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Identifying destructive fire in the fire affected areas using satellite images (Case Study: forest fires in Golestan province in 2011)

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Abstract

Fire is one of the main factors known to destroy ecosystems and forest fires destroy thousands of hectares of trees, shrubs and plants every year. Fires in natural or hand-planting forests, aside from the destruction of genetic resources and the environmental degradation that causes abnormalities in living organisms, imposes heavy reconstruction costs on society. Since this phenomenon occurs at different volume and ecological scales, the field data collection methods needed for study is costly and virtually impossible. Thus, in this regard, the data and techniques used in remote sensing are the most common and best practices that are currently used. In the phenomenon of forest fires, remote sensing technology can provide useful information about the environment before, during, and after the fire. NDVI (Normalized Difference Vegetation Index) is the vegetation index used in this study, and through analysis of this index in the processing of satellite images of forests in Golestan province caught fire in 2010, type of destructive fire is identified, and separated from types of surface and crown fire. Using the process measurement and the changes detected after the fire, fire affected areas are detected, and images are classified through Nearest Neighbor resampling. An area of 3625 hectares was detected as the area affected by destructive fire.

Keywords: fire, NDVI vegetation index, satellite images.

1. Introduction

Traditionally, and at different global to regional scales, many studies have been performed to detect fires or burning areas using AVHRR sensor for its high-precision in terms of time, a And in recent years, MODIS (Moderate Resolution Imaging Spectroradiometer) has opened a new way for studying the fires in the visible to the thermal infrared range. A unique vegetation index of MODIS sensor, with high temporal resolution for spatial and temporal analysis of vegetation, is designed to provide researchers with the appropriate information on the plants. This sensor has 36 spectral bands, and 2 bands of it have a spatial resolution of 250 m, 5 bands have a spatial resolution of 500 m, and other bands have a spatial resolution of 1000 meters and repeat imaging period of 16 days.

Vegetation indices are mathematical transformations, defined based on different sensor bands, and designed to assess and evaluate the plants in multi-spectral satellite observations. Most bands used in the calculation of vegetation indices are red, infrared, and near-infrared bands, since green plants in these two spectral ranges show big difference in the reflection due to the presence of chlorophyll in green leaves. These indices convert information about several spectral bands in satellite images to a single band (Jensen, 2005). One of the indices used to study vegetation in remote sensing and, also in this study, is NDVI index.

1. Materials and Methods

1.1. The area under study

The area under study of this research was Golestan province forests, where dozens of fires have happened in recent years. Golestan is a province in northeastern Iran, and in terms of weather, is located in mild weather of Mediterranean type, and rainfalls are mainly in autumn and winter from October to mid-May of the next year, and some rainfalls are rarely seen in summer. Vegetation mainly includes parrotia, hornbeam, beech, oak, and wild plants and forage, and has considerable precipitation and vegetation in comparison with most areas of Iran (Rahimizadeh Bajgiran et al, 2008).

Of total of two million and 150 thousand hectares in Golestan province, 865 hectares are dedicated to winter ranges in the north and rangelands in the south, and 451 thousand hectares are forests. Since 1990, fires have had an increasing trend in terms of number and level, that can be associated with changes in weather conditions, as from 16 November to 13 December of the current year, 135 fires are recorded in the forests of the province; of these, a total of 59 cases occured in Minoodasht, 29 in Azadshahr, 20 in Ramian, 11 in Kalaleh, 8 in Aliabad, 8 in Gorgan, 2 in Korkoy, and 2 in Bandar-e-Gaz (Department of Natural Resources Golestan - Iran).

Figure 1. Satellite image of fire from NASA on 12/12/2010

1.2. Fire studies

Studies on fire in Iran launched in 1959 by Jazire'i. He reported that the fire improves the mating of desirable species by reducing the thickness of dead vegetation of the soil. Khorasaninejad (1995) studied the impact of variables on the fire and concluded that in plain forests, heat is the effective factor in firing, occurred in the months November and December. He also reported that in Middle forest, the reduced moisture content of fuels, and in mountainous forests, reduced rainfall cause fire. Daneshrad (1992) bwlieves that return period in 16 regions of forest fires at north of the country is 10-14 years. Atrak Chali (2001), studied return period of fire in Golestan forest, and reported that average forest fires in the country is about 7,000 hectares, and the most severe fires have a return period of 11 to 13 years. However, the return period of forest fire in Golestan was 5-7 years.

