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Research and Full Length Article:

A Total Ratio of Vegetation Index (TRVI) for Shrubs Sparse Cover Delineating in Open Woodland

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Abstract. Persian juniper and Pistachio are grown in low density in the rangelands of North-East of Iran. These rangelands are populated by evergreen conifers, which are widespread and present at low-density and sparse shrub of pistachio in Iran, that are not only environmentally but also genetically essential as seed sources for pistachio improvement in orchards. Rangelands offer excellent opportunities for remote-sensing-based inventories; detection of each shrub using very high-resolution satellite data is typically easier in sparse rangelands where the distance between shrubs exceeds the height of trees. In this study, the densities of juniper and natural pistachio shrubs were estimated using remote sensing to help the sustainable management and production of pistachio in this rangeland. Satellite imagery was acquired in July 2008 by Advanced Land Observing Satellite (ALOS). A vegetation index including Total Ratio Vegetation Index (TRVI) was introduced for these rangelands with sparse shrub cover, and the relationship between the new index and shrub density was investigated by the data of ALOS using 3×3 and 5×5 maximum filtering algorithms in the summer of 2011. The results showed that the distinguishing and estimating of tree density in such an open woodland using maximum filtering 3×3 filtering algorithms were more effective than filtering on ALOS satellite imageries.

Key words: Open woodland, Total Ratio Vegetation Index (TRVI), Maximum filtering algorithms 3x3 and 5x5

Introduction

Rangeland areas of northeastern Iran cover about 3.4 million ha (FAO, 1992), and contain two main shrub species involving the broadleaf (pistachio) and the conifer (Persian juniper), which are found at different elevations.

Rangelands including open woodlands are an area with the density about 150 shrubs per hectare (Andrew and Fisher, 1996). Junipers are found from Turkey to Afghanistan as well as East and South of Iran (Fisher and Andrew, 1995) and at elevations ranging from 1500 to 2900 m a.s.l., they have a wide distribution in the rangeland. In Pakistan where it is fairly common, forming open forests was also found in Baluchistan and in inner dry valleys of the Himalayas between 1200 and 4000 m a.s.l. (Andrew and Fisher, 1996). However, the climate at these altitudes may be slight for the survival of Persian juniper, and even slight increases in climatic stress could hazard the present status of these woodlands (Fisher and Andrew, 1995).

Pistachio trees have been domesticated and cultivated about for 3000–4000 years in Iran. Currently, Iran is the largest producer of pistachio in the world, followed by the United States where the most pistachio production is in California. Natural stands of pistachio in Iran are important not only environmentally but also genetically as an important seed resource for pistachio production for the improved new varieties in orchards. In addition, natural pistachio stands which are managed by the Natural Resource Organization of Iran provide rural residents with opportunities to get an extra income by participating in harvesting.

Rangelands offer excellent opportunities for remote-sensing-based inventories; detection of each shrub using very high-resolution satellite data is typically easier in sparse rangelands where the distance between shrubs exceeds the tree height (Ozdemir, 2008).

In Iran, inventories of open woodland in the rangeland are based on transect sampling methods using GPS, and last stand parameters are derived by statistical extrapolation (Zobeiry, 2002). Totally, inventory is hard and requires much funds, time and labor even with the use of GPS. By remotely sensed data, inventories in arid and semi-arid areas can become more cost-effective, less time-consuming and less labor-intensive (Fadaei and Kolahi, 2008).

There are many practical methods for identifying or counting shrubs by aerial photographs or satellite images (Zhao *et al.*, 2016). A variety of algorithms has been proposed and developed for automatic individual tree-crown identification and delineation with increasing availability of large-scale high-resolution imagery. The local maxima method is one algorithm which searches for the “top” of a convex mound corresponding to the sun-lit top of a tree (Brandtberg *et al.*, 2003), that is commonly an identification tool used for tree census. As one of the simplest methods for shrub detection, the local-maxima approach can be applied to relatively coarse-scale imagery, where the pixel size is not smaller than the size of an individual shrub (Brandtberg *et al.*, 2003). In early versions of the method, Blazquez (1989) developed an individual shrub counting algorithm for citrus shrubs in Florida using digital aerial color-infrared photographs. As a recent example, Gougeon and Donahd (2006) gave the first assessment of the effects of 1- and 4-meter pixel spatial resolutions (panchromatic and multispectral bands, respectively) on the detection, delineation and classification of individual shrub crowns in Ikonos images.

