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# Fire risk potential detection using the Geographic Information System in the forest of north of Iran

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**Abstract**
Forest fires and forest loss as a crisis and part of natural hazards have always been important challenges in recent years, and therefore preparing a fire risk map and eliminating fire-prone areas in order to manage these areas is very important for executive units. The purpose of this research is to prepare a fire potential map using the geographic information system for the forests of Talesh County, Gilan Province. In this research, fire risk zoning was addressed using a spatial-analytical method. In this way, the initial steps are based on the model, a digital elevation model of the region is prepared from the ASTER sensor DEM with a pixel size of 25 meters by 25 meters. Using the digital elevation model, slope maps, geographical directions, and elevation above sea level are prepared. The maps of the vegetation type and density of the region were then classified according to the plant to be burned. Maps of roads, residential areas and agricultural lands of the region were also prepared. All information layers were rasterized using the Polygon to Raster and Euclidian Distance commands. Then, using a questionnaire and an hourly valuation table in the AHP model, the subclasses were weighted. The results of using the AHP weighting method in zoning the fire risk potential showed that of the total area of the study area, 42221.72 of the land was in the very low risk zone, 10528.67 of the land was in the low risk zone, 13567.94 of the land was in the low risk zone, 13827.32 and 13827.32 and 13867.32 were in the high risk zone in order of area. Therefore, the risk zones were high, medium, low, very high and very low in terms of area.

**Keywords:** *Fire potential, hierarchical download, Talesh forests.*

## Introduction

Today, the phenomenon of forest fires has threatened a large part of the world's forests. This phenomenon annually consumes thousands of hectares of trees, shrubs and plants. The average annual fire in the world's forests is estimated to be six to fourteen million hectares. Forest fires are considered one of the environmental disasters. Because they have harmful and destructive effects on human societies, whether natural or human-caused, directly or indirectly, and if they occur, they have a huge impact on the environment, forests, villages and their inhabitants due to the concentration of the population. Although forest fires are an integral part of these ecosystems, their lack of control may cause severe economic and environmental damage. In addition to economic losses, environmental pollution, and the impact on the region's climate, fires also have a significant impact on the destruction of forest fauna, flora, and landscape, and their effects are felt at every level of the ecosystem. Also, if fires are widespread, intense, and repeated in a forest, they change the qualitative value of species and cause the establishment of inferior and non-commercial species that have no economic value. Another harmful consequence of forest fires is their impact on global warming and the production of greenhouse gases. Given that trees generally absorb carbon dioxide and store it, carbon dioxide is released

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when they burn. Therefore, in recent years, forest fires have been considered as one of the reasons for the increase in carbon dioxide in the atmosphere and, as a result, global warming. Every year, a large area of the world's forests is affected by fire, which not only destroys vegetation in the fire area, but also disrupts hydrological processes, increases soil erosion, and produces runoff in these areas. Therefore, determining areas with high fire risk in order to prevent the spread of fire in susceptible areas when it occurs seems absolutely necessary and essential, which is difficult and costly to do using experimental and field methods. For this reason, using modern methods and technologies can be considered a suitable alternative to traditional methods. Among these modern techniques and methods, we can mention the geographic information system and remote sensing. Iran is one of the most disaster-prone countries in the world, and the phenomenon of forest fires is considered one of its most important natural hazards. Fire is considered one of the most important destructive factors of forests, always threatening these vital ecosystems (Marozas et al., 2007). Fire in forests annually consumes thousands of hectares of trees, shrubs and plants. So that the annual average of fire in the world's forests is estimated at six to fourteen million hectares (Incinas et al., 2007). And fire, if extensive, intense and repeated in a forest, causes changes in the qualitative value of species and leads to the emergence of inferior and inferior species that have no commercial value. In addition to economic losses, terrible fires also lead to environmental pollution. Also, forest fires of natural or human origin have harmful and devastating effects on human life (Poder et al., 2002). Considering the importance of forest fire prevention using geographic information systems and considering the occurrence of fires in Talesh forests, this study intends to identify critical areas of fire risk in the region's forests and introduce them to forest managers in order to provide a solution to prevent future fires in the region's forests as much as possible, which seems to be a suitable method for predicting future fires in the forests of the studied region. A large area of the world's forests is affected by fires every year, and these fires not only destroy vegetation in the fire area, but also disrupt hydrological processes, increase soil erosion, and produce runoff in these areas (Wadrow et al., 2014, Lasco, 2015). The increase in the occurrence of frequent fires in the forests of northern Iran during recent months has caused extensive damage and casualties to the environment, forests, villages, and their inhabitants.

