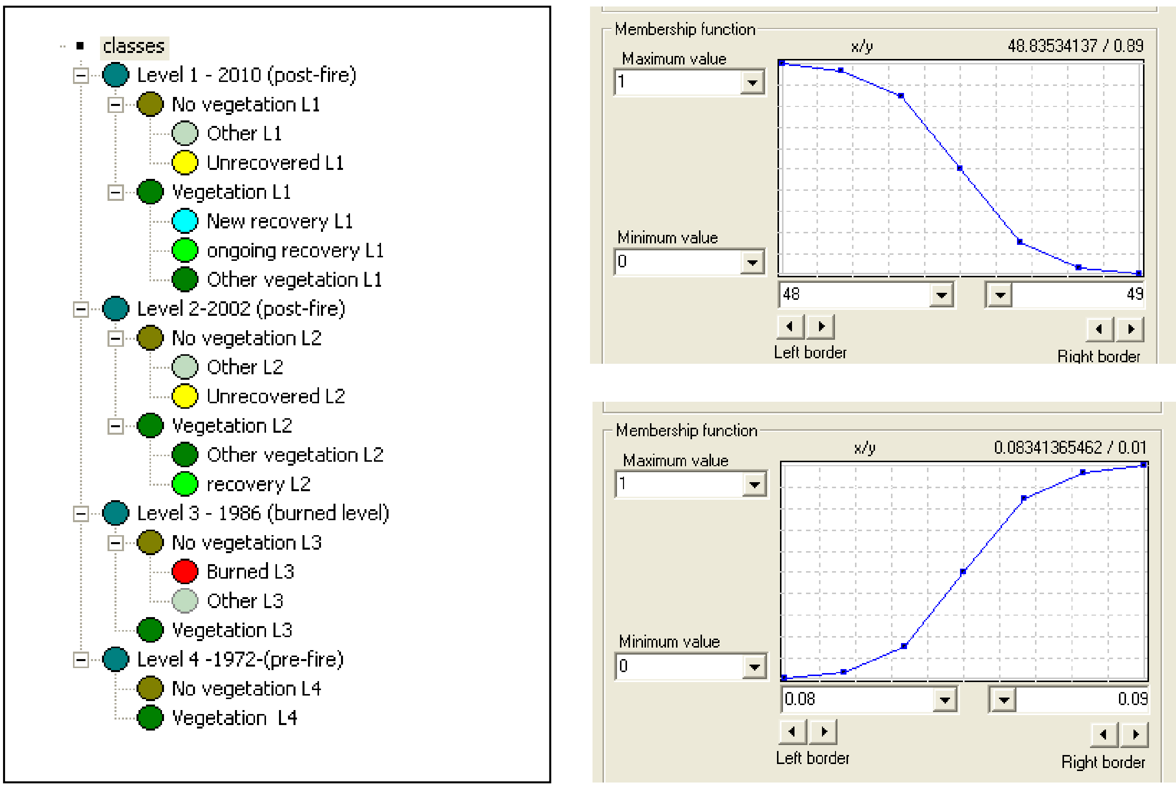

Figure 2: Class hierarchy (left), and the membership functions of mean band 4 of the 1986 image (top right) and NDVI of the 2010 image (bottom right).

Level 4 was the first to be classified followed by level, 3, 2 and 1 respectively. From the moment that an object is classified as burned at level 3, for instance, local intelligence was applied and, in principal, everything which was done from that moment at levels 2 and 1 with this object and its networked environment was done with a burned logic. Accordingly, the class “new recovery L1” at level 1 was identified using spectral and contextual features, namely NDVI of the 2010 image (Figure 2) and “existence of super-objects "unrecovered L2” at level 2. It is to be noted that "unrecovered L2” is also a sub-object of the class “burned L3” at level 3. The spectral feature “mean band 4 (Near Infra-red)” of the 1986 and the contextual feature “existence of super-object vegetation L4” were used for the classification of “burned L3”.

