World Applied Sciences Journal 16 (6): 791-798, 2012
ISSN 1818-4952

Skidding Routes Simulation for Opening Access to High-Risk Fire Areas

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Abstract: Physical barriers such as roads cause to decrease fire distribution through reducing fire speed and increasing accessibility to affected area and control fire. In this research it is necessary to (i) predict forest fire risk zones and (ii) simulation skidding routes in order to access of fire controller teams to risk zones. For this propuse, skidding routes was simulated through FORENG 1.0 software. The simulation results showed that the skidding routes with same length in gentle slopes have more coverage as compared to steep slopes. So that, was found significant diffrence between treatments (P_v < %5). Moreover, by reducing the straight length of skidding routes the overlapped area increased because of their spiral shape. So the coverage area decreased. Skidding routes had significant effect on covering natural fire risk areas (P_v < %5). About 58.5% of areas in the category of moderate fire risk and 48.6% of areas in the category of high fire risk are covered by this network. In order to prevent and control fire, the management team of tension must be created. Also, the fire risk zone map can be a guideline for providing fire controller and prevention of fire during the planning of forest road and skidding routes.

Key words: Fire risk zones · Skidding routes · Simulation · Coverage area · FORENG software

INTRODUCTION

Forest fire has been recognized as danger which has physical, biological, ecological and environmental consequents [1, 2]. Fire is occurred because of natural and man made reasons. A sunlight radiation is the most important reason of natural fire in forest. Human, animals and vehicle traffics on road will increase the probability of the occurrence of inadvertent fire by man [3].

Physical barriers such as roads cause to decrease fire distribution through reducing fire speed and increasing accessibility to affected area and control fire [4]. Minimization of probability of fire occurrence and its damage can be effective on forest stability and survival. These need investigations about effective factors on occurrence and distribution of fire. The prediction of forest fire behavior and dynamic is a main part of forest ecosystem management [5].

Nowadays it seems that the use of new methods such as geographical information system is unavoidable in accurate investigation and analysis of the fire effects on forest ecosystem [6]. Effective factors in determination of fire risk zone are include moisture of burning materials, direction of slope, distance and proximity to canals and streams, slope gradient and accessibility to road [7, 8]. The effect of burning materials moisture in fire occurrence is more than that of the wind, because if the moisture of burning materials is high the wind speed can not influence on fire occurrence. In contrast, if the burning materials are dry the fire is occurred rapidly [9].

Dong *et al*. [10], in a study in Jeilin province of China applied the satellite data and GIS techniques to provide new layers from effective factors on forest sensitivity to fire. They showed that the most important effective factor on beginning of fire is topography and human activity, respectively.

Brass *et al.* [11], in order to investigate the role of road as fire controller, considered a 150 meter buffer. They reported that the main reason for this distance was the dispersal of human activity along routes. Results showed that these areas were more sensitive to fire.

In Italy's forests a study was conducted by Marchi *et al*. [12] and a model of difficulty operation of fire control index (ODIF) was produced through GIS software. Moreover a system of decision making for prediction management (DSS) and fire control was used. The areas of water division, aerial support instruments and distribution of fire control tools were managed using this model.

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Eker and Çoban [6], conducted a research in Ezmir forests of Turkish. They investigated the route maps which were planned by fire controller team for temporary transportation. Results indicated that after the fire most of these routes could convert to temporary road network, because it is necessary to build a temporary transportation network to transfer wood productions from burned areas.

In this research it is necessary to (i) predict forest fire risk zones along with investigation of effective factors on fire. The other purpose of this research is to (ii) plan skidding routes in order to access of fire controller teams to risk zones.

MATERIALS AND METHODS

Description of the Study Area: DarabKola 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. The latitude, longitude and elevation ranges of this forest are 36° 33' 20˝ to 36° 33' 30˝ N, 52° 14' 40˝ to 52° 31' 55˝ E and 180-800 meter at sea level, respectively.