The density of forests in northern Iran, their concentration and interference in the daily lives of residents, the accuracy of the statistics of past fires and the extent of damage caused by them, indicate the importance of this issue and the need to provide necessary solutions (Liu et al., 2018, Gerzhova, 2014, Denham et al., 2012). Three factors of slope, direction, and NDVI were used to provide a simple and fast model to prepare a fire hazard map in forest areas. For this purpose, by formulating the above factors and applying them to the image, areas with high fire hazard were identified (Marozas et al., 2007). Forest and rangeland fire risk zoning has been carried out using geographic information systems and multi-criteria assessment in a part of Iran (Lozano et al., 2008). Using remote sensing, GIS and AHP techniques and based on slope, elevation, direction and vegetation cover factors, a fire risk map was prepared in a region of the Himalayas. The results showed that 4.42 and 26.92 percent of the region were classified as very high and high risk, respectively. These areas were identified as high priority areas for future fire management and prevention (Sunil, 2005). In Boolean logic, the membership of an element in a set is expressed as zero (non-membership) and one (membership). The fire risk map is related to the vegetation map of the region, such that most high-risk areas coincide with forests. Also, most areas with high fire risk are the same areas where fires have occurred before, which indicates the high reliability of the geographic information system models used (Gantham et al., 2013). Considering the importance of forest fire prevention using geographic information systems and considering the occurrence of fires in the forests of western Guilan province, this study intends to identify critical areas of fire risk in the region's forests and introduce them to forest managers in order to provide solutions to prevent future fires in the region's forests as much as possible, which seems to be a suitable method for predicting future fires in the forests of the study area.

## Materials and Methods

### Characteristics of the study area

The study area is located in the western part of Gilan province in the forests of mountainous areas. Talesh County is located between 48 degrees 32 minutes and 49 degrees 3 minutes east longitude and between 37 degrees 33 minutes and 38 degrees 16 minutes north latitude (Fig. 1).

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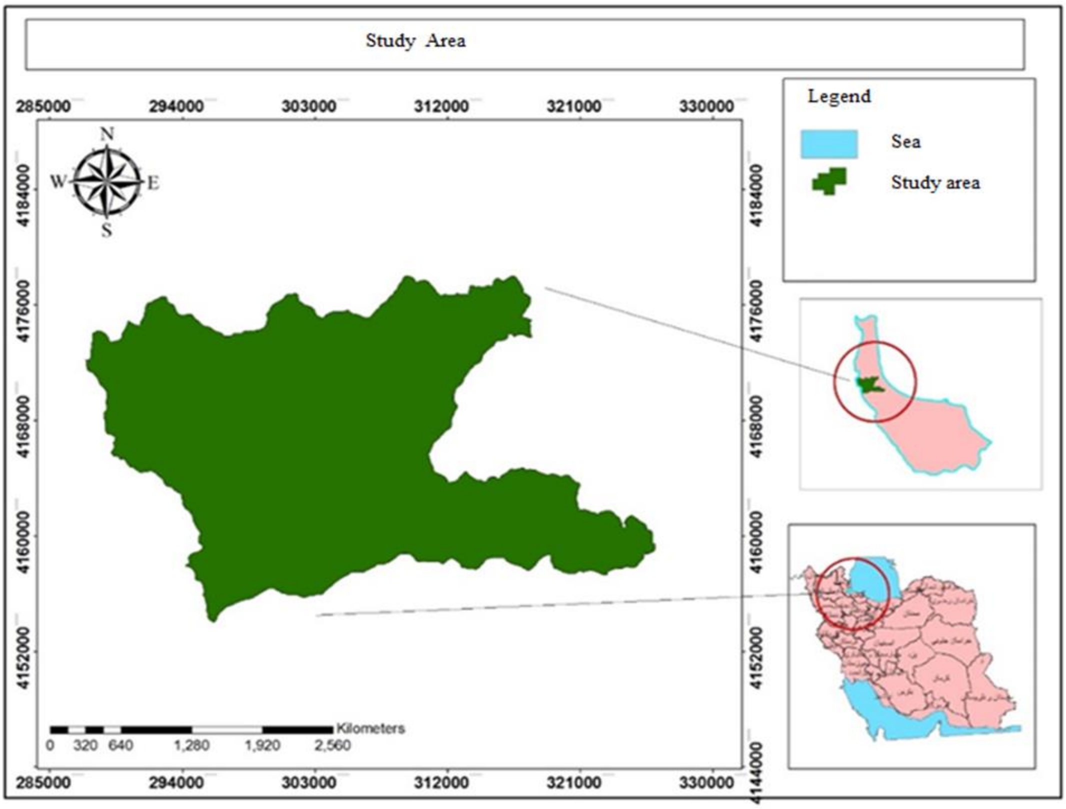


