Management of Forest Fire: a Case study in Manesht and Ghalarang Protected Areas, of Ilam Province in Iran

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Abstract

Forest firing seems to be an instant natural crisis, so crisis management program development and its implementation will be very effective in protecting these areas. Prevention is one of the most important stages of such measure in identifying the hazards and responsible factors as well. The applications of Geographic Information System (GIS) and Remote Sensing (RS) are very diverse in the management of forest fire crisis. Fire risk zone mapping, forest fire modeling, and effective management of the resources and the equipment in time of fire and in different stages of crisis management are among the most effective applications. In this study, fire risk zone map of Manesht and Ghalarang protected areas (30,000 ha), located in Ilam province, western forests of Iran, was prepared. At first, a model of land use layers, forest reservoirs, wildlife habitats, plant species and vegetative cover density, population density maps, distance from roads, farmlands and tourism favorable areas, slope, aspect and elevation, was prepared using the Analytical Hierarchy Process (AHP) and fire risk zone mapping was performed based on the definition of risk (which is the product of occurrence probability multiplied by consequence intensity). The area diagram of risk zone mapping classes is a normal bell-shaped curve. The area with mean and high or low risk classes were 78 and 10%, respectively. The statistics showed that 23 of 25 cases of the forest fire in 2010 occurred in areas with mean to very high risk classes.

1. Introduction

Nowadays, fire, following the agricultural and urban activities, is the most pervasive and devastating factor of natural ecosystems in dry regions (Hai-wei et al., 2004). Based on the origin of fire, forest fires can be categorized into three groups; natural fire where thunderbolt is one of the most prevalent pivots in starting a fire, prescribed fire (burning) arranged intentionally in a completely controlled manner and manmade fire where human activity is the main reason of fires and obviously the most important factor of fire occurrence.

Wildfire is a crisis and forest fire essentially falls in this group. Prescribed fire is a technique to prevent the occurrence of wildfire. Annual fires decrease the growth of grassy plants, bushes and shrubs which in turn, lead to soil erosion. Forest fire endangers the environmental, biological, and physical potentials (Hernandez-Leal et al., 2004; Jaiswal, 2002), and has severe effects on land use, products, economy, diffusion of gasses, and health of human being. Also, by generating irreparable losses in forest areas, it changes the ecology of the scene (Dong et al., 2005; Vakalis et al., 2004). For example, in less than the past 200 years, six million km^2 of the world's forest lands have been destroyed due to fire (Dimopoulou et al., 2002).

When a wildfire occurs, Geographic Information System (GIS) can locate the damaged area and show the status of topography, vegetation, climatic condition and slope of the area. Therefore, it can be determined that which areas contain more dense combustible materials and whether these areas are adjacent to vulnerable areas. However, due to the complex character of natural areas it is too difficult to gather information layers for fire risk zone mapping in Remote Sensing (RS) and GIS, these data contribute much to control the fire. In the traditional procedure, the type of the fuel is directly determined from the earth and the data are strictly and carefully collected. This is feasible in fine scales, but in order to predict forest fire, lot of information should be collected about the types of fuels

in broad areas. RS has been successful in coping with this problem (Darmawan et al., 2001).
When facing a crisis, there is nothing to do more than guiding and controlling the fire, and reasonable and timely decision-making is considered as the most important element in the process of firefighting. From the point of view of management to take reasonable decisions there is a need for information, data, and a potential to process and analyze them. But, unfortunately, the main sources of these are available already before the occurrence of the crisis, and if we have not arranged for the pre-occurrence, we will face the occurrence of a new crisis in the heart of the occurred one. Preparing digital fire risk zone map along with defining and locating the critical areas can enhance the control of the high fire risk areas through developing and applying prevention tools (Almeida, 1994). Crisis management is an applied science that through crisis systematic observation and analysis seeks to find a tool by which, crises can be prevented or in the case of occurrence, helps to take suitable actions to reduce the damage, provide assistance, arrange for preparedness, and amend the conditions. The best way to cope with the crisis is to prevent its occurrence. If the risk centers, which can be the starter of the crisis, be located and suitable actions taken to eliminate or control them, no crisis will occur and there will be no need to cope with it. So, pre-occurrence arrangements including risk assessment and fire consequence modeling would be very instrumental.

