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Determination of Fire Extent in Forest Zones Using Remote Sensing Data Case Study: Golestan Province of Iran

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ABSTRACT

Fire is one of the most serious hazards, which causes many economic, social, ecological, and human damages every year in the world. Fire in forests and natural ecosystems destroys wood, regeneration, forest vegetation, as well as soil erosion and forest regeneration problems (due to the dryness of the weather and the weakness of the soil). Awareness of the extent of the zones that have been fired is important for forest management. On the other hand, the difficulty of fieldwork due to the high cost and inaccessible roads, etc. reveals the need for using remote sensing science to solve this problem. In this research, MODIS satellite images were used to detect and determine the fire extent of Golestan province forests in northern Iran. MID13q1 and MOD13q1 images were used to detect the normal conditions of the environment. The 15-year time series data were provided for the NDVI and NDMI indicators in 2000-2015. Then, the behavior of indicators in the fire zone was studied on the day after the fire. The burned zones by the fire were specified by determining the appropriate threshold and then, they were compared to long-term normals. In the NDMI and NDVI indicators, the mean of the numeric value threshold limit for determining the burnt pixels was respectively 1.865 and 0.743 of the reduction in their normal long-term period, which are selected as fire pixels. The results showed that the NDMI index could determine the extent of the burned zone with the accuracy of 95.15%.

***Keywords*:** Fire; Satellite; Fire Extent; MODIS; Time Series

1. Introduction

The fire destroys a huge volume of wood and the elements in the forest in a short time. Fire heat causes the destruction of plants and animals (Brown & Davis, 1959). The main factors affecting the spread of forest fires include climate (moisture, temperature), topography (slope, direction, and altitude), vegetation type and density, distribution, and density of population, road, etc. (ZHANG *et al*., 2003; RAJEEV *et al*., 2002). Some of the damages caused by fire in the forest are the reduction or eliminating the value of the forest, the destruction of forest sapling, damaging the productive power of the earth, reducing the forest protection value, damaging the forest soil, damaging the forest beauty, damaging the forage value, destruction of non-domestic animals, and damaging the forest soil. Fire is considered as an integral part of natural ecosystems. In any case, the natural areas intentionally or unintentionally caught fire. Fire uses natural fuels, such as mulch, branches of plants and trees, etc., can easily spread in the natural area (Brown and Davis,

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1959). The conducted studies in this regard are as follows:

Studies on the fire in Iran have been started by Jazirei (Kazemi, 2008). Then, other researchers, including Khorasani Nejad (1996) and Ardekani *et al*. (2009), Adan *et al*. (2011), etc. conducted studies on forest fires and their impact on vegetation with satellite observations.

Ramo and Chuvieco (2017) used MCD43A4 products of MODIS satellite to classify burned zones. They could separate the burned zones with an accuracy of 94%.

In another research, Pereira *et al*. (2017) have used the combination of MCD64A1 MODIS and Landsat images to reveal the burned zones. Krylovat *et al*. (2014) identified fire prone zones for deploying fire stations using remote sensing. Jaiswal *et al*. (2002) studied the accuracy of the MODIS images in the fire discovery of South African using ASTER images. With the advancement of remote sensing and GIS in recent years, several studies have been carried out on fire detection, fire behavior, zoning and fire risk modeling in Iran and the world. According to Dong *et al*. (2005) and … evaluating the extent of the affected zones is based on the principle that the response of the plants to fire is different in the NIR and MIR bands (Gigolo *et al*., 2003; Menzel, 1992; Kaufman, 2003). These bands have many applications in detecting heat sources such as fires (Alavipanah, 2006). To study the burned zones, it is necessary to determine the appropriate thresholds proportional to the studied area compared to the normal and long-term conditions of the region.

Preparing the map of the burned zones (with the development of fire models) is one of the basic principles of management in natural resources. Identifying the burned zones is important for managers in forest restoration and reforestation activities. A comprehensive and accurate assessment of the damage caused by the fire in the forest and identification of its source will be easier with the comprehensive plan of the zone in normal conditions as well as in the event of the fire. However, some of the problems are the zone's inaccessibility, the high cost of fieldwork, etc. The conducted studies have determined the burned zones, but the present research has determined the threshold of the applied indicators to indicate the burned zones for using in all similar zones. One of the new issues in this study is the use of MODIS satellite MOD13Q1 data in 2000-2015 to create the NDVI and NDMI indicators. The vegetation indicators and time series were combined to know the normal and long-term conditions of the zone. In the next step, the images after the fire as well as the information of fire points have been used for fire detection. This is due to identifying the extent of the fire in the forest ecosystem and setting up more advanced management plans to deal with this crisis and rehabilitate the region (Fule *et al*., 2006).

