Mapping wildfire risk by using Fuzzy and AHP methods in forests of northern

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November 26, 2022

Abstract

This research is intended to map potential fires using GIS in forests in Talesh, Gilan Province. Spatial data analysis methods were used for zoning fire risk. First, a digital elevation model (DEM) model was prepared using the ASTERsensor . Slope, aspect and mean sea level (MSL) were also obtained by DEM. Then, maps of vegetation type and density were classified in terms of susceptibility to fire by using GIS. The roads, rural settlements and farmlands were mapped. Polygon to Raster and Euclidian Distance were used to rasterize all information layers. Fuzzy membership functions were used to value the parameters of the study area in each layer within a 0 to 1 range, and the subclasses were weighed in AHP model by Saaty valuation table and questionnaire. The use of Dong model and AHP and fuzzy weighing methods for zoning fire risk potentials showed that of the entire study area weighed by AHP method there were zones: 4221.72 Ha very low risk, 10528367 Ha low risk, 13567.94 Ha medium risk, 1382.32 Ha high risk and 6702.43 Ha very high risk, respectively. Therefore, risk zones in terms of surface area were high, medium, low, very high and very low. In fuzzy weighing method, very low, low, medium, high and very high risk zones were 6840.42 Ha, 6605.84 Ha, 12044.46 Ha, 15922.87 Ha, 15922.87 Ha, 7416.89Ha, respectively, which high erosion classes were of the highest priority and low erosion classes were of lowest priority.

Mapping wildfire risk by using Geographical Information System in forests of northern Iran

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Abstract

Forest fires and decrease in forest surface area as a crisis in recent year is a serious problem. Thus, wildfire risk mapping and delineation of areas prone to fires in order to manage such areas for concerned departments is of high importance. This research is intended to map potential fires using GIS in forests in Talesh, Gilan Province. Spatial data analysis methods were used for zoning fire risk. First, a digital elevation model (DEM) model was prepared using the ASTER sensor for an area with a pixel size of 25m by 25m. Slope, aspect and mean sea level (MSL) were also obtained by DEM. Then, maps of vegetation type and density were classified in terms of susceptibility to fire by using GIS. The roads, rural settlements and farmlands were mapped. Polygon to Raster and Euclidian Distance were used to rasterize all information layers. Fuzzy membership functions were used to value the parameters of the study area in each layer within a 0 to 1 range, and the subclasses were weighed in AHP model by Saaty valuation table and questionnaire. The use of Dong model and AHP and fuzzy weighing methods for zoning fire risk potentials showed that of the entire study area weighed by AHP method there were zones: 4221.72 Ha very low risk, 10528367 Ha low risk, 13567.94 Ha medium risk, 1382.32 Ha high risk and 6702.43 Ha very high risk, respectively. Therefore, risk zones in terms of surface area were high, medium, low, very high and very low. In fuzzy weighing method, very low, low, medium, high and very high risk zones were 6840.42 Ha, 6605.84 Ha, 12044.46 Ha, 15922.87 Ha, 15922.87 Ha, 15922.87 Ha, 7416.89Ha, respectively, which high erosion classes were of the highest priority and low erosion classes were of lowest priority.

Keywords :Risk of firing, GIS, Dong Model, Talesh forests

Introduction

A variety of factors including logging, conversion of forests to farms, overgrazing, pests, diseases, and fire are involved in degradation of forests, which the latter is of a particular susceptibility level compared to the other factors. Today, fire is threatening large parts of the forests in the world, burning thousands of hectares covered by trees, shrubs and bushes (Miller ,2013). Large areas of forests in the world are exposed to fire, which not only it degrades the vegetative cover, but upsets the hydrological processes, increases soil erosion and runoff every year (Vadrevu ,2015; Le etal.,2014)). Therefore, delineation of zones having a high risk of firing seems necessary to prevent spreading of fire in case it happens and expands through susceptible areas. For this reason, Geographical Information Systems (GIS) plays an important role in zoning the natural areas potentially exposed to fire (Gerdzheva ,2014; Denham etal.,2012; Liu ETAL.,2018) .Recently, frequent fires in forests of northern Iran have led to a great deal of losses and casualties to the environment, villages and the residents(Mohammadi etal.,2011;).

Compaction of the forests of northern Iran, their localization and contribution to livelihood of the inhabitants, precision of collecting data on the previous fires and their losses indicate the importance of this event and the need to suggest solutions (Mahdavi etal.,2012). Three factors were used to devise a simple and quick model for mapping risk of firing in forested areas: slope, aspect and NDVI. For this purpose, these factors were formulated and applied to the images to specify areas with very high risk of fire (Giglio ,2003). Zoning the forests and rangelands for risk of firing using GIS and multivariate evaluation has been performed in parts of Iran. used remote sensing, GIS, and AHP for mapping the risk firing in an area in Himalayas based on slope, aspect and vegetation. The results showed that 4.42% and 26.92% of the area were located in high and very high risk zones, respectively, which were introduced as areas of highest priority for fire management and prevention measures (Sunil ,2005).

Maps of the risk of firing are linked to vegetation map so that often hazardous areas are forests and high risk areas are the same areas which previously experienced fire indicating that GIS models are highly accurate (Ganteaume ,etal.,2013). With regard to the importance of preventing forest wildfires using GIS and to incidence of previous fires in Talesh forests, this research is seeking to identify critical areas and introduce them to the concerned authorities to suggest solutions for future fires, which seems to be an ideal method to predict future fires in forest of the study area.

