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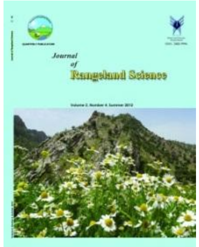

Full Length Article:

Determining the Most Suitable Vegetation Index for Seperating Ecotone Boundaries in Arid Rangelands Using Satellite Data

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Abstract. Ecotones are zones of gradual changes from an ecological system to another. Ecotones monitoring could be important to find out the reason for changes and limits. In this research satellite data were used to analyze the ecotone boundary in Fars steppic rangelands using IRS LISS III and Pan data of year 2006. The real vegetation map and ecotones prepared through Geo-eye images from Google earth software and calibrated using field study. Five soil line vegetation indices such as SAVI, MSAVI2, TSAVI, OSAVI and GESAVI from processed data were calculated. Each of these indices was classified by applying density slicing analysis method. Then the accuracy of produced maps was audited with error matrix method. The results show OSAVI and SAVI had the highest overall accuracy and kappa coefficient as 82.1% and 82% for overall accuracy and 76% for Kappa coefficient, respectively. According to this research, soil line vegetation indices have intermediate accuracy for separation of arid rangelands ecotones in Iran with IRS data, although, OSAVI and SAVI perform better than the others.

Key words: Soil line, Vegetation index, Satellite, Rangeland, Ecotone.

Introduction

In modern definitions, ecotone are usually referred to area of contact between ecosystems and take into consideration spatial and thermal scales as well as functional aspects (Holland *et al.*, 1991). The obvious characteristic of ecotones is vegetation changes such as changes in growth form and biodiversity which is the effect of environmental gradient. The identification and monitoring of ecotones has critical role in our understanding of biodiversity distribution and policies that are put in place to enhance it (Hill and Granica, 2006). Also the importance of monitoring ecotone is to find out the causes of changes. Many remote sensing studies utilize Vegetation Indices (VIs) to study vegetation, assuming that the properties of background are constant or that soil variation are normalized by the particular vegetation index used (Hanan *et al.*, 1991). Multi-spectral Satellite imagery can be efficiently used for vegetation classification and mapping extensive rangelands (Tueller, 1989 and Pickup *et al.*, 1994). In recent years many studies have been carried out to examine satellite data to monitor vegetation in rangelands, and in some cases ecotone have also been considered such as study ecotones with multi-spectral satellite data in Tundra-Taiga (Ranson *et al.*, 2004). In image classification an ecotone is often either ignored if it falls within a width of one or two pixels, or part of it may be mapped as a separate vegetation area, if it covers an area of several pixel widths (Hill and Granica, 2006). In sparsely vegetated areas the most usable index NDVI is influenced mainly by soil reflectance, therefore other indices like SAVI is recommended (Pettorelli *et al.*, 2005). A spectral VI is usually a single number derived from the spectral reflectance of two or more wavebands (Ji and Peters, 2007). Several spectral VI's have been developed over the last few decades which have been used to estimate vegetation canopy biophysical parameters (Jiang, 2008; O,Neill, 1996; Richardson and Wiegand, 1997; Gilbert *et al.*, 2002; Marsett and Jiaguo, 2006; Vescovo and Gianelle, 2008). Nevertheless these indices work differently in distinct vegetative zones. These indices attempt to minimize brightness- related soil effects by considering first order soil vegetation interaction by means of soil adjustment parameters (Gilbert *et al.*, 2002). Therefore, in this study soil line VI's were used to classified ecotone in Fars steppic rangelands because of sparsely vegetated area. So it's tried to audit the probability of local ecotone classification using the indices. To get the result, multi-spectral satellite data of IRS-1D were analyzed and density slicing method was used to classify indices.

Materials and Methods

This study was conducted on Arsanjan steppic rangelands of Fars province (5332 ha is; $29^{\circ}59'E$ to $53^{\circ}14'N$) with 1860m. average elevation, 319 mm average annual precipitation. Based on De Martonne aridity index, the study area was classified into semi- arid climate. The study area is shrublands with scattered sub-trees and trees physiognomically. The main species of the rangeland are combination of *Convolvulus acanthocladus*, *Ebenus stellata*, *Astragalus arbusculinus*, *Astragalus cephalanthus*, *Artemisia sieberi*, *Amygdalus scoparia*, *Amygdalus lycioides*, *Pistacia atlantica*, *Acer monspessulanum* dominantly. (Fig. 1) shows the study site location.

