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Landsat ETM+ Based Assessment of Vegetation Indices in Highland Environment

Solaimani K.*[1], Shokrian F.[1], Tamartash R.[2] and Banihashemi M.[1]

*[1]Corresponding author, GIS Centre, Sari University of Agriculture and Natural Resources, PO Box 737, Sari-Iran, Email- solaimani2001@yahoo.co.uk, Tel. (+98) 9111521858

[2] Academic Member, Sari University of Agriculture and Natural Resources, PO Box 737, Sari-Iran

Abstract

Vegetation cover change is expected to have significant impacts on wavelength reflectance, particularly along transition zones such as the treeline. Studies of vegetation composition and change in this ecotone have largely focused on local analysis of individual rangeland type using field intensive stand reconstruction techniques. Remote sensing may be well suited to monitoring recent changes across the ecotone because it captures integrated changes of all vegetation life forms over large spatial extents. This study examines rangeland vegetation composition and change along the northern treeline mapped using a high resolution, KFA-1000 archive from 1991[1]. In this study Landsat ETM+ (18/07/2000) and field data were used to consideration the vegetation indices of grasses, forbs, shrubs and bushy trees canopy cover in a mountainous area on the northern flank of Alborz, Iran. The used sampling techniques and field investigation with 306 collected quadrates (34 units) are described. The Global Positioning System (GPS) is used in order to adjust the used pixels to the ground control points. Pre-processing on satellite data such as geometric corrections were implied based on digital maps at 1:25000 scales. In order to acquire the vegetation indices the correlation coefficients were determined between dependent variables of vegetation species and indices as independent in SPSS software environment. The extracted results from this study illustrate a significant correlation between different bands of Landsat ETM+ and vegetation group. The highest correlation is belonged to the bands 4 and 3 of ETM+ with shrubs canopy cover that indicated in r of 0.34 and 0.37, respectively. The maximum rate of correlation with respect to the indices were identified for the vegetation cover such as MSI (Moisture Stress Index) for forbs cover ($r = 0.62$). The Ratio Vegetation Index (RVI) for grasses cover was indicated as $r = 0.53$; VNIR2 for shrubs cover as $r = 0.38$; and Transformed Chlorophyll Absorption Reflectance Index (TCARI) as $r = 0.50$ for bushy trees cover. Finally, the results indicated that the ETM+ sensor is the optimized data with the high efficiency to discrimination of different land covers using vegetation indices.

Key words: Landsat ETM+, vegetation indices, rangeland, vazroud watershed

Introduction

Remote sensing method works on the brightness values of land cover types and facilitates their characterization. Since the vegetation has specific absorption in visible range and reflects most of the near infrared (NIR) therefore vegetation biophysical characteristics can be derived from these ranges and from the mid-infrared portions of the electromagnetic spectrum. The rate of canopy reflectance in the visible and near infrared is strongly dependent on both structural (i.e. amount of leaves per area, leaf orientation, canopy structure) and biochemical properties (i.e. chlorophylls, carotenoids) of the canopy[2]. Several vegetation indices were greatly introduced using ratios of these reflections[3,4,5]. A number of spectral vegetation indices (VIs) have developed to estimate biophysical parameters of vegetation. A spectral vegetation index (VI) is usually a single number derived from the spectral reflectance of two or more wavebands. Since a VI is proportional to the value of biophysical parameters such as the leaf area index (LAI), green vegetation fraction (GVF), net primary productivity (NPP), and fraction of absorbed photosynthetically active radiation (APAR), it is commonly used to indicate vegetation dynamism and amount. A large number of spectral VIs have been developed and used in remote sensing. The most usual VIs is included the ratio vegetation index, simple ratio[6], normalized difference vegetation index[7], soil adjusted vegetation index[8], atmospherically resistant vegetation index[9], modified SAVI[10], enhances vegetation index[11,12], optimized SAVI[13], green ARVI[14], and green NDVI[14]. Additionaly, the other VIs is planned in recent years, such as the generalized SAVI or GESAVI[15], visible atmospherically resistant index or VARI[16], modified nonlinear vegetation index or MNVI[17], and wide dynamic range vegetation index or WDRVI[18], include the potential for wide application. The relationship between hyperion-derived vegetation indices, biophysical parameters, and elevation data was studied in a Brazilian savannah environment[19]. The gradual increase of biophysical parameters, from savannah grassland to semi-deciduous forest has produced large correlation coefficients with most of the indices, especially the near-infrared/red-based ones. To discriminating the invasive species, 'Lantana' have used 29 vegetation indices and remarked that SAVI (Soil Adjusted Vegetation Index) is most favorable in discriminating Lantana followed by perpendicular vegetation index-3 in the optimum biowindow. The hyperspectral vegetation indices was investigated for the Mediterranean pasture, to estimate the green biomass used leaf area index (LAI), but for the nitrogen content simple ratio indices and NDVI were used. Simple ratio index has indicated with a better validate green biomass with $r^2 = 0.73$ than NDVI. An optimization indices based on Landsat ETM+ and SPOT 5 were examined for detection of fire severity in sagebrush steppe[20]. The gained results showed that the Soil Adjusted Vegetation Index (SAVI) calculated from SPOT have the highest overall accuracy (100%) in marked out burned opposed to the other areas but using the higher spectral resolution of Landsat ETM+ (particularly band 7) probably need to detect of differences in fire severity in sparsely vegetated shrub-steppe.