2. Materials and Methods

2.1. Study area

Manesht and Ghalarang study areas are located at 46°20’31’’ to 46°38’45’’ E longitude and 33°34’27’’ to 33°48’32’’ N latitude in Ilam province of Iran (Plate 1). The area is climatically temperate, the annual rate of precipitation is 600-700 mm, and the annual mean temperature is 16.5°C. Oak, Corm, Maple, Puruplish, Persian hawthorn, Oleander, Rowan, Locoweed, Licorice, Inverse Tulip are among the plant species of the areas and deer, goat, swine, leopard, wild cat, brown bear, hyena, fox, Jackal, wolf, rabbit, porcupine, and Persian squirrel are among the important mammals of the areas.

2.2. Data

LISS-IV measured image of the satellite IRS-P6 was taken in 2006. In this image, the site resolution is 5.8 m and the topographic map is in 1: 50000 scale. Fire statistics of 2010, population statistics, maps of roads, bounds, elevation classes, slope and aspect are extracted from the topographic map. The maps of tourism areas and population density are prepared based on population statistics and land cuts. Land use map, NDVI and plant typology have been provided based on the interpretation of the satellite images and the information about forest reservoirs, wildlife habitats. Forest fires information of 2010 have been collected based on the data obtained from the General Office of Environment Protection. Arc GIC 9.3, PCI Geomatica 9.1, GPS Utility 5, Expert Choice softwares were used.

2.3. Procedure

The risk is defined as the occurrence probability multiplied by the consequence intensity. Occurrence probability means the probability of being encountered with the outcomes resulted from one incident, and consequence intensity means the extent of the outcomes resulted from one incident. Due to the great number of the layers, and the different classes of each layer, the Analytical Hierarchy Process (AHP) was used to map the fire risk zone. At first, the main factors including the consequence intensity and the fire occurrence probability was determined and the maps of both were prepared. They were compared and the weight of each factor, which is an indicator of the extent of its impact, was calculated. The weight of each factor was

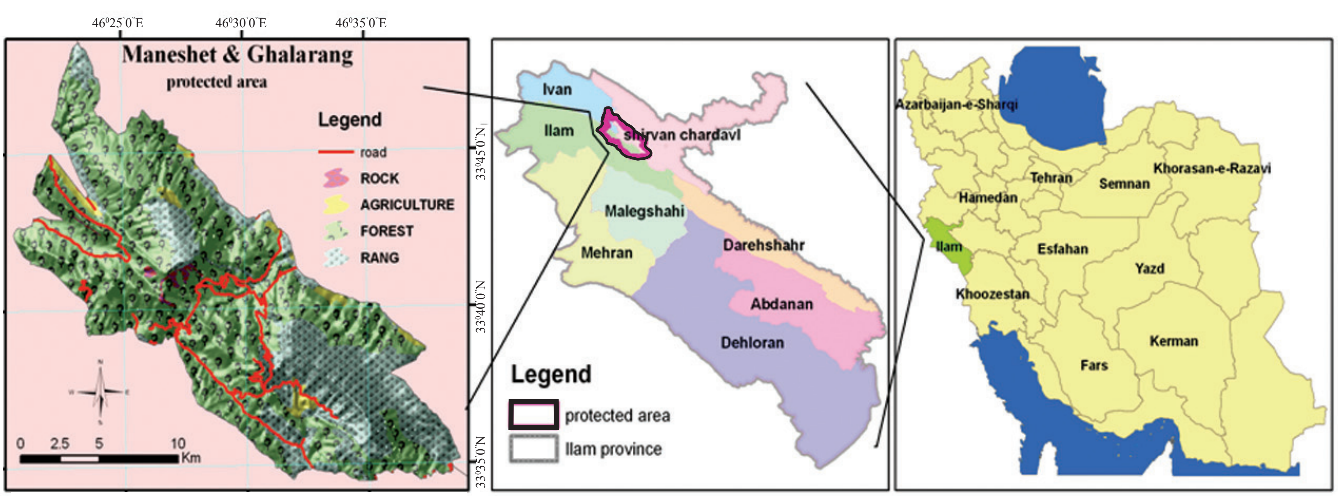


Plate 1: study area location, Ilam, Iran

calculated based on quantitative values.