**Figure1**
*Case study area*

## Methodology

To conduct this research, first, a digital elevation model (DEM) of the region was prepared from the ASTER sensor DEM with a pixel size of 25 m by 25 m. Using the digital elevation model, slope maps, geographical directions, and height above sea level were prepared. Maps of the type and density of vegetation cover of the region were also prepared and classified in GIS according to fire sensitivity. Initially, to obtain these weights, 30 questionnaires were distributed among fire experts in the fields of natural resources. By entering the small values obtained for the criteria and sub-criteria with fuzzy hierarchical software, the weight of each class was determined. After calculating the weight of the sub-criteria in fuzzy AHP, the weights assigned to each class were defined using the Reclassify function in the ArcMap environment. Next, using fuzzy membership functions, the evaluation of the criteria of the study area in each of the layers was evaluated in a range between 0 and 1. In the final stage, the weights calculated in the GIS environment were assigned to the effective raster fuzzy maps and finally weighted maps were obtained. In this process, all vector layers were converted to raster layers so that the necessary mathematical operations could be applied to them in the next stages. Among the functions available for rasterization in the Arc Map software environment, the Topo to Raster function can be used to generate a DEM of the area from 3D features, and the Polygon to Raster function to convert vector features with a polygonal nature to a raster, where the value of each pixel produced can be one of the descriptive information fields of the polygons. The Polyline to Raster function is used to convert linear vector features to raster, where the value of each generated pixel can be one of the polyline descriptive information fields, and the point to Raster function is used to convert point vector features to raster, where the value of each generated pixel can be one of the point descriptive information fields. However, one of the most important functions for rasterizing the feature area is the Euclidian Distance function. This function is a subset of the Distance functions from the Spatial Analyses section. This function actually calculates the direct distance from the center of each Pixel to the center of the feature Pixel and assigns a value to each pixel based on the calculated distance. This function was also used to rasterize and produce boundary maps. The layers of the present study include: digital elevation model layer, slope, geographic direction, road map, distance map from residential areas, distance map from agricultural land, vegetation type map, vegetation density map. In the Expert Choice software, the compatibility rate para-

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meter is calculated, and a compatibility rate number less than 0.1 is a confirmation of the pairwise comparison process of the criteria. As a result, the use of the resulting weights will be without any problems.

## Results and Discussion

### Results of layer matching using AHP fuzzy membership functions

Using fuzzy membership functions, the evaluation of the criteria of the study area in each layer was evaluated in a range between zero and one. To perform mathematical operations on information layers, all of them must be in the same value range (similar pixel va-lues in different maps become the same) in order to obtain acceptable results from combining layers. The fuzzy membership function of each of the criteria was obtained using the literature on the subject and the opinions of experts. In Figures 2 to 8, the fuzzy maps are shown. To fuzzify this layer, according to the opinions of experts and a review of articles in this field, the layers were first evaluated from zero to one. After reclassifying these classes with the GIS environment fuzzification tools, finally using the Small and large functions, the final fuzzy map was prepared. Figure 2 shows the fuzzy map of the geographical direction classes of the study area, where the lowest value is seen in the geographical direction of the southeast of the study area and the highest value is seen in the geographical direction of the east of the study area (Figure 2).

