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Detection and Diagnosis of Fire Areas in Golestan Forests Using Landsat Satellite Images

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Abstract

Fire is a major factor in the development of some plant communities, especially those exposed to lightning. Lightning is almost the main cause of natural fires in most plant communities. Fire is effective in the evolution of various species of forests, pastures, and shrubs in arid regions of the world's Mediterranean regions. Remote sensing and geographic information systems are appropriate in assessing the severity of burns. In this study, the intensity of the fire in Gorgan forests is evaluated and examined. The period of the study area was from 2013 to 2017 and Landsat 8 satellite imagery was used. First, the fire points were identified within an area of 500 meters by the IDW method. Then, by using NDVI, NBR, and dNBR indicators, fire points were evaluated and fire points were marked with red pixels which is clear in the two pictures before and after the fire. Finally, it was concluded that the NBR and dNBR index are the most accurate indicators with an accuracy of more than 74%.

Keywords*:* forest, fire, NDVI index, NBR index, dNBR index, regression.

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1. Introduction

Disasters or natural disasters are complex processes that affect all parts of the globe. Meanwhile, the Iranian plateau is one of the special geographical areas that are exposed to all kinds of disasters such as earthquakes, floods, landslides, droughts, storms, forest fires, etc. These events can be categorized in a variety of ways as one possible method is 1) purely natural events, 2) purely human events and 3) human error events. According to available statistics, more than 80% of the Iranian plateau is exposed to the serious damage caused by the seismic activities of various intensities. Periodic floods are another type of natural disaster that is often caused by the destruction of the natural structure of the earth by humans and in different periods provides the basis for major damage in some provinces of the country. Other phenomena such as landslides and droughts, droughts, fires, severe storms, avalanches, etc. are some of the factors that cause irreparable human and financial damage to natural habitats and landscapes every year.

Fire is an important environmental, climatic, natural, and artificial factor that, by its inherent and immutable main elements, maybe accidental, ecological, intentional, inadvertent, or as a modifier in vegetation management by managers. Since fire as a major and influential factor can change the types and genetic diversity and species, affect the quantitative and qualitative indicators in the rangeland and have a severe impact on the sequence and stages. Sustainable development in any country depends on the conservation and exploitation of its natural resources. Currently, one of the problems facing the country's rangelands is fires, which uncontrollably and unintentionally cause damage and change in the ecosystem of natural resources. Understanding the phenomenon of fire and the factors that affect the extent of fire can be used as a strategic study in risk management in order to control and reduce fire damage. In this regard, the use of geographic information systems and remote sensing can lead to the provision of practical and accurate results in the field of natural resources (Tavakoli et al., 2014).

Forests are one of the most important reservoirs for carbon dioxide absorption. Unfortunately, over-harvesting of forests, fires, and deforestation will reduce these reservoirs and thus destroy the environment. Forest fires are one of the most destructive natural hazards, which unfortunately cause a lot of damage every year (Hassanpour Chamachaei, 2006). Undoubtedly, the first step in reducing the damage caused by forest fires and pastures is to identify high-risk areas that can be explored using existing technology and facilities, along with accurate information and statistics.

Forest fires are one of the major environmental concerns that affect forest conservation and cause economic and environmental damage and human suffering. This phenomenon is due to various reasons, and despite the increasing costs of a large number of governments to control this phenomenon, millions of hectares of forest around the world are being destroyed every year (Kurtz and Morris, 2007). Rapid diagnosis is a key element in controlling such phenomena. Because traditional human supervision is expensive and influenced by mental factors, there is an emphasis on developing automated solutions. Diagnosis and identification of this phenomenon estimate the damage to the areas and controls and manages the burn areas as soon as possible, and it is also possible to predict the points of fire.

Firefighting can be divided into natural, prescriptive, intentional, and unintentional in terms of the causes. In natural fires, fires are caused by fermentation and chemical interactions of the earth's organic matter, or by lightning. In some countries, in order to clear the area of flammable materials, the surplus of sections resulting from the complete cessation and possibly destruction of weeds, as well as assistance in natural regeneration and regulation of wildlife, every year or every few years under certain conditions and the special facilities of the forests are set on fire in a controlled (prescribed) way. In some cases, in the Scandinavian forest due to the accumulation of dead cover due to the cold season and the presence of resin materials that cause delays in becoming humus. It coats the forest in a thick layer and prevents natural regeneration. Therefore, countries try to burn dead cover in different ways (Daneshrad, 1985).

Intentional fires can cause a shortage of farmland, create pastures for livestock, or destroy and hunt wildlife sanctuaries. Unintentional fires can also cause large-scale fires in forests and pastures due to fires to cook food and carelessness in not extinguishing the fire and spreading it by the wind. Ignition of dry leaves, flames from coal furnaces, burning of crop residues in order to clean agricultural lands adjacent to forests and pastures, etc., are also causes of unintentional fires. Remote sensing and geographic information systems have been developed as effective, advanced, and coherent tools in the crisis management process. In many countries, there are now plans to monitor the Earth by designing new satellites and equipping them with the tools needed to monitor accidents.

