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FOREST-FIRE BURNED AREA MAPPING USING COMBINATIONS OF SPECTRAL INDICES AS MEMBERSHIP FUNCTION IN OBJECT-BASED IMAGE ANALYSIS (OBIA)

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ABSTRACT

Object Based Image Analysis (OBIA) is a hierarchical classification approach which is applicable in solving numerous remote sensing research problems. Even though, the usage of OBIA for monitoring wildfire and burned area estimation are quite limited. This study focusses on comparing the potential of satellite-derived indices including Normalized Multi-Band Drought Index (NMDI), Normalized Burn Ratio (NBR), Burn Area Index Modified (BAIM), and Normalized Difference Vegetation Index (NDVI) for mapping the area of forest effected by forest fire. In this research, pre and post forest fire images of Landsat 8 (OLI) were processed using multi-resolution segmentation and assign class algorithm in eCognition software. Burned and non-burned areas were mapped using the combinations of selected indices (NMDI-NBR, BAIM-NBR and NDVI-NBR). The combination of BAIM-NBR index produced the highest accuracy of (80%). The study conclude that spectral indices, if use in combinations, assembled satisfactory outcomes in terms of classification accuracy.

Keywords: Wildfire, NMDI, NBR, NDVI, BAIM, OBIA.

INTRODUCTION

Margalla Hills, Islamabad lies in the far end of monsoon zone with hot summers, monsoon rains and cold winters with distributed snowfall in the hills. The mean monthly monsoon precipitation in the area is 254 mm with humidity levels ranged from 59% to 67% (Masroor, 2011). The hottest months in the study area are May and June as the temperature in these months rises up to 40°C, whereas, December and January are the coldest months in which temperature decreases below zero. The topography of the study area is rugged, comprises with various valleys as well as high mountains varying between elevation of 685 m at the Western end and 1,604 m on its East with mean height of 1000 m, comprising mainly steep slopes and gullies. Margalla Hills are also rich with wildlife ranging from wild boars to leopards (Iqbal *et al.*, 2013).

Remote sensing using satellite data combining Geographic Information Systems (GIS), has been extensively used and acknowledged as a dominant and effective tool in discovering pre and post-burned changes (Flasse *et al*., 2004; Hoseinali and Rajabi, 2009). It is an appropriate tool that obtained the satellite data and converts them into an attribute and projects the required results in respectable shape, because these changes play a leading role in the study of global change.

In the past, rare research studies focused on mapping burned areas after forest fire in Rawalpindi and Swat Region, Pakistan (Khan *et al*., 2014; Nafees and Asghar, 2009). Whereas, globally, several spectral indices has been used to observe forest fire-influenced vegetation changes, including regeneration and burn severity (Chen *et al*., 2011; Chuvieco *et al.*, 2002).

Object-based image analysis uses information about the spectra, texture and hierarchy of segments, grouping neighboring pixels with respect to relevant properties. Object-based image analysis may be more effectual for burned area mapping because, it deals with image objects that are spectrally homogeneous rather than individual pixels (Mitri and Gitas, 2004).

The purpose of this study is to investigate the applications of OBIA utilizing various combinations of spectral indices for mapping damages caused by wildfire in the Margalla Hills, Islamabad.

MATERIALS AND METHODS

Study area

Islamabad is the capital city, in the Northwest of Pakistan located on Potohar Plateau. To the North of the city Margalla Hills are located, and are the part of Murree Hills, lies between 73°7' 3.32" E longitude, 33°41' 59.61" N latitude having a distance of about 40 km in length (Malik and Husain, 2003). The Hills contain thick subtropical broadleaved and pine forest covering the entire mountain from foothills to the top (Fig. 1).