Finally, fire risk zone map was prepared using the weight layers and weight coefficient of each factor. The results indicated that since the AHP, compared to other approaches, is based on comparative comparisons, it would facilitate the necessary calculations and since it includes many factors, increases the accuracy of the results. The decision-making process was conducted in the following five levels:

Level one: The main hierarchical goal is embedded in the highest level and preparing the fire risk zone map was the main goal of this research.

Level tow: In this level, two influential factors in fire risk zone mapping were determined. These factors are the occurrence probability and the consequence intensity. The occurrence probability will be studied in three following levels (i.e. levels 3, 4 and 5) and the consequence intensity will be studied in the two subsequent levels (i.e. Levels 3 and 4).

Level three: In this level, in one hand, four contributing factors in fire occurrence probability zone mapping were determined. These factors are combustible materials, fire starters, fire spreaders, and factors that are needed to access the area in order to extinguish the fire. On the other hand , two affective factors in fire consequence intensity zone mapping were determined. These factors are land use and forest reservoir and wildlife habitats.

Level four: In this level, like level three, the relevant factors influencing each of the immediately upper parameters in hierarchy have been considered and pursued. In order to provide a spatial model and a zone map, third level factors relevant to occurrence probability were divided into more sub-parts. The combustible materials factor was drawn from NDVI map and plant typology maps and the fire starter factor was derived from several maps including road bound, population density, farmland bound, and tourism area maps. The fire spreader factor was provided based on elevation classes, slope and aspect maps, and the contributing factors in access to the area for extinguishing the fire were prepared based on elevations and road bound maps. Moreover, each elements of the third level related to fire consequence intensity, i.e. land use and forest reservoir and habitats wildlife distinctive species, was divided into different classes. These classes were exhibited in Table 1 .These layers were categorized following the preparation of various factors involved in the intensity of forest fire consequence.

Level five: In this level, each element of the fourth level was divided into different classes. Table 2 shows the hierarchical; and Table 3 and 4 show codes and characteristics of different factor classes in level 5 which were used in this research. According to the research methodology, the results are presented respectively. These layers were categorized following the preparation of various factors involved in the occurrence of forest fire.

2.4. Fire risk map

In the fire risk zone map, the value of the final weight is ranged

Table 1: Classes of fire consequence intensity in AHP

Level 2		Fire consequence intensity	Regional
Level 3		Land use (L)	Forest reservoir and habitats wildlife distinctive species (E)
Level 4	1	Rocky snag-ravines	Wildlife habitats
	2	Low and mean density pastures- Dry and irrigated farming	Forest reservoir
	3	Thin forests-Dense pasture	
	4	Semi-dense forests	
	5	Dense forests-Residential areas	

Table 2: The levels of effective factors in fire occurrence probability according to AHP

Level 2		Fire occurrence probability										
Level 3		Combustible materials (F)		Fire starting factors (Ig)				Fire spreading factors (D)			Access factors to extinguish the fire (R)	
Level 4		NDVI	Plant typology	Road bound	Population density	Farm-land bound	Tourism areas	Elevation classes	Slope	Aspect	Eleva-tion	Road bound
	1	*	*	*	*	*	*	*	*	*	*	*
	2	*	*	*	*	*	*	*	*	*	*	*
	3	*	*	*	*		*	*	*	*	*	*
	4	*	*	*				*	*		*	*
	5			*					*			