2. Materials and Methods

2.1 Study Area

Golestan province is located in the southeastern part of Caspian Sea. The area of this province is 20387 square kilometer. This province is located 36 ° 30 'to 38 ° 08' northern latitude and 53 ° 51 'and 56 ° 22' eastern longitude. The southern parts of this province are mountainous and northern parts of it are desert area. The area of forests in this province is 451705 hectare that is 22 percent of province total area. Due to lower annual precipitation and proximity to arid regions in the eastern part of the country, Golestan province forests are more vulnerable to fire (Yadgarnezhad *et al*., 2017). Geographical location of the study area is shown in **Figure (1)**.

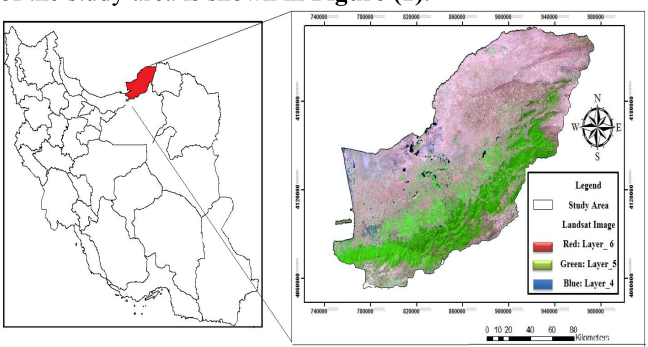

Figure 1. The geographical location of study area within Iran, Golestan provines

2.2 Fire behavior

With the onset of a surface fire, the fire gradually burns combustible materials around it and the surface is exposed to a circular fire. Nevertheless, the wind, which is an important factor, gradually makes it elliptical. The part of the oval that is facing the wind burns slowly and then quickly turns off (standing pole). In the opposite direction i.e. the opposite to the wind direction, the fire goes abruptly and its intensity increases, which is called the leading pole. Fire intensity is calculated in different ways:

1. The taken distance by fire in an hour.
2. The burned distance within one hour.
3. The length of the burned zone over a specified period.

2.3 Applied data

In this research, the MOD13Q1 data of MODIS satellite were used in 2000-2015. NDVI and NDMI indicators were applied to the images. Also, the information of the burned zones in 2000-2015 has also been used. The fire extent in the studied points was used by the fieldwork to assess the accuracy. Given that the Terra and Aqua satellites images of MODIS satellite are available every 8 days, the fires have been monitored, which have MOD13Q1 or MID13Q1 images on the day after the fire.

The total number of the burned zones in the research:

Determining the pixel properties in non-fire conditions:

Different points in different places have different conditions. The mean time series in 2000-2015 were used to investigate the normal properties of the affected zones. The maximum aggregate algorithm was used to eliminate the effect of the season in creating the time series.

NO	Y	X	MOD13Q1 & MYD13Q1	Data	Area(H)
1	4103185	336600	17_MAY_2013	08_MAY_2013	4939
2	5546432	372335	25_MAY_2013	23_MAY_2013	3000
3	4161400	393000	26_JUN_2013	25_JUN_2013	7686
4	4218288	371249		25_JUN_2013	20000
5	5546400	372335	12_JUL_2013	10_JUL_2013	9000
6	5546401	372335	20_JUL_2013	10_JUL_2013	9000
7	4103685	345324	29_AUG_2013	27_AUG_2013	4466
8	4122502	378022	08_OCT_2013	06_COT_2013	20000
9	4122176	360214		06_COT_2013	8000
10	4155900	378930	01_NOV_2013	30_OCT_2013	16900
11	5528711	370457	25_NOV_2013	25_NOV_2013	16800

12	4145900	375600	09_JAN_2014	08_JAN_2014	9800
13	4145001	379800		08_JAN_2014	6500
14	5527552	371350	25_JAN_2014	23_JAN_2014	1800
15	5539771	305718		23_JAN_2014	3000
16	4081200	335122	10_FEB_2014	09_FEB_2014	4500
17	4155902	378930	06_MAR_2014	05_MAR_2014	6800
18	4638442	332639	22_MAR_2014	20_MAR_2014	1200
19	4115422.55	373414.78	11_DES_2013	10+DES_2013	182.28