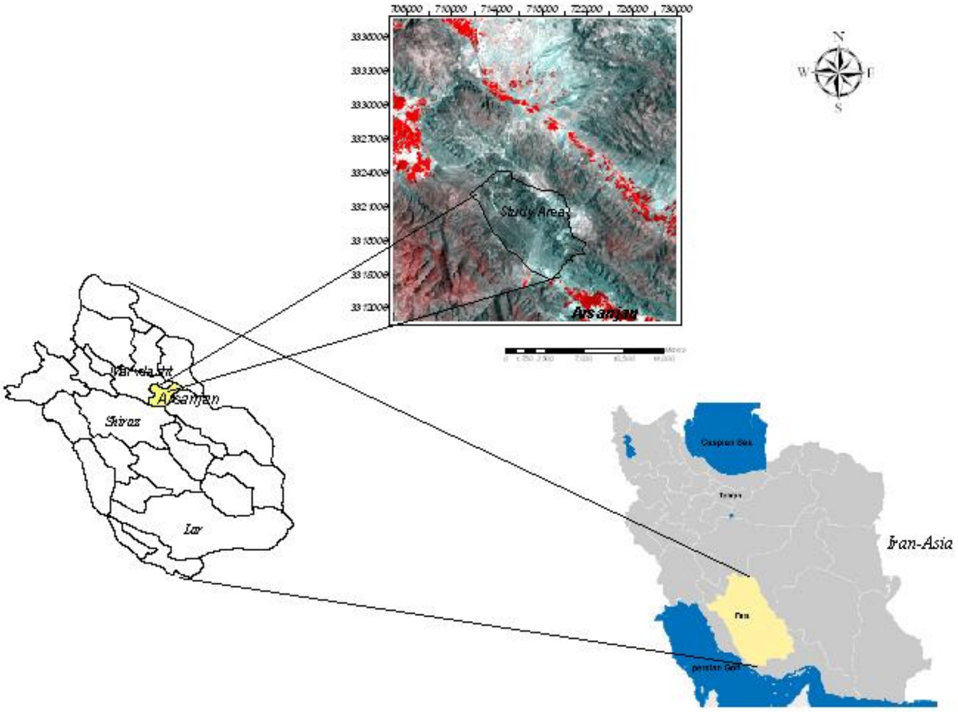

Fig. 1. Study area location

IRS-1D satellite data from LISS III and Panchromatic sensors of 12 May 2009 were used as Table 1 Shows.

Table 1. Bands characteristic

Spectral band width	Resolution	Band name
500 - 750 nm	5.8	Band 1(Panchromatic)
520-590 nm	23.5	Band 2 (Green)
620-680 nm	23.5	Band 3(Red)
770-860 nm	23.5	Band 4 (Near infrared)
1550-1700 nm	70	Band 5 (Middle infrared)

Field study for locating and mapping ecotones was prepared as reference data using high resolution true color Geo-Eye imagery (Acquired on 2009), and Panchromatic IRS data. The extratcted map was calibrated at field and rectified. In this map as (Fig. 2) showes, three types of ecotones as an area between low dense woodland and high dense one, an area between shrublands and low dense woodland and the grassland that is located in the middle of low dense wood land.