Material and methods

study area

The study area comprises of Khalesara and Dinajal basins in Talesh County, located between 48° and 32" eastern longitude and 37° and 33" northern latitude (Management and Planning Organization, Gilans Province, 2015).The area is full of forests and has a mild weather, which is topographically divided to two quite distinct parts: plain in the east and mountain in the west. The mountainous part is covered with forests and rangeland, due to proximity to Caspian Sea . The weather is mild and humid in the plain part and humid and cold in the mountainous part (Fig.1).

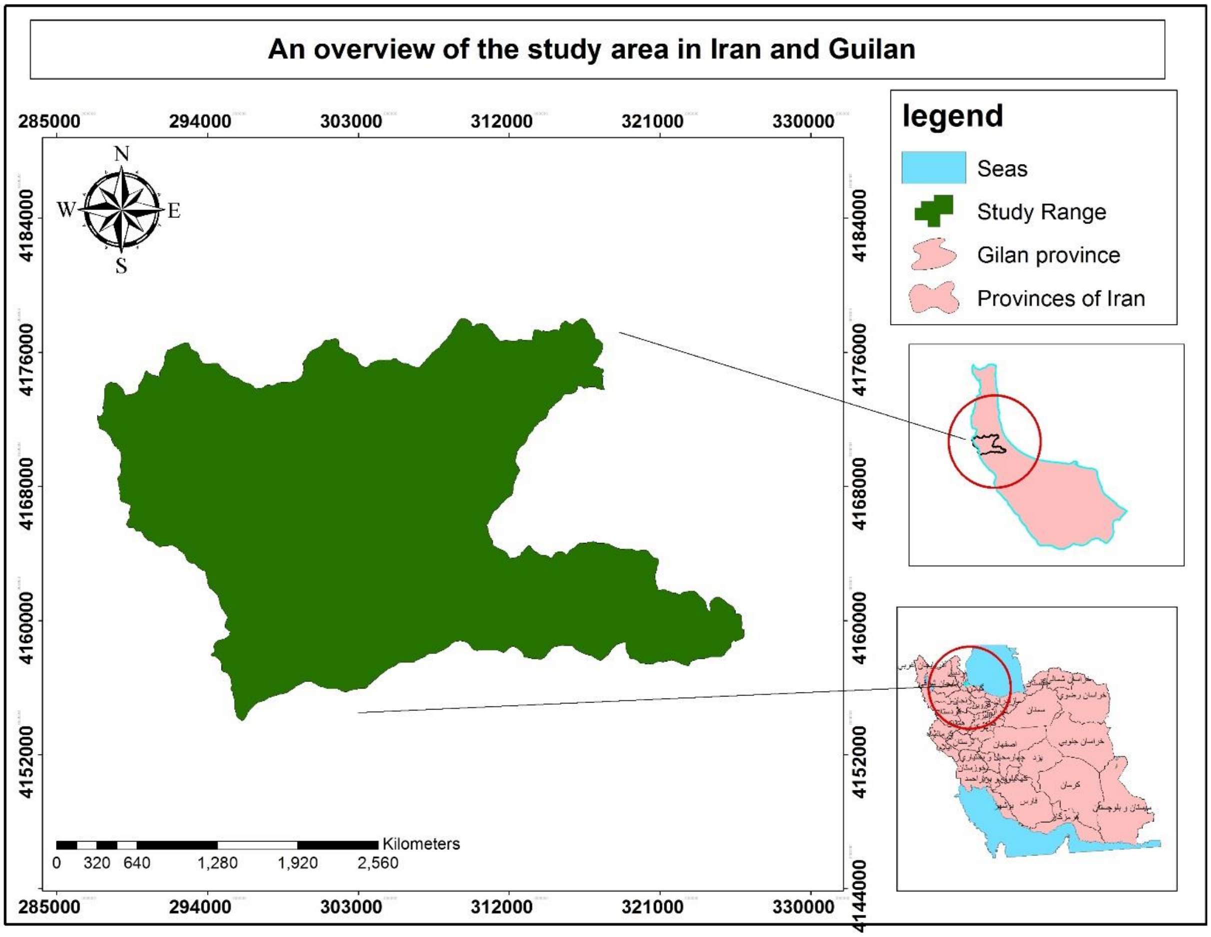


Figure 1. Study area comprises of Khalesara and Dinajal basins in Talesh County

Methodology

Since a variety of factors are involved in fire mapping, Dong model as one the most applicable models were used in this research, in which the most important factor was considered(Dong etal.2005),. The model is:

$R_c = 7 (V_t + V_d) + 5 (S+A+E) + 3 (D_r + D_f + D_s)$ (Eq.1)

where R_c: Numerical index of potential fire ;V_t: Vegetation type ;V_d: Vegetation density

S:Slope ; A: Aspect; E: Elevation; D_r: Distance from roads; D_f: Distance from farmlands ;D_s=Distance from (rural) settlement

Meanwhile, the integer values show the weight of each factor (cortical weight).In this research, the regional DEM model was prepared by ASTER (pixel size :25m by 25m), by which slope, aspect and elevation were mapped found. The vegetation type and density were also prepared by

GIS. Then, the vegetation type and density maps were classified in terms of susceptibility to firing. The maps of the roads, settlements and farmlands were also prepared. All of these maps were classified based on Dong model. By overlaying the weights, all of the maps in GIS and giving special weights to each factor using Dong model (weight 7 for vegetation type and density, weight 5 for slope, aspect and elevation, and weight 3 for distance from roads, farmlands and rural settlements) and using Raster calculator technique in GIS environment, the map of the risk of firing was prepared in 5 classes. The flowchart of the methodology is shown in Figure 2.

