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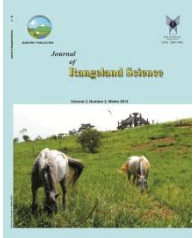

Full Length Article:

Presentation of Suitable Model to Estimate Vegetation Fraction Using Satellite Images in Arid Region (Case Study: Sadough-Yazd, Iran)

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Abstract. One of the influential tools concerning the rangeland and vegetation sciences is the technology of remote sensing and satellite data. Satellite data have played essential roles in preparing the needed information for studying the vegetation. Vegetation has been widely recognized as one of the best indicators for determining the land conditions. Using vegetation indices is one of the techniques of remote sensing to study the vegetation. The purpose of this research is to study the vegetation indices and also provide an appropriate mathematical model for estimating the vegetation fraction using the mentioned indicators. In this research, different vegetation indices were calculated by Landsat TM (2006) satellite images in order to evaluate their capability to estimate the vegetation in the arid regions. At the outset, vegetation fraction was measured using the sample quadrates and then the measured data were compared with the values of digital numbers for the site pixels. Multiple regression analysis was utilized for the actual values and parameters to select the validation and optimization models. Indices which have been calculated include MSR, DVI, TRVI, SARVI, SR, RDVI, DVI, NDVI, SAVI, ARVI and MSAVI. The results showed that the model in which ARVI was used had the highest accuracy (R^2=0.86) and therefore, it was chosen as the most suitable model for the estimation of vegetation fraction in the study area. One accomplishment of the above results is to suggest some mathematical equations with those indices to estimate the amount of vegetation. These results provide a strong foundation for the use of some vegetation indices for assessing the vegetation cover in central Iran.

Key words: Vegetation, Satellite image, Vegetation index, Arid regions, Sadough region

1. Introduction

Much of the country's renewable natural resources may be altered with a regressive trend due to the lack of proper management and optimum utilization (Ebrahimi *et al*., 2011). Due to incorrect recognition and lack of adequate information, these resources face with the planning and management constraints; consequently, accurate data and comprehensive information are required for the planning and proper utilization of natural resources' potentials.

In addition, multiple use of vegetation is necessary for proper management which refers to the soil and water conservation, decreased soil erosion and increased vegetation as well as increased income. Vegetation indices derived from satellite data are one of the primary sources of information for the operational monitoring of the earth vegetative and remote sensing technology can be used to investigate the vegetation of the arid region. Using satellite data provides a more exhaustive study on vegetation (Gilabert *et al*., 2002). However, most of the widely used vegetation indices are inappropriate for the arid and semi-arid areas of Iran where annual and perennial plant species are dominant. These plants often lack the contrast between red and infrared reflectance upon which the common vegetation spectral indices are based while making them difficult to distinguish from red-colored soils. Several multi-spectral indices that place less emphasis on vegetation's infrared response are more appropriate and have been widely used in the arid and semi-arid rangelands (Foran and Pickup, 1997; Pickup and Nelson, 1984; Pickup and Foran, 1987; Pickup *et al*., 1998; McGregor and Lewis, 1996). Approximately, all the rangelands are grazed by domestic livestock in central part of Iran.

The electromagnetic spectrum is a sequence of energies among which the long wavelength varies from nanometers to several meters (Booth and Tueller, 2003; Bastin and Ludwig, 2006; Wallace *et al*., 2006; Jafari *et al*., 2007; Hobbs, 1995). The main source is the sunlight which passes through the atmosphere and then strikes the vegetation, water and soil (Graetz, 1987; Tueller, 1987; Pickup, 1989; Apan, 1997). Kar (1980) introduced PVI[1] and SAVI[2] as suitable indices for estimating the desired values. Brena *et al*. (1995a) stated that SAVI, MSAVI[3] and TSAVI[4] were suitable. Brena (1995b) noted that PVI was appropriate in measuring the density of the species. Haijiang *et al.* (2008) used the TSAVI and ARVI[5] in estimating the range species. Ebrahimi *et al*. (2011) provided a model for estimating the vegetation in which MSAVI had the most impacts on the estimation of vegetation fraction. Joshi and Sahai (1993) reported that among several vegetation indices, NDVI[6] and AVI[7] were the global vegetation indices which have an appropriate application to provide spatial and temporal vegetation data. Friedel and Shaw (1997) stated that PVI and SAVI were not affected by soil properties; thus, they are suitable for estimating the vegetation parameters. Wilson *et al*. (1997) studied the vegetation rate and changes using TM and ETM+ images. Five indices involving NDVI, AVI, NRVI[8], PVI and SAVI were applied and according to the results, NDVI was recommended as the best index for providing the vegetation map. This index had also a correlation of 0.28 (r=0.28) with the plant cover in a study performed by Arzani (1998). The explanation should be searched considering the strong reflection of plant cover within the limit of band 3 of Aster gauge. Also, Khajedeen (1995) in his study in Jazmooriyan, Iran introduced ARVI index as the only