Table 3: Codes of different factor classes in fifth level				
Code	NDVI	Plant typology	Road access	Elevation access
1	-0.1 to -0.42	Farming under the forest floor/Locoweed	100	1100-1400
2	-0.1 to 0	Forests being planted/ Oak-Hawthorn	500	1400-1800
3	0 to 0.2	Oak/Oak-Corm-Maple/ Oak-Hawthorn/Oak-Corm- / Oak-Maple	1000	1800-2200
4	0.2 to 0.6	Purplish/Oak-Corm	>1000	>2200

Table 4: Characteristics of different factor classes in fifth level							
Code	Elevation (m)	Slope	Aspect	PE*	DR	F	TA
1	1100-1400	0-5	-	<1	<400	100 m bound	L
2	1400-1800	5-20	N&E	1-2	400	farming	M
3	1800-2200	20-30	S&W	>2	300		H
4	<2200	30-60			200		
5		<60			100		

N: North; S: South; E: East; W: West; PE: Population density; *in terms of persons; DR: Distance from roads; F: Farmland bound; Tourism areas; L: Low; M: Mean; H: High

from 0 to 100. This value was divided into five classes- 0-20 (very low), 20-40 (low), 40-60 (mean), 60-80 (high), 80-100 (very high).

3. Results and Discussion

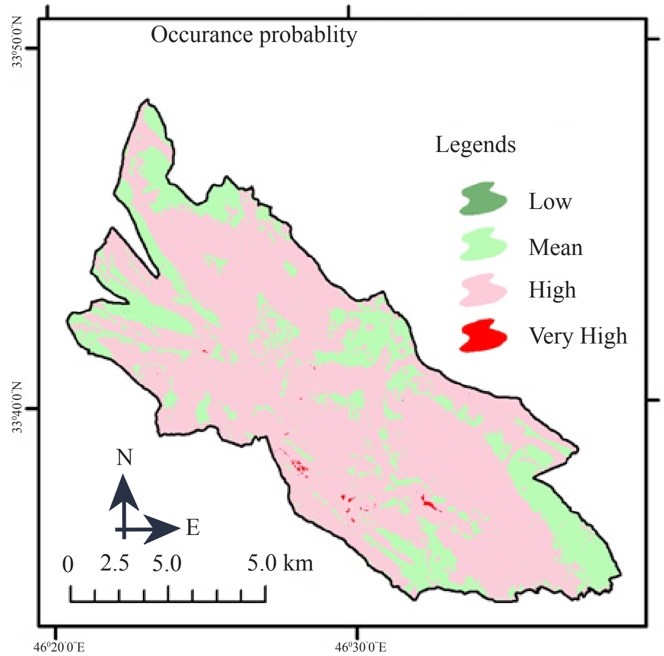
To evaluate the final weights of third level, experts asked to give comparative weights to different classes of levels 4 and 5 according to their experience and these weights were inserted in AHP to obtain proportions of all factors considered in hierarchal model up to level 3.

Fire risk zone map (level 1) was provided based on multiplication of consequences intensity by occurrence probability (level 2). The calculated weights were inserted into this relation and then were applied in the GIS matrix.

FFRZ=[0.5(2.59LI+4.93LII+6.43LIII+8.2LIV+10Lv)+0.5(7.9EI+10EII)]×[0.3(3.09FI+5.43FII+7.69FIII+10FIV)+0.3(3.89IgI+5.88IgII+8.23IgIII+10IgIV)+0.2(4.08DI+6.22DII+8.02DIII+10DIII)+0.2(4.08RI+6.22RII+8.02RIII+10RIV)]

Finally, three maps were provided- occurrence probability map, consequence intensity map (Plate 2), and fire risk zone map (Plate 3). Table 5 shows the area of different classes distinguished on plates 2 and 3.