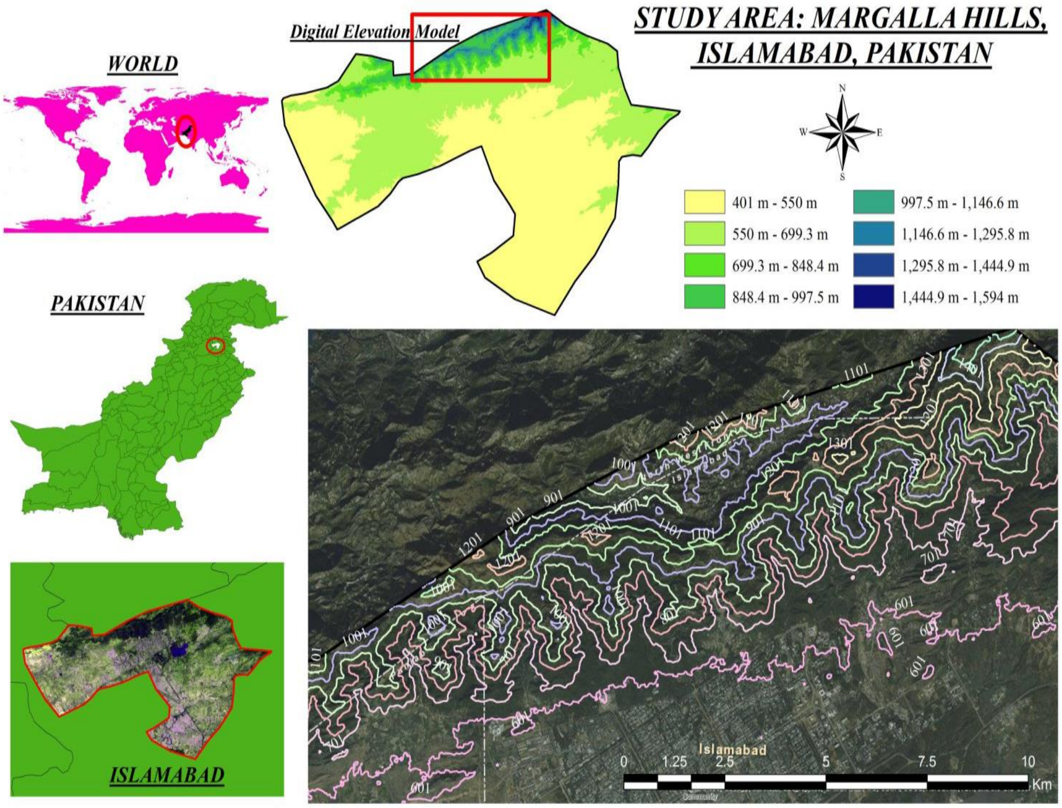

Fig. 1. Map showing the Location and Elevation of Study Area.

Datasets

This research is conducted to weigh up the alteration in Margalla Hills after forest fire. The object-based image analysis is used to identify pertinent changes because of forest fire by using cloud-free Landsat-8 images of pre and post fire time period (Table 1).

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Table 1. Data sets used in burned area mapping.

	Acquisition Date	Landsat sensors	Path/Row	Spatial Resolution (m) and Datum
Pre-burned	17 May 2016	OLI	150/036	30, WGS 1984
Post-burned	02 June 2016	OLI	150/036	30, WGS 1984

Image processing

In the first step after image acquisition, layer staking was performed for omitting SWIR 1 & 2 and thermal bands. Subsequently, atmospheric correction was performed using spatial modeler in ArcGIS software. Afterwards, subset of the study area (i.e. Margalla Hills) was extracted from full scenes of Landsat 8, for onward processing in eCognition Developer including image segmentation and classification. The methodological flow of this research is illustrated in Fig. 2.

In object-based image classification, segmentation is the first step which was performed to split the satellite image into small objects based on homogeneous characteristics (image layer weight, scale parameter, shape and compactness) using algorithm of multi-resolution segmentation. One of the parameter used for multi-resolution segmentation is scale parameter. The main purpose of scale parameter is to determine the maximum possible heterogeneity between image objects. Based on the information provided on the image one can set scale parameters. Small value of scale parameter will make small objects whereas higher value will make larger objects. In this study, for segmentation process scale parameter was set to 100 because the subset of study area is not much bigger.

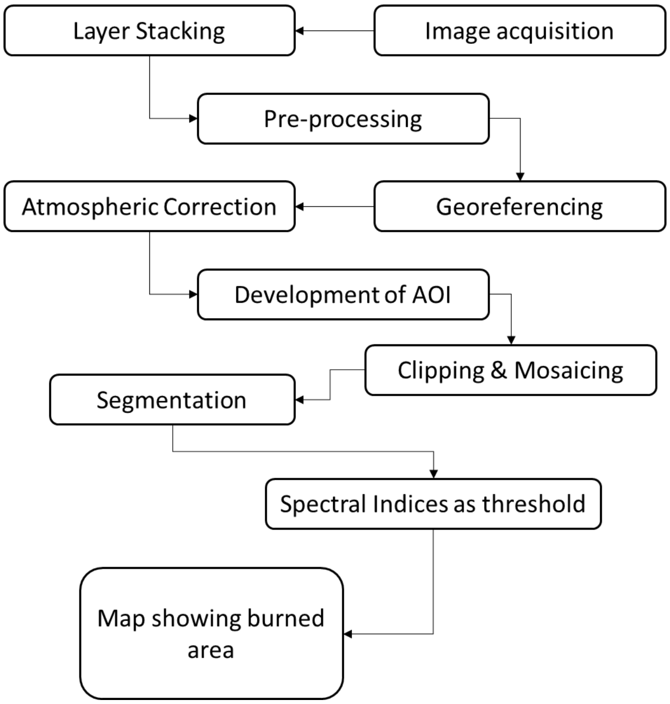

Fig. 2. Methodological flow of this study.