Determining Fire Risk Zone and Skidding Routes Simulation: In order to investigate the probability of surface fire occurrence by natural factors the digital elevation model (DEM) of Darabkola forests, slope gradient, slope direction and hydrology maps were extracted in Arcinfo 9.3 software. The main reason of this slope classification was the variations in natural fractions of study area as well as rapid distribution of fire in upward of steep slopes. Moreover, the slope of 40 percent is often considered as slope boundary to control fire [11]. Seasonal streams have main role on soil moisture of adjacent areas. So, the seasonal streams are divided into main streams and sub-main streams. Then the buffer map with 6 meter width in both sides of main streams and 2 meter width in both sides of sub-main streams was prepared. The slope direction map was classified into 9 classes to accurate investigation of intensity and duration of sunlight radiations.

In order to determine areas with probability of surface fire occurrence, the areas with mentioned characteristics in Figure 1 was characterized on slope gradient and direction maps and after the combination of these maps and removing streams limitations, the raster maps of forest risk with high to medium risk degree was prepared. In order to determine areas with probability of surface fire occurrence with human activity, in spite of the slope gradient, slope direction and hydrology maps with mentioned characteristics in Figure 1 the buffer map with was 150 meter widths at both sides of road and the camping of tourism and forest workers was characterized. The buffer of 150 meter was prepared because of high traffic of personnel at the edge of forest roads in order to working, hunting and recreation. The camping of workers and tourism was highlighted with circular shape of 50 meters and then was characterized with the label of high risk zones on map. The selected areas with the high degree of fire risk by human activity are the areas which the fire can distribute rapidly because of steep slopes. In addition, in the settlement areas the fire can distribute rapidly because of high traffic as compared to other areas. For this reason the areas with high degree of fire risk occurrence and distribution are investigated along with human activity.

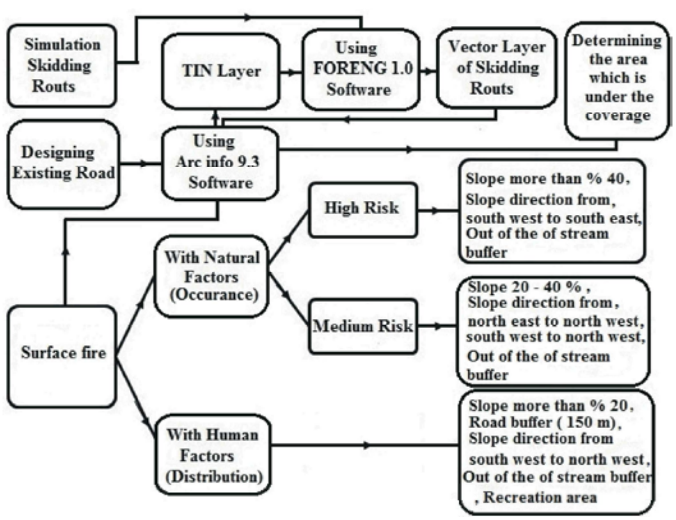

Fig. 1: Showing methodology [8,11, 14, 15, 16] in flow chart

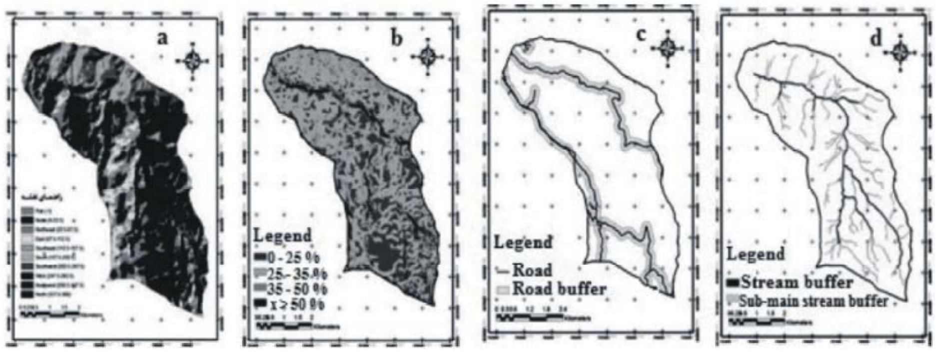

Fig. 2: The maps of slope direction (a), slope (b), road buffer (c) and streams buffer (d)