The area diagram of risk zone mapping classes was compared with normal distribution to evaluate fairness of experts in weighing of different factors. The results showed a well bell-shaped curve (Figure 1). The area with mean risk classes was 78% and the area with high or low risk classes was 10%. In order to evaluate the accuracy of the zone map, fire spread map and zone map were overlapped. From 25 cases of forest



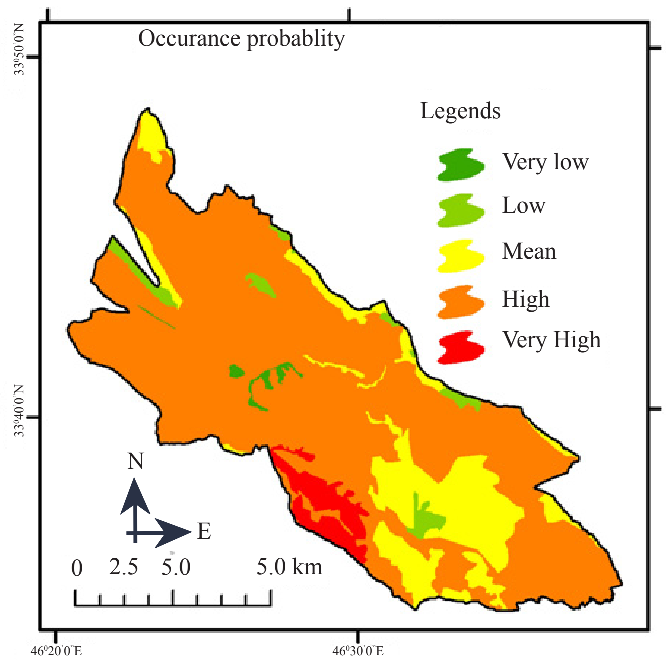


Plate 2: Occurrence probability map (on the left) and consequence intensity map (on the right)kany et al., 2010)

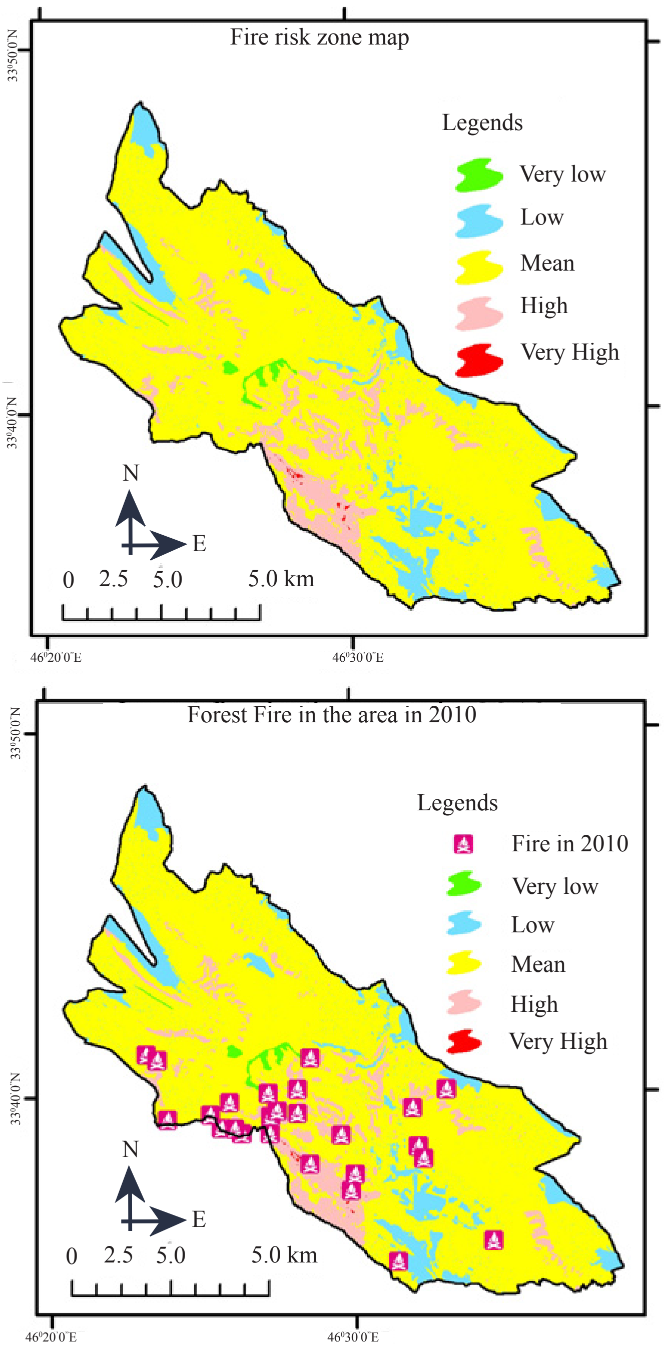


Plate 3: Fire risk zone map (on the left) and forest fire in 2010 (on the right)

fire in the area in 2010 (on the right of plate 3), only one case occurred in the low risk area and the rest occurred in areas with mean to very high risk.