[1] Perpendicular Vegetation Index
[2] Soil-Adjusted Vegetation Index
[3] Modified Soil-Adjusted Vegetation Indices
[4] Transformed Soil-Adjusted Vegetation Index
[5] Atmospherically Resistant VI
[6] Normalized Difference Vegetation Index
[7] Ashburn Vegetation Index
[8] Normalized Ratio Vegetation Index

suitable index for the study of plant cover in the region. The results presented by Sepehri (2003) also showed that in the regions with high plant cover percentage, this index is correlated with the plant cover. Zahedifar (2002) suggested that ARVI had a meaningful correlation with the plant cover percentage (R^2=83%) although the plant cover rate was low. But Farzadmehr *et al*. (2004) in a study performed in Semirom region, Iran have estimated the correlation of NDVI index and plant cover data ($P<0.05$). Moleele *et al*. (2001) also estimated the correlation of ARVI index and the bush herbaceous biomass in semi-arid ranges of Botswana ($P<0.05$).

Jianlong (1998) and also Told *et al*. (1998) provided similar results. For the preparation of the plant cover map of Kalahurd, Sadeghi (2009) employed the Aster Satellite data. The results of this research also showed that only NDVI index had a meaningful relationship with the plant cover crown percentage. This was supported by Schmidt and Karnelli (2001) as well as Sellers *et al*. (1999). In a study done by Abdollahi *et al.* (2008), no meaningful regression relationship between the plant indices and plant cover percentage was obtained.

This research aims to present a suitable model for estimating the vegetation fraction using satellite images in the arid region of Sadough, Iran.

2. Materials and Methods

Sadough city with the area of 5466 km^2 is located in the northwest of Yazd province, 20 Km far from the northwest of Yazd. It lays between the longitude of 53 and 54. Sadough is one of the cities of Yazd province located in central Iran. Location of the study area is presented in (Fig. 1).