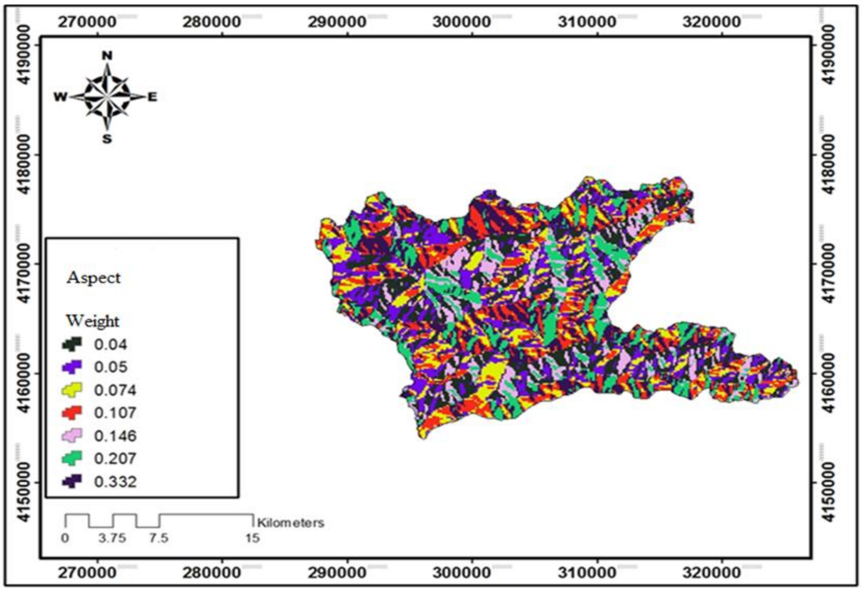


**Figure 2**
*Directional weighting map under direction criteria in the AHP model*

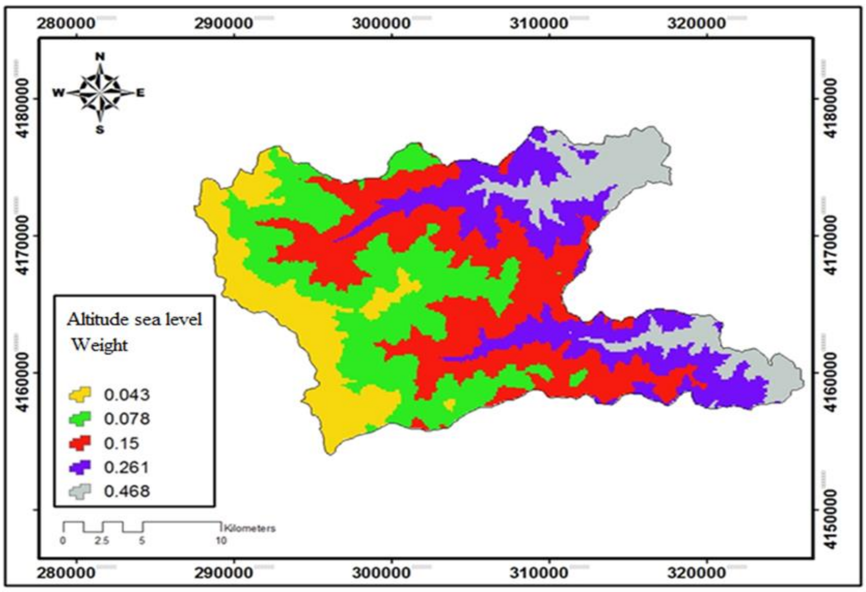


**Figure 3**
*Weighting map under height class criteria in the AHP model*

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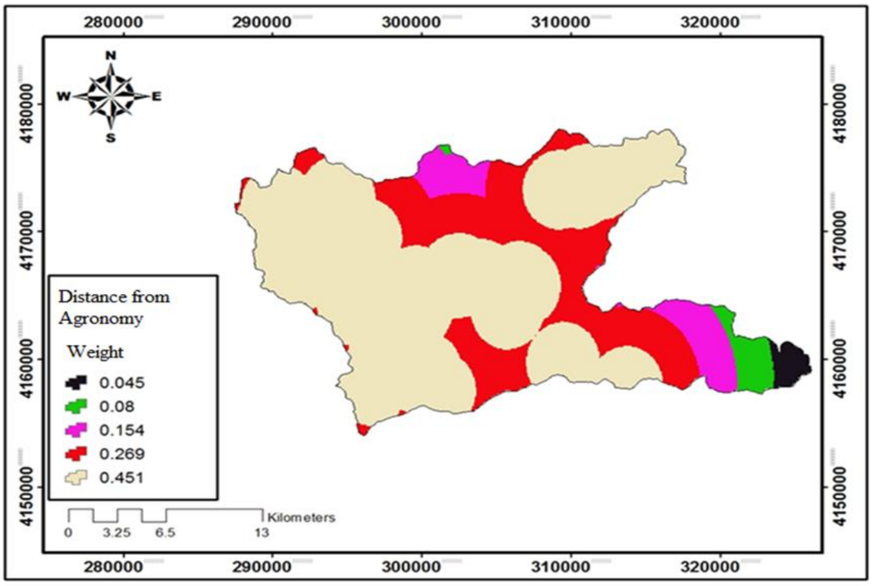


