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RATING AND MAPPING FIRE HAZARD IN THE HARDWOOD HYRCANIAN FORESTS USING GIS AND EXPERT CHOICE SOFTWARE

Alireza Ghomi Motazeh[1]*, Ehsan Farahi Ashtiani[1], Roghaye Baniasadi[2], and Fereidun Masoumpoor Choobar[3]

[1]Department of Natural Resource, Faculty of natural resource, Gilan University, Sowmesara, Iran. *Email: alireza.ghomi@yahoo.com
[2]Department of Agriculture, Birjand University, Iran.
[3]Department of Natural Resource, Faculty of natural resource, Sari University, Mazandaran, Sari, Iran.

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Abstract

Fire can be a destructive ecological factor, but a good plan can provide appropriate tools for ecosystem management. In this connection fire prevention must be paid special attention. For locating fire susceptible zones as a first step in this research, effective factors for forest fires were determined by studying different sources, and then we used weighed criteria to take advantage of experts' views. Maps of slope gradient, exposure, forest type, hydrography, topography, distance from roads and distance from settlements were studied. Results from the survey show that vegetation coverage allocates the greatest weight to itself. From the results it can be seen that, 11.7 % of the area is too adverse; it means that fire hazard is too high in these areas, 40.68 % is adverse, 14.48 % is average, 8.37 % is quite favorable, 18.72 % is favorable, and 6.05 % is very good. In general, we can say half of the local area is susceptible to forest fire, and we should plan the access to different areas for controlling probable fires, regarding the existing facility conditions and roads.

Key words: spatial distribution, forest fire, fire prevention, fire hazard factors, fire risk management.

Introduction

Forest fires cause many negative effects in various aspects of life such as natural environment, economics and health (Herawati et al. 2006).

Fire can be a destructive ecological factor, but a good plan can provide appropriate tools for ecosystem management. In this connection fire prevention must be paid special attention. People can play an important role in forest fire reduction by their cultural education concerning forest fire prevention, appropriate management, providing necessary facilities for fire fighting, forest protection during critical seasons by means of monitoring by trained people, and use of new tools such as remote sensing and GIS systems (Farahi et al. 2011).

Darmawan et al. (2001) integrated remote sensing techniques with GIS to create a model of forest fire hazard in East Kalimantan, Indonesia. Moreover, a forest fires risk model for West Kutai District in East Kalimantan Province, Indonesia was developed by Hadi (2008) using GIS, remote sensing and Multi-criteria Analysis (MCA).

Currently, data mining techniques are also applied in modeling forest fire risk. Stojanova et al. (2006) built predictive models based on geographic data, meteorological ALADIN data and MODIS satellite data.

The rate of change in communities after fires is influenced by severity, destruction power, fire period and season (Wright and Bailey 1982), also other factors such as raining cycle (Moore et al. 2006), and "why" patterns. Fires can influence natural ecosystems by vegetation destruction, changing sequence patterns, changing vegetation sources such as timber, branch, leaves, and wildlife habitat (Debano et al. 1998). Most of the world forests with different climates have experienced fires with different destruction power. The return time in temperate deciduous forests varies from decades (or less) to centuries (or more) (Sanford et al. 1985). Fires in the northern part of Iran are mainly surface ones and their flame height rarely exceeds 10–30 cm at normal fuel and humidity conditions. Annually 300 to 400 hectares of Iran north forests burn (Banj Shafiei et al. 2010). Having information about the natural fire effects can make us increase our understanding of the impact of fires on forests and help us make management decisions (Laughlin et al. 2004).

There are two main reasons for each fire: a natural reason, an unnatural reason (Naebi 2003). Fire is a natural power that affects vegetation communities over time and as a natural process has a significant effect on preserving special ecosystems health. Since twentieth century, increasing fires due to human activities turned fires to a major threat for forests (Nasi et al. 2002). Forest fires are started mainly by human factors, inattention and ignorant people.