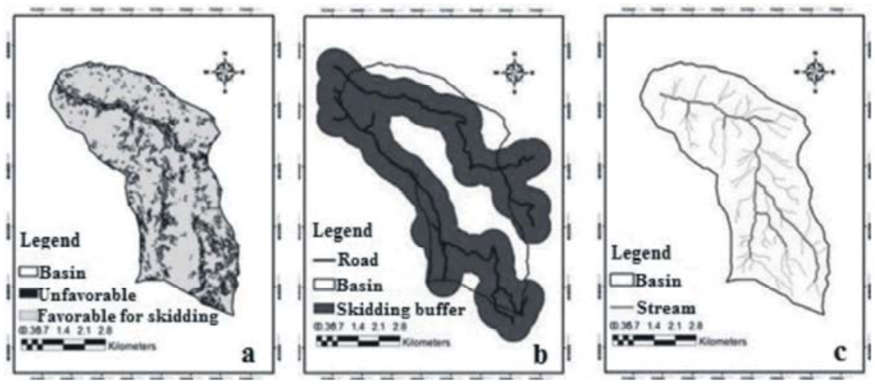

Fig. 3: The maps of favorable condition to skidding (a), skidding buffer (b) and existing streams (c)

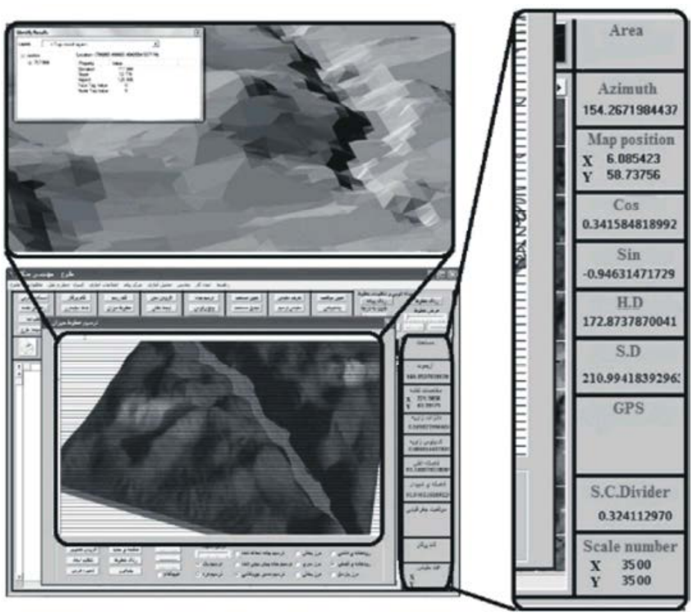

Fig. 4: Using TIN layer in FORENG software to skidding routes simulation

In order to assess the role of transportation network in forest on accessibility rate, the road network as well as micro texture network of routes was simulated through FORENG 1.0 software. This software was planned in Microsoft and can analysis and processes the images and digital data (Data base TDB). Moreover, by providing 3 dimensions environment and using routing ability (divider technique) the skidding routes can be planned automatically.

The trails network for the rubber tired skidder Timber jack 450 c was planned according to standards. At first the buffer of 600 meter (maximum direct distance of skidding in whole log system) and the suitable area for skidding was selected. The skidding routes were planed for rubber tired skidder to move to upward and downward of slope 25% in slope direction, from 25 to 35% in downward trails in slope direction and upward slopes 25 to 50 percent. The distance between two skidding routes is 140 meter and the distance of winching is 50 meters at each side of skidding routes. According to the average height of tree 20 meter, it is concluded that the timber can be winched from 70 meters of trails. In order to plan, at first the topography map of the region was converted to triangular irregular network (TIN) through 3D analysis in Arcinfo software. Then this layer was transferred to FORENGE 1.0 software to plan skidding routes. The simulated skidding routes network was inserted to Arcinfo 9.3 in vector format and after removing crossover skidding routes to streams and combining them with map of forest areas prone to fires the area of very high fire risk zones was calculated.

