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Development the Set of Criteria for Forest Fire Risk Mapping in the Zagros Region of Iran

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Abstract:
A list of criteria that effected on forest fire risk, based on literature was designed and then Delphi questionnaire was performed for expert evaluation. The results were shown that after analysis of the existing literature in combination with the fire regime of the study area, 5 criteria and 17 sub-criteria were selected. According to these criteria, a Delphi questionnaire was prepared and sent to fire protection experts for evaluation. Subsequently, a criteria-importance diagram was created based on the 'importance percentage' and the 'importance rank' of the criteria under study. The results showed that the type of vegetation cover was the most important criterion (32.62% importance percentage) and the air humidity was the most important sub-criterion (31.7%). These research showed that in this region all of the factors (ecological and social) had effect on the forest fire.

Keywords:
Questionnaire, Criteria, forest Fire, Izeh, Risk Mapping

1. Introduction

The introduction of your article is organized as a funnel that begins with a definition of why the experiment is being performed and ends with a specific statement of your research approach. And it highlights controversial and diverging hypotheses when necessary.

Understanding the behavior of forest fires, the factors that contribute to a fire prone environment and the factors that influence fire behavior is essential for forest fire risk assessment [4]. Khuzestan is one of the provinces of Iran with sub-Mediterranean climate. The fire season in Iran lasts for seven months and over 90% of forest fire are anthropogenic in nature [6,2]. Forest fire causes can be classified in three types: 1- natural factors, 2- human intentional factors and 3- other unintentional causes [4]. Fire risky area is the place where has potential fire or from which the fire easily spread to other areas. The risk from fire can be mapped commonly from related factors with remote sensing and GIS data. In particular, a weight is assigned to each factor, according to its sensitivity of causing forest fire [10]. The criteria for sustainable forests management (SFM) include preserving life diversity in forest areas, health, survival and sustainable forests management, function and productivity of forest ecosystems, protection and environmental responsibilities, protection and development of socioeconomic responsibilities and legal framework [8]. Wood International Organization criteria for sustainable management of forests in tropical areas include empowerment of circumstances for forest sustainable management, protecting forest resources, situation and health of forest ecosystem, cycle's circulation of forest product, biological diversity, water and soil, and socioeconomic and cultural aspects [13]. One of the main reasons to provide generic criteria is the wide range of biophysical, social, economic, and cultural differences among countries, each country will be able to specialize and match these criteria with the particular circumstances regarding its own natural-human interaction [17]. For this purpose, in this research we aim to choose appropriate criteria and modeling these criteria for detection forest fire in the Zagros region, in the Western and Southwest regions of Iran. The purpose of this study was, identifying, selecting and modeling the appropriate criteria for judicial and successful forest fire detection with the Delphi method, in the Zagros mountainous region of Iran.

2. Materials and Methods

2.1. Study Area

Zagros region has been located in the west of Iran from northwest to southwest (from Piranshahr west Azerbaijan to Fars province). Total of the forest area in this region is more than 5.2 million hectares, very rich flora and fauna with high diversity. The parent rock is limestone, while the Rendizinas, Lithosols and brown forest soils are the dominant soil types. The dominant forest species is *Quercus beranti* (*Quercus persica*). The average length of the Zagros region has been estimated to be 1,150 kilometers and its average width 75 kilometers [15]. The Zagros forests are located in the semiarid region of Iran, in the highlands with limited accessibility. The population has increased dramatically in this forest during the past decades. The increase in the number of livestock and the destruction of forest to expand agricultural lands and fuel wood supply, in combination with the general public poverty and unemployment, have led to overexploitation of these forests by human activities. On the other hand, the Zagros forests are valuable for preventing soil erosion and preserving the water balance in the region [9].