In European countries, fires are one of the main causes for forest destruction, so that in Southern Europe 10 billion hectares of forests have been ruined by fires for the last two decades. An important factor that leads to fires over different areas is the road development. Besides, passengers' and workers' inattention imposes irreversible damage to forests. In 2005 the International Food and Agriculture Organization reported that 0.06 % of Iran forests burn every year. FAO (1998) reported that in an 18-year period up to 1998, on average 42,100 arsons had been committed every year in Europe and the annual average of burnt areas is estimated to be 2 billion hectares. Amin Amlashi et al. (2010) reported that in the period 1977–1979 the large fires in the forests of Gilan were 37 and 285 hectares of the forests of Gilan were burnt as a result. According to statistical reports from 1993 to 2010 a total of 711 arson fires occurred in the forests and pastures of the Gilan province, 2063 ha of forests and 114 ha of pastures, and a total area of 2717 ha have been affected by fire (Department of Natural Resources, Gilan province 2010). The development of various models based on simulation and mathematics in developing countries such as Iran and Turkey should be considered, because traditional methods are now slowly fading and other ancient philosophies are less fit to the current world situation (Zeki and Keles 2005). That is why much research in the field with predicted fire behavior modeling has been performed in GIS environment (Giglio et al. 2006). In connection with forest fires, remote sensing can provide useful information about the environment before and after fires. Particularly widely used are the techniques for monitoring of current fires

(Roy et al. 1999). In this study we intend to examine and analyze the spatial distribution and characteristics of fires in Gilan, in order to identify areas prone to fires and by reviewing the process and its cycling to provide the necessary steps to deal with it.

Materials and Methods

The study area of 3559 hectare is located within the watershed number 7 in Northern Iran (Fig. 1). This forest is located between 48°44'36" and 48°49'58" latitude and between 37°37'23" and 37°42'31" longitude and the altitude is ranging from 280 to 2120 m.

The study area is mainly in rainy regions and according to the climatic classification its climate is humid. Most of the year it rains and the maximum rainfall is in September and October.

Tavalsh Hashtpar city is an administrative center adjacent to this forest situated 10 km away from the Nav Asalem. Because of Nav river, this forest has been named Asalem Nav forest.

Rating of layers

At first we rated the effective factors. In this rating method, both inner rating of layers and outer rating of layer have been made by using of experts views to combining this factors in GIS.

A. Internal rating of layers

Using various sources listed in the article, 6 factors were selected as factors affecting the forest fires in the Hyrcanian forests, namely as follows:

1. Forest type;
2. Distance from roads (meters);

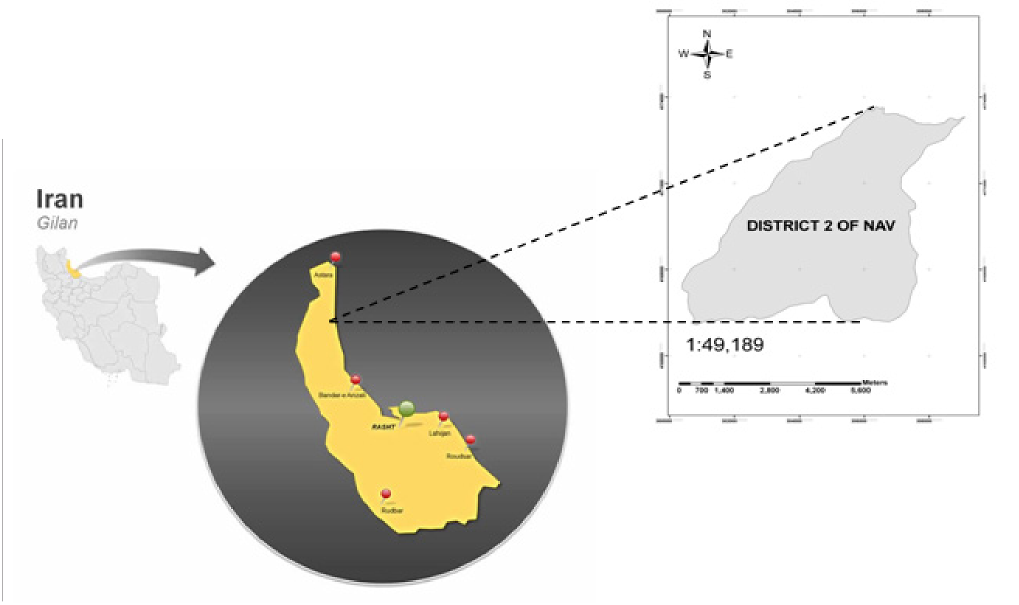

Fig. 1. Study area.

3. Slope gradient (%);
4. Distance from rivers (meters);
5. Distance from settlements (meters);
6. Exposure.

Each of these layers, on the basis of the value for the utility of fire, can be classified and rated internally (fire can be useful for growing some grasses). This rating was consistent with Gilan University Professors because of their acquaintance to this area. The rating levels within each layer are between 1 and 9. The parts of this region in the event of a fire that had more importance were given more value (number 9) and the less important areas go down with their values (down to number 1). The steep slopes increase, fire risk also increases. Now we will describe each item separately.

1. Forest type: forest trees type affects the severity or reduction of fire. The traditional field survey for determining the type of fuel which is detailed and labor intensive, is practicable for small areas. But forest fire prediction model needs to have information about fuel material types over large areas. Remote sensing successfully manages with this task. (Darmawan et al. 2001). Factors evaluation within each layer is shown in Table 1.

2. Distance from roads: close proximity to a passing road also increases the human impact on forests and the likelihood of fire.

3. Slope gradient: western and southern slopes are more sensitive to fire. Because of their sun exposure, they are drier and hotter. In contrast, these slopes have generally less fuel (Parsakhoo et al. 2009).

4. Distance from rivers: if the distance from a river and levels of wet lands increase, dry land will certainly increase, and this factor will cause more fires.

5. Distance from settlements: with increasing distance to the village, vegetation increases and the risk of fire decreases.

6. Exposure: Exposure, directly or indirectly, affects the other properties of the area. In the northern hemisphere southern and western slopes are set to sun longer compared to northern and eastern slopes, thus they are drier and more prone to fire. This also predetermines the difference between the vegetation density and the distribution of plants and plant communities on southern and western slopes and these on northern and eastern slopes. Thus, on western and southern slopes due to the greater solar radiation, evaporation and transpiration are higher and humidity is

Table 1. Inner rating of factors.

Forest type	Value	Distance from roads, m	Value	Slope gradi-ent,%	Value	Distance from rivers, m	Value	Distance from settle-ments, m	Value	Expo-sure	Value
Dense	9	<100	5	>35	5	<15	5	<1000	4	South	4
Plant	8	100–200	4	35–25	4	15–30	4	1000–2000	3	West	3
Woodland	7	200–300	3	25–10	3	30–100	3	2000–3000	2	East	2
Residential forest	6	300–400	2	10–5	2	100<	2	3000<	1	North	1
Semi-thin	3	400<	1	5>	1						
Sparse	2										

lower, respectively vegetation percentage is lower (Sagheb-Talebi and Yazdiyan 2005).

Rating of layers, respectively, described in Table 1 based on specified criteria.

B. External rating of layers

Now we are going to describe the external rating of layers, for which we used the EC software as it is explained in details below.

Expert choice software and Analytical Hierarchy Process (AHP)

Analytical Hierarchy Process is a flexible, robust and simple method, and is used for deciding when the conflicting criteria make it difficult to choose between options. This multi-criteria evaluation method, first time was proposed in 1980 by Thomas L. Saaty. AHP is one of the most effective methods for determining the criteria significance and the relative relationship between the criteria (Saaty 1980). In this method the importance of each criterion is measured relatively to other criteria. Then, based on a scale of 1 to 9 that indicates the factors average significance relative to each other, all factors are given weights. Coefficients are then calculated and if the conflict is less than 0.1 it is acceptable and already it has numerous functions in various sciences. In this study Analytical Hierarchy Process was used for rating the layers due to the simplicity, flexibility, qualitative and quantitative criteria utilization and the ability to simultaneously examine the consistency in judgments. This process is usually done by Expert choice software.