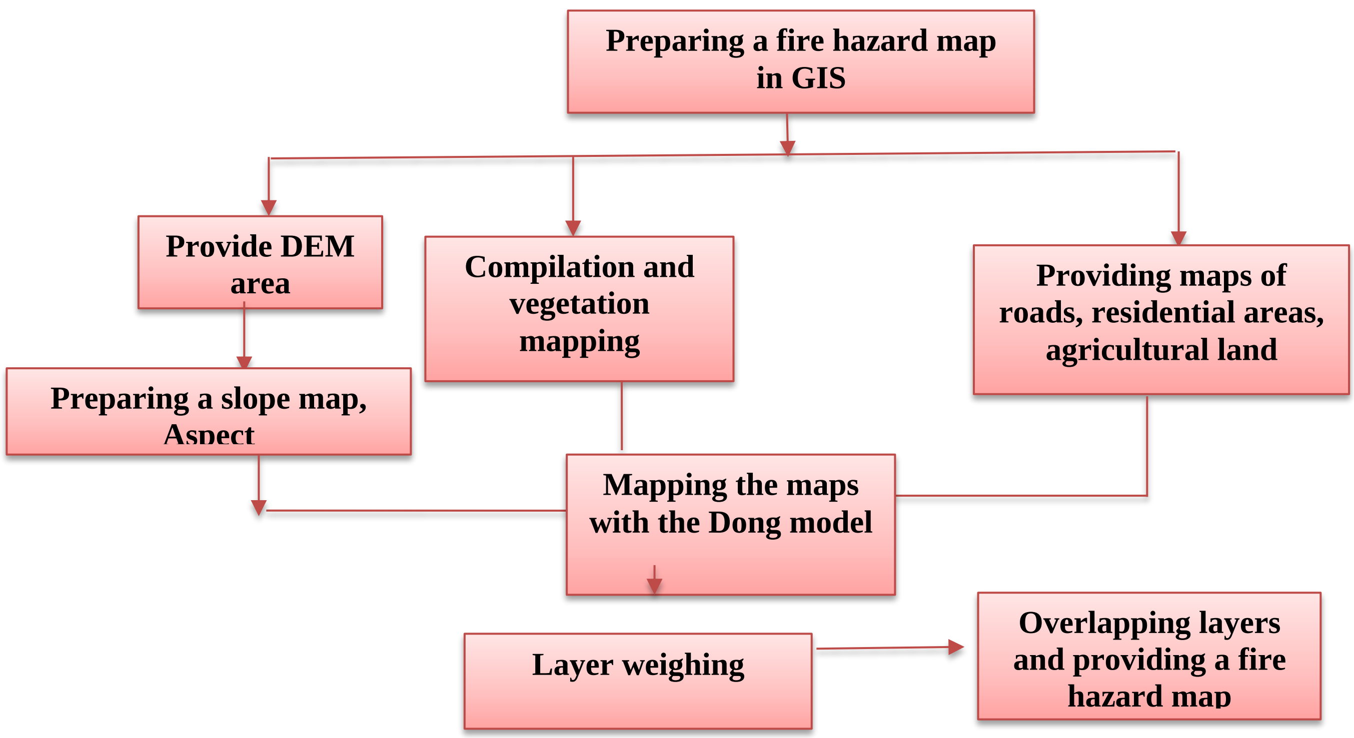
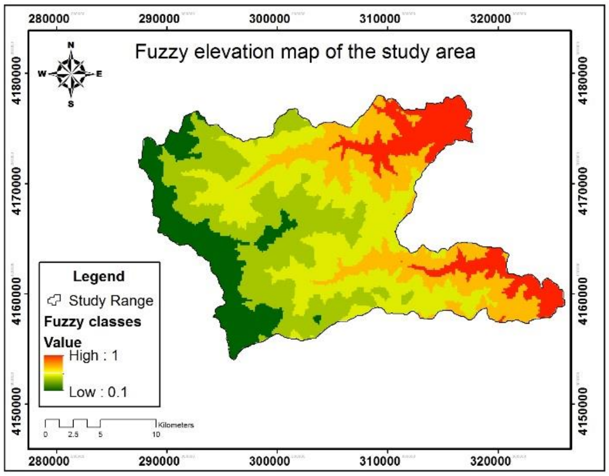


Figure2. Flowchart of the methodology

Results of assimilation of layers using fuzzy membership functions

Then, using fuzzy membership functions, the aforementioned factors were valued in a 0-1 range for each layer, which should be on the same value range and have similar pixel values on different maps so that merging the layers could achieve acceptable results. Fuzzy membership functions for each factor were obtained from the literature review and expert opinions (Figurs 3-10). For fuzzy membership function of these layers on this basis, they were valued between 1 to 10. Finally, these classes were re-classified by fuzzy membership function tools in the GIS atmosphere using Small and Large Functions. Table 4.1 shows the layers and subclasses. The results of weighing secondary factors by pairwise comparison using AHP in layers of aspect, elevation, slope, distance from rural settlements and roads, Vegetation density and Vegetation type and Residential area were shown in Figures (11-18).