**Figure 4**
*Weighting map under the distance from residential areas criteria in the AHP model*

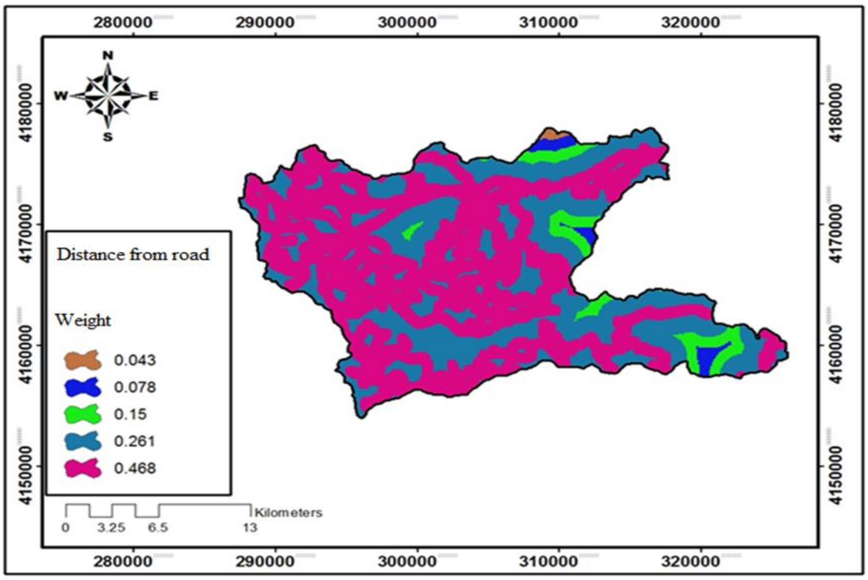


**Figure 5**
*Weighting map under the distance from roads criteria in the AHP model*

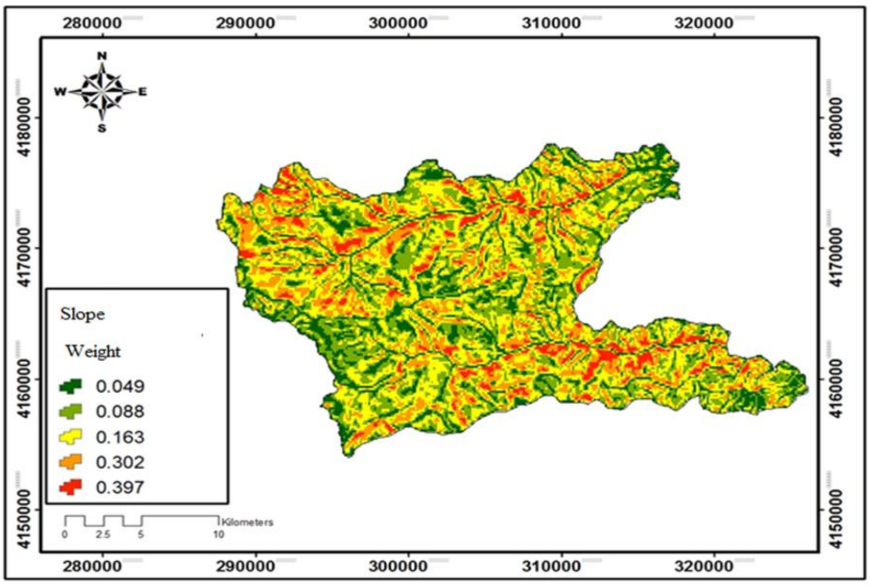


**Figure 6**
*Weighting map of the slope criteria in the AHP model*

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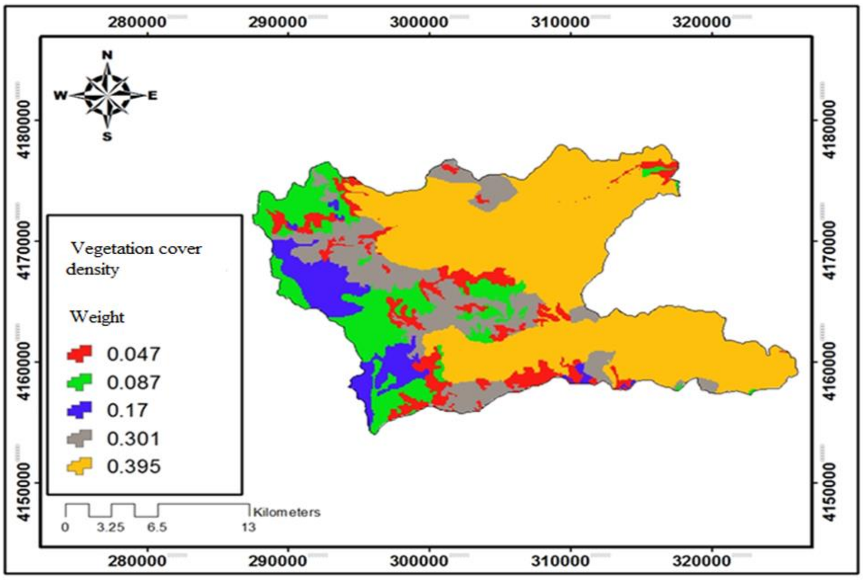