Three components create a suitable environment for fires, namely fuel, topography, and weather. These three components have mutual influence on each other and the sum of these interactions will determine the fire behavior. Although some sources consider weather, fuel, inflammation causes and human activities that affect the factors in fire activity (Johnson 1992). In this research effective factors for forest fires were determined by studying different sources and then taking advantage of the experts' views in order to attribute weighting. Twenty five questionnaires were designed and distributed among Department of Natural Resources experts of different provinces, Fire and AHP professionals, some professors of the Faculty of Natural Resources and Industries of Iran. After an explanation of the purpose and general principles of this technique, they were asked for their opinion about the importance of nine criteria considered to be comparable to the couple of parameters. After collecting the questionnaires, their data were entered into the Expert Choice (EC) software and the inconsistency rate was calculated for each questionnaire.

Now for more specific cases, we can take advantage of ArcGIS9.2 software. In fact we performed a schematic analysis for 6 factors, using their specific maps.

Used maps

The maps used for the study can be conditionally divided into two categories – existing maps and maps that had to be prepared.

1. Existing maps

These maps include area maps topographic maps and existing roads maps that have been prepared by the Technical Office of Forest in order to performing forestry projects study. These maps are produced for use in ArcGIS9.2 software.

2. Prepared maps

2.1. Maps of distance from roads and distance from settlements

First, we prepared a "Distance from roads" map (Fig. 2) and a "Distance from settlements" map (Fig. 3) according to the data in Table 1.

The word "suitable" in the legends is used for the areas which are susceptible to fire. Then other maps were prepared, respectively of forest type, slope gradient, exposure. Also, hydrographic maps were extracted from the basic maps (using the ArcGIS 9.2 software) and the data presented in Table1 was collected.

2.2. Slope gradient and exposure maps

With respect to Digital Terrain Model of the map, slope map was prepared, valued, and divided into 5 categories according to the data in Table 1 (Fig. 4). Then, range of directions map was produced and classified into four main directions (Fig. 5).

2.3. Forest type map

Forest type is a very significant factor, from the standpoint of appropriate Species position for operation, extinction of species, and conditions that are genetically susceptible. In Iran, the type scheme consideration is based on the presence, abundance of species percentage and species dominant criterion. For mapping of types habitat, first the tree cover type information was extracted from the manual design book, and the accuracy was controlled by using a GPS device on the terrain. Finally, a variety of existing types was obtained by using Arc GIS 9.2 software (Fig. 6).

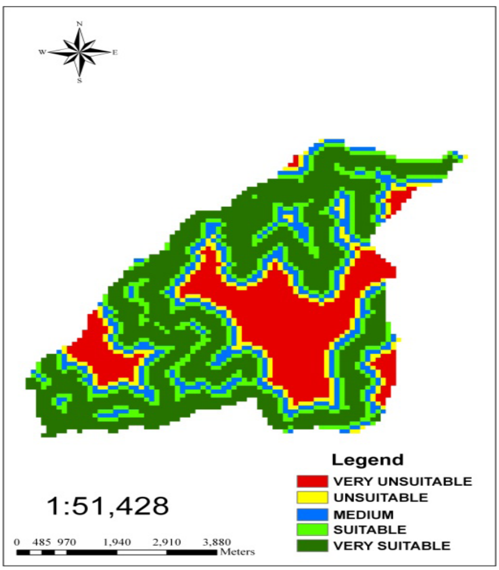

Fig. 2. Map of distance from roads.