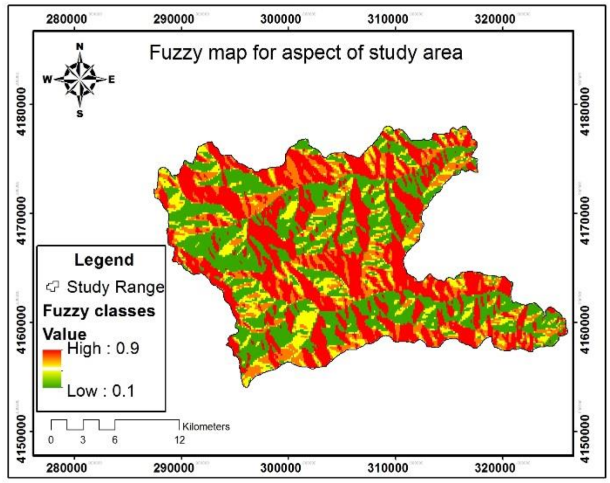
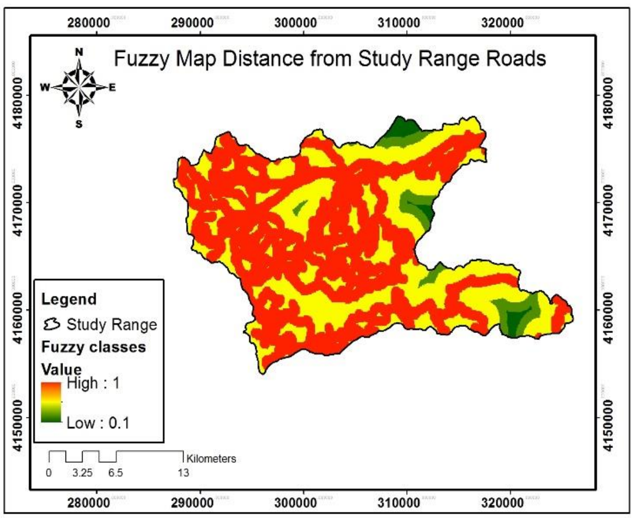


Figure 3 Altitude sea level of study area

Figure4 . Aspect



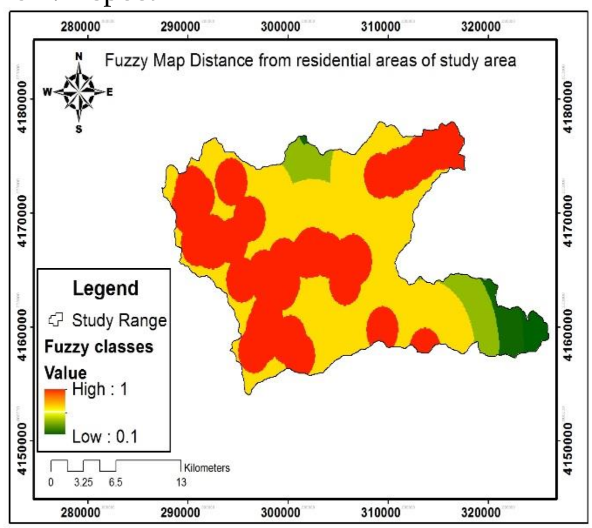
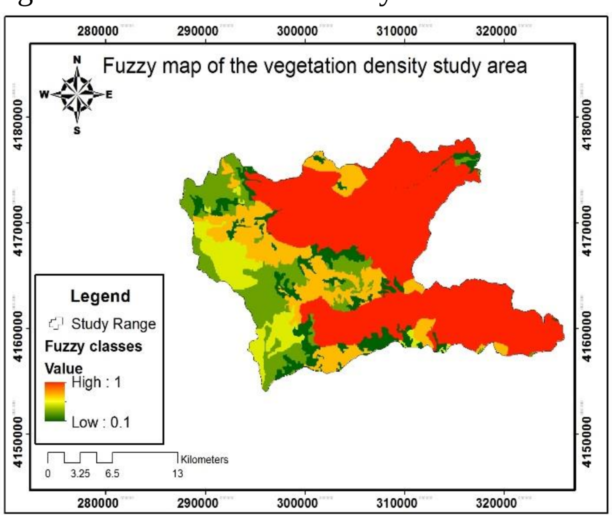


Figure 5.Distance road of study area

Figure 6.Residential area



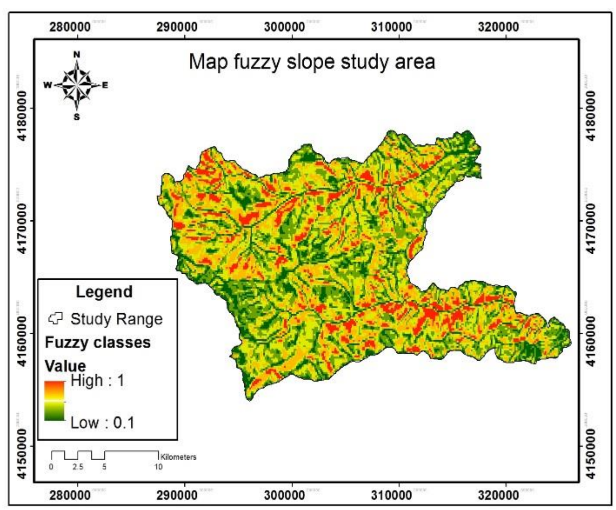
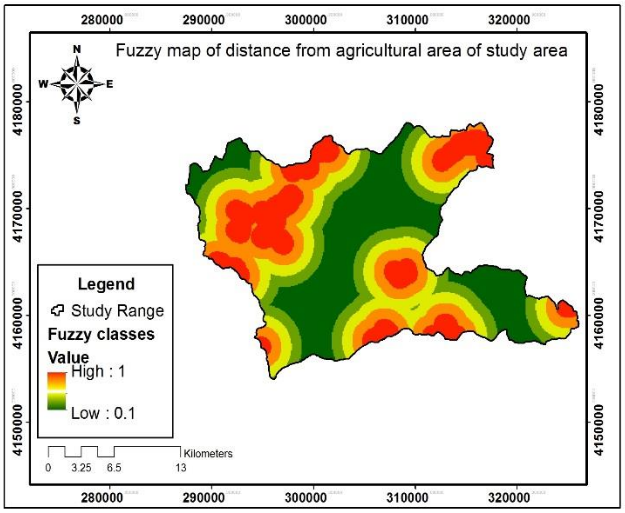