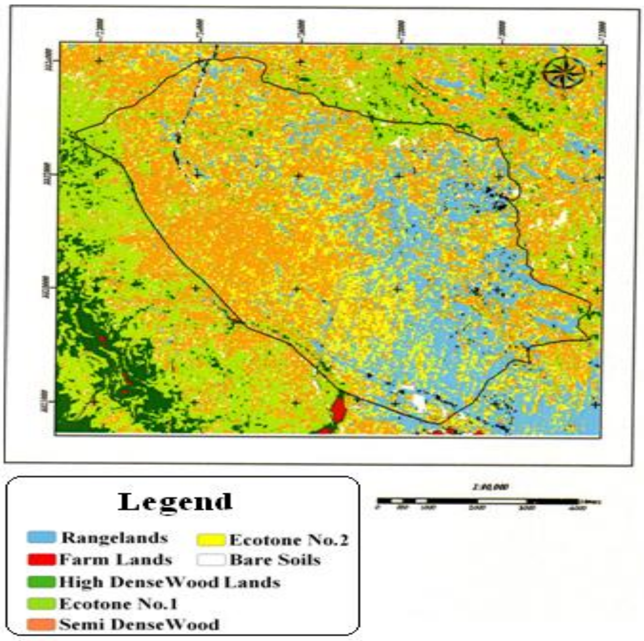

Fig. 2. The Ground- truth map

A Number of data processing steps was taken before calculating indices and classifying them. All the steps were done by Erdas Imaging Image ver. 8.7, ILWIS Academic ver. 3.3, ENVI ver 4.3 and ArcGIS ver. 9.3 packages. The preprocessing steps included atmospheric and geometric correction using linear regression algorithmand Ground Control Point (GCP). As the PAN and LISS III image geo-referenced with 23 and 21 points respectively, the calculated Root Mean Square (RMS) was 0.42 and 0.29 pixels respectively. Then nearest neighbor re-sampling method was used to preserve the individual pixel value. Before calculating the VIs, the multi-spectral data enhanced with linear contrast stretch method. Also false color composite and fusion image were made with IHS method which is recommended for IRS data to check the vegetation condition more accurately. Table 2 illustrates the indices equations that were used in this study. To get soil line coefficient, soil line equation obtained according to the theory of Hurcom and Harrison (1998). Hence, the equation is as follows:

$$NIR_{soil} = 0.69RED_{soil} + 21.1$$

Finally, each of the imagery of indices was classified with density slicing method (Jensen, 2005). The accuracy of each class and the overall accuracy were calculated with confusion error matrix method.

Table 2. Vegetation and soil indices

Index	Abbr.	Formula	Reference
Soil adjusted vegetation index	SAVI	$SAVI = \frac{NIR - RED}{NIR + RED + L}(l + L)$	Huete, 1988
Transformed soil adjusted vegetation index	TSAVI	$TSAVI = \frac{a(NIR - a * RED - b)}{a.NIR + RED - a.b + X(1 - a^2)}$	Baret and Guyot, 1991
Modified soil adjusted vegetation index	$MSAVI_2$	$MSAVI_2 = \frac{2NIR + 1 - \sqrt{(2NIR + 1)^2 - 8(NIR - RED)}}{2}$	Qi *et al.*, 1994
Generalized soil adjusted vegetation index	GESAVI	$GESAVI = \frac{(NIR - BR - A)}{(R + Z)}$	Gilbert, 2002
Optimized soil adjusted vegetation index	OSAVI	$OSAVI = \frac{(NIR - RED)}{NIR + RED + Y}$	Rondeaux, Steven and baret, 1998

Results

As the results of this research showed three ecotone zones could be separated as (Fig. 2). Ecotone no.1 is located between semi-densed and densed wood-rangelands, no.2 is between shrub lands and semi-densed wood- rangelands and no.3 is distributed among semi-densed wood- rangeland which is originally considered as grassland. Estimating and comparing the indices from single band data image and using some image processing techniques such as density, slicing, supervised classifying and extraction digital numbers of pixel images for ecotone locating being considered as Figs. 3-7 showed respectively. According to the results none of the indices be able to classify grassland as an independent ecotone and none of them separates it from shrub lands or wood-lands. Accuracy of each classified index was determined by comparison with ground- truth map. To do this, equalized random sampling (Smith and Brown, 1999) was used and a total of 80 samples were selected for the whole region. The Comparison method is confusion matrix (error matrix) that is widely used in remote sensing studies. Results show that the overall accuracy of all indices are relatively high, and are between 67 to 82 percent, although the Kappa coefficient of some of them is not high enough as (Table 3) showed.

Table 3. Accuracy of soil line vegetation indices

Kappa Coeffient	Overall Accuracy	Average Reliability	Average Accuracy	Index
0.76	82.1	73	83.5	OSAVI
0.76	82	72.1	85.9	SAVI
0.75	80.3	63.8	83.4	MSAVI2
0.59	69.3	69.6	74.3	GESAVI
0.56	67.2	69.7	74.1	TSAVI