The length of planned skidding routes and the area (the length of straight route × winching distance) which is covered by them were analyzed statistically for 30 simulated skidding routes in different classes.

Data Analysis: Completely randomized block design was used for statistical investigations. Data were analyzed using SAS program. The effects of slope classes (Block) on area wich is under coverage and straight length (Air navigation) of skidding routes were investigated using univariate linear analysis and Tukey HSD test.

RESULT AND DISCUSSION

Skidding Routes Simulation

The Role of Slope on the Rate of Straight Length and Coverage Area: The simulation results showed that the skidding routes with same length in gentle slopes have more coverage as compared to steep slopes.So that, was found significant diffrence between straight length (Air navigation) in slope classes of 0 to 25, 25 to 35 and more than 35 percent (P_v < %5). Moreover, by reducing the straight length of skidding routes the overlapped area increased because of their spiral shape. So the coverage area decreased. There was significant difference between coverage area in slope classes of more than 0 to 25 percent and other classes (P_v < %5). Topography factor have important role on occurrence and distribution of forest fire [10]. The fires in Hyrcanian forest of Iran is often occurred as a surface fire. The slope causes to distribute fire with out regulation and this make the work of fire controller too hard [13, 14]. The simulation of skidding routes in different slope classes showed that the slope causes to decrease straight routes of skidding and consequently inaccessibility to very high fire risk zone. In steep slopes the planning of skid trail network is conducted diagonal [15, 16], so the surveyed straight distance (Air navigation) is less than that of real length of routes. If the straight surveyed distance is decreased, less area of forest would cover by skidding routes. This cause to decrease the probability of the coverage of fire risk zone by skidding routes.

Table 1: Statistically comparison of coverage area and straight length in different slope classes

	Slope classes (%)		
Treatment	0-25	25-35	35-50
Coverage area (ha)	5.73^{a*}	2.55^{b}	1.86^{b}
Straight length (m)	526.3^{a*}	305.2^{b}	168.7^{c}

Note:* means followed by different lower-case letters are significantly different at probability level of 5%; Straight length = Air navigation

The Role of Transportation Network in Opening Access to Fire Risk Zone

With Natural Factors: There are dispersed areas with high probability of natural fire occurrence in the watershed. The total area of this region is 218 hectare which includes 8.34% of the total area of Darabkola forests. Results showed that the skidding routes had significant effect on covering natural fire risk areas. About 58.5% of areas in the category of moderate fire risk and 48.6% of areas in the category of high fire risk are covered by this network. Planning of mountainous routes on side slopes causes to built cut slopes with steep gradient [17, 18]. On these slopes the skid trail can not be planned because of low movement ability of skidding machines [19]. In steep slopes the heat of fire can be transferred easily, so the fire distribute with high intensity. Fire travels most rapidly up-slopes and least rapidly down-slopes [8]. Slope gradient causes to fire controller team to be tired. If surface fire convert to crown and/or trunk fire, trees may be broken [20]. Moreover, it is difficult for chain saw-man to cut burning trees on steep slope during the fire. Of 8 recreation points in forest, 5 of them are covered by skid trail network. The coverage of skid trail network in more than forest road network, because skidding routes has been dispersed on watershed and their slope classes in same to considered slopes for skid trail planning. Skid trails can be planned truly according to fire risk zone when