Table 2. Spectral indices used in this study.

Spectral Indices	Abbreviation	Formula
Normalized Multi-Band Drought Index	NMDI	NIR - (SWIR1 - SWIR2)/ NIR + (SWIR1 - SWIR2)
Normalized Difference Vegetation Index	NDVI	(NIR - RED) / (NIR + RED)
Burn Area Index Modified	BAIM	$1 / ((\rho_{NIR} - 0.05)^2 + (\rho_{SWIR2} - 0.2)^2)$
Normalized Burn Ratio	NBR	(RED - SWIR1) / (RED + SWIR1)

Afterwards, four spectral indices (NMDI, NDVI, NBR and BAIM) were calculated using the formulae given in Table 2 to differentiate between burned and unburned surfaces (Fig. 3). The indices were calculated using the wavelength bands comprising; NIR (0.851 - 0.879 micrometer), Red band with (0.636 - 0.673 micrometer), SWIR1 (1.566 - 1.651 micrometer), SWIR2 (2.107 - 2.294 micrometer); for each spectral region.

In the next step, spectral indices were grouped into three different combinations (NDVI-NBR, BAIM-NBR, NMDI-NBR) to map water, vegetation, burned, and unburned areas. Thresholds of objects with respect to their spectral characteristics utilized the membership function. To extract water, SWIR1 band and NDVI values were used in membership functions of spectral information. Burned and unburned lands distinguished more precisely by enhancing the NBR with Landsat thermal band (Veraverbeke *et al.*, 2011).

In the last step, assessment of classification outcomes was performed using high resolution satellite data from Google earth and Spectral indices values. The accuracy assessment results for all three spectral indices combinations are presented in Table 3.

RESULTS AND DISCUSSION

Membership functions permit users to specify the link between object values and the degree of membership to a class using fuzzy logic. Maximum and minimum values fix the upper and lower limits of this function (Trimble Documentation, 2013). The fuzzy sets were established by membership functions to determine feature attributes based on spectral and contextual info. Then, classifications were performed on segmentation in order to make different classes (i.e.Water, Vegetation, Burned and Unburned) to discriminate the results. Moreover, the NDVI has also been used in monitoring fire affected vegetation areas (García-Haro, 2001).

Then on next level, three classes representing vegetation, burned area, and unburned area were produced. In the first combination which was based on NMDI-NBR, with the help of NMDI index, the dry and wet region can be easily distinguished using NIR and SWIR wavelength, then dry soil area was separated from moist soil area by applying NMDI, and then NBR index was used to separate burned areas, but this classification was not accurate because it considered some water and vegetative areas as burned (Fig. 4A). The overall accuracy for this combination was 68% (Table 3).

In next step, BAIM-NBR combination was applied to represent the burned scars (Fig. 4B). The burn area index (BAI), has a high ability to discriminate burned areas in the RED and NIR spectral environment (Chuvieco *et al*., 2002). The segments were categorized as burned area and unburned area using NBR based threshold values and omitting the BAIM based threshold values and vice versa, the results of BAIM-NBR combination was quite satisfied to map burn areas as compare to other two combinations. The overall accuracy of this classification was calculated as 80% (Table 3). In the last step, NDVI-NBR combination was tested (Fig. 4C). The results showed similar trend as in the NMDI-NBR combination with slightly less accuracy.

Table 3. Accuracy assessment results for NMDI-ANBR, BAIM-NBR and NDVI-NBR analysis.

Spectral indices combination		**Overall accuracies**
1	NMDI-NBR	68%
2	BAIM-NBR	80%
3	NDVI-NBR	66%