In this study, using ground data before and after fires and satellite images and by analyzing the data, goals such as predicting the amount of damage to forest vegetation in the area, forest fire forecasting using statistical analysis, classification of the province's regions according to the amount and intensity of fire using fire indicators and plant index and finally comparing plant and fire indicators and selecting the best index to predict the amount of damage to Vegetation was done.

2. Materials and Methods

2.1 Study Area

Golestan province is one of the northern provinces of Iran and its capital is Gorgan city. The province is located in the geographical area of 5600-5400 east longitude and 3630-3815 north latitude. Golestan province with an area of about 2043.77 square kilometers is equivalent to 1.3 percent of the total area of the country and the twenty-first province of Iran in terms of area. This province leads from the north to the Republic of Turkmenistan, from the west to Mazandaran province and the Caspian Sea, and from the south to Semnan province. Nearly 18 percent of the province's surface is covered by forests, but grazing livestock grazing, agricultural expansion, deforestation, fires and floods in the province over the past few years have severely damaged the province's forests.

Fire is an important environmental, climatic, natural, and artificial factor that, by its inherent and immutable main elements, maybe accidental, ecological, intentional, inadvertent, or as a modifier in vegetation management by managers. Since fire as a major and influential factor can change the types and changes of genetic diversity and species, affect the quantitative and qualitative indicators in the rangeland and have a severe impact on the sequence and stages.

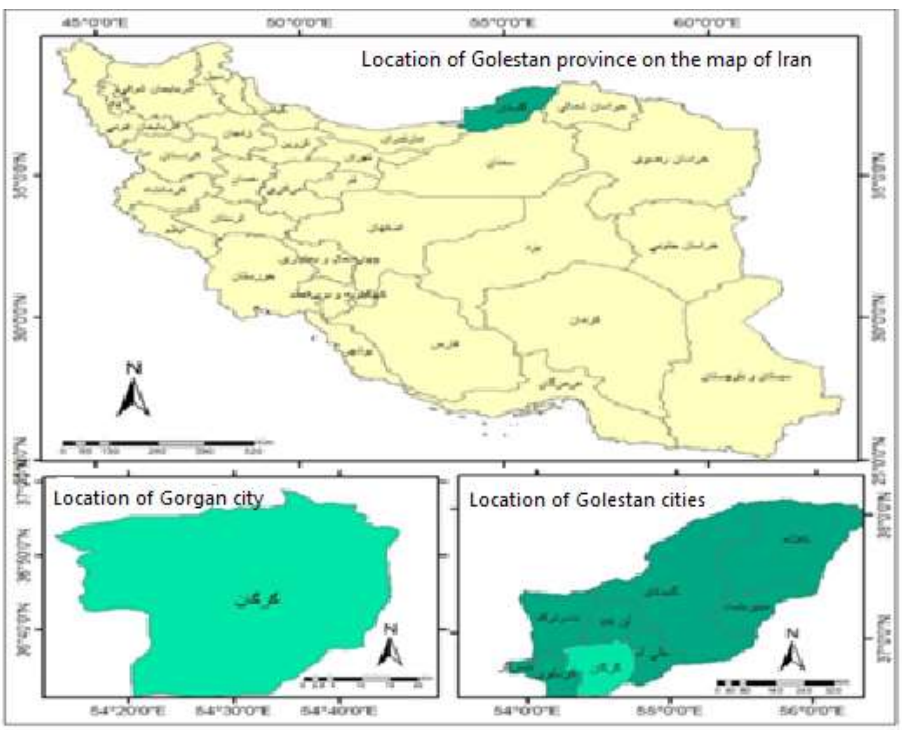


Figure 1. Location of the study area

The received data from the Golestan Environment and Natural Resources Environment Organization include the name and geographical location of the area, the exact time and date of the fire, the area and the amount of damage to the vegetation of the area. First of all, fire zoning and preparation of fire risk zoning map and its area is important in the region.

Landsat satellite images have been downloaded directly from the USGS site after the date and time of the fire were determined. In order to determine the required indicators in the study, the last image was taken from the above site before the first fire in July and the first image after the last fire in August in each of the studied years. The data in this study are evaluated in July and August from 1392 to 1396. According to the surveys and evidence, in these two months, due to the heat of the weather and other factors that will be examined, there have been the most fires in the study area.