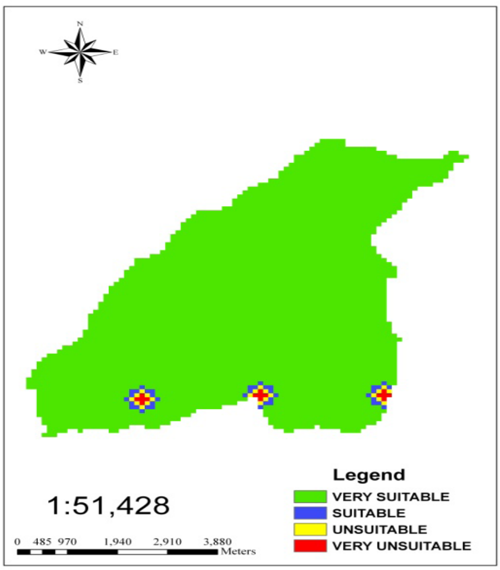

Fig. 3. Map of distance from settlements.

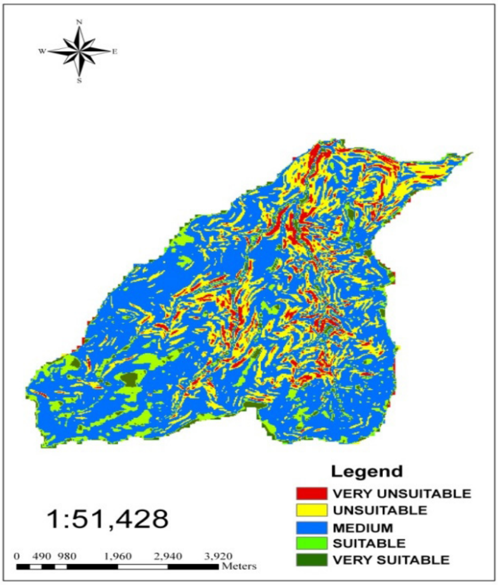

Fig. 4. Map of slope gradient.

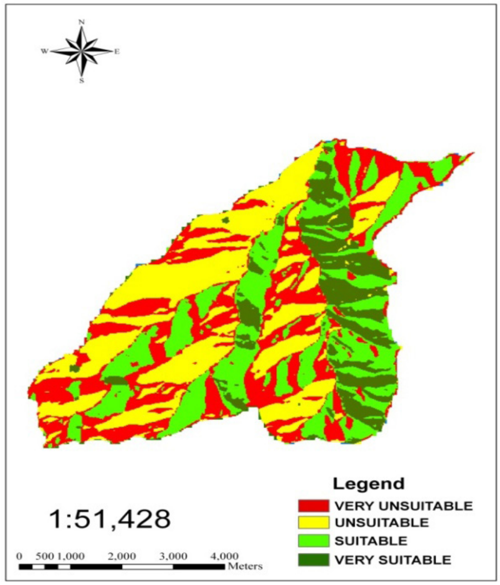

Fig. 5. Map of exposure.

2.4. Hydrologic map

DGN drawings, prepared by the State Geological Survey were used for preparing a Layer for waterways. Thus, using the DGN map, the desired area was separated, then DEM and TIN maps were created. Next, to determine the width of the rivers, Hill shade layer was prepared in the Arc GIS 9.2 software. In this way a hydrological layer was prepared and the area was divided and valued on the basis of fire desirability in the obtained map (Fig. 7).

Results

The results from the Analytical Hierarchy Process survey are presented in Fig. 8. Obtained numbers represent the value or importance of priority. So, the highest weight (0.444) is assigned to vegetation and next we have the distance from settlements (0.219) and slope gradient (0.153), and finally – exposure (0.037). It