MIR bands were used in vegetation indices to estimate the grassland biophysical parameters in the Alps region of Trentino (Italy) which shown a better results than the NIR, Red or Green bands[21]. A comparison of vegetation indices and red-edge parameters was done to estimate the grassland cover using canopy reflectance data[22]. Their analysis have indicated that MSAVI2 and RVI yielded more accurate estimations for a wide range of vegetation cover than the other vegetation indices and red-edge parameters for the linear and second-order polynomial regression, respectively. Application of a new vegetation index in Leaf Area Index of rice was experimented. They have remarked that comparison on the capabilities of the vegetation indices derived from all kinds of combinations of red, green and blue bands to LAI estimation indicated that GNDVI (Green NDVI) and GBNDVI (green-blue NDVI) had the best relations with LAI. The capabilities of GNDVI and GBNDVI in LAI estimation have qualified under different circumstances with the same result. There is a suggestion that GNDVI and GBNDVI have better execute to predict LAI than the conventional NDVI. A significant relationship between grassland LAI and VIs have been reported earlier[23]. The performance of the renormalized difference vegetation index (RDVI), adjusted transformed soil-adjusted vegetation index (ATSAVI), and modified chlorophyll absorption ratio index 2 (MCARI2) was slightly better than that of the other VIs in the groups of ratio-based, soil-line-related, and chlorophyll-corrected VIs, respectively. The spectral simulations of vegetation indices were studied using Landsat data continuity. They have used eight indices and remarked that the Global Environment Monitoring Index (GEMI) proved to be the least sensitive to spectral dissimilarities between sensors and hence GEMI is worth considering for quantitative monitoring of environmental change using images from multiple sensors.

Study area

The Vazroud Watershed of Mazandaran province as the upland range of Alborz, lies between the central part of Alborz and the Caspian Sea Plain in the north of Iran. The rangelands of Noujmeh, located approximately between 36°14'26" to 36°25'54" N and 52°01'46" to 52°12'30" E in upper