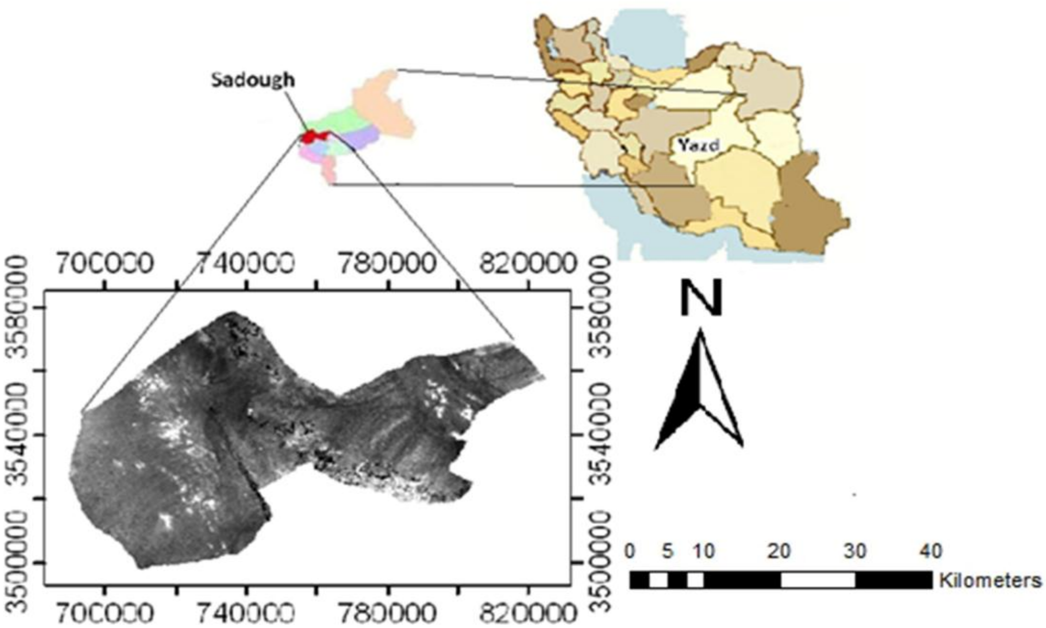

Fig. 1. Location of the study area

Studies have shown that vegetation indices and spectral measurements could serve as a useful approach in this regard. TM (2006) satellite images were used in this study. GPS was utilized for field visits and image processing was performed by PCI-Geomatica$_{8.1}$, ENVI$_{4.2}$ and Arc GIS $_{9.3}$ software. Regression analysis has been conducted by $SPSS_{16}$ software and backward method. In order to calculate the percentage of vegetation in each plot of 75 x 75 m, the percentage of vegetation was determined by the area covered by the plants. Finally, the average of 1 m^2 plots has been taken out as the cover percentage per plot of 75 x 75 m. In regression analysis, the data set was considered as the dependent variable and the indices obtained from satellite images were considered as independent variables in backward method. In real environments, samples and satellite images of vegetation indices have given the vegetation fraction of total region. By selecting the ground points on the reference images and the corresponding points on raw images, the quadratic equation and re-sampling method were chosen (Price *et al.*, 2002).

Field measurements were performed to determine the relationship between vegetation fraction and the indices obtained from satellite images. Therefore, correlation and regression were made between vegetation fraction of the study area and vegetation indices to obtain suitable satellite images of the model. In order to measure vegetation fraction, 35 plots were used in this study. These plots with a good distribution are presented in (Fig. 2).

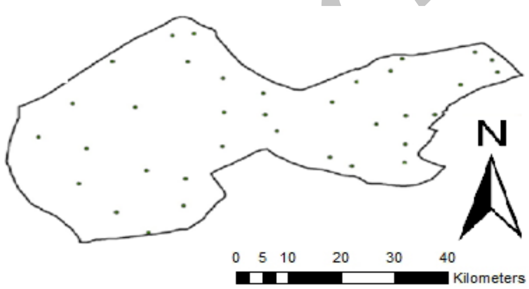

Fig. 2. Distribution of the plots in the study area

Presented figure was recorded by digital sensors in the first stage using formula 1 (O'Neill, 1996) as follows:

$$L = Lmin + \left({(L_{max} - L_{\min})}/{1023} \right) \quad (1)$$

In the formula of L-valve sensor spectral irradiance, L_{max} and L_{min} are scanner parameters and DN is the pixel value of the digital. The radiation spectrum has been regarded and then, it was utilized to propose the formula 2 (Told *et al.*, 1998):

$$P = \frac{\pi . L . d2}{ESUN . COS(S_Z)} \quad (2)$$

Where:
P= Spectral Reflectance
π= Unit less planetary reflectance
L= Spectral radiance
d= Earth-Sun distance in astronomical units
ESUN= Mean solar exo-atmospheric irradiances
S_z = Solar zenith angle

Afterwards, spectral reflectance was calculated. Then, the value of corresponding points of field sampling was extracted by applying a mean filter on the images. For modeling, all indicators based on infrared and near-infrared bands were used. Different vegetation indices were calculated by applying the satellite single-bands and formulas. The corresponding spectral reflection of all sampling points in natural and artificial bands was extracted to estimate the regression models. Then, the desired coefficients and regression models were calculated with regard to the components of vegetation fraction and all natural and artificial bands using SPSS software.

The models have been validated based upon the corrected values of the coefficient of determination and the standard error. Then, the statistics of field control points and estimated amounts of vegetation fraction for the corresponding points were compared to determine the model. Finally, the map of vegetation fraction was prepared by fitting the best model to the bands. Indices and their relationship are given in (Table 1).