Investigating the relationships between the amount of green vegetation cover and vegetation indices derived from spectral reflectance measurements using ground-simulating Advanced Very High Resolution Radiometer (AVHRR)

data, and evaluated the performance of vegetation indices for estimating grassland vegetation cover (Purevdorj *et al.*, 1998). With individual shrub information extracted from remotely-sensed data, biogeochemistry models can be parameterized to scale up from individual shrubs to landscapes to make clear various ecological processes (Chen *et al.*, 2006). For statistical analyses and image classification, eight vegetation indices have been developed based on reflectance factors calculated as the responses of Landsat instruments (Zhao *et al.*, 2016).

The purpose of the present study was to find the shrub density of natural pistachio and Persian juniper stands using remotely sensed data, especially Advanced Land Observing Satellite (ALOS) data to help the sustainable management and effective production of these rangelands in North-East of Iran.

Materials and Methods

Study area

Juniper area

The Persian Juniper shrubs are found naturally in the north-eastern rangeland of Iran (Fig. 1). The annual precipitation is 156 mm (Fadaei *et al.*, 2009; Gintzburger *et al.*, 2006) and the study site covers 15.21 km² (3.9×3.9km) between 37°20'31.19"–37°18'22.30"N and 58°49'59.13"–58°52'34.40"E. The elevation is 700–900 m and the slope ranges from 21 to 27 degrees (Fig. 1).

Among 169 grids (300m×300m) in a 13×13 arrangement, 12 sampling plots were randomly chosen for the analysis

(relationship between number and TRVI) (Fig. 2).

Pistachio area

The study site was in an arid area in the North-East of Iran where pistachio shrubs grow wildly. The annual precipitation is 200–300 mm (Gintzburger *et al.*, 2006) (Fig. 1). The site was 15.21 km² (3.9×3.9 km) with latitudinal and longitudinal ranges of 36°17'2.60"–36°7'2.09"N and 60°30'21.91"–60°30'18.22"E. Natural pistachio shrubs occur mostly at elevations of 900–1500 m, and the elevation of the study site was 500–1200 m. The slope of the site generally ranged from 15 to 35 degrees. Among 169 grids (300m×300m) in a 13×13 arrangement, 15 sampling plots were randomly chosen for the analysis (Fig. 2). Wild pistachio shrubs at the study site were typically 3–4 m high with the crown diameters of 3–5 m.

These rangelands were sparse and the shrubs were widely spaced. The distance between two pistachio shrubs was often more than 3 m, and these gaps contained the shrubs such as *Amygdalus spinosissima*, *Atraphaxis spinosa*, *Cerasus pseud prostrata*, *Ephedra intermedia*, *Tamarix androssowii*, and *Zygophyllum eurypterum* adapted to dry terrain. Soil salinity at the study site measured by the Natural Resources Organization of Iran was 0.6–20 mmhos/cm (U.S. Salinity Laboratory Staff, 1969) indicating that the site arranges from non-saline to strongly saline.