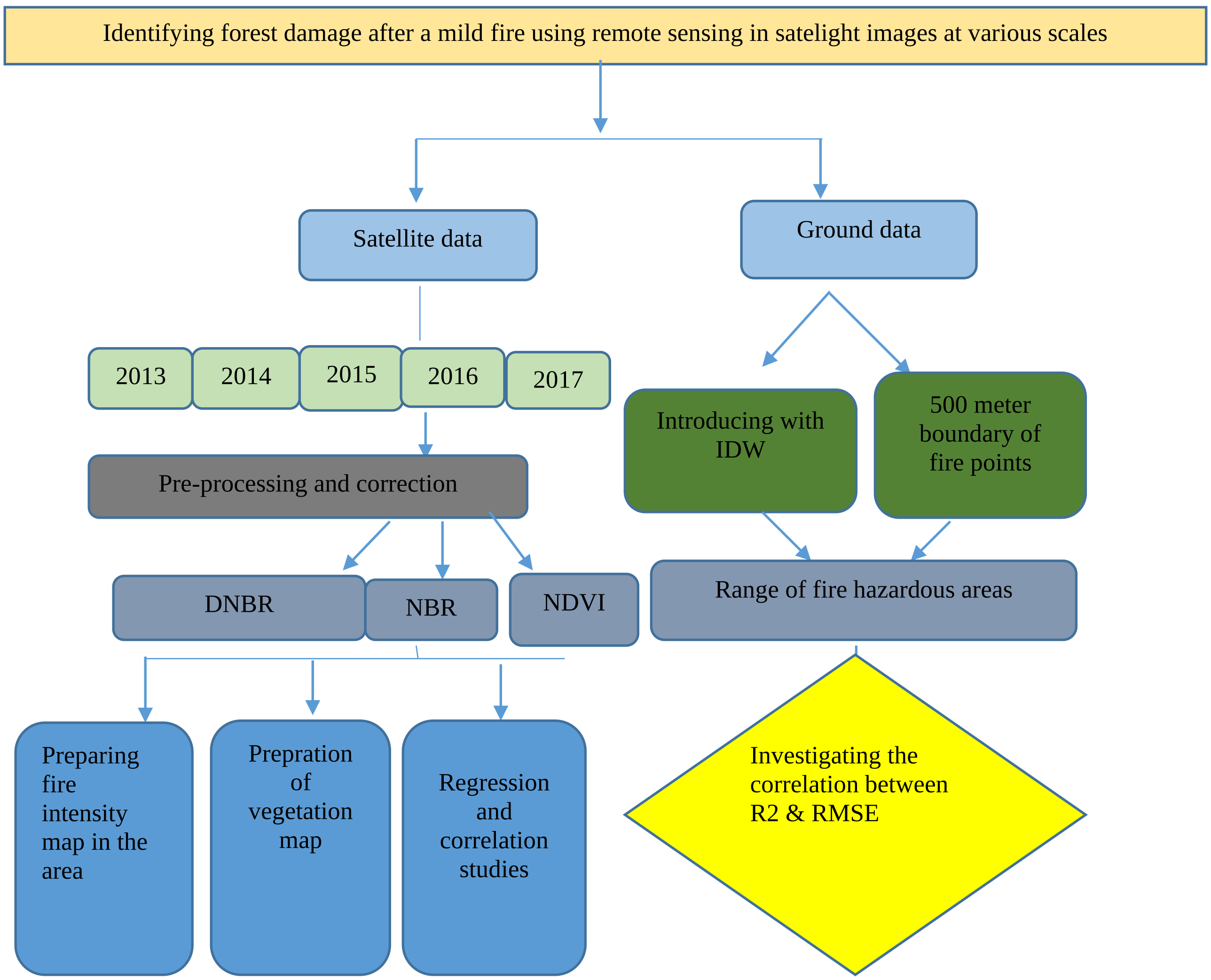


Figure 2. Stages of the research

Table 1. Dates Used in Landslide 8OLI Image Research

Row	Date (solar)	Date (AD)	Fire situation
1	9/4/1392	30/6/2013	Before the fire
2	18/3/1393	8/6/2014	Before the fire
3	30/3/1394	20/6/2015	Before the fire
4	8/3/1395	28/5/2016	Before the fire
5	11/4/1396	2/7/2017	Before the fire
6	17/5/1392	8/8/2013	After the fire
7	5/6/1393	27/8/2018	After the fire
8	23/6/1394	14/8/2015	After the fire
9	4/6/1395	25/8/2015	After the fire
10	6/6/1396	28/8/2017	After the fire

The fire ratio indicator is used to determine the fire area. Its formula is similar to that of the plant index (NDVI), except that it uses the near-infrared (NIR) and short-wavelength (SWIR) sections of the electromagnetic spectrum (Lopez, 1991; Key and Benson, 1995).

$$NBR=\frac{(NIR-SWIR)}{(NIR+SWIR)} \quad (1)$$

To calculate the difference between NBR, NBR after the fire is subtracted from NBR before the fire as follows:

$$dNBR \text{ or } \Delta NBR = prefireNBR - postfireNBR \quad (2)$$

3. Discussion and Results

In the zoning section of the fire points, with the area of the fire, the area of 500 meters of the fire points has been determined, and then the IDW method was examined and found. The fire zones are classified into 5 classes, a) very severe burns b) severe c) moderate d) low r) very low classification. Areas with very high burns were marked in red (*Figure 3*).