Figure 7.Vegetation density of study area

Figure 8. slope



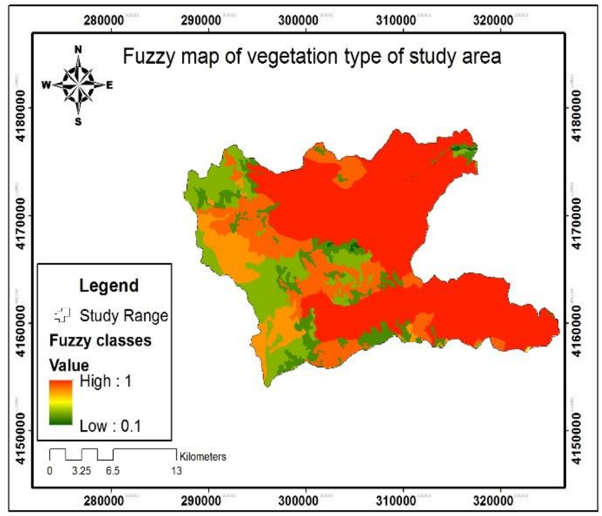
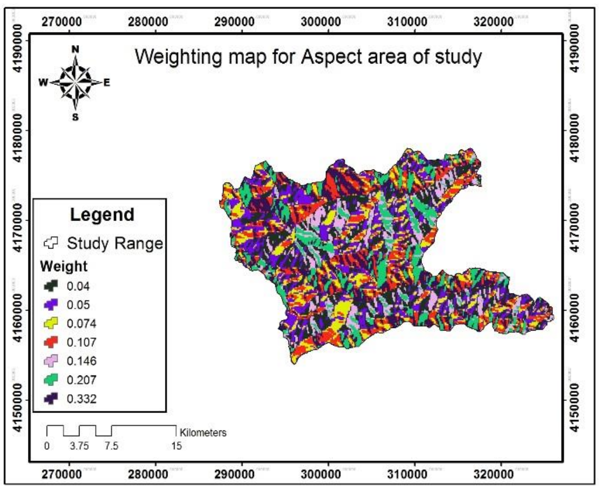


Figure9. Distance from agriculture area

Figure 10.Vegetaion type of study area



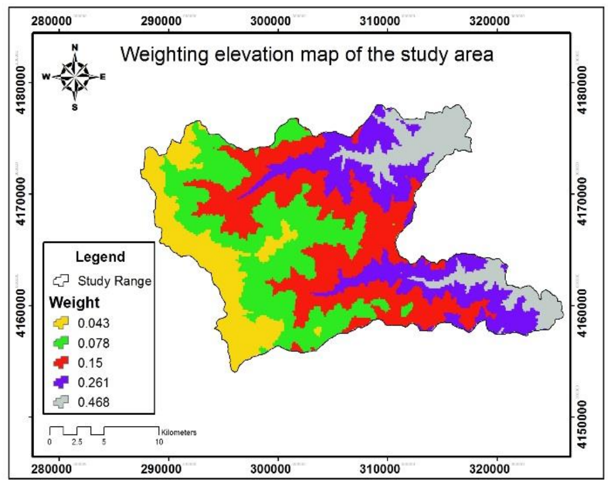
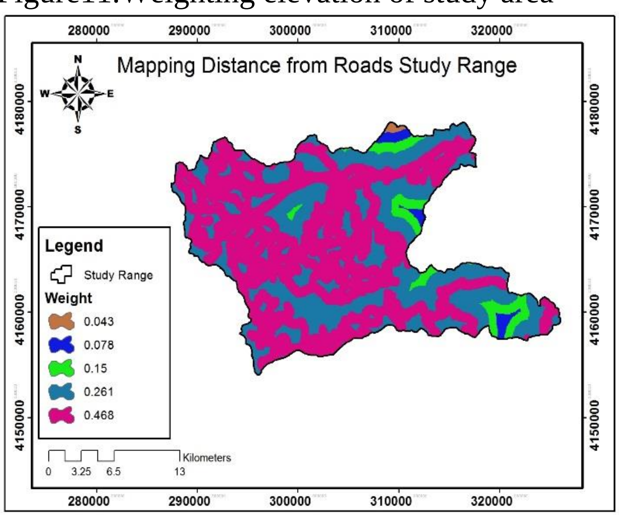