Table 1. Indices formula

Indices	Formula	Refrence
ARVI	$R_{NIR} - (R_{RED} - 1 * (R_{BLUE} - R_{RED})) / R_{NIR} + (R_{RED} - 1 * (R_{BLUE} - R_{RED}))$	Kamrs *et al*. (2002)
MSR	$(R_{NIR}/R_{RED}) - 1 / SQRT((R_{NIR}/R_{RED}) + 1)$	Person and Miller, (1972)
DVI	$R_{RED} - R_{NIR}$	Hom, (2004)
TRVI	$(0.5 \times (120 \times (R_{RED} - R_{BLUE}))) - (200 \times (R_{NIR} - R_{BLUE}))$	Baret and Guyot, (1991)
SARVI	$(1 + 0.5) \times (R_{NIR} - ((R_{RED} - 1) \times (R_{BLUE} - R_{RED}))) / (R_{NIR} + ((R_{RED} - 1) \times (R_{BLU}$	Jimin *et al.* (2005)
SR	$R_{NIR} - R_{RED}$	Richardson and Wiegand, (1997)
RDVI	$(R_{NIR} - R_{RED}) / SQRT(R_{NIR} + R_{RED})$	Gilabert *et al*. (2002)
DVI	$2 \times ((R_{NIR} - R_{RED}) - (R_{GREEN} - R_{BLUE}))$	Graetz, (1987)
NDVI	$(R_{NIR} - R_{RED}) / (R_{NIR} + R_{RED})$	Rouse *et al*. (1974)
SAVI	$1.5 \times (R_{NIR} - R_{RED}) / (R_{NIR} + R_{RED} + 0.5)$	Hobbs, (1995)
MSAVI	$2 \times (R_{NIR} + 1) - (SQRT((2 \times R_{NIR}) + 1)^2)) - 8 \times (R_{NIR} - R_{RED}) / 2$	Price *et al.* (2002)

ARVI= *Atmospherically Resistant Vegetation Index*
MSR= *Modified Simple Ratio*
DVI= *Difference Vegetation Index*
TRVI= *Total Ratio Vegetation Index*
SARVI= *Soil Adjusted Ratio Vegetation Index*
SR= *Simple Ratio*
RDVI= *Renormalized Difference Vegetation Index*
DVI= *Difference Vegetation Index*
NDVI= *Normalized Difference Vegetation Index*
SAVI= *Soil Adjusted Vegetation Index*
MSAVI= *Modified Soil Adjusted Vegetation Index*
R_{NIR}=*Near IR band*
R_{RED}= *RED band*
R_{BLUE}= *BLUE band*
R_{GREEN}= *GREEN band*

3. Results

The models derived from the cross of vegetation fraction with vegetation indices, environmental factors and single-bands in experimental points are presented in (Table 2). Then, the obtained models were validated on the basis of higher F value, the lower standard error and higher coefficient of determination (Table 2).

Table 2. Models obtained in this study

Step	Models	R^2	F **	S.E
1	$190.118 + 1161.798\ \mathrm{ARVI} - 152733.319B4 - 668.809\ MSR + 920396.592\ DVI + 14712.879 - 11662.202\ TRVI$	0.821	13.42	0. 318
2	$208.539 + 1237.165\ \mathrm{ARVI} - 166257.241\mathrm{B}_4 - 743.840\mathrm{MSR} + 951742.120\mathrm{DV} - 11006.179\mathrm{TRVII}$	0.827	16.70	0.317
3	$110.161 + 811.620\mathrm{ARVI} - 89660.627\mathrm{B}_4 + 359178.889\mathrm{DVI} - 7420.743\mathrm{TRVI}$	0.832	20.76	0. 316
4	$83.945 + 622.287\mathrm{ARVI} - 11589.534\mathrm{B}_4 - 1835.606\mathrm{TRVI}$	0.835	26.87	0.315
5	$63.179 + 367.415\mathrm{ARVI} - 7190.826B_4$	0.836	40.49	0.315
6	$56.814 + 399.746\mathrm{ARVI}$	0.864	82.44**	0.314

ARVI= Atmospherically Resistant VI
$B4= R_{NIR}$
MSR= Modified Simple Ratio
DVI= Difference Vegetation Index
TRVI= Total Ratio Vegetation Index
**= Significant at a confidence level of 0.01

A curve was drawn on the basis of the observed values of the control points and estimated values. Fig. 3 shows a strong correlation (R^2=0.864) for this curve.