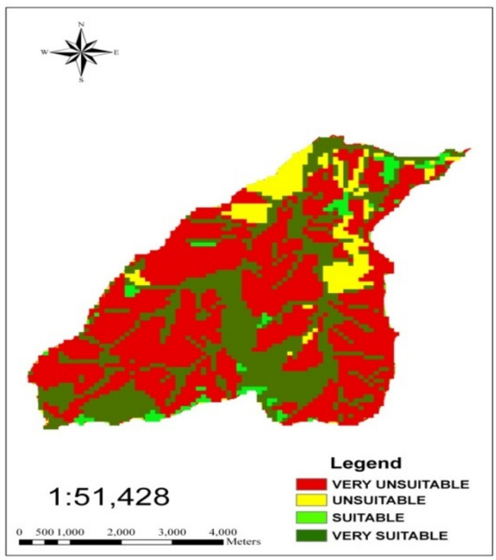

Fig. 6. Map of forest types

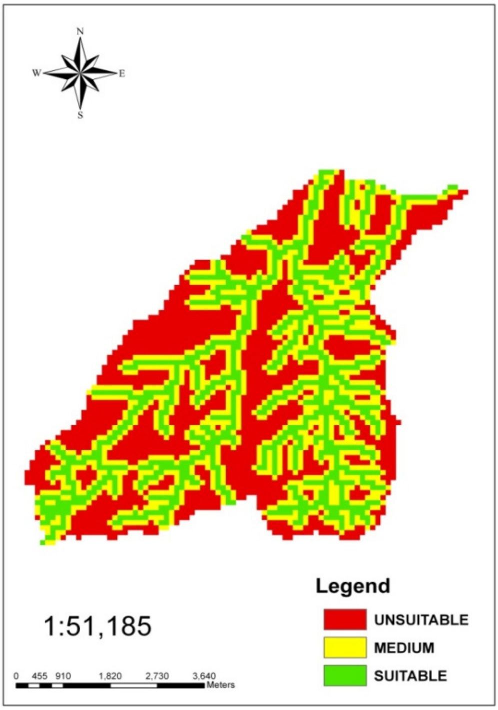

Fig. 7. Hydrologic map.

is worth noting that due to the inconsistency coefficient (0.05), that is smaller than (0.1), there is no need for revision of judgments.

Final map of fire susceptible zones in the area

It is required to combine prepared maps in previous stages based on internal and external layer rating in order to prepare fire prone zones in the area. For this purpose the rated maps were overlaid. The resultant final map is shown as Fig. 9.

This means that from the coefficients of the layers in Fig. 8, an external layer rating was obtained. Then using these external layer coefficients a map overlay procedure was performed in GIS environment thus creating the final map.

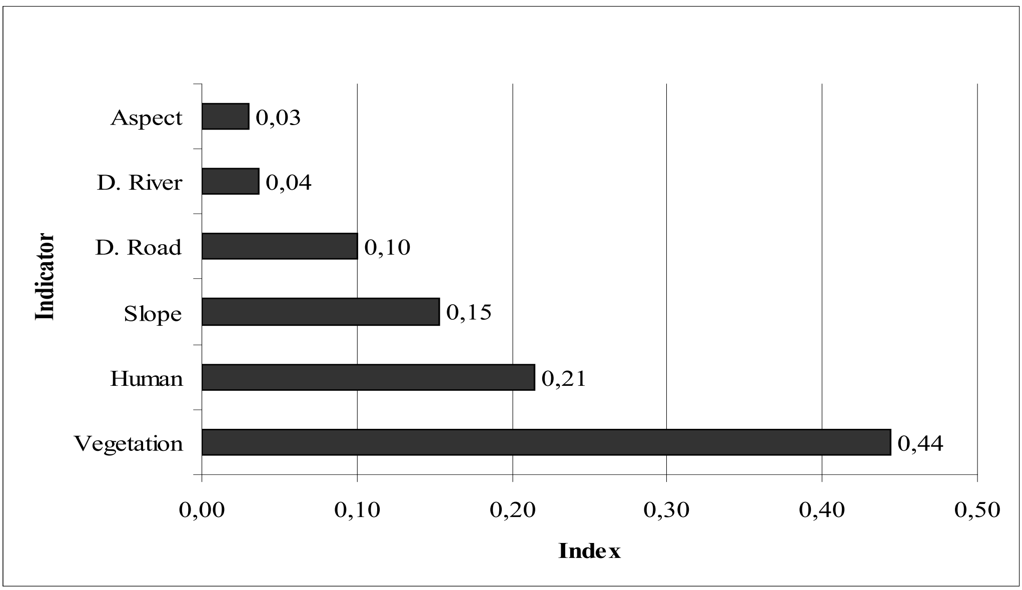

Fig. 8. Prioritization criteria that influence forest fires resulting from AHP.