2.2. Methodology

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

Delphi questionnaire (DQ), as a multi-criteria method was selected to priority of criteria (C). In this method 5 main criteria including climate (Cl), vegetation cover (Vc), sensitive habitats (Sh), topography (T), and human activities (Ha), and 17 sub-criteria including Humidity (H), Temperature (Te), Evaporation (E), Wind (W), Slope(S), Aspect (A), Elevation (El), Forest type (Ft), Rangeland type (Rt), Canopy percentage (Cp), protected areas (Pa), Human settlements (Hs), Agriculture (Ag), Horticulture and Range management practices (HRm), were considered as significant factors affecting on forest fire detection practices. Figure 1 illustrates the conceptual model of the interrelation between criteria and sub-criteria. Subsequently, experts polling questionnaire (Delphi questionnaire) and the criteria significance diagram were sent to 26 fire experts of the region in order to rank the significance of the criteria and sub-criteria used and to identify fire sensitive areas in the region. The experts were asked to assign significant levels (inconsiderable, low significance, significant, medium significant, highly significant) to the criteria and sub-criteria, with each level bearing different weights (1, 3, 5, 7, and 9, respectively). Hence, the number of choices for every significance level for a given criterion was used as a point index. Then, the weighted average significance level for every criterion was calculated and considered for the final selection. In weighting of criteria, it was cared that sum of weights for every criteria (according to significance level) did not exceed 10. Each significance level presented a weight range for every criterion. Thus:

Point 1 for inconsiderable level presents a range of 0-2

Point 3 for of low significance level presents a range of 2-4

Point 5 for significant level presents a range of 4-6

Point 7 for of high significance level presents a range of 6-8

Point 9 for of very high significance level presents a range of 8-10

Therefore, modulated weight index of every criterion was calculated by Eq. 10 $(\frac{10}{\sum x_i} \times x_i)$ divided by sum of weights of the criteria and then it was multiplied by the criteria weight number. Modulated weight was multiplied by each criterion point to obtain weighted point of that criterion. In order to obtain significance percentage of each criterion, sum of weighted point (respecting modulated weight) was divided by maximum obtainable weighted point. Maximum obtainable weighted point in its turn was obtained by multiplying maximum expected point (in this study 26 which is total respondents) by maximum modulated weight [10]. Accordingly by dividing total sum of weighted points for every criterion by maximum obtainable point, the proportion of points taken in every criterion was calculated and then presented in percentage (the result was multiplied by 100). In the next step, weighted average of significance level for each criterion was determined by summation of the products of multiplication of point by weight (significance level) divided by total sum of points (equaling total respondents, here 26) and the result was taken as significance level of each criterion. Finally, by plotting of criteria significance diagram in which the horizontal axis is significance percentage and the vertical one is significance level of each criterion, it was judged about the possibility of accepting the identified criteria. This diagram was separated in 4 parts as per half numerical value of each vertical and horizontal axis and in order to choose the best criteria, the criteria bearing more than one half of numerical value of every axis were used.

The above method has the following mathematical relations [11]:

xi: Primitive weight

n: The number of people voted a significance level (point)

$\frac{10}{\sum x_i} \times x_i$: Modulated weight index yi = $\frac{10}{\sum x_i} \times x_i$: Modulated weight

zi = n×yi: Weighted point

$\frac{\sum z_i}{A} = \frac{Z_i}{220} \times 100$: Criteria significance percentage

A: Maximum obtainable point

$\frac{\sum (x_i \times n)}{N}$: Criteria significance level

N: Total respondents

3. Results and Discussion

Forest fire criteria were applied for forest fire mapping. At first, the results of analyzed criteria showed that topography with 32.91% and vegetation cover with 31.64 % had maximum importance in forest fire mapping (Figure 1). Additionally, slope with 12.65 % and forest type and Rangeland type with 11.39 % were selected as the most important sub-criteria (Figure 2, Table 1).

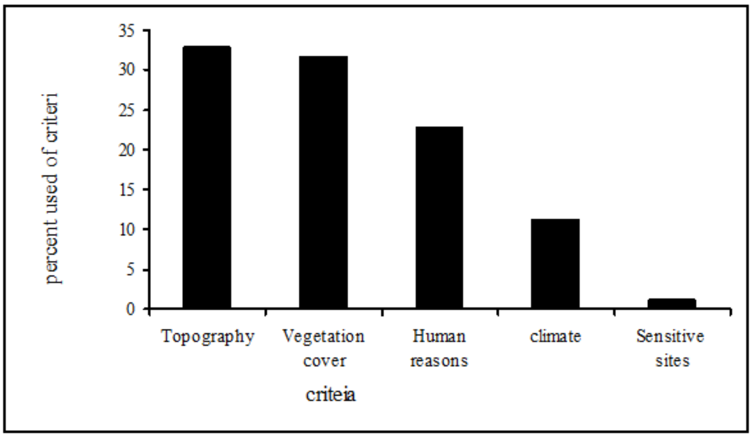

Figure 1. *Most important criteria selected with the Delphi method among experts.*