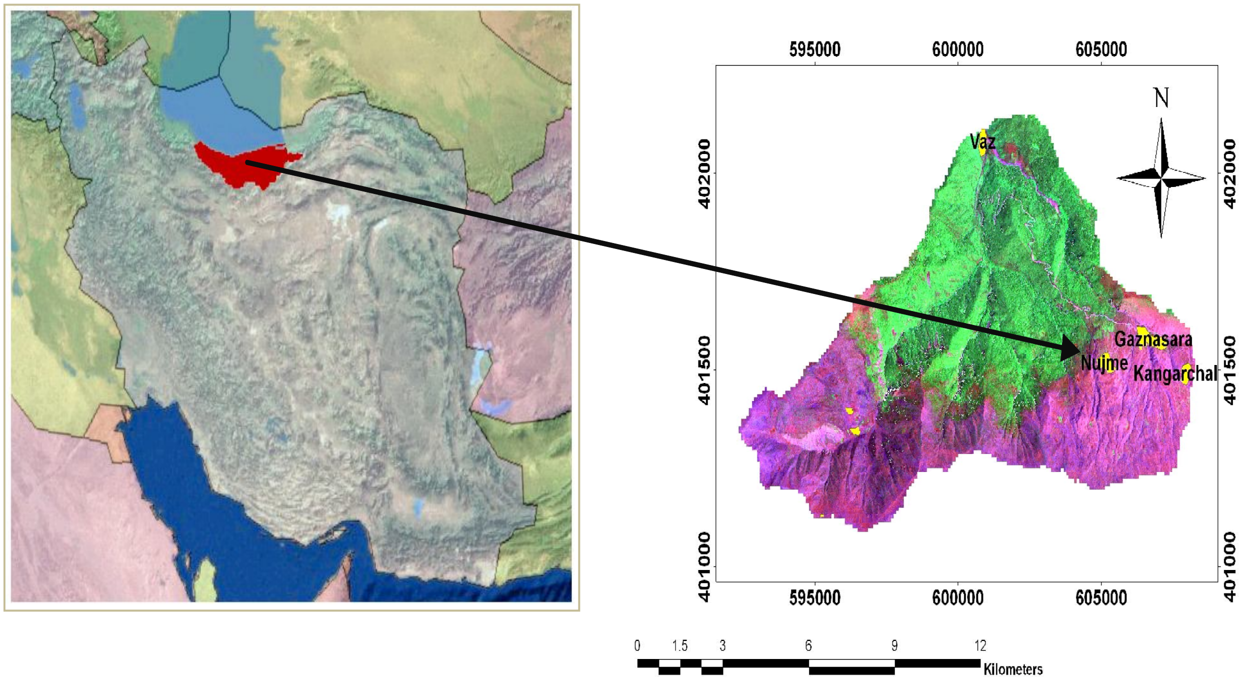


Fig.1. Location of the study area in relation to Iran

vazroud in the northern flank of Alborz, have been selected as a test site for this study (Figure 1). It is situated between 1840 to 2650m above sea level (ASL), has an Alborzian cold to semi-arid climate with mean annual temperature and precipitation of 10.6°C and 800mm respectively[1]. The climate based on Demarton was cool wet and according to Amberje method has classified in mountainous conditions. From 14123 hactare of the study area 5000 ha is belonged to the rangelands.

Experimental

Landsat Enhanced Thematic Mapper (ETM^+ data)

The grassland vegetation growth peak period in Noujmeh upland of Vazroud watershed occurs during the 2^{nd} half of June. However, this period often corresponds to high cloud covers and thus limits the selection of cloud free images. All available Landsat-Multi Spectral Scanner (MSS), Thematic Mapper (TM) and Enhances Thematic Mapper (ETM^+) images in our remote sensing centre's archives were reviewed for the growth period and cloud free images were selected (Table 1). Because of the lack of satellite images for period 2009 and 2010, the years when we conducted major field work, a cloud free Landsat (ETM^+), 30m spatial resolution image was used for this period.

Pre-processing

The Landsat ETM^+ captured on 16 June 2000, which has good visibility and is almost cloud free, was rectified first with 112 ground control points of topographic map (1:25,000). Using the information provided in the header file and following the equations and calibrating coefficients[24] for Landsat images, all images were converted to at sensors radiance. Following[25] we used the dark object subtraction approach to minimize the noise due to atmospheric effect on satellite radiance and calibrate at sensor radiance to scaled surface reflectance[26,27]. After geometric, radiometric and atmospheric correction, all images were covered by study area boundary for further analysis. Only rangeland area, excluding area covered by three villages (Nojmeh, Gaznasara and Kangarchal) and river channels, was selected for analysis. The NDVI, which is most common index used to monitor green vegetation cover, was computed for the used images[4, 28-30].

Field data collection

Field work was conducted during June-September 2009 and in June/August 2010. During the field visits, data have been collected by means of a detailed household survey of all 80 households of Nojmeh, Gaznasara and Kangarchal villages, semi to unstructured interviews with key persons in the villages. Questions included vegetation growth peak period, composition and trend, grazing patterns and processes of rangeland changes. During the group discussion, to identify pasture unit boundaries and major trails of livestock movements, participants were asked to mark relevant information in the maps, using printed KFA-1000 and topographic maps at 1:50,000 as reference. Subsequently, these sketches were saved and exported to Arc GIS9.3. Later these layers were finalized via verification with GPS observation points and a topographic base map at 1:25000 scale. Location of all sample points were recorded with the help of a GPS.