Figure11.Weighting elevation of study area

Figure 12. Weighting aspect of study area



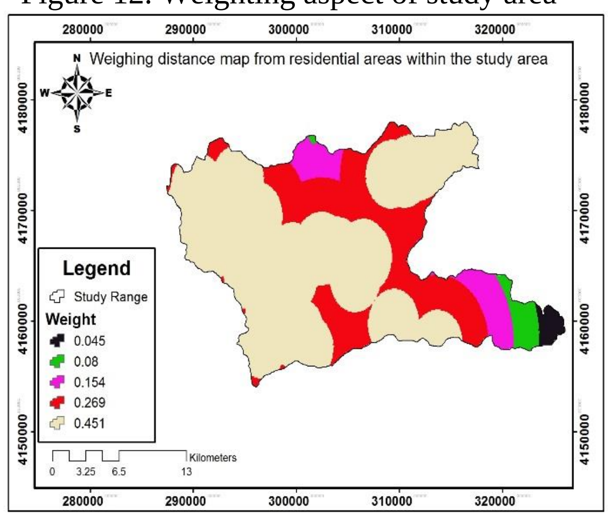
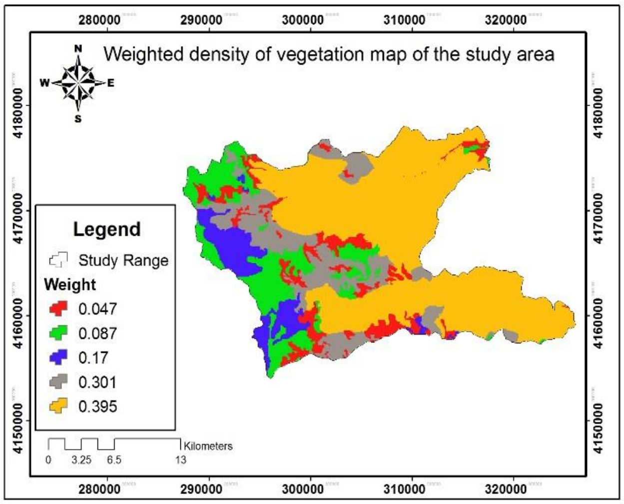


Figure 13. Weighting distance from road

Figure 14. Weighting distance from residential



Figur 15. Weighting vegetation density

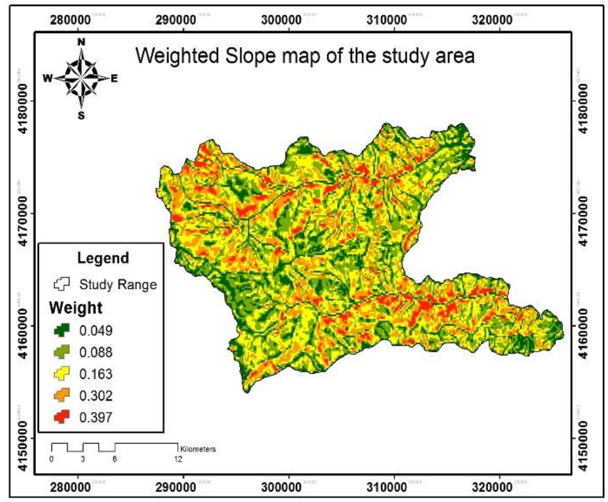


Figure 16.Weighting slope of study area

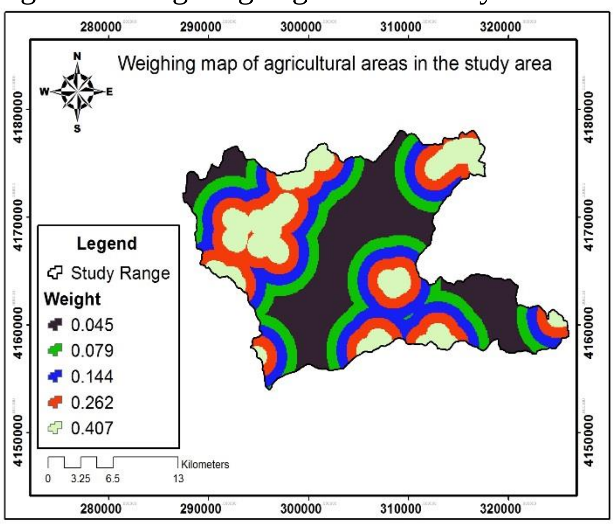


Figure 17. Weighting agriculture area

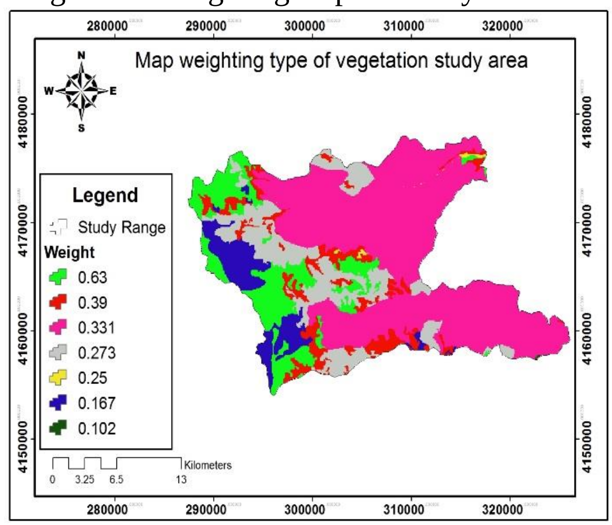


Figure 18. Weighting vegetation type

Final fire zoning by Dong model

In this phase, the maps were overlapped based on Dong formulae using fuzzy and weighed maps as well as Eq.1, and the zoning maps were obtained (Fig.19 and 20).

By AHP weighing and Dong model, the very high risk area was 6702 ha and by fuzzy weighing and Dong model it was 7416 ha (Tables 1 and 2).