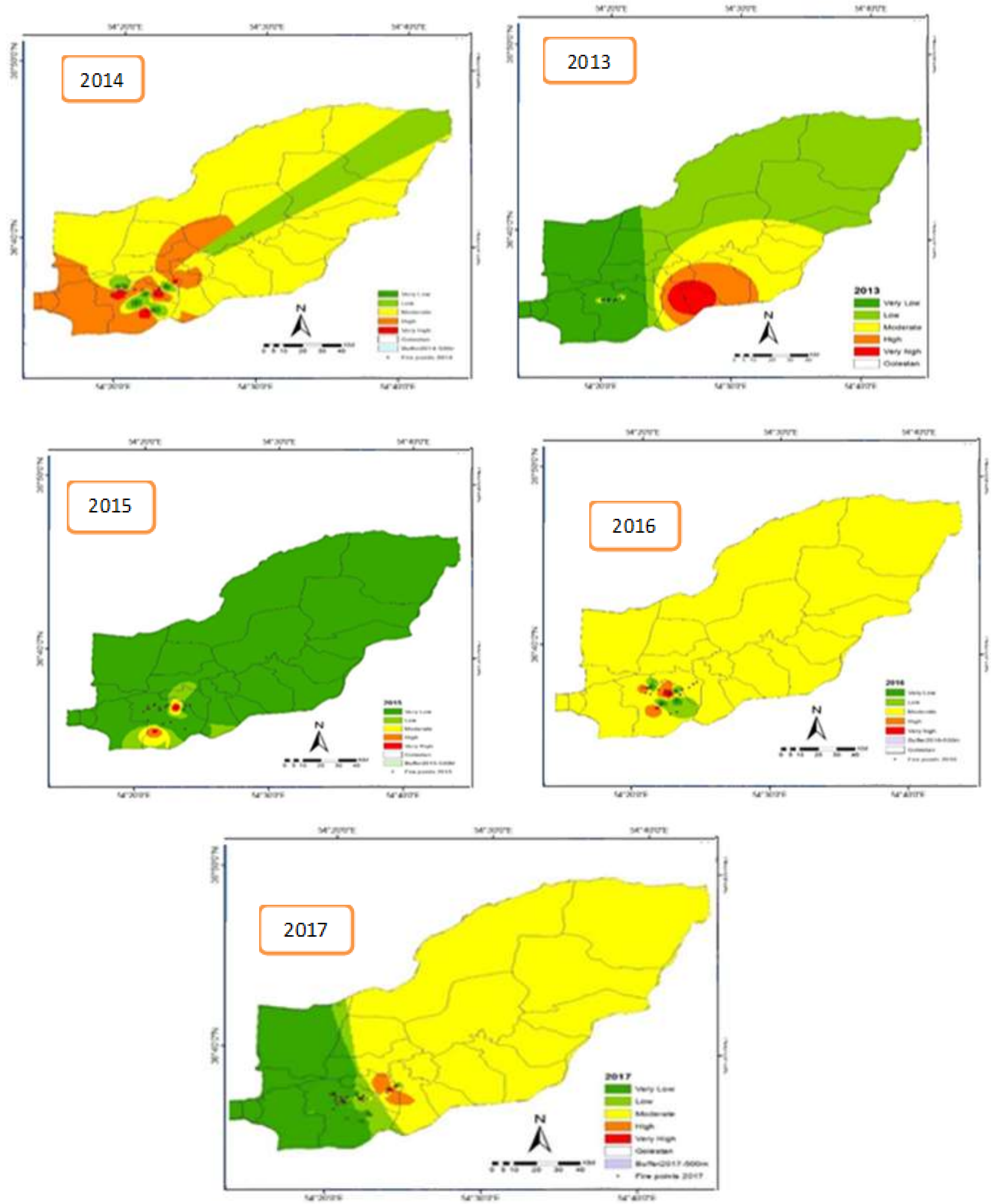
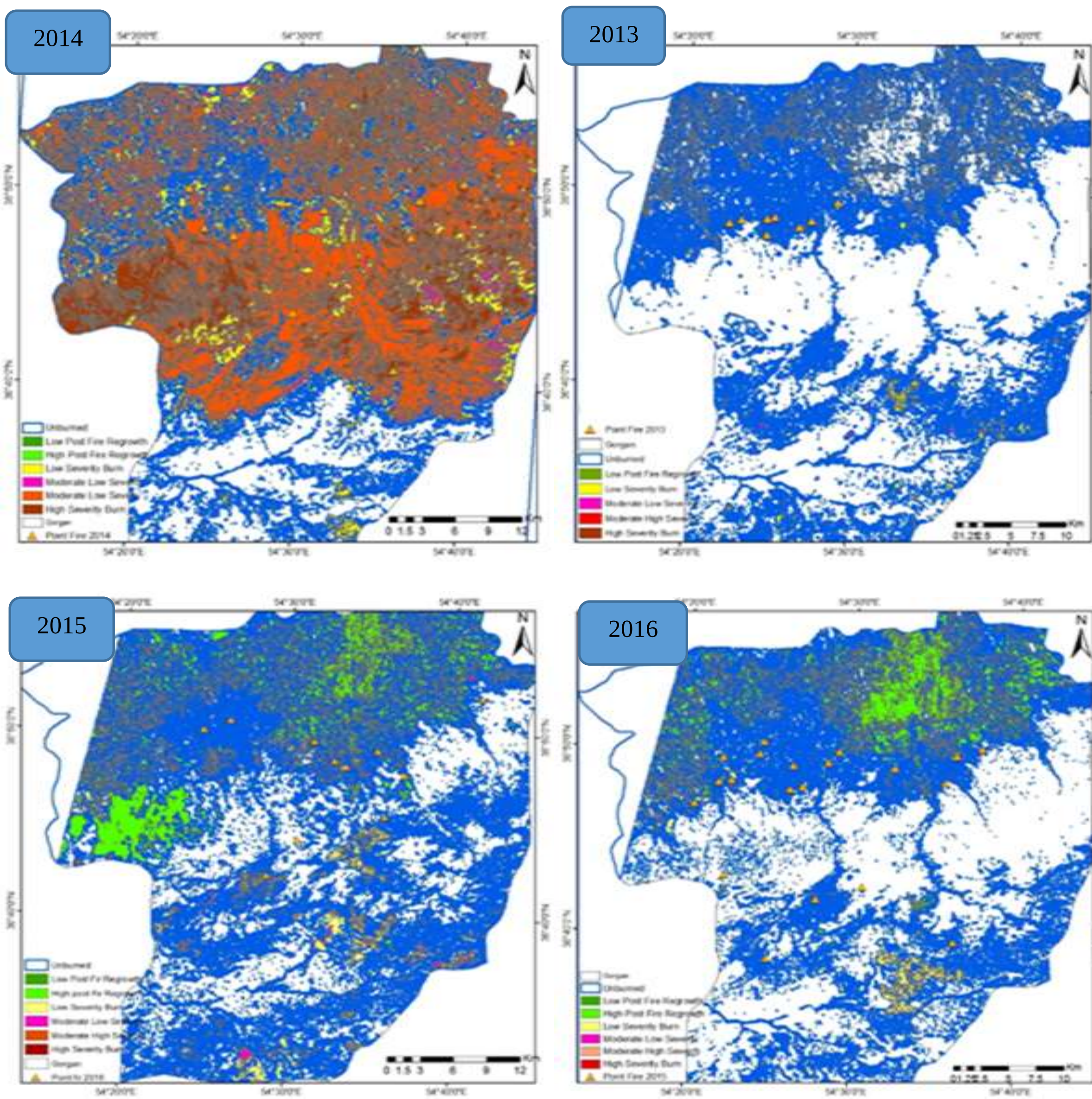