Table 1. Date, source and characteristics of the used satellite image

Date	Source	Resolution (m)
June 18, 2000	Landsat ETM^+	30

Methodology

Contemporaneous to the satellite overpass in 2000, ground truth sampling was conducted in two steps. First, one investigational site was placed in the ecotone areas at the Nojmeh and Gaznasara experimental stations and the second in hilly and slope units located in the upland plain area. The sampling period was chosen to correspond with the satellite overpasses. The experimental unit was a nine block design (30x30m for each block) and five sampling locations therein. A total of 306 points were sampled within period in the years 2000 and 2010 to minimize the effect of vegetation change. Each point within a block was pre-determined using randomly selected grid coordinates. In every sampling point, the following attributes were recorded: floristic composition, visual estimation of bare soil and percentage of vegetation cover. All recorded attributes were used to calculate the trend and 27-cover index (Table 2). The essential indicated image values were then averaged within the 30x30m^2 transects cells. Finally, a simple regression model was built between the used band and indices for the available satellite overpasses of the year 2000. For validation of the relationship, vegetation type and index was interpolated in ArcGIS Spatial Analyst, ERDAS IMAGINE 8.3.1, ENV14, Excel and SPSS software. Correlation coefficients were determined between dependent variables of species and indices as independent. Then linear regression appointed between vegetation indices and vegetation cover with a high correlation and extracted equations. Finally, multiple regression used in order to select the best model for each vegetation groups.

Most of the VI equation cover the red band (670nm) or the NIR band (800nm), but some of them consist of the green band (550nm). The reason to employ these region is related to the abundance and activity of green vegetation, which contain LAL green cover per cent, chlorophyll, green biomass and absorbed photosynthetically active radiation[31].

Results

Rangeland management is an efficient option to support sustainable and environmente friendly agricultural land-use[32]. A land cover map containing grasses, forbs, shrubs, bushy trees canopy, classes was obtained from ETM^+ bands (1-5 & 7) in the study area. The achieved highest correlation related to the bands 4 and 3 of ETM^+ with shrubs canopy cover that were indicated in r of 0.34 and 0.37, respectively. In comparison to the other vegetation cover, these extracted results were reasonably good considering the level of detail of the classification approach. All major cover features could be identified with sufficient quality. In the following, we concentrate on rangeland vegetation types only.

Rangelands located on the ecotone area were clearly separated from those on the upland and hills area. Dried rangelands, either on upland and hills or on ecotone, were discriminated with excellent accuracy. Regarding areas that had been dried before acquisitions in 18 June 2000, slightly lower accuracies were recorded. Furthermore, present results demonstrate also that dried bare soil areas and intensive rangeland utilization exhibited bigger coverage on plains whereas on upland hills, intensively grazed areas were predominant. Overgrazed areas were geographically located in the plain area, near springs where permanent water supply is ensured. The poorest accuracies were detected for class wetland probably due to the fact that this class was poorly characterized in the reference data set.