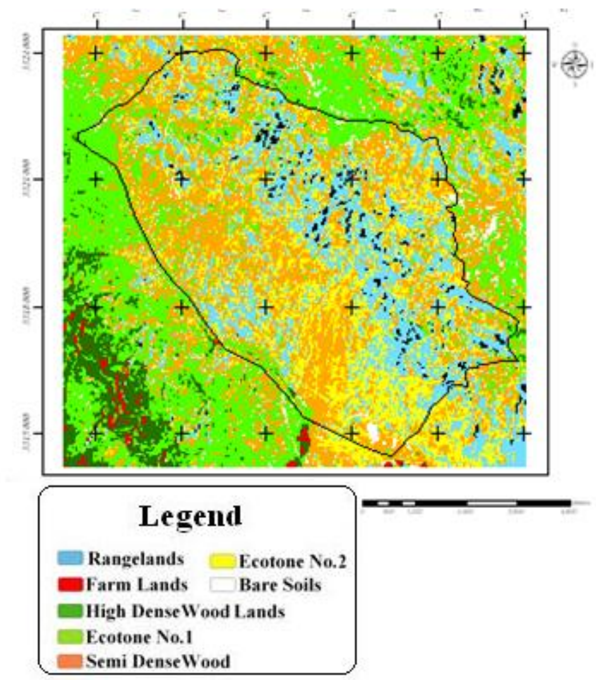

Fig. 3. Classified image with MSAVI2

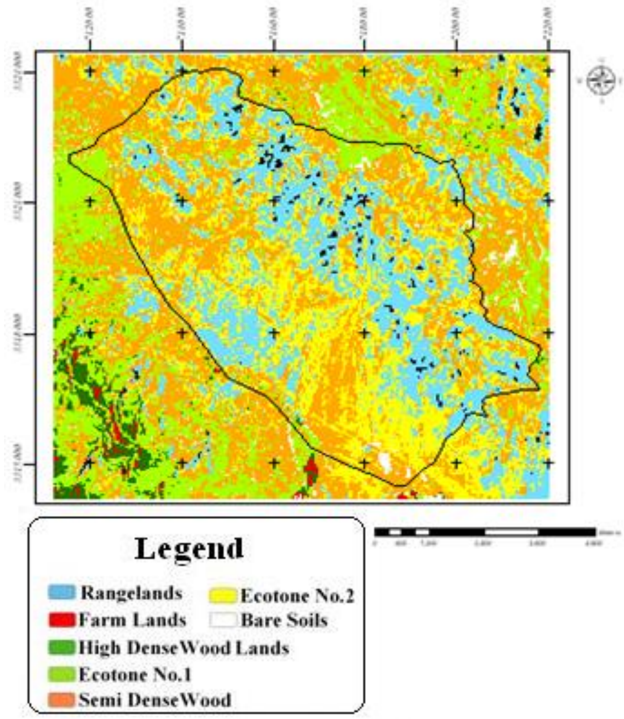

Fig. 4. Classified image with GESAVI

Discussion

Reviewing the accuracy of classes in different indices shows that ecotone no.1 has high classification accuracy among other indices. As the accuracy of this ecotone is more than %80, only the accuracy of TSAVI index was low (%60). This was due to the high percentage of vegetation cover (> %30) and more homogeneity in this zone of study area. Hence, the indices are less affected by background soil reflectance due to higher vegetation cover.