Discussion and Overall Conclusions

In the 25 years period between 1968 and 1992 more than 14 million saplings and 2 million trees have been destroyed in Iran because of forest fires (56,216 ha). In northern Iran, forest fires occurred 37 times and 285 ha of forest sites have been disturbed in 1998–2000 (Jazirei 2000).

Based on the above results, 11.70 % of the study area is very poor, with low value and high level of fire hazard. 40.68 % of the area is poor, 14.48 % is average, 8.37 % is quite valuable, 18.72 % is valuable, and 6.05 % is very good, it means that the value is high and fire hazard is low in these areas. In general we can say half of the area is prone to forest fires, and fire hazard is very high.

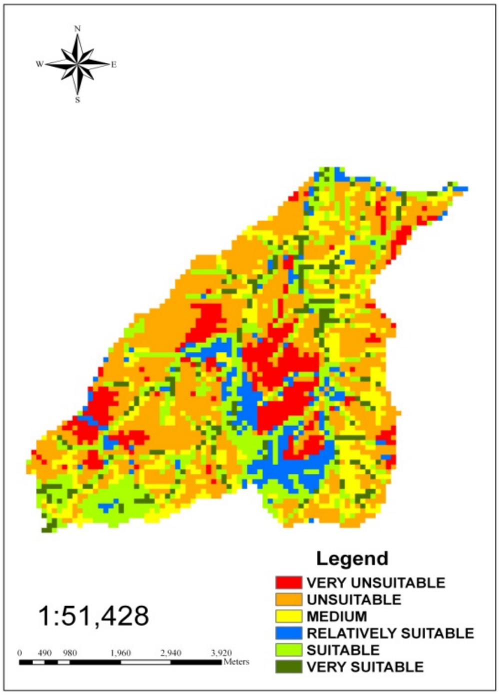

Fig. 9. Final map of fire prone zones.

Suggestions

We propose: general cultural education and stimulating the public conscience to protect forests; organizing seminars, festivals and gatherings with influential people in rural areas especially the target areas; applied research for gathering required information; preparing educational tools, compact discs; exploration efforts and achieving a rapid and timely focus on forest fires; protecting forests in critical seasons with monitoring by trained personnel, and providing necessary facilities and logistics that can be effective in timely prevention and fire control. By regarding the divisions, Squads focus use in critical and semi critical areas is recommended According to a survey, conducted in the listed areas, establishing some posts is essential, and each post should be provided with some human resources, a car driver and firefighting facilities.

References

Amin Amlashi M., Mirakhorloo Kh., Salehi M., Yousefi K. 2010. Extent of forest degradation and possible restoration of semi-arid habitats in Gilan province with the help of satellite images. Third National Conference on Forest, Tehran, Iran. Available at: http://www.civilica.com/Paper-FOREST03-FOREST03_120.html (in Iranian).

banj Shafiei A., Akbarinia M., Jalali G., Hosseini M. 2010. Forest fire effects in beech dominated mountain forest of Iran. Forest Ecology and Management 259: 2191–2196.

Darmawan M., Masamu A., Satoshi T. 2001. Forest fire hazard model using remote sensing and geographic information systems: Toward understanding of land and forest degradation in lowland areas of East Kalimantan, Indonesia. Proceedings of the 22nd Asian Conference on Remote Sensing, November 5–9, 2001, Singapore: 1–6.

Debano L.F., Neary D.G., Folliott P.F. 1998. Fire's Effects on Ecosystems. Wiley, New York, 335 p.