Figure 3. Zoning of high-risk areas of fire

In this study, by examining the characteristics of NBR, dNBR, and NDVI, the fire phenomenon of Golestan forests was highlighted. In the burn intensity index, fire was classified into 7 classes 1) no burns 2) re-growth after fire 3) low plant growth afterburn 4) high plant growth afterburn 5) low burn intensity 6) moderate burn intensity 7) Severe burns. In this study, a multi-time difference was obtained to increase the contrast and changes before and after the Landsat 8 image fire using bands and their differences (*Figure 4*).



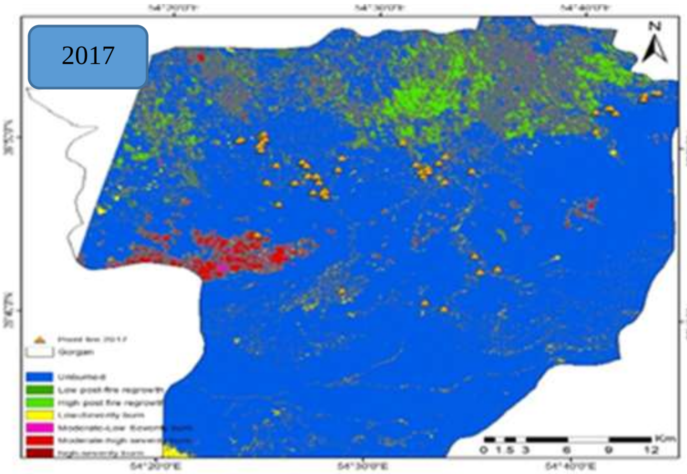
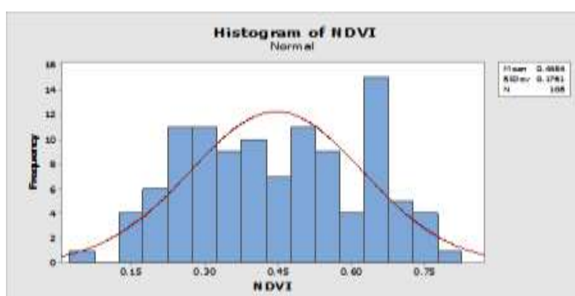


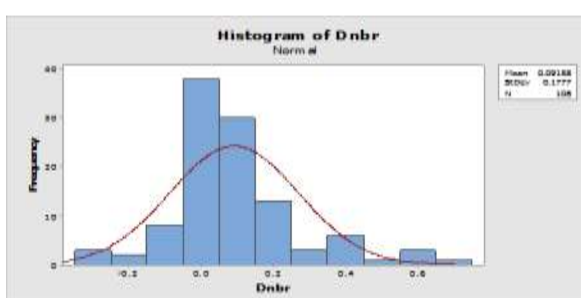
Figure 4. Burn intensity

Then, the correlation between the burn intensity index of pre-fire and post-fire dates were examined and the statistical relationship between burn index and vegetation index was shown. Level Value P, R ^ 2, and RMSE are expressed in graphs. Figure 4 shows the frequency distribution of the parameters used in the study as a graph. The relationship and correlation between the indicators and the points of fire expressed are used. The following graphs show the correlation and relationship between the two indicators.