Table 2. The used indices

Vegetation Indices	Equation
Normalized Difference vegetation Index (NDVI)	$(\rho 800 - \rho 670)/(\rho 800 + \rho 670)$
Renormalized Difference Vegetation Index (RDVI)	$(\rho 800 - \rho 670)/\sqrt{\ }\ \rho 800 \times \rho 670$
Modified Simple Ratio (MSR)	$(\rho 800/\rho 670\text{-}1)/\sqrt{\ }(\rho 800/\rho 670 + 1)$
Soil-Adjusted Vegetation Index (SAVI)	$(1 + L)(\rho 800 - \rho 670)/(\rho 800 + \rho 670 + L)$, where $L = 0.5$
Modified Soil0Adjusted Vegetation Index (MSAVI2)	$(0.5) \times (2 \times (\rho 800 + 1) - \sqrt{\ }((2 \times \rho 800 + 1)\ 2 - 8 \times (\rho 800 - \rho 670)))$
Transformed Vegetation Index (TVI)	$(NDVI + 0.5)^{0.5}$
Modified Chlorophyll Absorption Ratio Index (MCARI)	$[(\rho 700 - \rho 670) - 0.2\ (\rho 700 - \rho 550)](\rho 700/\rho 670)$
Modified Triangular Vegetation Index (MTVI1)	$1.2\ [1.2\ (\rho 800 - \rho 550) - 2.5\ (\rho 670 - \rho 550)]$
Wide Dynamic Range Vegetation Index (WDRVI)	$(a \times \rho 800 - \rho 670)/(a \times \rho 800 + \rho 670)$, $a = 0.2$
Visible Atmospherically Resistant Index (VARI)	$(\rho 550 - \rho 670)/(\rho 550 + \rho 670 - \rho 450)$
Normalized Difference Water Index (NDWI)	$(\rho 857 - \rho 1241)/(\rho 857 + \rho 1241)$
Infrared Percentage Vegetation Index (IPVI)	$\rho 800/(\rho 800 + \rho 670)$
Enhances Vegetation Index (EVI)	$2.5\ (\rho 800 - \rho 670)/(1 + \rho 800 + C1\ \rho 670 + C2\ \rho 450)$, $C1 = 6$, $C2 = 7.5$, $L = 1$
Difference Vegetation Index (DVI)	$\rho 800 - \rho 670$
Ratio Vegetation Index (RVI)	$\rho 800/\rho 670$
Green Normalized Difference Vegetation Index (GNDVI)	$(\rho 800 - \rho 550)/(\rho 800 + \rho 550)$
Modified Normalized Difference (MND)	$\rho 800 - (1.2 \times \rho 670)/(\rho 800 + \rho 670)$
VNIR1 Near Infrared	(ETM4 – ETM1)/(ETM4 + ETM1)
VNIR2 Near Infrared	(ETM4 – ETM2)/(ETM4 + ETM2)
MIRV1	(TM7 – TM3)/(TM7 + TM3)
MIRV2	(TM5 – TM3)/(TM5 + TM3)
MSI (Moisture Stress Index)	$\rho 1550/\rho 760$
Modified Chlorophyll Absorption in Reflectance Index (MCARI)	$[(\rho 700 - \rho 670) - 0.2 \times (\rho 700 + \rho 550)] \times (\rho 700/\rho 670)$
Optimized Soil-Adjusted Vegetation Index (OSAVI)	$(1 + 0.16) \times (\rho 800 - \rho 670)/(\rho 800 + \rho 670 + 0.16)$
Greenness Index (GI)	$\rho 554/\rho 677$
Transformed CAR Index (TCARI)	$3 \times [(\rho 700 - \rho 670) - 0.2 \times (\rho 700 + \rho 550) \times (\rho 700/\rho 670)]$
Non Linear Index (NLI)	$(\rho 800^2 - \rho 670)/(\rho 800^2 + \rho 670)$

Estimation of forbs covers using vegetation indices

Four vegetation indices showed significant correlation with forbs cover (Figure 2). The maximum rate of correlation in respect to the indices were identified for the vegetation cover such as MSI (Moisture Stress Index) of forbs cover identified as ($r = 0.62$), ($p<0.01$).

Estimation of grass cover using vegetation indices

Grasses covers with six vegetation indices have significant correlation. Between these indices Ratio Vegetation Index (RVI) was indicated with specific coefficient ($r = 0.53$), ($p<0.01$) than the others (Figure 3).

Estimation of shrub covers using vegetation indices

Shrub cover with VNIR2 has indicated with the highest correlation of ($r = 0.38$), ($p<0.05$) as showed in Figure 4.

Estimation of bushy trees using vegetation indices

Bushy trees is commonly related to Difference Vegetation Index (DVI) but with Transformed Chlorophyll Absorption Reflectance Index (TCARI) has better correlation ($r = 0.50$) than DVI ($p<0.01$) as determined in Figure 5.

In Figure 6 different vegetation indices have compared together as the used indices of Ratio, MSI, VNIR2 and TCRI which have described in Table 2 for the study area.