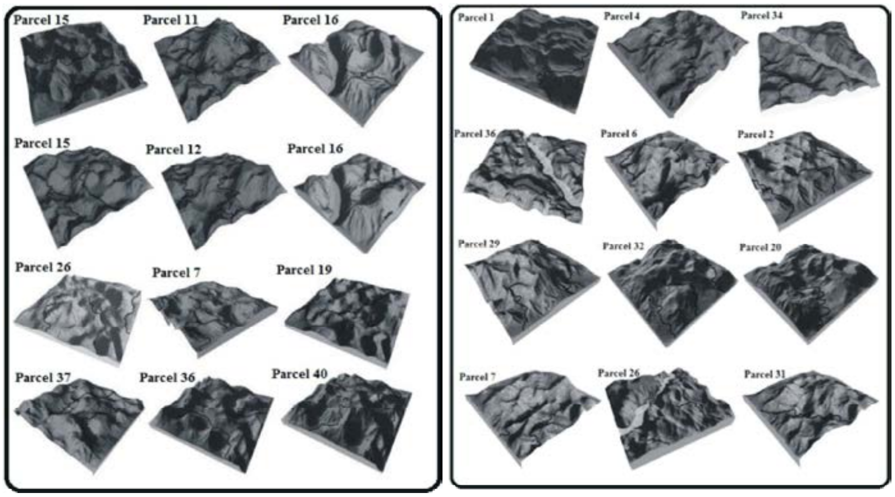

Fig. 5: Three dimensions (3D) designing of skidding routes given to topography conditions

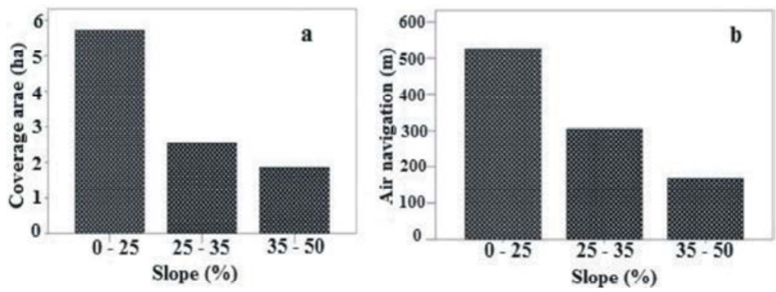

Fig. 6: Comparison of coverage area (a) and straight length (b) in different slope classes

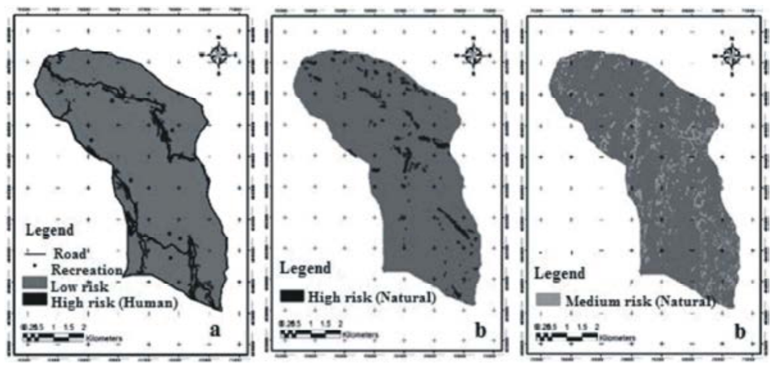

Fig. 7: The maps of risk fire areas with human factors (a) and natural factors (b)

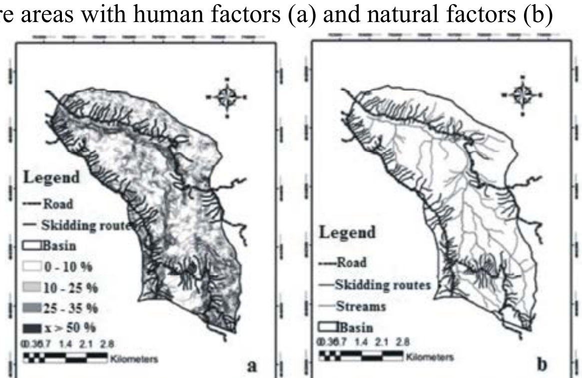

Fig. 8: Skidding routes simulation given to slope classes (a) and streams crossing (b)