**Figure 7**
*Weighting map of vegetation density criteria in the AHP model*

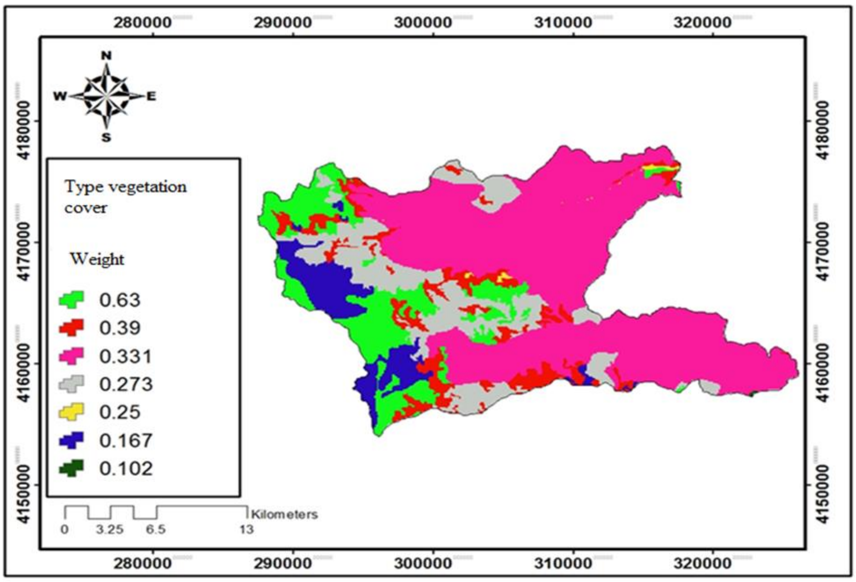


**Figure 8**
*Weighting map of vegetation type sub-criteria in the AHP model*

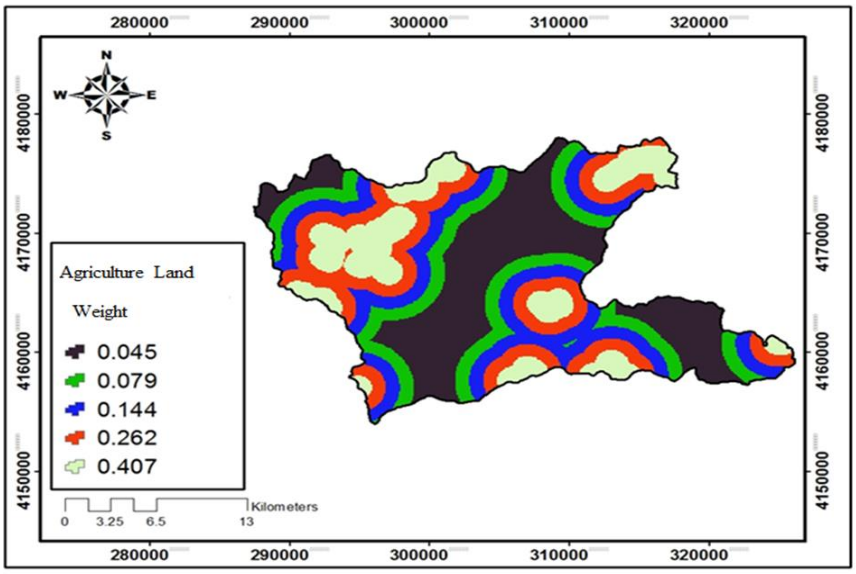


**Figure 9**
*Weighting map under the criteria of distance from agricultural areas in the AHP model*

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The fuzzy map of the distance from residential areas of the study area in Figure 4 shows that the lowest value is seen in the geographical direction of the west of the study area and the highest value is seen in the geographical direction of the southeast of the study area (Figure 4). Figure 3 shows the fuzzy map of the height classes of the study area, where the lowest value is seen in the geographical direction of the west of the study area and the highest value is seen in the geographical direction of the east of the study area (Figure 3).The fuzzy map of distance from residential areas in Figure 5 shows that the lowest value is seen in the geographical direction of the west and the center of the study area and the highest value is seen in the geographical direction of the east of the study area (Fig. 5). The fuzzy map of the slope of the study area in Figure 6 shows that the lowest value is seen in the geographical direction of the west and the center of the study area and the highest value is seen in the geographical direction of the north and south of the study area (Fig. 6). The fuzzy map of the vegetation density of the study area in Figure 7 shows that the lowest value is seen in the geographical direction of the west of the study area and the highest value is seen in the geographical direction of the east of the