An Ignition Probability Index for the Early Detection of Wildfires in the Eastern Mediterranean Region

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Abstract
Wildfires continue to form a major disturbance factor in Mediterranean ecosystems, often associated with significant loss of properties and human lives. Fast detection and suppression within the first minutes after ignition constitute one of the pillars for successful wildfire management and prevention of its catastrophic consequences. The current study aims to develop a Fire Ignition Probability Index (IPI) which will be integrated in an automatic fire detection system composed by optical and thermal land cameras and UAV. The IPI index will be calculated based on the pyric history, the anthropogenic influence and the simulated fire behavior in a study areas in Southern Greece. The pyric history will be represented by point data and through a Kernel Density Estimation will calculate a risk factor. The anthropogenic influence will be estimated based on an inverse relationship with the Euclidean distance from roads and settlements. Finally, fire behavior will be calculated using fire simulation models and data on fuel properties, estimated using state of the art remote sensing methods and field data. The integration of the IPI in the automatic fire detection system is expected to form a significant contribution to its improved accuracy.
Keywords: Forest Fires, Ignition Probability Index, Remote Sensing, Fire Detection.

1. Introduction

The occurrence of wildfires and especially large ones is the result of the combined action of three driving forces, namely fuel availability and continuity, weather patterns and anthropogenic activity. Over the last years several studies have revealed significant changes in the fire regime of the Mediterranean Europe after the 1970s with a significant increase both in total number of fires and area burned as a result of increased fuel load and changes in weather patterns (Pausas & Fernandez-Munoz, 2012).

The increased amount of resources allocated in fire suppression and yet the inability to prevent the catastrophic megafires imposes the need to rethink of the problem and pay serious attention to fire prevention and quick fire detection. In the current study anthropogenic factors, pyric history and vegetation flammability properties are integrated into an Ignition Probability Index (IPI), which will identify vulnerable areas and it will be integrated in an automatic fire detection system composed by optical and thermal land cameras and UAVs.

2. Materials and Methods

2.1. Study Area

The study is conducted in the Kotychi and Strofylia Wetlands National Park in south east Greece which is a designated national park since 2002. The dominant species of the forested areas are *Pinus pinea* and *P. hallepensis* while several different vegetation formations are present including phryganic ecosystems, grasslands and shrublands.

2.2. Data and Methods

The IPI developed in the current study is based on two important components of fire regime, which are the fuel availability and the anthropogenic activities, and it also integrates the pyric history of the area. The fuel availability was determined by the integration of remote sensing data and methods and *in situ* data on fuel load.

Fuel load was calculated using data collected from 50 plots and used in literature derived allometric equations for fuel load estimation. Each of the identified fuel types was assigned into one of the Fuel Models described in the literature with some necessary adjustments (Dimitrakopoulos, 2002; Scott, & Burgan 2005). The fuel load map was then used, along with additional data, in the fire simulation model Flammap (Finney, 2006), to provide an estimation of the potential intensity of a fire. The fireline intensity, estimated in flammap was rescaled to a scale of 0 (low intensity) to 1 (maximum intensity to produce a Flammability Index (FI) for the integration in the final IPI.

The anthropogenic activity (Human Index; HI) was integrated in the final IPI using the distance from roads

and settlements in a scale of 0 (maximum distance) to 1 (minimum distance).

A Kernel Density estimation function was employed to convert the point data of fire occurrence over the last 40 years into an estimation of the fire risk. The values were also rescaled in a scale of 0 (low risk) to 1 (high risk) to generate the Pyric History Index (PH).

The three components were integrated in the final ignition probability index using the following formula:

$$IPI = 0.7 * FI + 0.2 * HI + 0.1 * PH$$

3. Results and Discussion

The vegetation mapping and the analysis of fuel load showed high variation both between and within the various vegetation types, indicating the diversity of Mediterranean vegetation in terms of composition and structure. The highest fuel loads were observed in the pure or mixed stands by *P. halepensis* while the phryganic and grassland formations had the lowest. This variation is reflected in the Flammability Index shown in Figure 1a.

The analysis of the anthropogenic activities (Figure 1c) revealed a high vulnerability almost in the entire area due to the dense network of roads and fuel breaks which allow easy access everywhere. The analysis of the pyric history, on the other hand, (Figure 1b) reveals a fire hot spot in the central and northern part of the study area.

The developed IPI (Figure 1d) indicates high vulnerability to forest fires in the largest part of the study area and especially in the forested parts, due primarily to the combined action of high fuel loads and easy access by humans. Since it integrates these two important aspects of wildfires it can be used to identify the most vulnerable areas and increase the degree of preparedness and alert. Furthermore, the generated index will be integrated in the THEASIS system which is developed within the frame of the SFEDA project and aims in the quick and accurate detection of forest fires using optical and thermal cameras as well as UAVs.

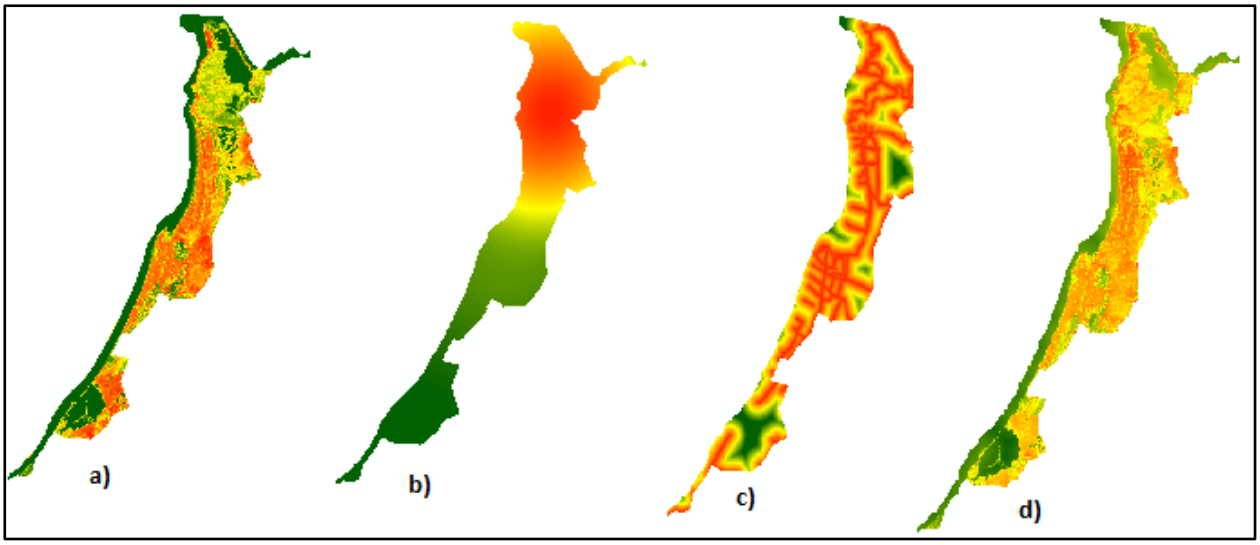

Figure 1. Flammability Index (a), Pyric History Index (b), Human Index (c) and Ignition Probability Index (c)

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