Using roads and fire extinguishers, the protected area was divided into seven parts. Risk classes of each part are represented in the following Table 6. In the crisis management plan, the risk in high and very high risk areas should be decreased by reducing the occurrence probability to an acceptable level. Also, applicable solutions should be developed and implemented.

Table 5: The area of occurrence probability, consequence intensity, and fire risk categories

Class	Fire occurrence probability		Fire consequence intensity		Fire risk	
	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
Very low	-	-	186	0.64	189	0.64
Low	2	0.01	733	2.5	3034	10.35
Mean	8157	27.81	4870	16.6	23014	78.48
High	21127	72.05	22441	76.52	3072	10.48
Very high	46	0.16	1095	3.74	23	0.08

Table 6: The risk classes area of each part

Unit	Total area	Very low	Low	Mean	High	Very high
1	136948	0.00	131.70	572.47	656.73	8.58
2	2431.21	0.00	32.68	1580.37	807.64	10.52
3	3648.77	64.09	81.14	3145.85	357.69	0.00
4	879.48	0.36	249.60	503.51	121.61	4.40
5	8547.75	0.25	755.28	7352.50	439.72	
6	8551.58	8.21	1068.33	7106.39	368.65	
7	984.88	13.59	63.19	852.76	55.33	

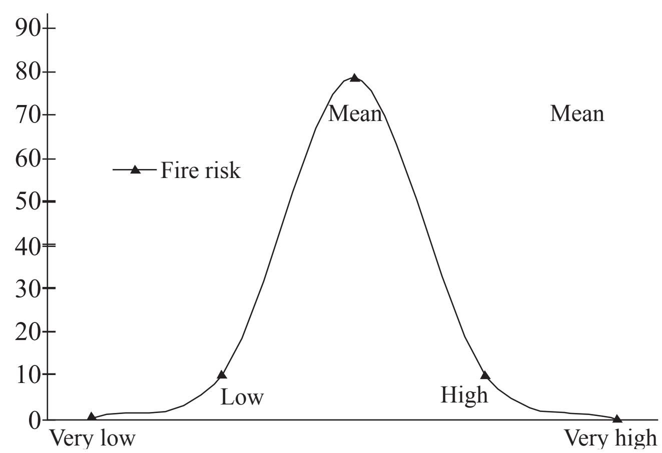


Figure 1: Zone mapping accuracy evaluation

In this research, AHP was used in order to determine the importance of fire measures, and based on the resulted pattern, forest fire risk zone map was provided by integrating several layers including satellite images, topographic data, forest reservoirs, habitats, roads, tourism areas in the GIS. The results showed that this approach is very useful in preparing risk zone map. Consistent with the results, vegetative cover was recognized as the most important factor of forest fire occurrence (Almeida, 1994; Darmawan, 2001; Jaiswal, 2002; Dong, 2005) because the combustible material is derived from different plant types, and vegetative cover density plays a significant role. On the other hand, the most important consequence of fire forest is the ravage of vegetative cover.

4. Conclusion

The area diagram of risk zone mapping classes was a normal bell-shaped curve where mean and high or low risk classes were 78% and 10, respectively. The statistics showed that 23 of 25 cases of the forest fire in 2010 occurred in areas with mean to very high risk classes.

Such research plays an important role in studying and evaluating the extent of forest areas vulnerability and taking reasonable management decisions and actions to prevent or extinguish forest fires otherwise the vegetative cover will be disappeared.

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