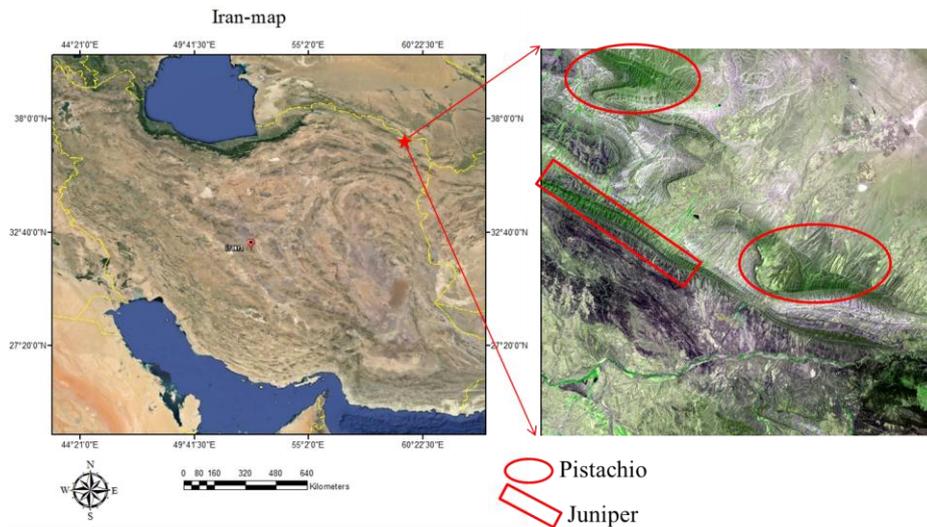


Fig. 1. Locations of the study areas in northeast of Iran and the locations of pistachio and juniper shrubs at different places and different elevations above sea level (1000-1500m)

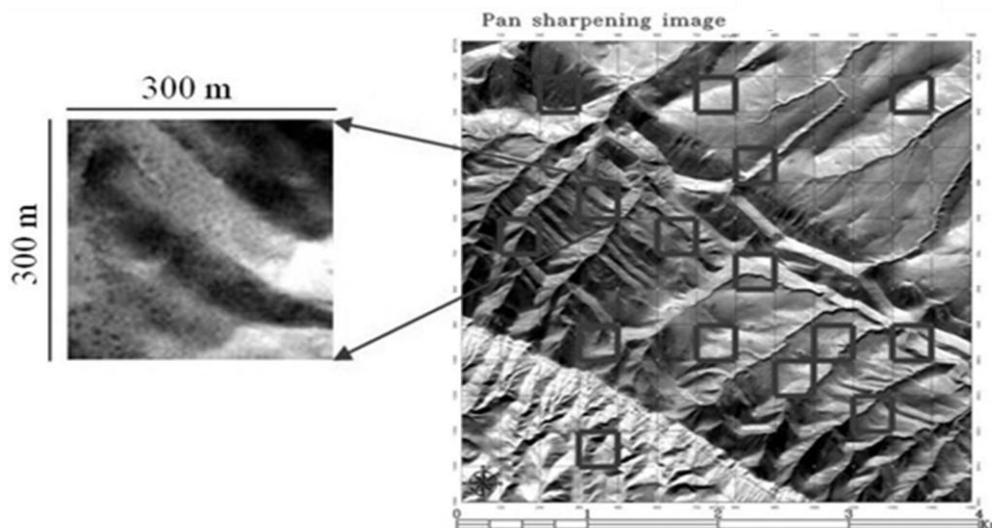


Fig. 2. Arrangement of the 9-ha sampling plots. The 15 highlighted plots randomly chosen for analysis

Image data

We used satellite imagery that was acquired in July 2008 by ALOS. ALOS data have a good resolution in the panchromatic and multispectral bands which are for the study area and are relatively inexpensive. Among three remote-sensing instruments on-board ALOS, the Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) and the Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2) were used for digital elevation mapping

and precise land coverage observations, respectively. PRISM is a panchromatic radiometer with 2.5-m spatial resolution at nadir and has one band with a wavelength of 0.52–0.77 μm (JAXA EORC). AVNIR-2 is a visible and near infrared radiometer for observing land and coastal zones with a 10-m spatial resolution at nadir and has four multispectral bands: blue (0.42–0.50 μm), green (0.52–0.60 μm), red (0.61–0.69 μm) and near infrared (0.76–0.89 μm) (JAXA EORC) (Fig. 3).