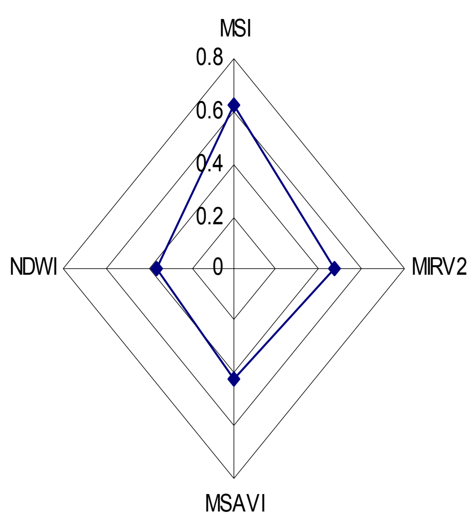


Fig 2. correlation coefficient between vegetation indices and forbs cover

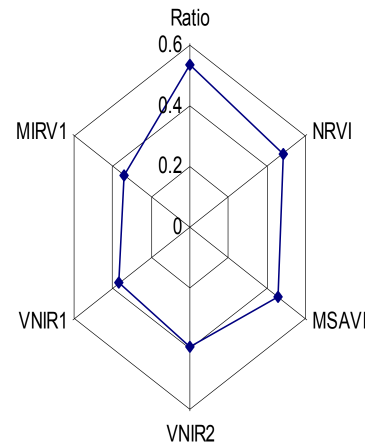


Fig 3. Correlation coefficient between vegetation indices and grass cover.

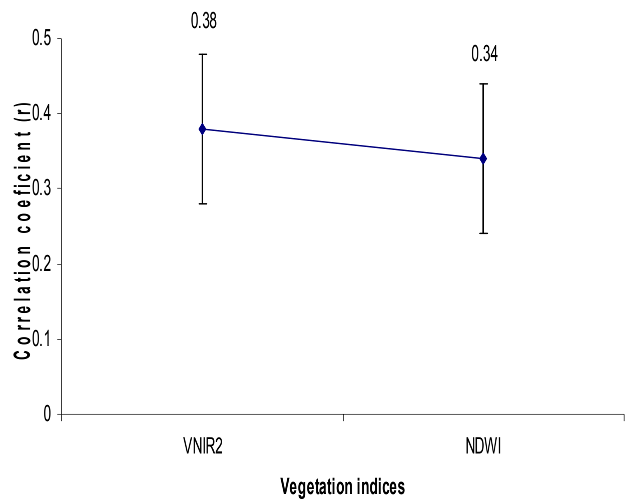


Fig 4. Correlation coefficient between vegetation indices and shrub cover

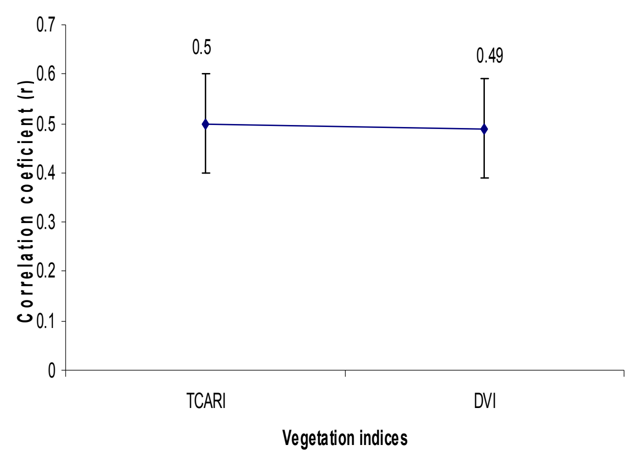
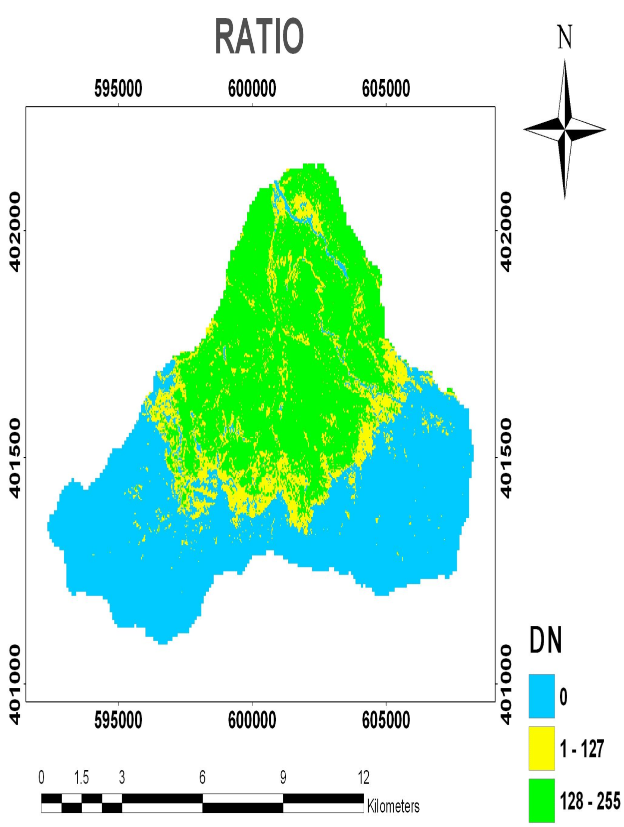