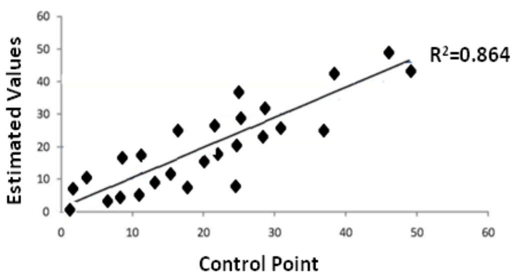

Fig. 3. The accuracy of the selected model

The vegetation map (the map of the vegetation fraction) was drawn by fitting the mentioned model to the bands (Fig. 4).

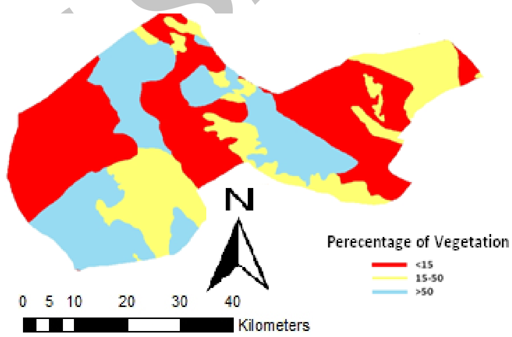

Fig. 4. Vegetation map (the map of vegetation fraction) obtained from satellite images

4. Discussion

According to the results, model 6 was identified as the best model for Sadough region due to the low standard error and high F value. Also, a high correlation (R^2=0.86) was found between the observed and estimated values. ARVI had the most influence on vegetation fraction of the region. Indices of NDVI, SARVI, MSAVI, MSR, DVI, SR, RDVI, TRVI, DVI and SAVI had less accuracy, respectively.

So far, many plant spectral indices had been introduced to study the conditions of quality and quantity specifications of plant cover. But the selection of the best index for quantity analysis of plant cover is one of the important problems for the users. In most similar researches, one index has been used as an independent variable. Therefore, in the arid and semi-arid regions, one appropriate index by itself can describe the plant cover of the region. ARVI index was the only index with a relatively higher relationship with the plant cover percentage which was related to the use of bands 2 and 3 in this index.

The results of the present study are in conformity with those reported by Arzani (1998) who had studied the vegetation indices. Khajedeen (1995) in his study in Jazmooriyan, Iran showed that ARVI was one of the most important indicators of vegetation to estimate vegetation percent. Sepehri (2003) introduced this index as the best index in the same region conducted a research by studying the current match. The results of study done by Apan (1997) indicated that the impacts on soil and vegetation percentage estimated by the means of ARVI index are similar with those proposed in this study. This study was consistent with the research results suggested by Zahedifar (2002) in Isfahan, Iran. This research did not match with the results of Farzadmehr *et al.* (2004) in which NDVI has estimated the vegetation index. The current study also was similar to the studied performed by Moleele *et al*. (2001), Hobbs (1995) and Sadeghi (2009). The results of their studies showed that the meaningfulness of the relationship of the total cover crown with the bands 2 and 3 of the gauge can be attributed to the high reflection of plant cover in Red and NIR regions which is therefore an acceptable result. Due to the effects of high reflection of the background soil and the percentage of annual and perennial grasses in plant composition in the arid and semi-arid regions, the correlation indices between the cover crown percentage and the plant indexes drops. Because of the low percentage of cover crown in the region under study (25%) and the prevailing effects of the background reflection as well as the nonlinear nature of relationships between spectral reflection and pant specifications, the correlation relationships have practically lower justification coefficients. This was supported by Schmidt and Karnelli (2001) as well as Sellers *et al*. (1999). The study results were different from those suggested by Pickup *et al*. (1998) who have studied vegetation indices in several dry areas.

