ARTICLE IN PRESS

Climate Risk Management xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Climate Risk Management

journal homepage: www.elsevier.com/locate/crm

A novel method to identify likely causes of wildfire

Mario Mhawej [a,b,*], Ghaleb Faour [a], Jocelyne Adjizian-Gerard [b]

[a] National Center for Remote Sensing, National Council for Scientific Research (CNRS), Riad al Soloh, 1107 2260 Beirut, Lebanon
[b] St Joseph University, Department of Geography, Damascus Street, Mar Mickael, 1104 2020 Beirut, Lebanon

ARTICLE INFO

Article history:
Received 3 April 2016
Revised 19 January 2017
Accepted 24 January 2017
Available online xxxx

Keywords:
Wildfire
Likelihood
Combination of factors
Python
Lebanon
Natural hazard

ABSTRACT

Natural phenomena, such as wildfires, usually require the coincidence of several related factors in both time and space. In wildfire studies, literature-based factors were collected and listed in Mhawej et al. (2015). The question remains: which combination of factors leads to wildfires? In this context, a novel combination of wildfire likelihood factors was proposed in three different Lebanese forest covers (i.e., pine, oak, and mixed) and related literature-based factors to historical wildfire occurrences. The threshold values of each factor were deduced from the relationship between the element and number of fire occurrences. Each combination of factors was given a unique number. These mixtures corresponded to two, three, four or five factor groupings. The result was the association of each likelihood probability (i.e., low, medium, high, and very high) with different combinations of factors. Ultimately, using these combinations, the wildfire likelihood in Lebanese forests was efficiently and instantaneously generated. This approach could be portable to other Mediterranean regions and applied to several natural hazards.

1. Introduction

A wildfire may appear to be a natural disaster. Nonetheless, wildfire causes numerous primary and secondary consequences to humans and the ecosystem. In this context, many studies worldwide have tried to assess and mitigate wildfires (e.g., Balice et al., 2000; Quayle et al., 2004; Malevsky-Malevich et al., 2008; Scott, 2013). While some authors focused on post-fire impacts (e.g., Miller and Yool, 2002; MacDonald and Huffman, 2004; Chafer et al., 2004; Johnson et al., 2005; Robichaud and Ashmun, 2013), others tried to evaluate and map wildfire hazards (e.g., Piñol et al., 1998; Peng et al., 2005; Peters et al., 2013; Mhawej et al., 2015), vulnerability (e.g., Beeson et al., 2001; Cova et al., 2013; Chuvieco et al., 2014), and risk (e.g., Preisler et al., 2004; Martínez et al., 2009; Mhawej et al., 2016).

Similar to other natural or man-caused phenomena, wildfires only occur when multiple factors (e.g., climatic, topographic, anthropogenic, etc.) coexist. Previous studies focused on weighting these elements to produce the wildfire likelihood across a region (e.g., Mercer and Prestemon, 2005; Martínez et al., 2009; Salis et al., 2013). These factors included precipitation, temperature, wind speed and direction, and soil moisture. In addition, the cause of wildfire classifications were categorized worldwide (e.g., Stephens, 2005; Genton et al., 2006; McGee et al., 2015). In 2013, these causes were grouped into natural, accidental, use of fire or glowing objects, responsible and irresponsible fire use, and rekindling (Camia et al., 2013).

* Corresponding author at: St Joseph University, Department of Geography, Damascus Street, Mar Mickael, 1104 2020 Beirut, Lebanon.
E-mail addresses: mario.mhawej@gmail.com (M. Mhawej), gfaour@cnrs.edu.lb (G. Faour), jgerard@usj.edu.lb (J. Adjizian-Gerard).

http://dx.doi.org/10.1016/j.crm.2017.01.004
2212-0963/

In the first approach, the generalization that each the factor included in each wildfire and had a static weighting factor throughout the region was questionable. In the second approach, illustrating the general causes without relating them to natural and/or anthropogenic factors, which have tremendous effects on wildfire ignition, was improper. Consequently, none of the previous studies or research, to our knowledge, have attempted to identify the possible reasons behind each wildfire's ignition in terms of wildfire likelihood factors.

A Lebanese forest had an approximate area of 2000 km^2. With a prevailing Mediterranean climate, this forest contained 2500 vegetation species, including 92 endemic plants (Faour et al., 2006). Oak trees covered nearly half of the forest (Mhawej et al., 2016). The other half of the forest included pine trees (~13%) and other species (~36%) (Mhawej et al., 2016). Most forest fires occurred between June and October (Mhawej et al., 2016), representing 82.47% of the total number of wildfires between 1982 and 2015.

