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Determining the Priority of Effective Factors on Forest Fire from Analytical Hierarchy Process

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Abstract

In this study which was conducted in Darab Kola forest, the analytical hierarchy process (AHP) in Expert choice software was used for determining of the priority of effective factors on fire occurrence. Our criteria were NDVI as vegetation cover, soil moisture, distance to cattle pen, and distance to road, sloe gradient, slope direction (Aspect) and altitude. Required data were gathered through pairwise comparison questionnaires filled by forest experts. Results showed that the priorities of the effective factors on fire occurrence in forest was plant and soil moisture (0.366) > density of vegetation cover (0.256) > slope gradient = slope direction (0.121) > distance to cattle pen and road (0.057) > altitude (0.023).

Keywords: AHP, Fire, Priority, Criteria, Darab Kola forest.

INTRODUCTION

Forest fires represent one of the most critical issues in global change. They are responsible of several devastating damages like loss of biodiversity, decrease in forests, alteration of landscape, soil degradation, increase in greenhouse effect, etc [12]. Smith et al. [10] showed that, in the case of Savanna fires, surface spectral reflectance increases with increasing fire severity due to the formation of increasing quantities of white mineral ash. Also, their studies showed linear relationships between fire duration and post-fire surface spectral reflectance, with the optimal relationship being a ratio of the 450 and 2034 nm spectral reflectance observations. In recent years, large fires with high rates of tree mortality have raised interest in land management policies and the effect such policies may have on wildfire severity in the western United States. The primary management tools are the application of mechanical treatments (thinning or masticating) and prescribed fire [9].

In Korea, massive loggings for fuel or agricultural purpose or other developmental needs were the most disturbance factors until 1970s. The forest fire could influence the soil micro arthropod assemblage in two ways; direct killing by the blaze and indirect impacts by altering the arthropods' habitat by changing the composition of forest vegetation or by disturbing the balance of soil chemicals, water levels, and soil pH. In addition, burning out of leaf litter and other organic matter may cause the depletion of food source of soil arthropods since decomposers are closely associated with those organic substrates [6]. In Turkey, forest fire is still one of the greatest natural hazard problems. According to the study, last six decades, 1.504.245 ha of the forests has been affected by fire. In other words, it shows annual affecting forest areas over 24.000 ha. In addition to this, along the cost line from Antalya to stanbul, approximately 12 billion hectares forests are in the first order fire sensitive region [3]. Fire in the Brazilian Amazon remains an important tool for clearing of forested land and maintenance of cleared areas used for agricultural production, however, recent extreme drought conditions in Brazil experienced during El Niño years of the 1997–1998 and the 2005–2006 dry seasons have contributed to escaped fires burning up to 1000 km^2, endangering human health, private property, forested landscapes, and national and state infrastructure [2].

The use of satellite imagery to measure the impact of fire on vegetation communities has become a popular topic of discussion in recent years In the Sydney region of Australia, it has been demonstrated that a relationship between fire severity and soil damage can be deduced in eucalypt forests by fire severity measures an important finding for understanding the interrelationship between wildfire, soil erosion and water quality [11]. The objective of this study is to determine the priority of the effective factors on fire occurrence in a forest with the analytical hierarchy process (AHP) and Expert choice software.

MATERIAL AND METHOD

Study Site

Darab Kola forest with an area of 2612 hectare is located in watershed number 74 and in southeast of the city of Sari in Mazandaran province, Iran (36° 33′ 20″ to 36° 33′ 30″ N, 52° 14′ 40″ to 52° 31′ 55″ E). The bed rock is marl, calcareous sandstone and limestone. The general aspect of the hillside is north and its average slope is 40%. The main woody species in Darab Kola are *Fagus orientalis Lipsky*, *Ulmus glabra* Huds, *Acer velutinum* Boiss, *Carpinus betulus*, *Parottia persica* and *Alnus glutinosa L*. The dominant species in our research area is *Fagus orientalis Lipsky*. Herbaceous vegetation in the forest encompasses Asperula (*Asprula odorata*), Ferfion (*Ephorbia sp.*), Metumeti (*Hypericum androseamum*) and fern (*Polystichum sp.*). The climate is very moist with average temperature ranging from 26.1°C in August to 7.5 $^{\circ}$C in February. Mean annual air temperature is 16.7 $^{\circ}$C. The region receives 983.8 mm of precipitation annually. Minimum and maximum rainfall is 36.1 to 119.8 mm which occurred in July and November respectively (Figure 1).