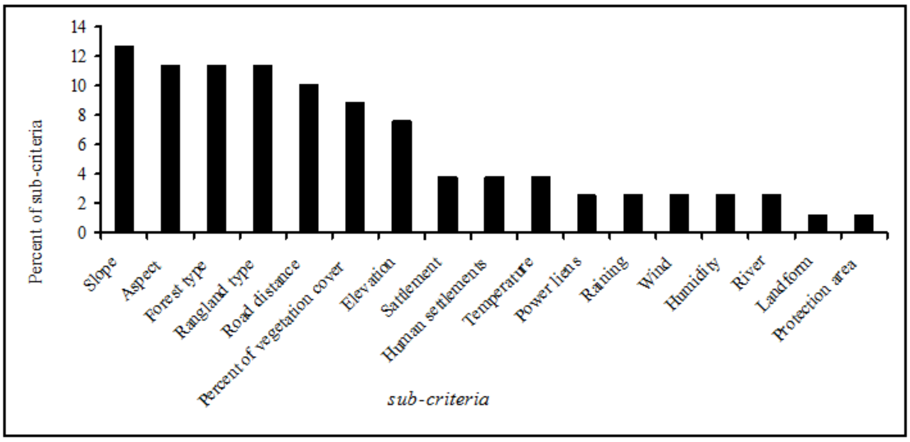

Figure 2. *Sub-criteria ranking in terms of significance with the Delphi method.*

Table 1. *Enclose table- The final rating criteria and sub-criteria.*

Percent		sum		Almedia, 1994	D. Vakalis. et al. 2004	Akbari et al., 2007	Mohamadi et al, 2010	Huyen and Tuan.,2008	Akpinar and Usul.,2003	Patah et al.,2000	Dong et al.,2005	Sowmya Somashek et al., 2010	Jaiswal et al.,2002	Sub-criteria	criteria
2.53	11.39	9	2		•		•							Raining	Climate
3.79			3		•		•			•				Temperature	
2.53			2		•					•				Wind	
2.53			2		•					•				Relatively humidity	
12.65	32.91	26	10	•	•	•	•	•	•	•	•	•	•	Slope	Topography
11.39			9	•	•	•	•	•	•	•	•		•	Aspect	
7.59			6		•		•	•	•	•	•			Elevation	
1.26			1						•					Forest type	Vegetation cover
11.39	31.64	25	9	•	•		•	•	•	•	•	•	•	Rangeland type	
11.39			9	•	•		•	•	•	•	•	•	•	Canopy percentage	
8.86			7		•			•	•	•	•	•	•	Protection area	Sensitive habitats
1.26	1.26	1	1										•	Sensitive Habitats	
3.79	22.78	18	3				•		•				•	Human	Human factors
3.79			3						•		•	•		Agriculture and horticulture	
2.53			2						•			•		Range management	
10.12			8	•	•		•	•	•		•	•	•	Road distance	
2.53			2				•		•					Natural promenade	
100	100	-	79	5	11	2	10	7	12	9	8	7	8	17	5

The linear model was used to analyze the data after determining the important criteria and sub-criteria by experts. The derived formula from linear model is as below (Table 2):

Liner Model 1: FFR=0.196*Vc+ 0.264*Cl+ 0.226*Hu+ 0.156*Sh+ 0.158*T

Table 2. *Calculating the significance percentage of forest fire criteria.*

Criteria	Percent of importance criteria	Degree of importance criteria	Importance factor	Importance coefficient	Ranking	Significance level
Climate	29.85	7.50	2.239	0.264	1	High Significance
Topography	23.08	5.80	1.339	0.158	4	Significant
Vegetation cover	32.62	5.10	1.664	0.196	3	Significant
Sensitive habitats	23.08	5.71	1.318	0.156	5	Significant

Human factors	27.69	6.93	1.919	0.226	2	High Significance
Total			8.479	1	-	

Results of sub-criteria analysis showed that the most significant sub-criteria for the detection of forest fires in the study area are: Humidity, Temperature, Canopy cover, Forest type, Rangeland type with 31.17, 30.15, 29.84, 28.92 and 27.68 values, respectively (Figure 3, Figure 4 and, Table 3). The result showed that were importance the all of the criteria that assessment of this study (Figure 3, and Figure 4).