Table 1. Data used in research

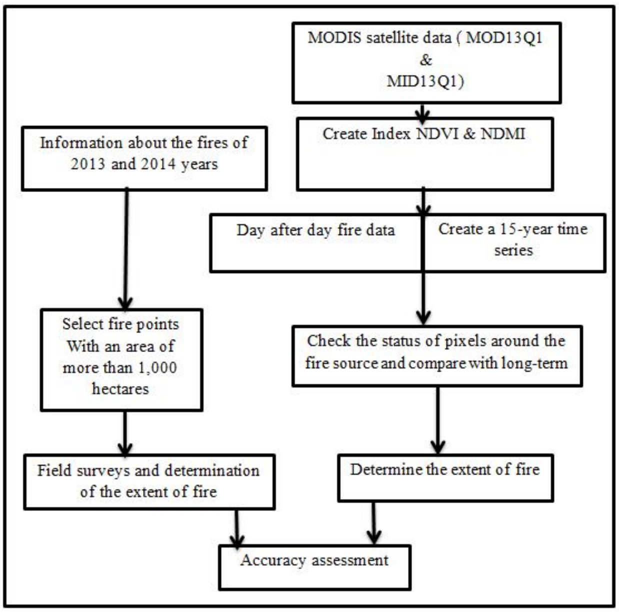

Figure 2; The first step is to provide forest map and fire points**.**

2.4 The burned zone discovery algorithm

The fire data in 2013-14 were applied to extract the fire pixels and 18 fires with an area exceeding one hectare have been identified (**Table 1**). Then, the MOD13q1 and MIDI13Q1 data of MODIS satellite in RED, NIR, and MIR bands, and NDVI and NDMI vegetation indices have been used. The behavior of pixels around the fire source location was investigated and analyzed against its long-term mean. Then, the threshold of the numerical value reduction of indicators has been selected. In Table (2), the damaged and undamaged zones around the fire have been separated.

The mean index of NDMI was better able to determine burned zones with the highest reduction rate as much as 1.856. Therefore, it had been applied to determine the extent of burned zones.

3. Discussion

Due to the high volume of information, one of the fires that occurred in 10/DES/2013 on coordinates Y: 4115422.55 and X : 373414.78 is briefly explained. The extent of this fire was estimated during fieldwork as much as 199.84 hectars Then, NDVI and NDMI indicators were created on the day after the fire and the behavior of pixels around the fire source was investigated. Then, they were compared with their 15-year long-term mean images of the fire location.