One of the main objectives of this study was to identify vegetation indices that were the best predictors of vegetation cover in Sadough region in center of Iran. Criteria that make an image-based vegetation index suitable for the study of regional were of strong relationships with vegetation cover considering the vegetation types of the district and the ability to predict this cover within the semi-arid region. Simple red-infrared contrast indices, in particular ARVI can be widely used with success in the studies of arid lands throughout the world and our results confirm that they are the best indices for recording the vegetation cover rate. However, this suggests that ARVI is useful for general cover monitoring regardless of more localized soil and vegetation variation. Consequently, it is possible to estimate the vegetation fraction using the obtained model and satellite images. Therefore, the changes of vegetation fraction could be monitored in this region consistently with minimal cost because vegetation changes are considered as suitable criteria for the occurrence or non-occurrence of degradation in the region.

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ارائه مدل مناسب جهت تخمین درصد پوشش‌گیاهی در مناطق خشک با استفاده از تصاویر ماهواره‌ای (مطالعه موردی: صدوق یزد، ایران)

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سعیده کلانتری، دانشجوی دکتری بیابانزدایی دانشکده منابع طبیعی دانشگاه تهران (نویسنده مسئول)

چکیده

یکی از ابزارهای موثر در مطالعه مراتع و پوشش‌گیاهی، فن‌آوری سنجش از دور و داده‌های ماهواره‌ای است. داده‌های ماهواره‌ای در آماده‌سازی اطلاعات مورد نیاز برای مطالعات پوشش گیاهی نقش مهمی را ایفا می‌کنند. پوشش‌گیاهی به طور عمده، به عنوان یکی از بهترین شاخص‌ها برای تعیین وضعیت زمین شناخته شده است. یکی از تکنیک‌های سنجش از دور در مطالعات پوشش‌گیاهی استفاده از شاخص‌های پوشش گیاهی است. هدف از این تحقیق، مطالعه شاخص‌های پوشش‌گیاهی جهت تخمین درصد پوشش‌گیاهی بود و همچنین ارائه یک مدل ریاضی مناسب به منظور برآورد درصد پوشش گیاهی با استفاده از شاخص‌های مذکور. در این مطالعه با استفاده از تصاویر سنجنده TM ماهواره لندست (۲۰۰۶)، اقدام به محاسبه شاخص‌های مختلف پوشش‌گیاهی و بررسی قابلیت آنها در برآورد پوشش‌گیاهی مناطق خشک گردید. بدین ترتیب که ابتدا درصد پوشش گیاهی با استفاده از پلات‌های نمونه بصورت مطالعه میدانی اندازه‌گیری شده و سپس مقدار اندازه‌گیری شده با مقادیر اعداد رقمی پیکسل‌های محل نمونه مقایسه گردید. پس از انجام محاسبات رگرسیون چند متغیره بین مقادیر واقعی و شاخص‌های مذکور، مدل‌های مختلف اعتبارسنجی و مدل‌های بهینه انتخاب گردید. شاخص‌های MSR، DVI، TRVI، SARVI، SR، RDVI، DVI، NDVI، SAVI، ARVI، MSAVI محاسبه شد. نتایج نشان داد که مدل که ARVI در آن مورد استفاده قرار گرفت بالاترین دقت ($R^۲$=۰/۸۶) را بخود اختصاص داده و بنابراین به عنوان مناسب‌ترین مدل برای برآورد درصد پوشش گیاهی در منطقه مورد مطالعه انتخاب گردید. یکی از دستاورد نتایج فوق ارائه مدل ریاضی بود که بوسیله آن مقدار پوشش‌گیاهی تخمین زده می‌شود. این نتایج روش مناسبی برای استفاده از برخی از شاخص‌های پوشش گیاهی برای ارزیابی پوشش گیاهی در مرکز ایران ارائه می‌نماید.

کلمات کلیدی: پوشش‌گیاهی، تصویر ماهواره‌ای، شاخص پوشش‌گیاهی، مناطق خشک، منطقه صدوق