study area (Fig. 7). The fuzzy map of the vegetation type of the study area in Figure 8 shows that the lowest value is seen in the geographical direction of the west of the study area and the highest value is seen in the geographical direction of the east of the study area (Fig. 8). The fuzzy map of the distance from the agricultural areas of the study area in Figure 9 shows that the highest value is seen in the geographical direction of the northwest and southeast of the study area, and the lowest value is seen in the geographical direction of the north and center of the study area (Fig. 9). The risk of fire occurrence showed that of the total area of the study area, in the AHP weighting method, 4221.72 hectares were in the very low risk zone, 10528.67 hectares in the low risk zone, 13567.94 hectares in the medium risk zone, 13827.32 hectares in the high risk zone, and 6702.43 hectares in the very high risk zone.

**Table 1.** *Area of fire-prone areas with AHP weighting*

| Area Hectare | Fire Hazard |
|---|---|
| 4,221.72 | Very low |
| 10,528.67 | Low |
| 13,567.94 | Average |
| 13,827.32 | High |
| 6,702.43 | Very hugh |

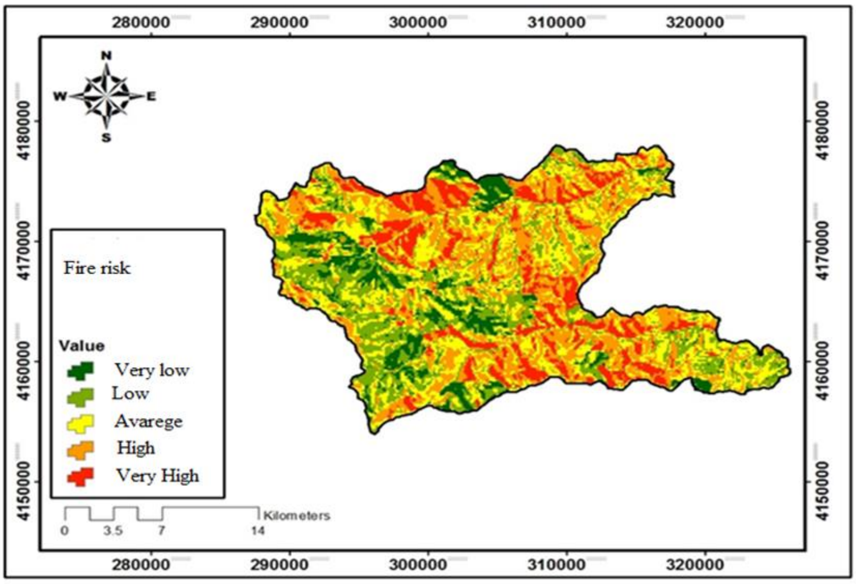


**Figure 10**
*Map of fire-prone areas with AHP weighting*

## Conclusions

According to the slope and direction map and the weighting of these criteria by experts and selected fire-prone areas, it was observed that the slope height and direction are also powerful factors in the occurrence of fires, and steep slopes and southern and south-western directions are the most susceptible areas to fire occurrence. Studying the road network and access to the study area can be effective in controlling and protecting the area by preparing the road network and