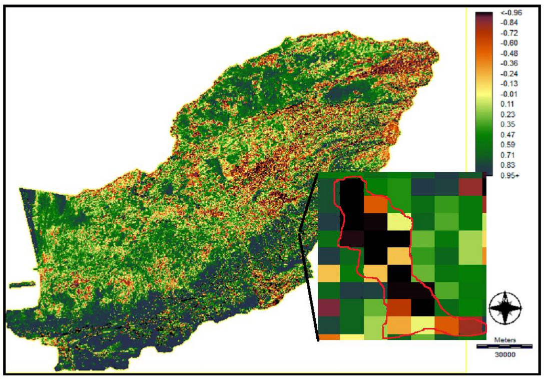

Figure 3; Frontier fire**.**

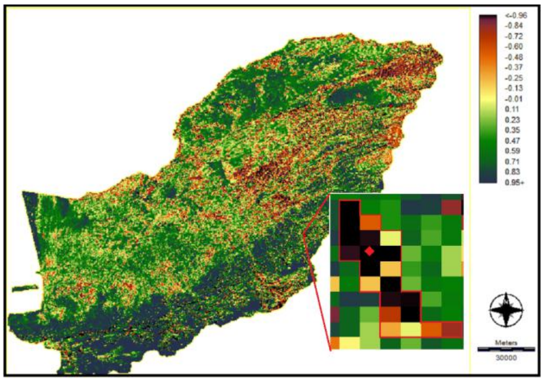

Figure 4; NDMI index of the day after the fire in history 11-des-2013**.**

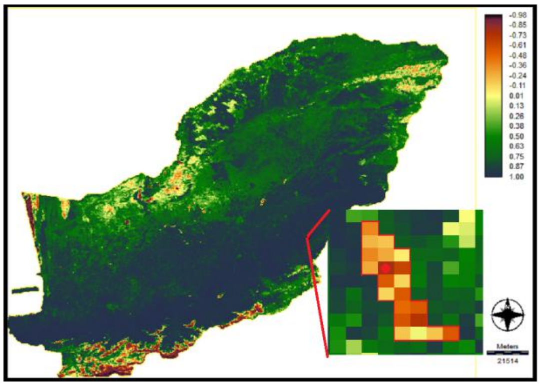

Figure 5; NDVI index of the day after the fire in history 11-des-2013**.**

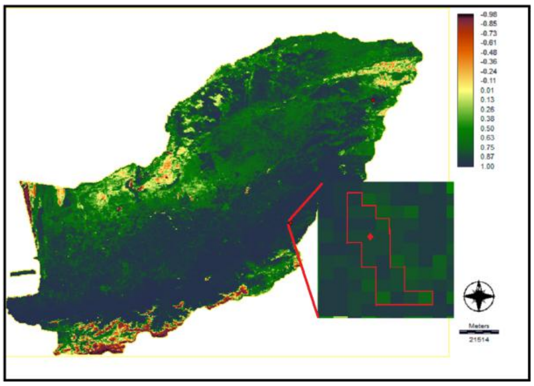

Figure 6; Time series 2000 to 2015 at the site of the NDMI index**.**

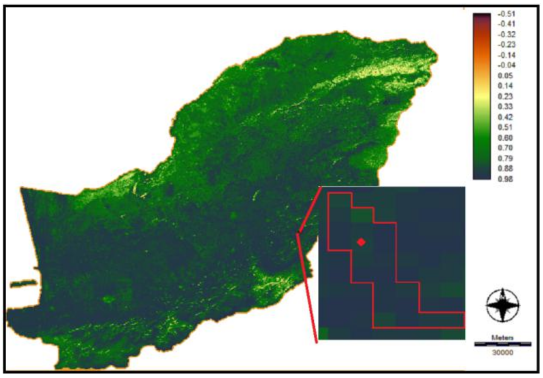

Figure 7; Time series 2000 to 2015 at the site of the NDVI index**.**

4. Results

The area error rate estimated by the NDMI index was measured regarding the field sampling and the results were provided in **Table 2**. As specified, the analysis of the extent of the fires detected by the NDMI index is 4.86% error and 95.15% precision relative to the field intensity.

NO	Acre Area (Field (Sampling	The Area Obtained from NDMI images	Error rate%
1	4945	4838.92	2.35
2	3000	2951.2	1.63

3	7686	7534.24	1.97
4	20000	19530	3.7
5	9000	8992.48	2.35
6	9000	9282.0	3.14
7	4360	4470.02	2.53
8	21000	19990.04	4.9
9	8400	7994.28	4.83
10	18900	16899.96	10.58
11	16000	16804.48	5.09
12	10800	9808.4	9.18
13	6500	6786.4	4.41
14	1800	1814.12	6.34
15	3000	2917.2	2.76
16	4500	4630.82	2.91
17	6800	7586.32	11.56
18	1200	1240.4	3.37
19	199.84	182.28	8.78

Tabel 2. Fire comparisons in different ways

5. Conclusion and Recommendations

In this research, the extent of burned zones was obtained using the data of the 15-year time series, along with field sampling and using maps after the occurrence of fire. Compared to similar types of research, in this study, the successive data of several years have bead used to assess the normal conditions of the area to ensure the accuracy of results and less bias. Due to the difficulty of fieldwork and sampling, the applied data in this research was completely dependent on remote sensing science to assess the potential of remote sensing in this field. The thresholds of the fires occurred in different seasons have been evaluated in order to assess the comprehensiveness of this model in all conditions.

Generally, it can be said that the detection of burned zones is more accurate by using of vegetation indicators in NIR and MIR bands. The NDVI indicator using NIR band is more cautious about showing burned zones. It is recommended to use the combination of the obtained images and with higher spatial resolution images to increase the precision of the results.

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Author's Contributions

In writing this article, the authors had an equal share of participation and participated in all stages, including writing, editing, arbitration, and all stages of scientific work.

Ethics

In this article, all ethical principles related to scientific-research articles such as validity and authenticity, originality, data collection in a standard manner, integrity and accuracy of research, etc. are observed.

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