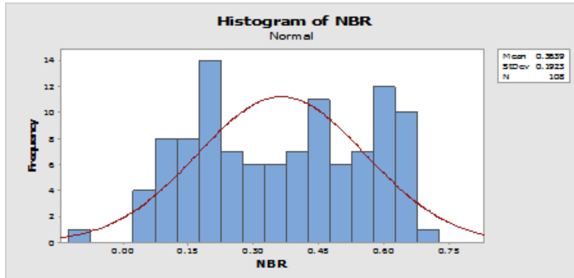
Figure 5 shows the relationship between the fire intensity index and vegetation, which represents = 49% R ^ 2 and has a positive linear relationship and discarded data. Therefore, with increasing vegetation in the area, the fire rises. The relationship between the NDVI index and the dNBR index was 2.4% R ^ 2 = no correlation. In the NDVI graph, there is no correlation with the area of the fire points = 0.4% R ^ 2. Then, in the post-fire dates, the relationship between the parameters was determined, the vegetation index with the highest correlation with NBR burn intensity, which was = 74% R ^ 2, and the NBR burn intensity index with dNBR = 0.2% R ^ 2 without correlation with each other. The vegetation index with the area of fire points is the value of = 1.1% R ^ 2. and it has the least correlation (*Figures 5* and *6*).



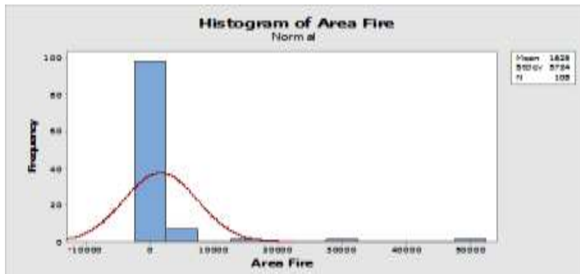
Vegetation



dNBR

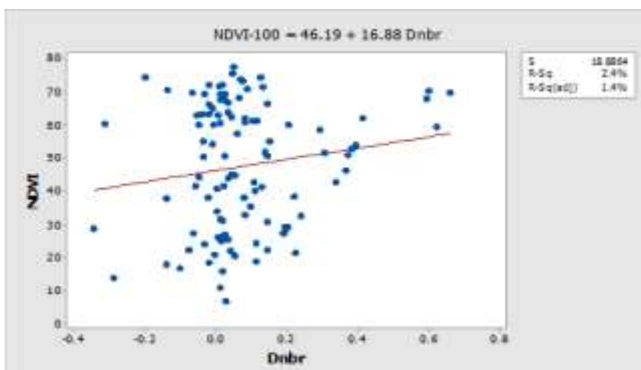


NBR

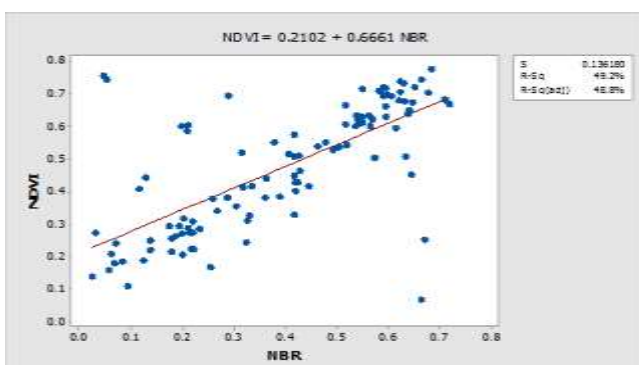


Fire points

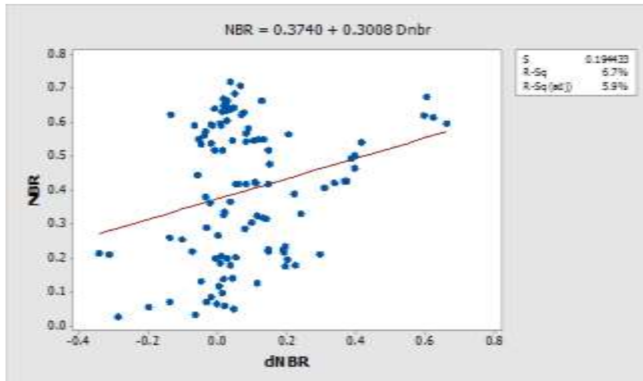
Figure 5. Frequency distribution of the variables studied in the study



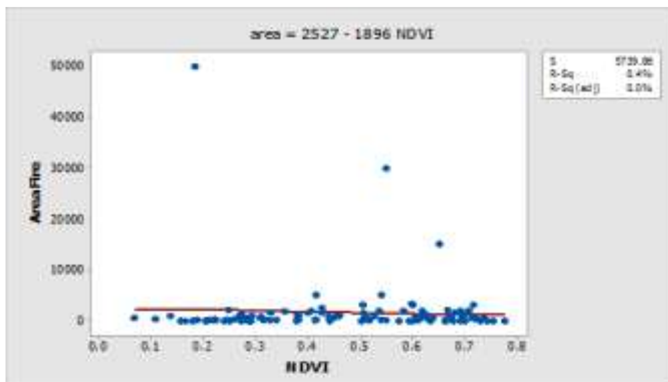
The relationship between vegetation and dNBR index