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scoring in the information system. Geographical information can be useful in preparing a fire potential map. By preparing fire-prone area zoning maps and designing roads and identifying the closest fire routes to reach areas where the risk of fire is high, it is possible to achieve a great deal of control and protection of hazardous areas. Identifying the factors affecting fire occurrence and risk zoning is one of the basic tools for achieving fire control and response strategies. This research was conducted to prepare a fire potential map using a geographic information system in the forests of Talesh County in order to identify high-risk areas of fire using the AHP analysis method in the criteria evaluation stage. For quantitative validation of the fire potential map obtained from AHP, the area of high-risk and very high-risk fire classes within the area of past fires was obtained, which is shown in Table 1. The results of the comparison of the fire risk potential map based on the AHP method with the map of past fire areas showed that the areas that have previously been burned in the region have a relatively good overlap with the high-risk and very high-risk areas in terms of fire, and approximately 60 percent of the burned areas are in the high-risk and very high-risk area. Considering the map obtained and the purpose of the study defined in this research, this map can be used as a guide in better fire management and control and optimal allocation of firefighting facilities in high-risk areas. By examining the map obtained with the fuzzy AHP method, 40% of the study area is in the high and very high risk class, which will be of special use for the management of the forest fire crisis and its subsequent consequences, as well as the management of fires in these areas. With this approach, in this study, a fire potential map was prepared using a geographic information system in the forests of Guilan province. Using a digital elevation model (DEM) study of the ground surface can affect the severity of the fire. According to the elevation class map and the weighting of this criterion by experts and selected fire-prone areas, it was observed that altitude is an important factor in the occurrence of fires and that lower altitudes are the most susceptible areas to this crisis. Examining the slope map and geographical directions used in the fire model showed that the slope and direction are effective in the movement and spread of the fire. According to the slope and direction map and the weighting of these criteria by experts and selected fire-prone areas, it was observed that height, slope and direction are also powerful factors in the occurrence of fire, and steep slopes and southern and southwestern directions are the most susceptible areas to fire (Figure 10). Studying the road network and access to roads in the area and scoring in the geographic information system can play an effective role in control and protection. Preparing zoning maps of fire-prone areas and designing roads and identifying the closest access routes to reach areas with high fire risk can greatly control and protect risky areas. The AHP model is effective for zoning the potential for fire risk in Iranian forests, while the results of this study and the results of similar studies conducted using this model in forests indicate that it has relatively good validity for preparing a fire potential map in northern Iranian forests (Insinas et al., 2007, Poder et al., 2002). Fire risk showed that of the total area of the study area, in the AHP weighting method, 4221.72 hectares were in the very low risk zone, 10528.67 hectares in the low risk zone, 13567.94 hectares in the medium risk zone, 13827.32 hectares in the high risk zone, and 6702.43 hectares in the very high risk zone. By examining the map, it was observed that 40% of the area is in the high and very high risk zone, which, in line with the results of other researchers' research, also showed that approximately forty% of the area of past fire areas is located in places that have a very high potential for fires (Mahdavi et al., 2008, Miller, 2013, Mohammadi et al., 2013). Every year, fires threaten forest areas in our country, especially the northern forests, and reduce their quantity and quality. Despite the efforts of managers to combat fires, hundreds of hectares of forest are destroyed every year. The continuation of fires and their direct effects will reduce or destroy the commercial value of forest trees, destroy seedlings, soil, leaf litter, wildlife habitat, recreational and scenic value of the forest, increase mineral content, reduce soil acidity, reduce nitrogen storage, and change the ecological sequence of the area by replacing inferior species. Managing the forest fire crisis and its subsequent consequences, as well as predicting the likelihood of future fires in these ecosystems, is of particular importance in investigating the factors affecting the occurrence of forest fires. With this approach, in this study, a fire potential map was prepared using a geographic information system in the forests of Talesh County, Gilan Province. It is suggested that fire potential maps be produced using geographic information systems in other counties of the province to prepare a comprehensive map of fire potential in Guilan province, and that by using maps produced in environmental and natural resources or-

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ganizations in high-risk areas of fire, firebreaks and other protective factors such as the use of fire retardants and the establishment of monitoring stations in fire management and county fires should be used. Preparing fire potential maps increases the decision-making power of managers for allocating resources, manpower, and facilities in the province. It is suggested that in future research, the aforementioned model be made a local model considering the characteristics of northern Iranian forests to increase its accuracy with real fire data in each region. With this method, the presented model can be used as an auxiliary system in fire monitoring and creating efficiency in the management of forces and facilities of natural resources and environmental protection organizations during fires.

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