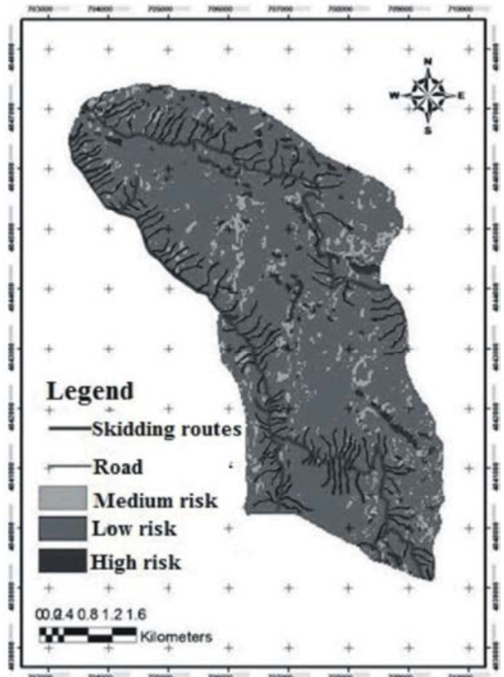

Fig. 9: The risk fire area which is under the coverage of skidding routes

Table 2: The rate of coverage area by transportation network

Network coverage / total area (%)	Road network coverage (ha)	Skidding routes coverage (ha)	Total area / Basin area (%)	Total area (ha)	Fire risk
58.5	6.8	61.1	4.44	116	Medium
48.6	8.1	41.5	3.90	102	High

Table 3: The rate of coverage area by transportation network

Passable area for fire control (ha)	Road network coverage (ha)	Skidding routes coverage (ha)	Total area / Basin area (%)	Total area + recreation area (ha)	Fire distribution risk
65	108.1	1.4	4.2	109.5	High

the combination of species and fire behavior investigated completely. For example, maple leaves facilitate fire cross distribution because of their widths [8]. This issue is important in prediction of roads and skid trails as fire controller. If the skid trails network is planned truly, a large area of fire prone areas would covered by this network. Of course the low accuracy in maps may cause to appearance the errors in planning skid trail network. To solve this problem it is necessary to control and correct the planned network on nature.

With Human Factors: In low intensity fires, the slope have significant role on fire distribution, whereas in high intensity fires the effects of slope is poor. So, the fire distribute with out regulation [21]. It was found that the high manmade fire risk zone (surface fire distribution) were concentrated in the center of forest and the edge of forest roads. The area of this region (with considering recreation area) is 109.5 hectare which includes 4.2% of the watershed. Forest roads have important role in preventing and controlling fire. If the forest roads are constructed and maintained truly, they can be the suitable barrier against forest fire. Moreover, the road is vital infrastructure to transfer the necessary tools of fire control [22]. Road network causes to increase coverage on these areas (except for recreation area in the forest). The fire control in areas with slope gradient more than 40% (about 44.5 hectare) is too hard. In such areas the required time to control fire increase. Forest road fragment forest into pieces and this can be as a fire controller. Moreover, roads in adjacent to recreation area can increase the probability of fire by human activity [23].

CONCLUSION

In order to prevent and control fire, the management team of tension must be created. Under this situation the operational programs is presented. Village people in adjacent to forest have a great role to prevent fire in forest. For this people the didactic programs must be presented to improve their partnership in control fire. Also, The fire risk zone map can be a guideline for providing fire controller and prevention of fire during the planning of forest road and skidding routes. It is necessary to plant low sensitive species to fire at the edge of forest road networks. Alder trees are the main species at the edge of some roads in Hyrcanian forest. Alder species at the edge of forest roads is useful for slope stability and soil drainage, but the tolerance of this species to fire is low. So it is recommended that the tolerant species is planted to decrease the fire distribution speed.

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