The relationship between vegetation and NBR index



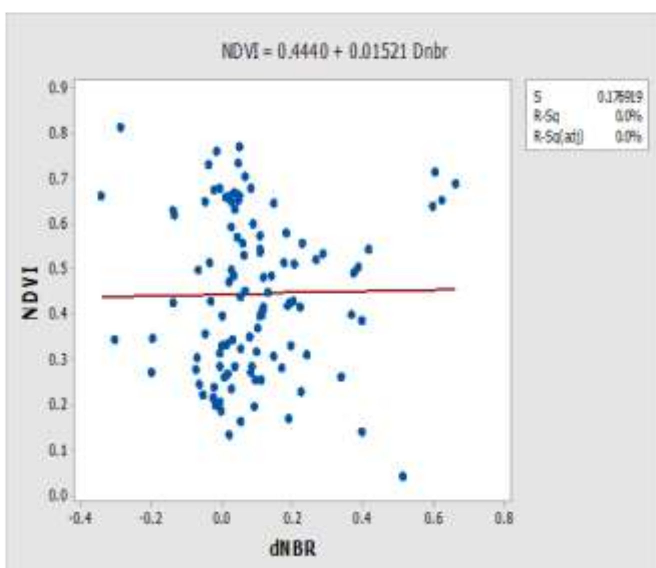
The relationship between NBR index and dNBR index



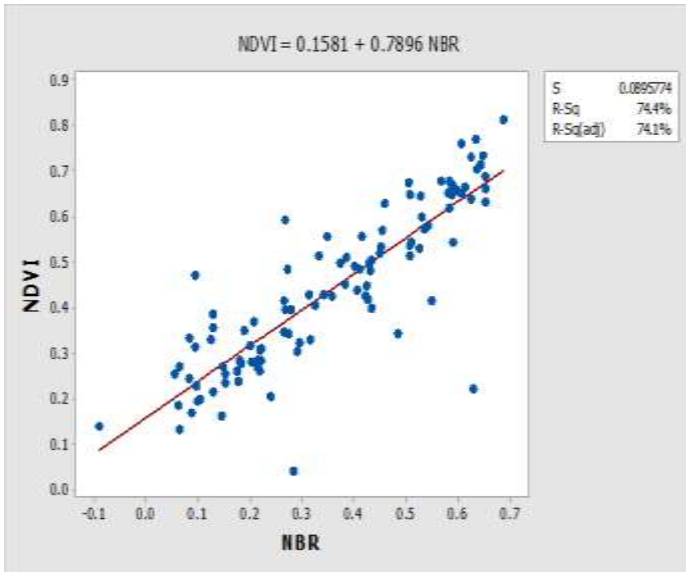
The relationship between the fire points and vegetation

Figure 6. Correlation between vegetation and fire indicators in pre-fire history

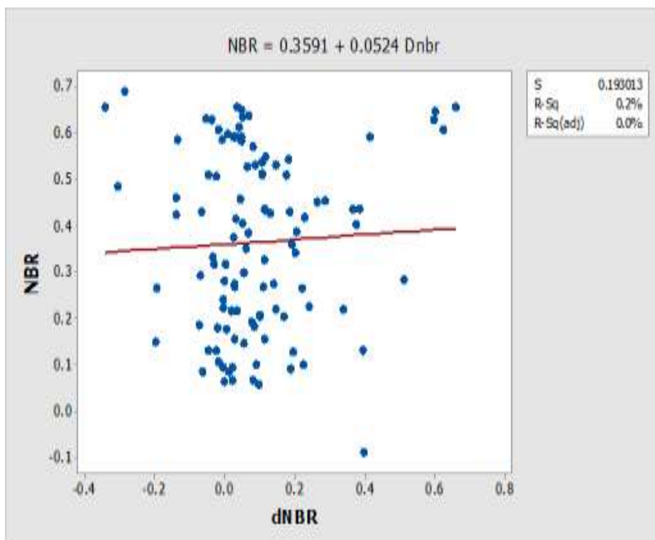
In the next section, the relationship and correlation of the burn intensity and vegetation indices with burnout difference in the post-fire history of the study area were shown.