Many factors are certainly effective in the fire. The most important factor that cause fires in the forest is reduced relative humidity of the air, that occurs by warming weather and drought. Reduced rainfall and dry weather followed by numerous fires in the forests of Gorgan and Behshahr over the past few years of drought (2000-2002) are examples of the impact of dry air on forest fires.

1.3. Fire regime

A fire regime by is divided and determined titles such as the type, intensity, duration, size, power and the fire season. Among these, type, severity and duration of the fire are reported to be the most important ones. Based on their level, fires are classified as underground, surface, trunk, and crown (Ag ee-1993).

1.4. Classification of fires to the surface, crown, and trunk fires that may be helpful, harmful, and destructive.

1.4.1. Controlled surface fire (useful):

This type of fire has environmental hazards, and creates significant negative impact in increase of air pollution, degradation of soil humus, and problems in animal environment. This type of fire is limited to burn of forest floor litter and fuels, and technically, increased NDVI of these spots are clear, and by improving growth and seed germination will result in increased vegetation in the year following the firing.

Figure 1: Useful surface fires

1.1.2. Crown fires or harmful type

This type of fire, in addition to hazards of the useful type of fire, creates significant negative impact in the volume of standing trees. This type of fire causes damage to the tops of the trees in the forest. Technically, no NDVI significant differences was observed in the year after the fire, and interestingly, this type of fire generally does not create change in vegetation and related parameters.

Figure 3: Harmful crown fires

1.4.3. Trunk fires or destructive type

This type of fire, in addition to hazards of the useful and harmful types of fire, creates significant negative impact on the volume of standing trees. This type of fire creates damage to branches and trunks of forest trees, and is mostly observed in the conifer forests. Technically, NDVI in the year after the fire has significant difference and results in change the amount and type of vegetation and related parameters.

Figure 4: fire or destructive type of trunk

1.5. NDVI vegetation index

This index was first introduced by Rouse et al. (1967) as an important vegetation index which can be used in remote sensing. This index is appropriate for areas where vegetation density is higher than average, since it is less sensitive to the bright background soil and atmospheric effects, but is not suitable for areas with low vegetation.

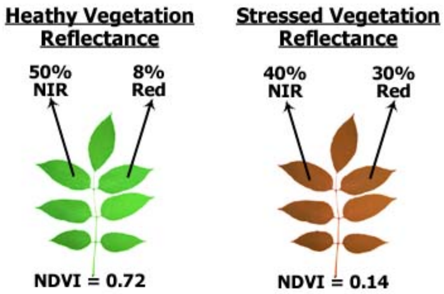

Figure 5: NDVI = NIR - RED / NIR + RED

In technical terms, this index works based on a band ratio, and in its spectral graph, lines with the same chlorophyll converge at the center, so that changes in pixel values are between +1 and -1. In fact, the basis of its function is high reflection of healthy plants in the NIR band, and low reflection in the RED band of the electromagnetic spectrum. Accordingly, healthy plants usually have a high NDVI about 0.5 to 1, while environments devoid of vegetation, such as seawater have usually negative NDVI, and arid areas with very weak vegetation have NDVI values of almost zero due to the equal reflection in RED and NIR bands (Lille sand, TM, Keifer, W., 1994).

NDVI values for each pixel of a satellite image of a region with special vegetation depends on numerous parameters, including the type and density of plants, plant health, and volume of water in plant tissues. Therefore, these circumstances should be considered in the interpretation and comparison of different images (Lille sand, T.M., Keifer, W., 1994).

1.6. Change detection

The process of identifying changes in the status or level of a phenomenon that occurs in observations with time variation is called change detection (Singh, 1989). Different methods of change detection in remote sensing analyze a sequence of images of a region, and include differences and their display in spatial images. Since there are numerous ways to detect changes, this study used image subtraction and change explorations to compare the results of the maps of the surface vegetation. In general, change detection methods are different and usually relative. In this study, the basis of operations is to detect changes in NDVI vegetation index, which was evaluated using techniques of remote sensing and change detection:

1. visual interpretation of images
    A - k-means
    B - IsoData
2. Images subtraction and change detection
3. Principal components analysis

2. Research Methods

In this study, library-based studies, review of other studies, interviews with Forestry experts, and gathering statistics and data collected by GPS in fire affected areas in Golestan province. Field data include primary data related to the fires in 2010, and satellite data used in this study are images extracted from MODIS sensor from the Terra satellite.