In this paper, a novel combination of wildfire likelihood factors was proposed. First, Lebanese forests were subdivided into three main categories (i.e., pine, oak, and mixed). The wildfire occurrences were generated using historical wildfire datasets between 1982 and 2015. We used thirteen wildfire-ignition factors that were deduced from the literature (Mhawej et al., 2015, 2016) to associate the likelihood probabilities (i.e., low, medium, high, and very high) with factor combinations. They python programming language was used to designate each mixture with a unique number. Hence, the real cause behind each wildfire was revealed. Wildfire likelihood was generated in a time-effective and resource-saving manner by consulting these combinations in relation to forest type.

2. Materials and method

Datasets of the thirteen factors affecting wildfire likelihood in Lebanon (Mhawej et al., 2016) were mainly acquired from remote sensing imageries and GIS (Geographic Information System) databases. Precipitation values were retrieved from the Tropical Rainfall Measuring Mission (TRMM) satellite, which has a spatial resolution of 2.5 km. Temperature, evapotranspiration and climatic drought were calculated from the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite, which has a spatial resolution of 1 km. Vegetation index datasets were obtained from Landsat images, which have a high spatial resolution (i.e., 30 m). Altitude, slope and aspect were retrieved from the Lebanese topographic map, with a spatial resolution of 10 m. The Lebanese soil map from the year 2003 was used to calculate soil water retention values.

There is controversy regarding the uses of distance or neighbourhood parameters in Geographic Information Systems and remote sensing. For instance, Tobler's first law (Tobler, 1970) states that "everything is related to everything else, but near things are more related than distant things." Many authors have argued that this law is no longer valid because "transportation and communication technologies have shrunk the world to an incredible degree [...] and "nearness" as a concept can be extended to include both space and time" (Janelle, 1995; Miller, 2004). As per our study, human impact on wildfire ignition can only be highlighted to be a steady relationship using the proposed factors (i.e., proximity to agricultural land, proximity to roads, proximity to urban areas, proximity to recreation areas, breeding grounds, exploitation zones, etc.), mainly because of the lack of socio-economic databases. The Land Cover/Land Use of 2005 was needed to retrieve these factors. The complete list of factors used in this study and their sources are shown in Table 1.

Datasets were orthorectified and sampled. Only the Lebanese forest, which was divided into three vegetation types (i.e., pine, oak, and mixed), was included. This classification was based on the fact that pine trees (i.e., *Pinus pinea* and *P. brutia*) had the worst economic losses (Masri, 2005) and are the most inflammable species (Behm et al., 2004; Ellair and Platt, 2013; Varner et al., 2015). Pine trees were followed by oak forests (i.e., *Quercus cerris*, *Q. infectoria*, and *Q. calliprinos*) (Williamson and Black, 1981; Rebertus et al., 1989). The other species were labelled as "mixed" (e.g., *Cedrus libani*, *Juniperus excelsa*, *J. drupacea*, *Ostrya carpinifolia*, and *Platanus orientalis*) (Mhawej et al., 2016). The forest was also divided equally into 1 km^2

Table 1
Factors used for the determination of wildfire likelihood, their sources and their units (*Source:* Mhawej et al. (2016)).

Ignition factors	Sources	Unit used
Precipitation	TRMM2B31, 1998–2009, 2.5 km	Millimetres (mm)
Temperature	MOD11A2, 2000–2014, 1 km	Celsius (°C)
Evapotranspiration	MOD16A2, 2000–2012, 1 km	Millimetres (mm)
Climatic Drought	Aridity Index, 2000–2009, 1 km	Classified according to UNEP, 1992
Altitude	Lebanon's Topographic Map, 10 m	Metres (m)
Slope	Lebanon's Topographic Map, 10 m	Degree (°)
Aspect	Lebanon's Topographic Map, 10 m	Degree (°)
Soil Water Retention	Lebanon's Soil Map, 1/50,000	Classified according to UNSW, 2007
Vegetation Index	NDVI from LandSat 8, 2014, 30 m	No unit; values range between −1 and 1
Proximity to agricultural land	Land Cover/Land Use, 2005, 1/20,000	Metres (m)
Proximity to roads	Land Cover/Land Use, 2005, 1/20,000	Metres (m)
Proximity to urban areas	Land Cover/Land Use, 2005, 1/20,000	Metres (m)
Proximity to recreation areas, breeding grounds, exploitation zones, etc.	Land Cover/Land Use, 2005, 1/20,000	Metres (m)