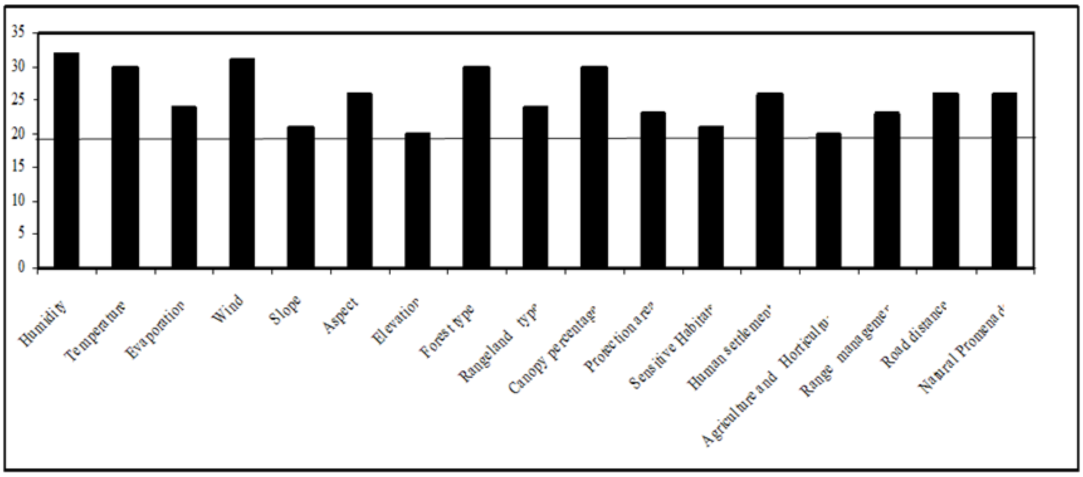

Figure 3. *Sub-criteria chosen by experts.*

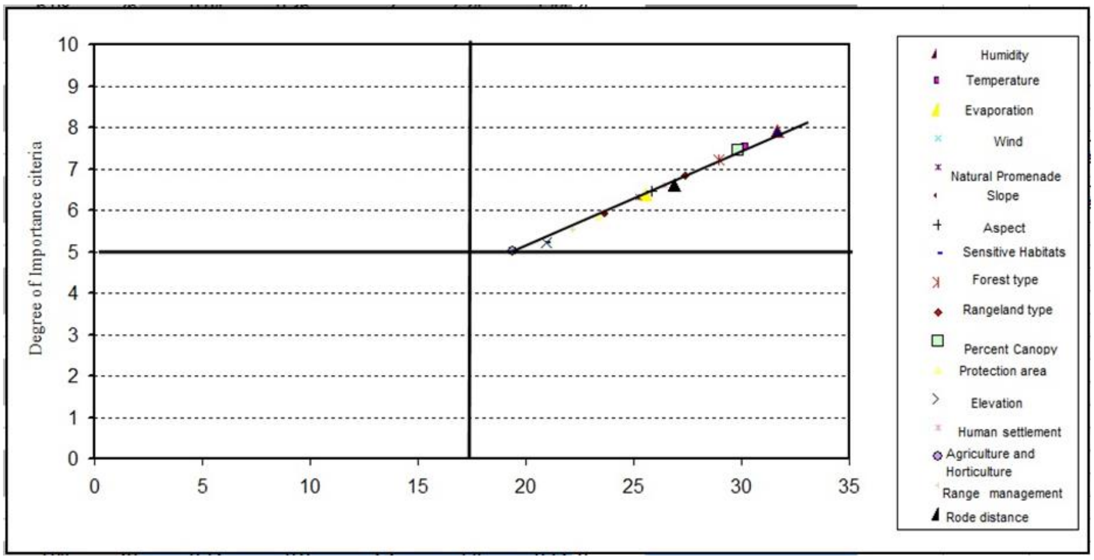

Figure 4. *Percentage and degree of importance sub-criteria of forest fire risk detection.*

Table 3. *Calculating significance percentage forest fire sub- criteria.*

criteria	Sub-criteria	Percentage of Importance sub- criteria	Degree of Importance sub- criteria	Important factor	Importance coefficient	Significance level
Climate	Humidity	31.7	7.92	2.510	0.089	1
	Temperature	30.15	7.54	2.273	0.080	2
	Evaporation	23.38	5.84	1.365	0.049	12