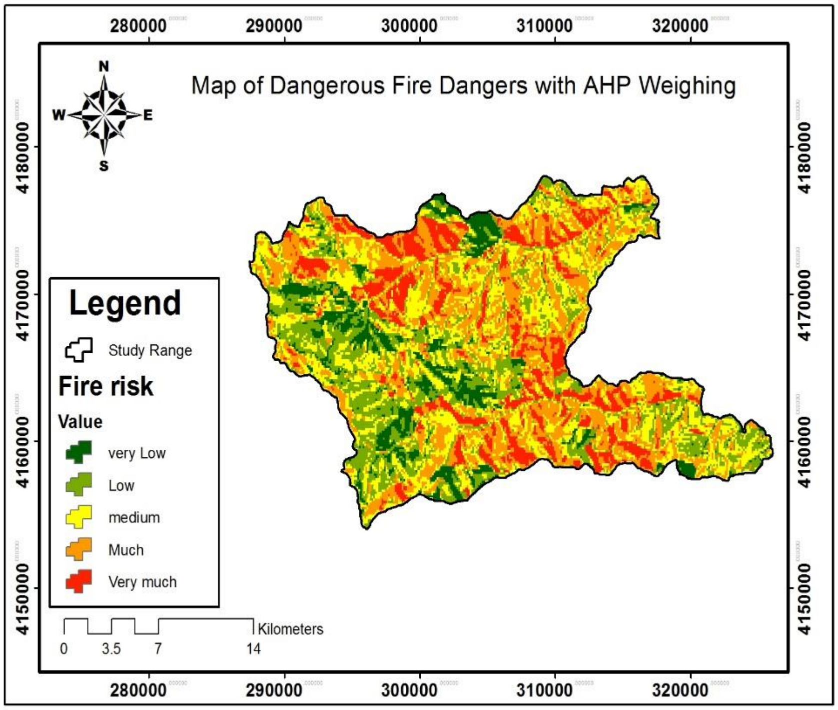


Figure 19. Fire zone with AHP weighting

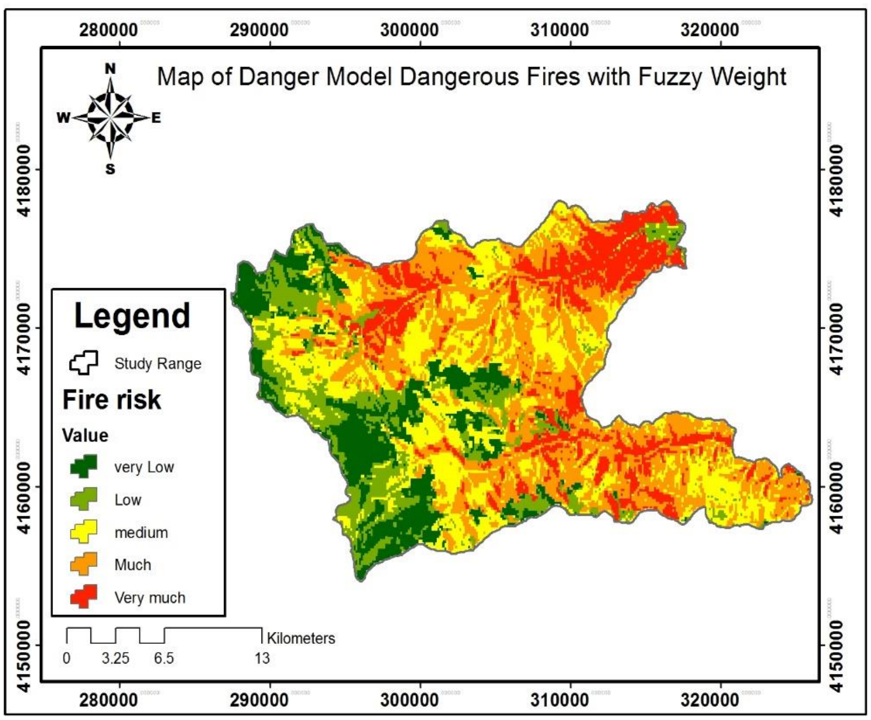


Figure 20. Fire zone with Fuzzy weighting

Table 1. Surface area of prone to fire zones (obtained by AHP weighing)

Class of firing risk	Area (Ha)
Very low	4221.72
low	10528.67
moderate	13567.94
high	13827.32
very high	6702.43

Table 2. Surface area of prone to fire zones (obtained by fuzzy weighting and Dong model)

Class of firing risk	Area (Ha)
Very low	6840.42
low	6605.84
moderate	12044.46
high	15922.87
very high	7416.89

Identification of factors influencing the incidence of fire and zoning its hazard is a fundamental tool to find the solutions to control and combat. This paper used GIS for mapping the risks of firing in the forests of Talesh County in order to identify high risk areas using AHP and fuzzy methods during valuation of the criteria and Dong model during overlapping the layers.

Discussion and conclusion

DEM model can be useful to determine the intensity of fire. Based on the maps of elevation classes and weights given to this factor by the experts in the selected zones of firing risk, it was observed that elevation is a crucial factor in firing and lower elevations are more prone to this crisis (Figures 19 ,20). Slope and aspect influence fire moving and spreading. Thus, the maps slope and aspect, their weights and the zones prone to firing revealed that steep slopes and south and south western aspects are the most susceptible areas (Figures 19,20). Analysis of the weights of roads and their accessibility in GIS can be helpful for mapping the fire risk. As the fire prone zones were determined, the roads were designed and the closest trails were found, hazardous areas could be largely controlled and protected.

Fires threat the forests particularly in the northern part of Iran every year resulting in deterioration of their qualitative and quantitative parameters. Hundreds of hectares of forests are ruined despite the attempts of the authorities to combat the firing. Successive fires directly reduce and eliminate commercial values of the forests, seedlings, soil, humus, wildlife habitats, recreational values, landscapes, minerals, soil pH, nitrogen reserves, and modification of ecological succession to invasive species (Pourmajidyn and Parsakhoo, 2008). It is critically important to analyze fire parameters for managing the crisis of forest wildfires and their consequences, and prediction of potential fires in these ecosystems.