Farahi Ashtiani E., Ghodskhah Daryayi M., Mohammadi Sammani K., Amin Amlashi M., Ghomi Motazeh A., Sedighi M. 2011. Study of Fire place Distribution and Quantitative and Qualitative Characteristics of Fire and their Prevention solutions in Natural Recourses Sites of Gilan. The first international conference on wildfire in natural recourses lands, Gorgan, Iran, 79 p.

FAO 1998. International Forest Fire News, No 16.

Giglio L., Csiszar I., Justice C.O. 2006. Global distribution and seasonality of active fires as observed with the Terra and Aqua MODIS sensors. Journal of Geophysical Research: Biogeosciences, Vol. 111 (G2), G02016, DOI:10.1029/2005JG000142.

Hadi D.P. 2008 A RS/GIS based multi-criteria approaches to assess forest fire hazard in Indonesia (Case study: West Kutai district, East Kalimantan province). Master's thesis, Bogor Agricultural University, Indonesia.

Herawati H., Heru S., Claudio F. 2006. Forest fires and climate change in Indonesia. Background Document for the Southeast Asia Kick-Off Meeting of the Project Tropical Forests and Climate Change Adaptation (TroFCCA), 5 p. Available at: http://www.scribd.com/doc/125463814/Forest-Fire-CC.

Jazirei M. 2000. Patronage of forest, Mehre Iran publication, Tehran. Iran: 68–69 (in Iranian).

Johnson E.A. 1992. Fire and Vegetation Dynamics: Studies from the North American Boreal Forest. Cambridge University Press, 129 p.

Laughlin D.C., Bakker J.D., Stoddard M.T., Daniels M.L., Springer J.D., Gildar C.N., Green A.M.P Covington W.W. 2004. Toward reference conditions: wildfire effects on flora in an old-growth ponderosa pine forest. Forest Ecology and Management 199: 137–152.

Moore M.M., Casey C.A., Bakker J.D., Springer J.D., Fule P.Z., Covington W.W., Laughlin D.C. 2006. Herbaceous vegetation response (1992–2004) to restoration treatment in a ponderosa pine forest. Rangeland Ecology & Management 59: 135–144.

Naebi H. 2003. Identifying and combating of forest fires. Publication of Program Planning Promotions office, Tehran, Iran, 29 p. (in Iranian).

Nasi R., Dennis R., Meijaard E., Applegate G., Moore P. 2002. Forest fire and biological diversity. Unasylva 53(209): 36–40.

Parsakhoo A., Hosseini S.A., Pourmajidian M.A. 2009. Plants canopy coverage at the edge of main communications network in Hyrcanian forests. Journal of Ecology and the Natural Environment 1(2): 037–044.

Roy D.P., Giglio L., Kendall J.D., Justice C.O. 1999. A multi temporal active-fire based burn scar detection algorithm. International Journal of Remote Sensing 20: 1031–1038.

Saaty T.L. 1980. Analytical hierarchy process. McGraw-Hill Inc. NY, 269 p.

Sagheb-Talebi KH., Yazdiyan F. 2005. A look to the forests of Iran. Iranian Research Institute of Forest and Rangelands, Iran, 285 p.

Sanford R.L., Saldarriaga J., Clarck K.E., UHI C., Herrara R. 1985. Amazon rain-forest fires Science 227: 53–55.

Stojanova D., Panov P., Kobler A., Dzeroski S., Taskova K. 2006. Learning to predict forest fires with different data mining techniques. Proceedings of the Conference on Data Mining and Data Warehouses, October 9, 2006, Ljubljana, Slovenia: 255–258.

Wright H.A., Bailey A.W. 1982. Fire Ecology: United States and southern Canada. John Wiley and Sons, New York, NY, 501 p.

Zeki E., Keles S. 2005. Developing Alternative Wood Harvesting Strategies with Linear Programming in Preparing Forest Management Plans. Turkish Journal of Agriculture and Forestry 30: 67–79.