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	Wind	23.84	7.46	1.778	0.063	3
Topography	Slope	23.69	5.92	1.402	0.050	11
	Aspect	25.84	6.46	1.669	0.059	8
	Elevation	20.92	6.21	1.299	0.046	15
Vegetation cover	Forest type	28.92	7.23	2.090	0.074	5
	Rangeland type	27.68	6.84	1.893	0.067	6
	Canopy percentage	29.84	7.46	2.226	0.079	4
Sensitive Habitats	Protection area	23.38	5.84	1.365	0.048	13
	Sensitive habitats	20.62	5.23	1.078	0.038	16
Human factors	Human settlement	26.46	6.61	1.075	0.062	7
	Agriculture and horticulture	19.38	4.84	0.937	0.033	17
	Range management	22.15	5.53	1.23	0.044	14
	Road distance	25.53	6.38	1.63	0.058	9
	Natural promenade	25.23	6.30	1.59	0.056	10
Total				28.089	1	

The model that has been resulted from the sub-criteria analysis and determined the Forest Fire Criteria is:

Liner Model 2:

Humidity* 0.089+ Canopy cover *0.079+ Wind*0.063+Forest type* 0.074+Rangeland type* 0.067+Human factors* 0.062+ Aspect* 0.059+ Road distance* 0.058+ Natural Promenade* 0.056+ Slope* 0.050+ Evaporation* 0.049+ Temperature*0.080+ Protection area* 0.048+ Range management* 0.044+ Sensitive habitats* 0.038+ Elevation* 0.046+ Agriculture and Horticulture practices* 0.033.

They shape species composition and the spatial pattern of vegetation cover, as well as pose a threat to humans [20,21,3]. Forest fire depends on various factors which they have different influence on that. Different parameters have different characteristics which play their own role in the ignition and spread of forest fire. The Delphi method among 29 experts was applied in order to identify the most important factors that affect on forest fire risk in the Zagros mountainous region of Iran. It was determined that climate, human factors and vegetation cover were the most important criteria, while air humidity, temperature, wind, canopy cover, forest type, rangeland type and human settlement were the most important sub-criteria. Fire weather plays a key role in fire occurrence in the most fire-prone regions of Switzerland [23]. [16] In their study on prediction of forest fire applied wind speed, wind aspect, humidity and temperature factors. Amongst the non-climatic factors, anthropogenic ones in particular affect fire activity. They include human demographic patterns and activities, especially land use and fire management [5,18]. Different vegetation types have different resistance characteristics towards forest fires. Such as thickness of break, humidity content, size of foliage. Apart from these characteristics density of the vegetation also affect the occurrence of forest fires. Different aspects will have different exposure to the sun rays both in angle and distance. Forest fire mapping in Vietnam, applied aspect and slope, vegetation cover and road distance factors [12] Forest fire hazard mapping in Chine, used of slope, aspect elevation, and road density factors [7]. Forest fire hazard mapping in Indiana used of vegetation mapping, power line, slope and settlement factors [22]. Forest fire mapping with application of vegetation, human, climate and topography criteria in the French [12]. [14], applied of type/density of forest, slope, aspect and road distance for forest fire mapping. The results of using Analytical Hierarchy Process showed that the most important factors that affecting forest fires are topographical factors, as slope with 0.196 weights, shows the highest importance factor [24].

The results of this study demonstrated the robustness of Delphi method for determination of forest fire criteria.

4. Conclusions

Forest fires are a natural disturbance and a potentially major hazard in many regions of the world. Therefore every parameter in contribution in forest fire is not equal. Some parameters plays more significant role than others in forest fire. Thus there is a need to identify the characteristics of different parameters and their effect on forest fire and to assign them weight age according to their contribution to forest fire. The results of this study showed that climate, human factors and vegetation cover were the most important criteria, while air humidity, temperature, wind, canopy cover, forest type, rangeland type and human settlement were the most important sub-criteria. Different vegetation types have different resistance characteristics towards forest fires. Thus different vegetation types with combination of characteristics will have different behavior towards ignition of forest fire, i.e. Different aspects will have different exposure to the sun rays both in angle and distance. Thus those aspects which are in direct exposure to sun rays and close to the sun are more likely to catch fire as fuel is dried very fast. With increase in slope, forest fire spread increases because the flame comes in direct contact with the fuel with increase in slope percentage, and with increase in slope accessibility to the fire affected areas becomes difficult and unreachable after further increase in slope. Thus, slope plays a crucial role in fire spreading. Slopes between 1-10% will not affect too much to respond map, but after that they respond time is adversely affected till 110-120% slope & after this, it will be inaccessible different features like road, elevations, and other barrier those are responsible for increasing the time to respond. These results showed that Delphi methods is suitable approach to determine importance factor in forest fire ignition and it can be applied to other study and other forest region.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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