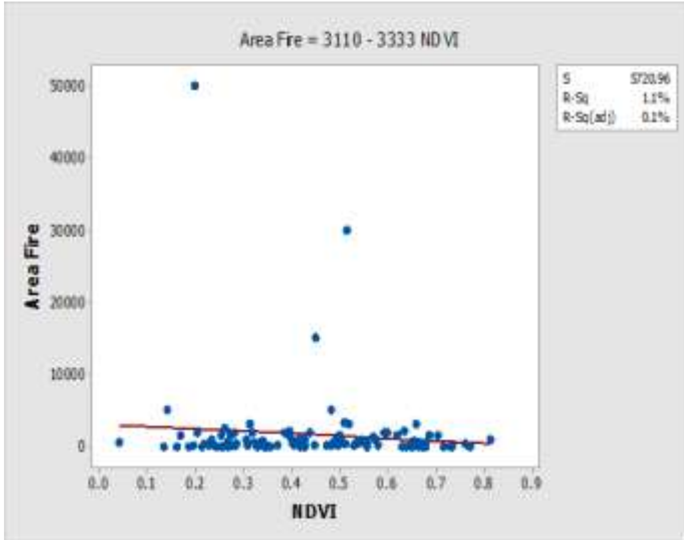
The relationship between vegetation and dNBR index



The relationship between vegetation and NBR index



The relationship between NBR index and dNBR index



The relationship between fire points and vegetation

Figure 7. Correlation between vegetation and fire indicators in the post-fire dates

The real validity of regression relations depends on its adaptation to the underlying hypotheses of regression analysis. This assumption is mainly related to errors (residues) and includes zero mean errors, variance stability, independence and randomness, and normal distribution of errors (Rezaei and Soltani, 2003). It is not a regression model and this is because the models with high values of R and R ^ 2 maybe weak for estimation and predictions, and this makes it necessary to validate the model before using them (Khorami, 2004).

$$R^2 = 1 - \frac{\sum_{i=0}^{n}(y_j - y_j)}{\sum_{i=0}^{n} y_j^{\,2} - \frac{\sum y_j^{\,2}}{n}} \quad (3)$$

.

$$\text{RMSE} = \sqrt{\frac{\sum_{i=0}^{n}(y_j - y_J)^2}{r}} \quad (4)$$

Table 2. Evaluation Results of Regression Model in Pre-fire Dates

P Value	S(Standard deviation)	R^2	RMSE 0/0	regression
0.113	0.188	2.4%	50.87	NDVI-dNBR
0.000	0.13	49%	50.54	NDVI-NBR
0.000	0.19	6.7%	0/38	NBR-dNBR
0.517	5739.86	0.4%	0/0058	NDVI-Area Fire

Table 3. Results of Regression Model Evaluation in Post-fire Dates

P Value	S (Standard deviation)	$\mathbf{R^2}$	RMSE 0/0	Regression
0.875	0/178	0.0%	47/56	NDVI-dNBR
0.000	0/089	74%	47.25	NDVI-NBR
0.619	0.193	0.2%	0/37	NBR-dNBR
0.291	5720.96	1.1%	5887.4	NDVI-Area Fire

Masaedi and his colleagues (2011) studied climate change in 5 synoptic stations across the country over a period of about 56 years. For this purpose, the parameters of rainfall, temperature, relative humidity, cloudiness, wind, sundial, and daytime degrees in both summer and autumn seasons were examined on monthly. Then, due to the great influence of the environmental factor on the intensity of the fire, they described the relationship between the changes in the mentioned parameters and fire. While examining the above parameters, they theoretically explained their relationship with the phenomenon of fire. In this study, according to the used data, the relationship between vegetation parameter and vegetation index (NDVI) index with forest fire intensity was examined and it is observed that these two indicators are related to each other with 49% accuracy.

The fire hazard index is a combination of information about wind speed and fuel content and is inherently reduced by increasing the moisture content of the fuel and increasing by increasing wind speed. To test the validity of their proposed index, Sharpels et al. (2009) compared its results with the results of four other leading indices used in Australia and the United States, FFWI, GFDI5, GFDI4, and FFDI. They used the half-hour data from November 1, 2006, to March 31, 2007, at the Canberra Automatic Station in Australia. In total, with the help of 572 triple temperature modes, relative humidity and wind speed compared F and 4 other indicators. Dispersion maps showed a logical and significant relationship between F and 4 others. They also showed that the correlation between F and other indicators is close to the unit and that F provides an acceptable measurement of fire risk rating. With the help of a set classification of other indicators (low, medium, high, very high, and severe), they determined this classification for the F index in the study area. The F index is much simpler than the other four indicators. This is because other indicators include fuel-containing information that requires more knowledge of the history of precipitation, while the F index is only a function of temperature, relative humidity, and wind speed. In this project, the DNBR and NBR indices with the intensity of forest fires were compared and finally, it is concluded that the NBR index, due to the high correlation between NDVI and NBR and = 0.74 R2, is the most accurate index and the dNBR index between images. Before and after the fire, it provides a better result for predicting fire.

4. Conclusion

Using data from the Natural Resources and Environment Organization, the area of high and low burn intensity was investigated and zoned. According to the results of the 1393 map, the rate of burnout in the north and the middle of the region's forests was the highest in the fire, and in 1396, the western regions of the region had the most burns. With the IDW internalization method, the fire rate of the area was classified with 5 classes, and the high-risk area of 500 meters in the area and fire points was determined. As a result, it showed that in 1392 in the middle part and 1393, the center and north were towards the center of the high-risk part and there were fewer fires to the west and southwest. In 1394 in the southeastern part and 1395 the center of the region and in 1396 the center and west of the region had the most fires. Finally, it is concluded that the NBR index is the most accurate indicator due to the high correlation between NDVI and NBR, and the dNBR index between images before and after fire provides a more appropriate result for fire forecasting.

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