Fig 5. Correlation coefficient between vegetation indices and bare soil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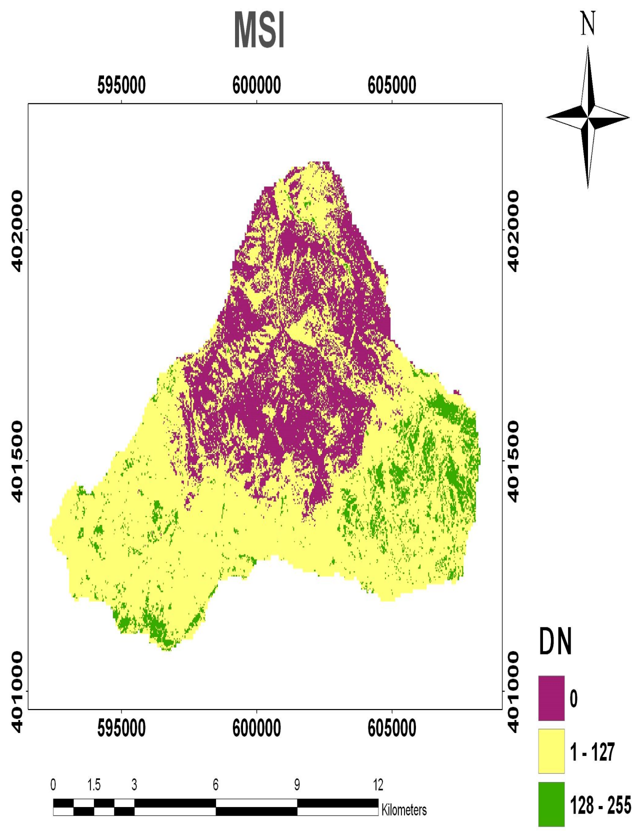
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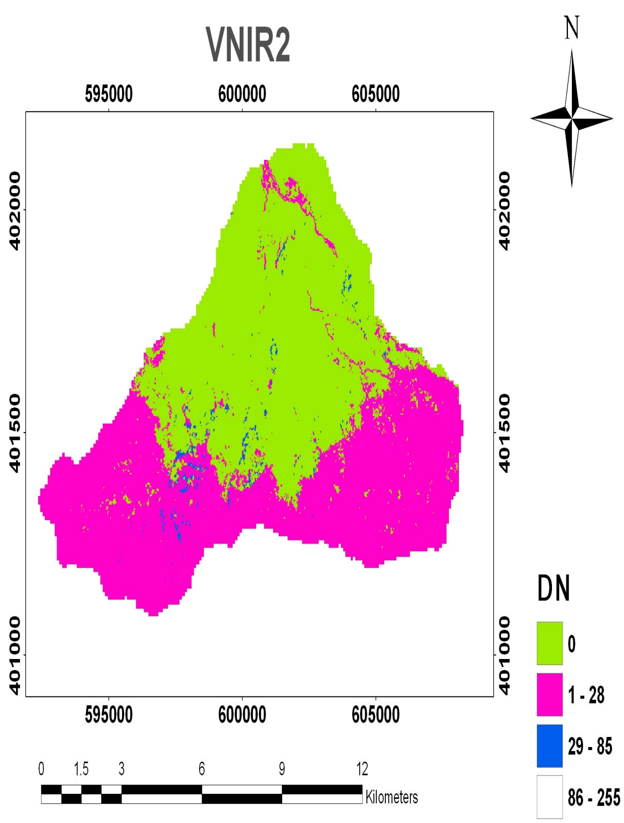
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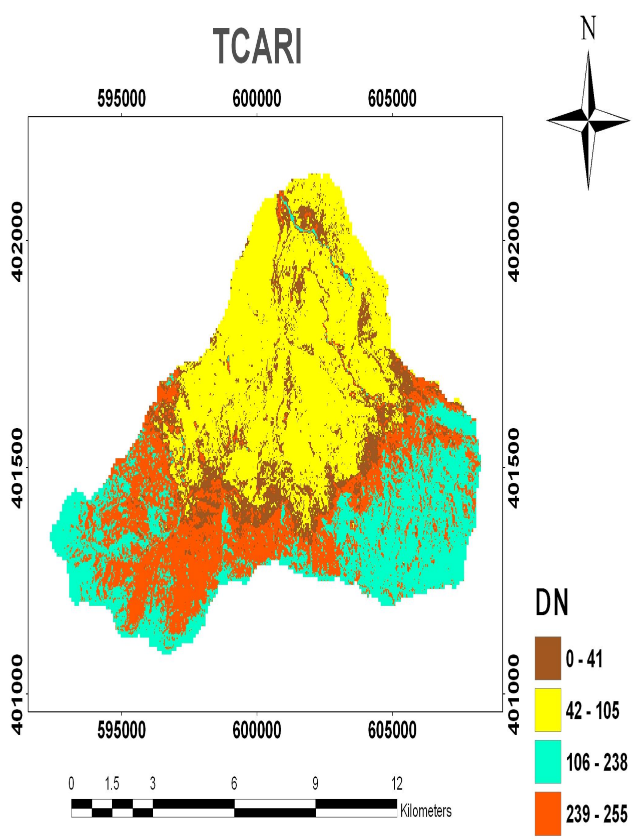
TCARI
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DN
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106 - 238
239 - 255
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Kilometers