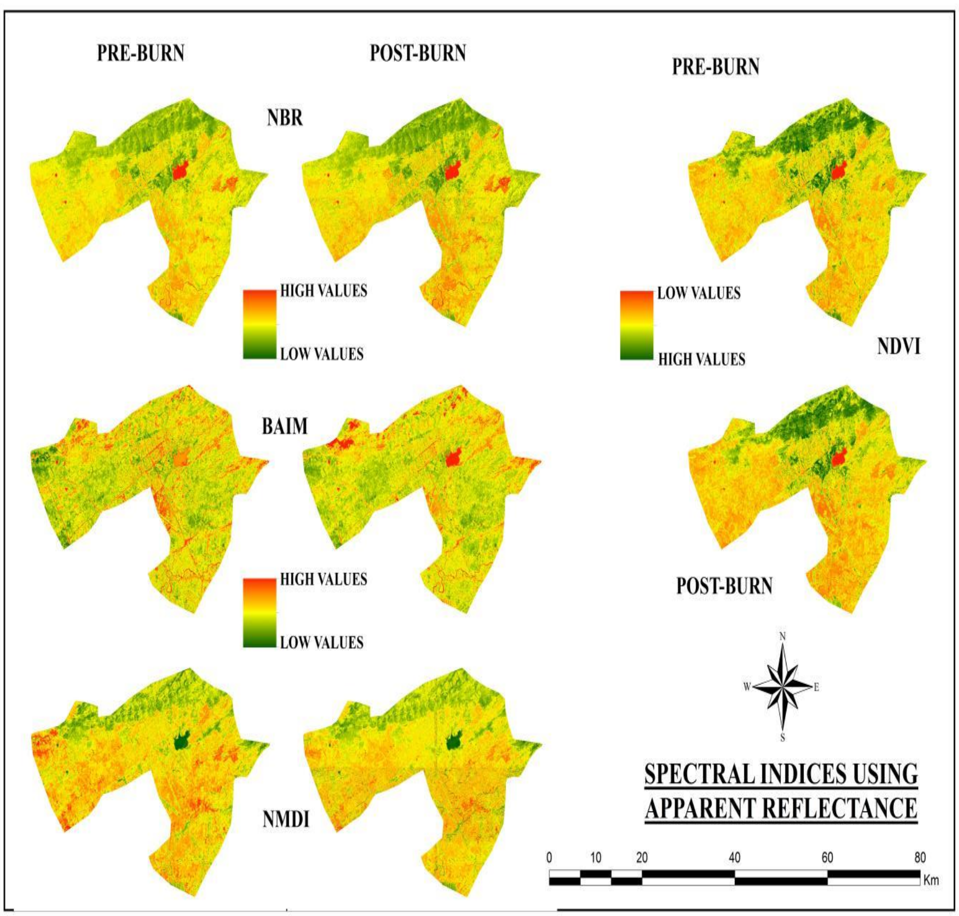

Fig. 3. Spectral indices showing different spectral characteristics in pre and post-burned image.

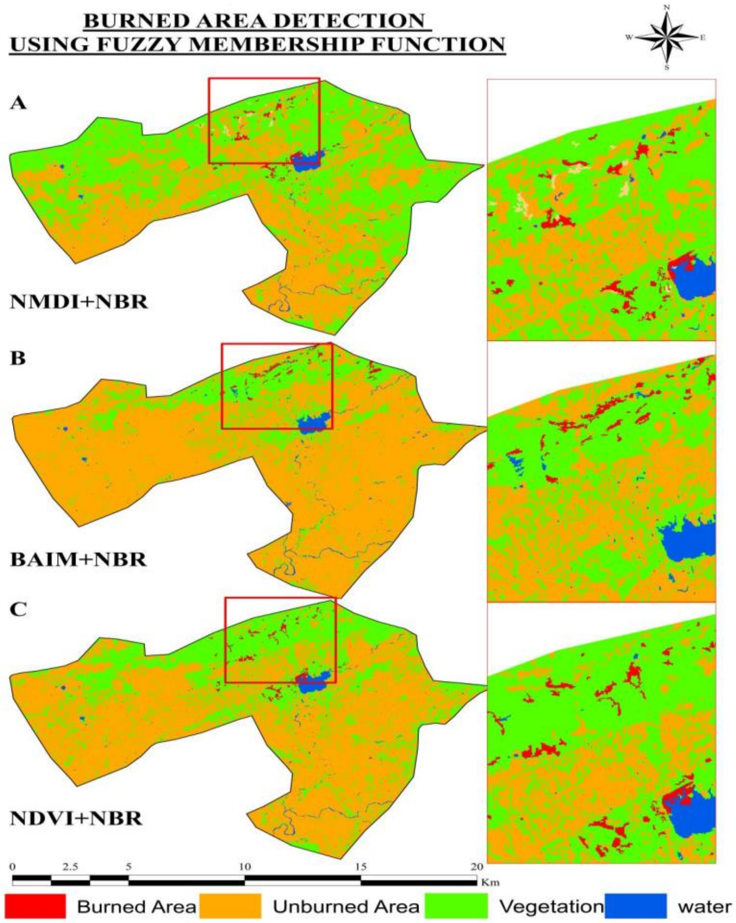

Fig. 4. Results of OBIA with three different combinations: (A) NMDI-NBR, (B) BAIM-NBR, (C) NDVI-NBR.

CONCLUSION

This study was carried out to measure the strength of object-based image analysis for the mapping of burned areas at Margalla Hills, Islamabad, Pakistan. In this research, to determine the burned area, fuzzy membership function classifier followed by multi-resolution segmentation were applied. By making various combinations of spectral indices we found that the better combination for burnt area mapping was BAIM-NBR, with highest accuracy of 80%. Rest of the two combinations showed misclassified pixels. It is concluded that combinations of spectral indices can be successfully used to map burned areas in forest fire at mountainous terrain.

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