RESULTS

The classification results (Figure 3) were exported as a shape file and all statistics were made available for extraction. When investigating one specific fire event in 1986, a total of 1164 pixels were classified as burned (level 3). Then, a total of 1148 pixels were classified as recovered vegetation in 2002 (level 2) within the same fire affected area. An additional area of 16 pixels was mapped as recovered vegetation by 2010 (level 1).

The mapping approach reflects how each classification task addressed a certain scale. Thus, it was possible to represent image information at different scales simultaneously by different object layers. Bringing different images in relation to each other can contribute to the extraction of further valuable information.

An important characteristic of the method is the multitude of additional information which can be derived based on image objects. Beyond tone, contextual information from other object layers was used. Using this information, the classification approach allowed a better differentiation of objects and led to more specific results.

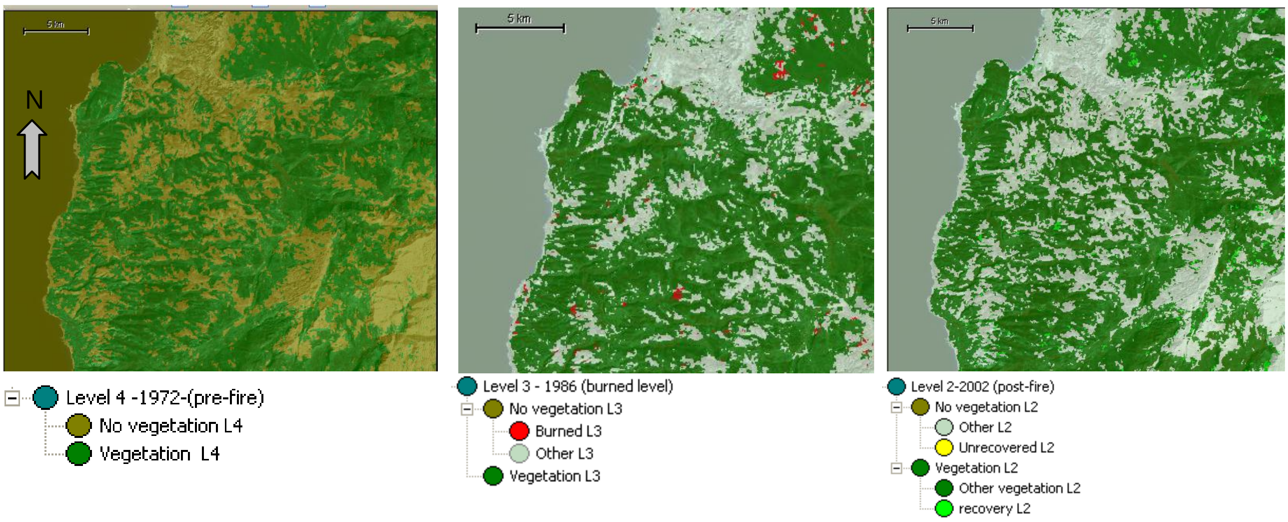

Figure 3: Subset of the classification results at level 4 (left), level 3 (centre), and level 2 (right).

CONCLUSIONS

The role of remote sensing has become increasingly very important in monitoring post-fire vegetation cover dynamics. The development of new methods and advanced techniques in satellite remote sensing image analysis are expected to move forward research and facilitate the use of an operational tool for post-fire monitoring. This can also help in improving the assessment of fire potential danger.

The developed object-based classification scheme in this work is found flexible enough to be employed for a continuous monitoring of vegetation dynamics. Instead of processing all areas of an image with the same algorithms, a differentiated procedure proved to be appropriate. This is a specific strength of the applied method. In future work, it will be possible 1) to narrow the monitoring down to a yearly basis by importing multi-temporal satellite data acquired on every year after the fire event, and 2) to assess the accuracy of the results by conducting field visits,

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