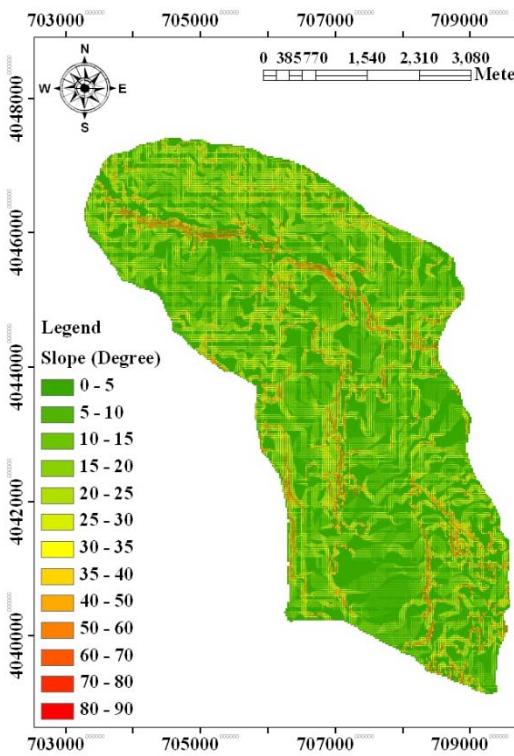

Figure 1. Location of the study area

Sampling and Variables Measurement

AHP developed by Saaty, is a method that enables reaching a decision by using quantitative and qualitative data. As the problem is stated in the hierarchical tree structure in this method, the problem becomes easy to understand. A hierarchical tree comprises a minimum of three stages: ‘target, criteria and alternatives’. AHP is based on determining the relative priorities (weighting) of the criteria by pairwise comparison. In pairwise comparison, the question is asked that ‘how many times is a criterion more important than another one?’ and it is answered according to the scale in Table 1. For controlling the consistency of comparison, the consistency ratio is determined. Firstly, the consistency index (T_i) of the matrix is determined by equation 1:

$$T_i = (\lambda_{\max} - n)/(n-1) \quad (1)$$

Where $\lambda_{\max}$ is the maximum value and n is the size of matrix. The random consistency index (R_i) is obtained by equation 2:

$$R_i = 1.98(n-2)/(n) \quad (2)$$

The consistency ratio is determined by the T_i/R_i ratio. If the ratio is below 0.1 this shows the comparison is consistent. Lastly in AHP, the normalized eigenvectors created by the scoring of the alternatives considered for each criterion are turned into a matrix, and this matrix is multiplied with the normalized eigenvector, including the weights of the criteria. The result gives the preference values of the alternatives. The Expert choice software was used for determining of the priority of effective factors on fire occurrence. Our criteria were NDVI as vegetation cover, soil moisture, distance to cattle pen, and distance to road, sloe gradient, slope direction (Aspect) and altitude. Required data were gathered through pairwise comparison questionnaires filled by forest experts.

Table 1. Scale for pairwise comparison 2, 4, 6 and 8 can also be used.

Definition	Degree of importance
Equal	1
Moderate	3
Strong	5
Very strong	7
Extreme	9