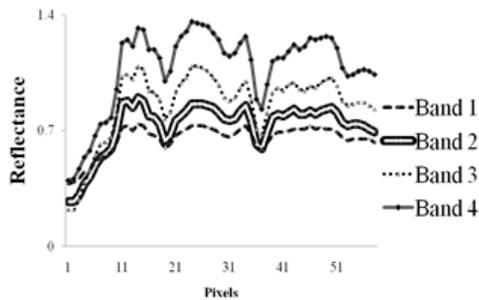


Fig. 3. Multispectral reflectance in rangeland areas from the study site by ALOS data

Total Ratio of Vegetation Index (TRVI)

We applied the local-maxima approach to find the shrub density of natural pistachio and Persian juniper stands, and this led us to propose a new vegetation index called the Total Ratio of Vegetation Index (TRVI) which is more efficient for arid and semi-arid rangelands. TRVI has been evaluated with other convolutional vegetation indices such as Normalized Difference Vegetation Index (NDVI), Soil-adjusted Vegetation Index (SAVI), Modified Soil-adjusted Vegetation Index (MSAVI), and Optimization of Soil-Adjusted Vegetation Indices (OSAVI). The results for the pistachio forest showed the regression coefficients of NDVI, SAVI, MSAVI, OSAVI and TRVI ($R^2 = 0.68, 0.67, 0.68, 0.68, \text{ and } 0.71$). The results for juniper forest showed the regression coefficients of NDVI, SAVI, MSAVI, OSAVI and TRVI ($R^2 = 0.51, 0.52, 0.51, 0.52, \text{ and } 0.56$) (Fadaei *et al.*, 2012; Huete and Jackson, 1987; Huete *et al.*, 1985; Richardson and Wiegand, 1990; Roller, 1973; Rouse *et al.*, 1974).

In rangeland, soil background has more reflectance in the Near Infrared (NIR) and red (RED) wavelengths of vegetation. Soil components that affect the spectral reflectance include color, roughness, and water content. The effect of surface roughness due to an increase in multiple scattering and shading caused the decreased reflectance. RED-NIR scattergrams termed the “soil lines” are used as a reference point in the most

vegetation studies. The problem is that real soil surfaces are not homogeneous and contain a composite of several types. Analysis has shown that for a given soil characteristic, variability in one wavelength has been often functionally related to reflectance in another wavelength. Vegetation sparse cover is usually compared to soil background and soil and plant spectral signatures tend to be mixed non-linearly. Thus, arid plants tend to lack the strong red edge found related to the plants of humid regions due to ecological adaptations to the harsh desert environment. Photosynthetically active radiation absorbed by vegetation absorbs most of the red band while reflecting much of the NIR band. In contrast, vegetation that is dead or stressed reflects redder region and less NIR region. Similarly, non-vegetated surfaces have much more reflectance across the light spectrum (Fig. 4) (Colwell, 1974).

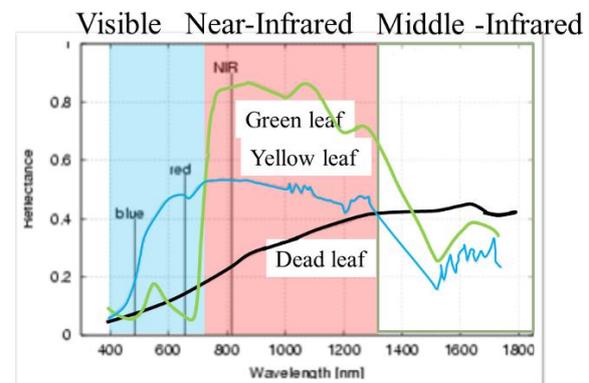


Fig. 4. Different vegetations have different reflectance properties (Colwell, 1974)

Given these observations, we decided to apply a vegetation index based on the total wavelength (visible and NIR). It is calculated using the following equation (Fadaei *et al.*, 2012) (Equation 1):

$$TRVI = 4 \left(\frac{NIR - RED}{(NIR + RED + G + B)} \right) \quad (\text{Eq. 1})$$

Where: RED= spectral reflectance measurements in red (0.61–0.69 μm)
NIR= near-infrared regions (0.76–0.89 μm)

G= Green band (0.52–0.60 μm)
 B=Blue band (0.42–0.50 μm)
 “4”= the measured reflectance.

The normalized difference is divided by the total of visible and near infrared wavelengths.