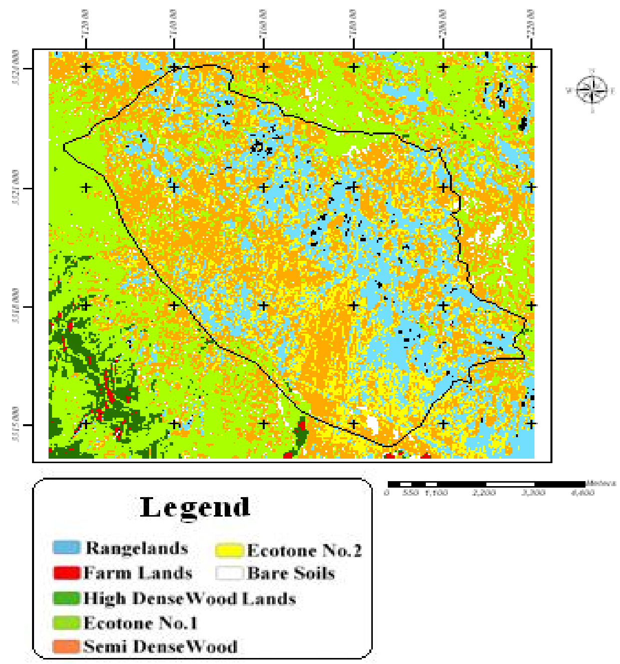

Fig. 5. Classified image with OSAVI

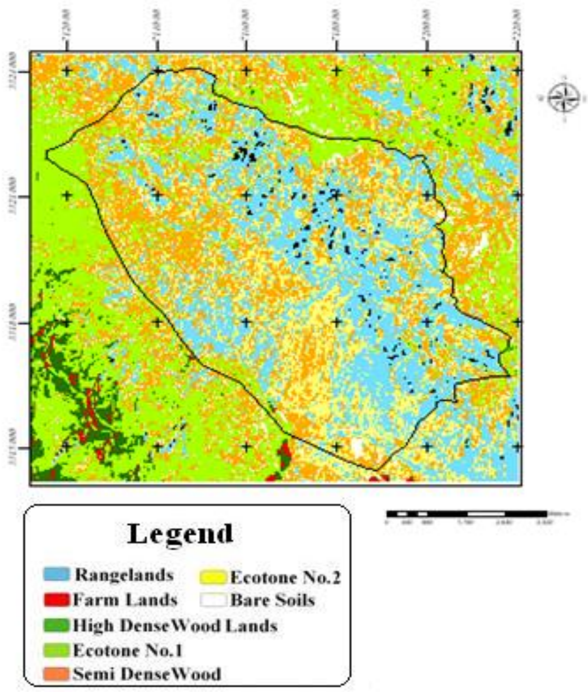

Fig. 6. Classified image with SAVI

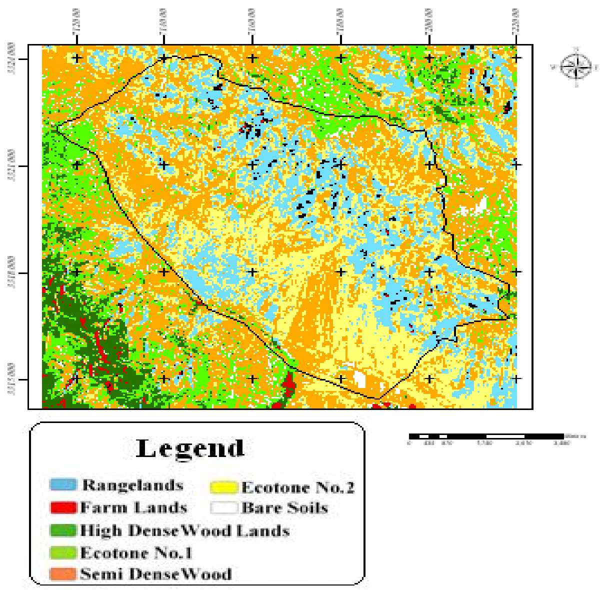

Fig. 7. Classified image with TSAVI

The accuracy of ecotone no.2 in classification with GESAVI, SAVI and TSAVI was high and suitable. But it was low with other indices. Heterogeneous pixel in ecotone no.2 because of combination of two different communities causes the low accuracy. However, visual checking of indices classification showed that GESAVI determines low density vegetation cover with little changes better in compare with SAVI. But GESAVI was less accurate in higher density vegetation cover when using for seperating farms and agricultural ecosystems. Gilbert (2002) also reported that the new generation of SAVI family index such as OSAVI and GESAVI, in many cases of sparse vegetation give better results. The highest classification accuracy for ecotone no.3 was obtained when SAVI and OSAVI indices were used. Certainly, in this zone, vegetation indices in this study showed that, SAVI and OSAVI have highest accuracy in separation of ecotones and other communities in our study area. The low percentage of vegetation cover (< %20). In general, assessing the soil line the surface reflectance. The reason was accuracy of these indices was 82.1 and factors other than vegetation cover, affect 80, respectively. Although, in separating ecotones the SAVI index had higher accuracy and the average accuracy for classification ecotones (%85). However, the Kappa coefficient of these two indices, which was %76, indicates the intermediate ability of them to assessing ecotones in the study are. These results were consistent with Baret and Guyot (1991) reported that the SAVI, TSAVI and MSAVI had the ability to estimate canopy cover in arid and semi- arid area with sparse vegetation. Kasawani (2010) also reported that between soil-based VIs, SAVI and MSAVI were best indices to map mangroves with sparse vegetation canopy. Soil line vegetation indices or the vegetation indices that adjust the effect of background soil reflectance, was a kind of processing method that could be used for monitoring vegetation cover with satellite data in arid shrub lands and wood-lands. Between all soil line vegetation indices, the OSAVI and SAVI, with the accuracy of 82 percent, were the best to monitor ecotone changes. However, it was recommended to determine plant density variation with same lifeforms in arid rangelands, satellite data with higher resolution or hyper- spectral satellite data should be used.

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