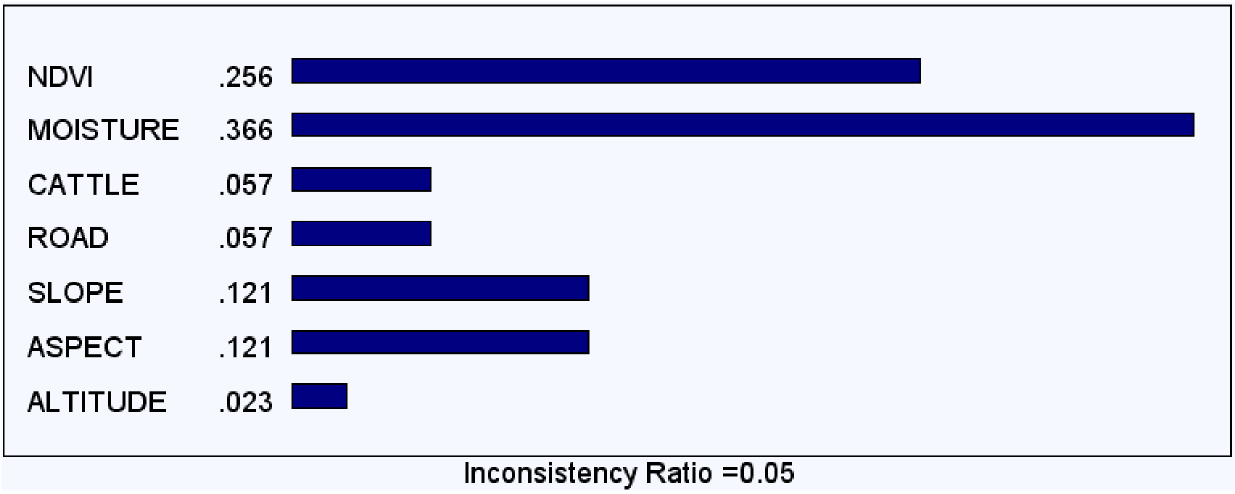

Figure 2. Derived priorities with respect to effective factors on fire occurrence in forest

RESULTS AND DISCUSSION

Table 2 shows the pairwise comparison matrix of the criteria. Therefore the priorities of the effective factors on fire occurrence in forest was plant and soil moisture (0.366) > density of vegetation cover (0.256) > slope gradient = slope direction (0.121) > distance to cattle pen and road (0.057) > altitude (0.023) (Figure 2). The suppression of wildfires in ponderosa pine (*Pinus ponderosa Dougl*. ex Laws.) forests in the southwestern United States has dramatically changed forest structure, composition, and function. Breece et al. [1] found that canopy damage from fire as a strong and consistent predictor of post-fire mortality of ponderosa pine and bark beetle attacks and bole char rating as less consistent predictors because of temporal variability in their relationship to mortality. The small increase in tree mortality and bark beetle attacks caused by prescribed burning should be acceptable to many forest managers and the public given the resulting reduction in surface fuel and risk of severe wildfire.

Table 2. Pairwise comparison matrix of the criteria

	MOISTURE	CATTLE	ROAD	SLOPE	ASPECT	ALTITUDE
NDVI	(2.0)	5.0	5.0	3.0	3.0	7.0
MOISTURE		6.0	6.0	4.0	4.0	8.0
CATTLE			1.0	(3.0)	(3.0)	5.0
ROAD				(3.0)	(3.0)	5.0
SLOPE					1.0	6.0
ASPECT						6.0

Row element is _ times more than column element unless enclosed in ()

In this study we found that moisture of soil and vegetation cover was most important factor in fire occurrence in forest (Figure 2). The influence of forest fires in Siberia, Mongolia, and China have been observed in many places. The forest fires in far eastern Siberia from August to October in 1998 gave an impact on enhancement of surface CO concentrations over Rishiri in northern remote island of Japan [7]. After a wildland fire, hydrological processes such as runoff and erosion at the hillslope scale are known to change significantly. This is because the heat produced by the fire vaporizes organic compounds that cool and precipitate to form a hydrophobic coating on subsoil particles. The extent and magnitude of overland flow due to this mechanism would strongly depend upon the severity of the fire, the amount of ash and burned material remaining on the soil surface following the fire, and the amount and intensity of the rainfall during the storms following the fire [8].

Fire regimes in Mediterranean pine forests are poorly understood and have been largely inferred from morphological, chemical, and life history traits [13]. Surface-fire-adapted species do not have an effective canopy seed bank and seeds are susceptible to heat, so regeneration of *P. nigra* and *P. sylvestris* forests after wildfire has been poor [5], to the point of extirpation of some of these forests following fire. These species are important ecologically and commercially, covering approximately 3.8 million hectares (ha) in the Mediterranean Basin. Severe wildfires in recent years have been especially damaging in these forests, between 1990 and 2000, over 25% of the *P. nigra* forests in Catalunya, northeastern Spain, were killed by severe fire and post-fire regeneration from seed has been minimal [4]. In concluded it is suggested that the forest fire risk map is prepared for Darab Kola forest to better management of region under critical status.

CONCLUSIONS

We found that the priorities of the effective factors on fire occurrence in forest was plant and soil moisture > density of vegetation cover > slope gradient = slope direction > distance to cattle pen and road > altitude.

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