In fact, this equation expresses the ratio of normalized difference of reflectance and measured reflectance of all bands; in other words, the four bands in the multispectral image of AVNIR-2 are as follows:

Band 1 is a blue that is 0.460 μm ,
 Band 2 is green that is 0.560 μm ,
 Band 3 is a red that is 0.650 μm ,
 Band 4 is near-infrared that is 0.825 μm wavelengths.

Shrub counting

We located the center and corners of each 9-ha plot based on satellite imagery using a GPS device. Then, starting from a plot corner, we measured the densities of juniper and pistachio shrubs on all the plots. This was done in cooperation with

the regional natural resource organization of Khorasan-e-Razavi province (Fig. 2).

Satellite image processing

In this case, after image pre-processing, threshold TRVI values were computed for each pixel. Land cover was then classified into three categories depending on two images (pan sharpening and vegetation index image (TRVI image); Figs. 5 and 6).

The TRVI thresholds used to find land covers were previously obtained as follows. First, the extracted Digital Numbers (DN) for each plot were imported to Microsoft Excel. Then, Visual Basic macro was used to find the best combination threshold and the calculated number of shrubs in a plot. Subsequently, the simple linear coefficient regression between the number of pistachio or juniper shrubs was recorded during field surveys and the spectral values for pistachio and juniper shrubs in all plots from vegetation indices based on maximum filtering (3 \times 3 and 5 \times 5 for pistachio, 5 \times 5 for juniper).

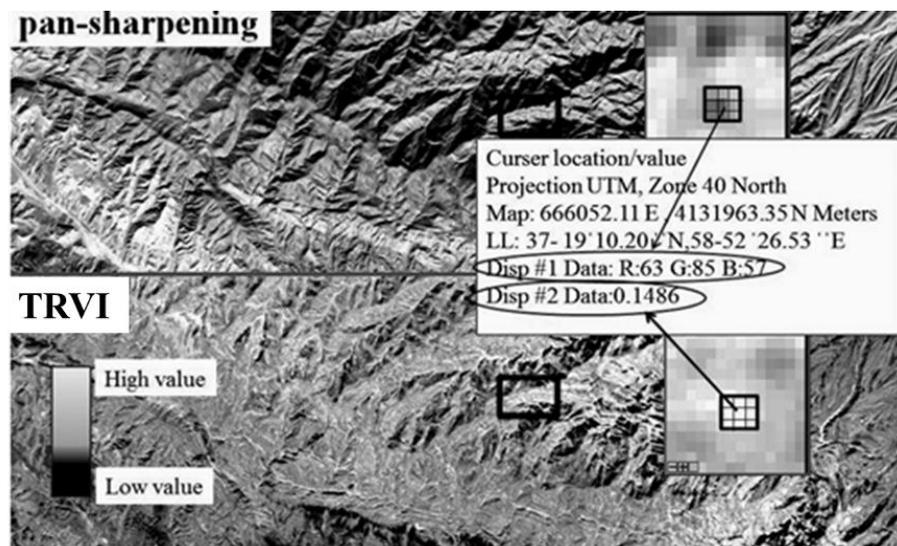


Fig. 5. Identifying TRVI thresholds value and top of shrubs

Pistachio shrub

As illustrated in Fig. 6, the first class with a high value was grassland and sand; the second class with a median value was the pistachio area; the third one with a low

DN value was the area in shadow. For example, in the TRVI, there were high values from 0 to 0.439 for grassland and sand, medium values of 0–0.247 for

pistachio areas, and low values from -0.008 to 0.06 for shadow (Fig. 6).