Zoning the fire risk was performed by a spatial analysis in this research. First, the parameters influencing the model were prepared by a DEM model using ASTER sensor with a 25m by 25 pixel sizes, by which map maps of slope, aspect and elevation were found. The vegetation type and dynasty were also prepared by GIS. Then, the maps of vegetation type and density were classified in terms of susceptibility to firing. The roads, residential areas and farmlands were mapped. Polygon to Raster and Euclidian Distance were used to rasterize. All information layers Using fuzzy membership functions, the criteria of the study area in each layer was valued within a 0 to 1 range, and the subclasses were weighed in AHP model by Saaty valuation table and questionnaire.The use of Dong model by AHP and fuzzy weighing methods for zoning fire risk potential showed that the study area weighed by AHP method had these zones: 4221.72 Ha very low risk, 10528367 Ha low risk, 13567.94 Ha medium risk, 1382.32 Ha high risk and 6702.43 Ha very high risk, respectively. Therefore, risk zones in terms of surface area were high, medium, low, very high and very low. In fuzzy weighing method, very low, low, medium, high and very high risk zones were 6840.42 Ha, 6605.84 Ha, 12044.46 Ha, 15922.87 Ha, 15922.87 Ha, 7416.89 Ha, respectively, which high erosion classes were of the highest priority and low erosion classes were of lowest priority. Comparing the two maps suggested that over %40 of the area are in high and very high risk zones, which is in agreement with another research conducted in Zarin Abad forests, Mazandaran Province using Dong model showing that approximately %40 of the previously fired areas were located in places with high or very high potential of firing (Mahdavi et al., 2019; Mohammadi et al., 2011; Vadrevu K et al., 2015; Zhang etal.,2010). Since based on Dong model, 40 % of the area are located in high and very high risk of firing, the forests will be exposed to future fires. Therefore, preventive measures in these forests with the aid of intelligent spatial information tools and systems.

As concluded by the results, most fires happen in areas where they are more available to humans. In other words, desirable slope and the same elevation of the villages in the study area resulted in further and easier availability of the forests for recreational, grazing, farming and other purposes of the human who carelessly ignite fires and leave it.

Totally, the study area has a great potential of firing so that based on the resulting map over %40 of the area is located in the very high risk zones and the potential fire might threat the forests, rangelands, farmlands and other land uses. Thus, this map can serve as a guide for managing fires in highly hazardous areas and mobilizing the equipment and services.

References

Denham M, Wendt K, Bianchini G, Cortes A, Margalef T (2012) Dynamic data-driven genetic algorithm for forest fire spread prediction. J Comput Sci 3(5):398–404

Dong X, Li-min D, Guo-fan SH, Lei T, Hui W (2005) Forest fire risk zone mapping from satellite images and GIS for Baihe Forestry Bureau, Jilin, China. J For Res 16(3):169–174

Dong, X.U., Li-min, D., Guo-fan, Sh., Lei, T., and Hui, W. 2005. Forest fire risk zone mapping from satellite images and GIS for Baihe Forestry Bureau, Jilin, China, Journal of Forestry Research, 16(3): 169-174

Eva H, Lambin EF (1998) Remote sensing of biomass burning in tropical regions. Remote Sens Environ 64(3):292–315

Ganteaume, A.; Camia, A.; Jappiot, M.; San-Miguel-Ayanz, J.; Long-Fournel, M.; Lampin, C. A review of the main driving factors of forest fire ignition over Europe. Environ. Manag. 2013, 51, 651–662

Gerdzheva AA (2014) A comparative analysis of different wildfire risk assessment models (a case study for Smolyan district, Bulgaria). Eur J Geogr 5(3):22–36

Giglio L, Descloitres J, Justice CO, Kaufman YJ (2003) An enhanced contextual fire detection algorithm for MODIS. Remote Sens Environ 87(2):273–282

Le TH, Nguyen TNT, Lasko K, Ilavajhala S, Vadrevu KP, Justice C (2014) Vegetation fires and air pollution in Vietnam. Environ Pollut 195:267–275

Liu, Q.; Shan, Y.; Shu, L.; Sun, P.; Du, S. Spatial and temporal distribution of forest fire frequency and forest area burnt in Jilin Province, Northeast China. J. For. Res. 2018, 29, 1233–1239.

Mahdavi, A., Fallah Shamsi, S.R., and Nazari, R. 2012. Forests and rangelands' wildfire risk zoning using GIS and AHP techniques, Caspian Journal of Environmental Sciences, 10(1),43-52.

Miller C, Ager AA (2013) A review of recent advances in risk analysis for wildfire management. Int J Wildland Fire 22:1–14

Mohammadi F., Shabanian N. Pourhashemi H., Fatehi P.(2011). Risk zone mapping of forest fire using GIS and AHP in a part of Paveh forests. Iranian journal of Forests and Poplar Research.18(4): *586-569* .

Sunil C. (2005). Application of Remote Sensing and GIS Technology in Forest Fire Risk Modeling and Management of Forest Fires: A Case Study in the Garhwal Himalayan Region. Geo-information for Disaster Management , 1239-1254

Vadrevu K, Lasko K (2015) Fire regimes and potential bioenergy loss from agricultural lands in the Indo-Gangetic Plains. J Environ Manage 148:10–20

Zhang ZX, Zhang H, Zhou DW (2010) Using GIS spatial analysis and logistic regression to predict the probabilities of human-caused grassland fires. J Arid Environ 74(3):386–393