Discussion and Conclusion

Landsat ETM+ enabled the generation of a detailed land cover indices with emphasis on vegetation and the separation of different surface cover intensity levels in rangelands of the upper Vazroud Watershed in northern flank of Alborz range, Iran. A precise vegetation cover map for rangelands managing can be produced with relatively little endeavor in areas that are difficult to access. Although problems remain with respect to validation of land cover classifications, the present study gives insight into land-use patterns and intensity levels which had so far not been available. The procedure we have chosen was optimal for the geographic constraints present in the study area. However, the key to an improved land cover product lies primarily in the sensor quality and repetition rate of the satellites. Upcoming sensor systems and satellite constellations will provide improved capability in near future.

Landsat ETM+ different bands have used in order to estimate the vegetation quantities parameter based on vegetation indices. The linear regression has conducted to examine the relationship between indices and vegetation quantities parameters. The gained result showed significant correlations between ETM+ bands and vegetation groups such as grasses, forbs, shrubs, and bushy trees. When compared separately for vegetation, the relationship was better in Ratio Vegetation Index (RVI) with the highest correlation for grasses canopy cover ($p<0.01$), which consists the red and near infrared bands with a reasonable estimation of plant cover. Moisture Stress Index (MSI) has the highest correlation for forbs canopy covers ($r = 0.62$), near infrared band, one of the components of this index has caused a significant relationship between forbs cover and index. In addition, plants on xerography were green and on the other hand forbs have high reflectance in comparison with the grasses and shrubs. Also, the angles of forbs leaves are more horizontal and larger than grasses and shrubs. However, for these reasons forbs expects to have more reflectance than the other vegetation groups. In addition, middle infrared band (1.55μm-1.75μm) used in the index that have ability to estimate plant cover. Absorption in spectrum area of the middle infrared band (1.55μm-1.75μm) related to the plant wetness, although the green covers have identified with high absorption and the lowest reflectance.

The used index of VNIR2 (near infrared) has showed maximum correlation for shrubs cover. This index equation is same as NDVI but in contrast of red band used green band which is intensive to chlorophyll rate. In addition, this band can display low amount of green covers. Vegetation indices were applied for vegetation parameters measurements using remote sensing data in arid areas and concluded similar result[33]. The used near infrared band in this index has indicated that the plant covers have the highest reflectance in this region. Transformed chlorophyll absorption reflectance index (TCARI) has the peak and significant relationship for bushy trees cover. ETM+ band 2 in this index has indicated the highest reflectance in (0.52μm-0.60μm) region. This band has designed for the plant vigor and peak reflectance measurement. Band 3 of the same sensor is also involved in this index, which is sensitive to the soil surface lightness and is also able to plant cover approximation in high precision level[34].

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