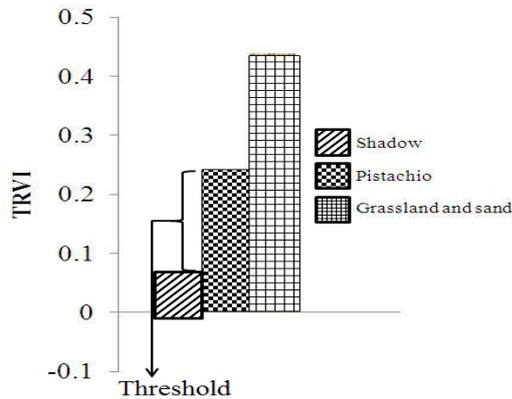


Fig. 6. Distribution of pistachio areas based on the spectral value of TRVI vegetation index

Persian juniper

The TRVI had high values from 0 to 0.49 for grassland and sand, and medium values from 0.11 to 0.29 in the areas of juniper; the third class with low spectral values (-0.02–0.11) was a shadow (Fig. 7).

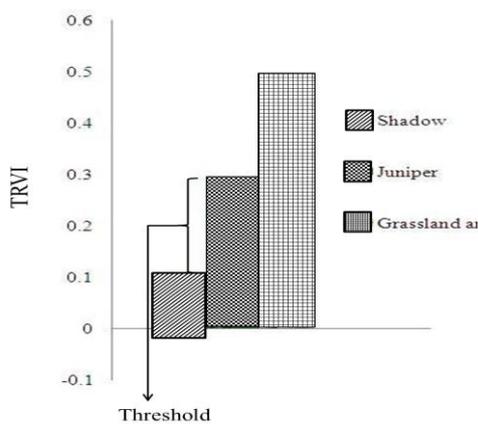


Fig. 7. Distribution of areas in a juniper rangeland based on the spectral value of TRVI

Data analysis

Linear regression coefficients were calculated between shrub density and vegetation index values. Shrubs density for each plot was obtained from the field surveys. Vegetation index was calculated using ALOS satellite data for each 9-ha plot (14400 data points). Subsequently, maximum filtering algorithms of 3×3 and 5×5 were used for vegetation index data from each plot to find the optimum maximum spectral value for pistachio and

juniper shrubs. Frequency results for 3×3 and 5×5 maximum filtering of vegetation indices were calculated from each plot. Finally, simple linear regressions between shrub density and vegetation index values were calculated based on the best threshold vegetation index values. All of these analyses were performed using ENVI (Environment for Visualizing Images) software and Microsoft Excel 2007.

Results and Discussion

Pistachio shrub

TRVI vs. shrub density (3×3 maximum filtering algorithm)

A simple linear regression between values of the new vegetation index and shrub density based on the 3×3 maximum filtering algorithm was calculated. There was a positive relationship between TRVI and shrub density with $R^2=0.71$. The maximum filtering algorithm has been applied by the 3×3 pixel to solve the mixed problem of pixel.

TRVI vs. shrub density (5×5 maximum filtering algorithm)

A simple linear regression between the new TRVI and shrub density based on the 5×5 maximum filtering algorithm was calculated. There was a positive relationship between TRVI and shrub density, with $R^2=0.74$. Soil and sand are typically highly reflective in the visible, NIR, and mid-IR wavelengths, and soil background has a large part of the pixel reflectance attributed to the sparse vegetation cover (Todd *et al.*, 1998) because of poor reflectance in the NIR and RED from a large area.

Persian juniper

TRVI vs. shrub density (5×5 maximum filtering algorithm)

Linear regression was performed in order to determine the correlation coefficient (R^2) between vegetation index and tree density. There was a significant Positive relationship between the vegetation index and juniper shrub density ($R^2=0.56$); with

the increase of the dense vegetation, the TRVI was increased.

In arid and semi-arid rangelands, vegetation indices could not be able to show significantly strong differences due to poor reflectance in the NIR and RED wavelengths. Standard vegetation indices are based on NIR and RED wavelengths, and their values are low. TRVI for arid and semi-arid regions, however, is based on all wavelengths (visible and NIR); it is thereby more applicable for sparse rangelands with small shrubs. A linear regression between ground cover (grassland and juniper shrub) and vegetation index was estimated, and a negative relationship was found.