3. Methodology

To remove the cloud, humidity, and dust importantly, smoke from fires in the atmosphere, first images of RGB True Color were used in the same area, that were taken with a resolution of 250 meters, on three times with an interval of at least three days before and after the fire, of the study area in RED and NIR wavelengths from MODIS of Terra satellite, and NDVI max vegetation index is produced before the fire using ERDAS image processing software. Then, NDVI max images after the fire in the same year are obtained in the previous method. In estimating the total fire area, the difference between pre- and post-fire vegetation index images are compared using

ERDAS 9.3 software and Cheng Detection tools via the famous Nearest Neighbor resampling. Then, through image classification, level achieved in the field visits is controlled by GPS data, and fire level detection threshold of 33.33% was determined, and with an accuracy of 95%, the area of 11250 hectares of forest fires was detected in the province (Moghadam, 2015).

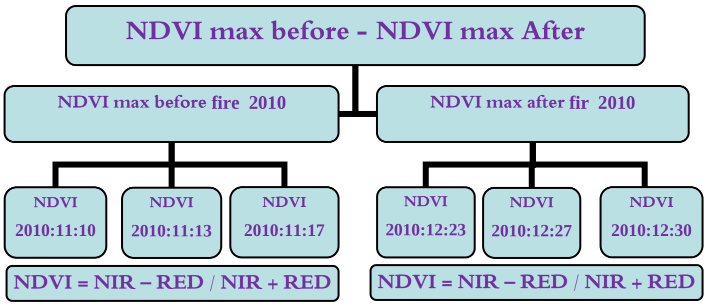

Figure 6: Flowchart to estimate the total level using the NDVI MAX images produced before and after the fire in the first year

4. Findings (Results)

In estimation of trunk (destructive) fire, that part of the forest area that was not restored in the second year and its pixel values of NDVI-max were 33.33% (Percentage based on the experience gained by the author and may also be different based on the different parts of the forest) less than the value before fire, so as it causes serious damage to the forest, is called destructive. The results demonstrated the destructive fire area, so that the number of pixels that their value was reduced 33.33% were identified to be 580 pixels, that represents 3625 hectares of destructive forest fire. Finally, based on this study, of 11250 hectares of forest area of the province with fire, 3625 hectares had destructive fire.

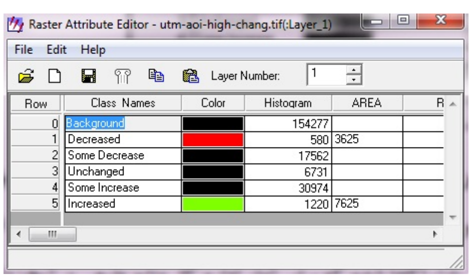

Figure 7: Output of ERDAS after change detection

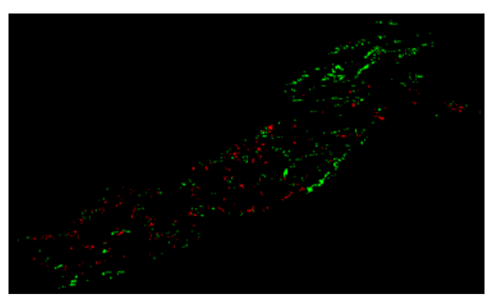

Figure 8: Trunk or destructive fire

5. Discussion and conclusion

Images subtraction and change detection using NDVI can be an appropriate criterion to explain the extent and density of destroyed vegetation. Using of remote sensing techniques and information from MODIS, the extent and intensity of the fire can be determined. The results of change detection in chlorophyll index before and after the fire, showed an area of 3625 hectares under destructive fire. This method is inexpensive and also very fast, and results can be highly updated. This study only identified and assessed the extent of destructive fires, and sufficed to the MODIS data with low spatial accuracy. Obviously, other satellite data, with different spatial and spectral resolution are necessary for more comprehensive and accurate study of fires phenomena. The author proposes modeling of this study to evaluate useful fires.

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