This can be explained by the fact that photosynthetically active radiation absorbed by vegetation was done more at the RED band than the NIR band. Vegetation that is dead or stressed reflects more RED and less NIR. Likewise, non-vegetated surfaces have much more reflectance across the light spectrum. Vegetation cover is usually sparse as compared to the soil background showing that soil and plant spectral signatures tend to be mixed non-linearly. In recent studies, the estimation of canopy cover with remotely sensed data revealed to be a challenge in arid and semiarid rangelands (Gill *et al.*, 2017). This is in particular due to the spectral reflectance of bright and often saline soils mixed with sparse vegetation cover and small scale shadow effects. The soil background effect is an important element in sparse vegetated areas (Purevorj *et al.*, 1998).

Conclusion

In this study, we find pistachio and juniper density shrubs to help monitoring in an open woodland in Iran using two window sizes of 3×3 and 5×5 maximum filtering algorithms. We present a new vegetation index (TRVI) for this kind based on the full spectrum of wavelengths. Results showed the utility

of the ALOS products in providing useful spectral information for arid sparsely rangeland characterization. One limitation of this research is the method used to distinguish shrubs from other forms of vegetation. The best algorithm has been selected for determining the spectral values of pistachio and juniper by applying the maximum filtering algorithm. The relationships derived between the number of pistachio or juniper shrubs and TRVI were all positive for green biomass. The maximum filtering algorithm was found to be useful for sparse shrubs in rangelands. The 3×3 maximum filtering algorithm was found to be the most appropriate tool for the studied area due to the spectral values obtained for pistachio shrub. Spectral values from the 5×5 maximum filtering algorithm had limitations in reflectance attributed to soil background leading to low spectral values because higher spectral values found over all the 3×3 filter size examined are necessary to avoid soil surface. The new vegetation index (TRVI) provides the ability to produce fidelity measurements in arid and semi-arid areas. Further studies are needed to evaluate this vegetation index against conventional vegetation indices. It should be necessary to investigate the effects of Persian juniper chemical emissions (Mehdi *et al.*, 2012). In this situation, arid and semi-arid rangelands have special adaptations for water and thermal stress which may be a key to extract vegetation cover using hyperspectral wavelengths.

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شاخص جدید نسبت پوشش گیاهی کل (TRVI) برای تخمین پوشش درختچه-های تنک

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چکیده. مراتع شمال مشرق ایران رویشگاه طبیعی ارس و پسته است. در این مراتع از گیاهان پهن برگ (پسته) و سوزنی برگان (درختچه‌های ارس) به صورت گسترده ولی با پراکنش کم رویش دارند. درختچه‌های پسته نه تنها از لحاظ زیست محیطی بلکه از نظر ژنتیکی به عنوان ذخیره‌گاهی برای اصلاح و تهیه نهال و بذر پسته در باغات کشور اهمیت دارند. در مراتع مشجر امکان استفاده از سنجش از دور مبتنی بر آماربرداری فراهم می‌باشد. در این مراتع، چون فاصله بین درختان از ارتفاع آنها بیشتر است، تشخیص آنها با دقت بالا امکان پذیر می‌باشد. در این مطالعه، با استفاده از سنجش از دور در راستای کمک به مدیریت پایدار مراتع مشجر، نسبت به بررسی تراکم درختچه‌های ارس و پسته در رویشگاه طبیعی آنها پرداخته شد. تصاویر ماهواره زمینی ALOS در تیر ماه ۱۳۸۶ دریافت شد و از شاخص پوشش گیاهی نسبت کل (TRVI) به عنوان شاخص جدیدی برای پوشش گیاهی مراتع مشجر با درختچه‌های پراکنده، معرفی گردید. رابطه رگرسیونی بین شاخص گیاهی (TRVI) و تراکم درختچه‌ها با استفاده از الگوریتم فیلتر حداکثر 3×3 و 5×5 از طریق سنجنده چند طیفی AVNIR-2 محاسبه شد. نتایج نشان داد که در مراتع مشجر مذکور فیلتر حداکثری 5×5 عملکرد قابل توجهی در شناسایی دقیق داده‌های ماهواره ALOS داشت.

کلمات کلیدی: درختچه‌های تنک، شاخص نسبت کل پوشش گیاهی (TRVI)، فیلترینگ حداکثری

3×3 و 5×5