World Applied Sciences Journal 11 (12): 1537-1546, 2010
ISSN 1818-4952

Using Remote Sensing Data for Vegetation Cover Assessment in Semi-Arid Rangeland of Center Province of Iran

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Abstract: To determine suitable indices for vegetation cover and production assessment based on remote sensing data, simultaneous digital data with field data belonged to summer rangeland of southern part of Isfahan province were analyzed. During 2 years of monitoring, annuals, grasses, forbs and shrubs vegetation cover and total production data from sixty 1 square meter plots in each site were collected. The Global Positioning System (GPS) was used to measure coordinates of plots and transects. Geometric correction and histogram equalization were applied in image processing and image digital numbers were converted to reflectance numbers. In the next stage, all vegetation indices were calculated from ASTER (Advanced Spaceborn Thermal Emission and Reflection Radiometer) image data and compared with vegetation cover estimates at monitoring points made during field assessments. A linear regression model was used for selecting suitable vegetation indices. The results showed that there are significant relationships between satellite data and vegetative characteristics. Among indices, NDVI vegetation index, using high infrared and low red ASTER bands, consistently showed significant relationships with vegetation cover. Estimation of vegetation cover with NDVI vegetation index was more accurate predicted within rangeland systems. Using produced model from NDVI index vegetation crown cover percentage maps were produced in four classes percentage for each image. Generally introduced indices, provided accurate quantitative estimation of the parameters. Therefore, it is possible to estimate cover and production as important factors for range monitoring using ASTER data. Remote sensing data and Geographic Information System are most effective tools in natural resource management.

Key words: Rangeland · Remote sensing · Vegetation cover · Production · Vegetation index · Monitoring · Semi-arid rangeland

INTRODUCTION

Sustainable utilization of rangelands needs updated information based on permanent vegetation parameters measurement in a long term. This is valuable for management planning and land holders in a national level [1]. So it is important for calibrated, objective, repeatable and cost-effective information for large areas and it can be empirically related to field data collected by traditional means [2, 3, 4]. One of the influential tools in studying rangelands and vegetation cover is remote sensing and the use of satellite data. Remote sensing and vegetation indices in Natural Resources management especially rangelands provides possibility to collect vegetation parameters information from for wide range areas assessment [5-9]. Their results proved efficiency of vegetation indices for quantitative estimation of vegetation parameters.

Vegetation indices (VI) combine reflectance measurements from different portions of the electromagnetic spectrum to provide information about vegetation cover on the ground [10]. These VI are radiometric measures of the spatial and temporal patterns of vegetation photosynthetic activity that are related to canopy biophysical variables such as leaf area index (LAI), fractional vegetation cover and biomass [11-14].

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Perry and Lautenschlager (1984) compared 20 VI and found most of them to be functional equivalent [15]. Most VI are called broadband because they are based on algebraic combinations of reflectance in the red (R) and near infrared (NIR) spectral bands [16-19]. This strong contrast between red and near-infrared reflectance has formed the basis of many different vegetation indices. When applied to multispectral remote sensing images, these indices involve numeric combinations of the sensor bands that record land surface reflectance at various wavelengths. Pearson and Miller (1972) first presented the near infrared/red ratio for separating green vegetation from soil background [20]. Since then, numerous vegetation indices have been proposed, modified, analyzed, compared and classified [16, 21, 22].

Some vegetation indices are simple arithmetic combinations of reflectance measurements, contrasting the high infrared and low red reflectance's that characterize photosynthetic vegetation. This contrast has been widely used to generate several vegetation indices such as the simple vegetation index (SVI) [20], normalized difference vegetation index (NDVI) [23] and soil adjusted vegetation index (SAVI-1,3,4) [20]. Masoud and Koike (2006) used SAVI indicator to prepare a vegetation cover map of the Siwa Region of Egypt, paying attention to the desertification of area, this was done by reducing the afterward influence of soil and assuming a value of the soil coefficient of 0.5 [24]. The NDVI has been widely used in many applications including regional and continental-scale monitoring of vegetation cover [25-29]. Jin and Sader (2005) reported that SAVI, NDVI and PVI indices or even simple band ratios depend on shrub types and phonological stages were more sensitive than reflectance from green, red and near infrared bands. These indices had ability to distinguish various shrub species and separate shrub lands from grasslands [30].

The perpendicular vegetation index (PVI) [31] was the first of this type of index. The PD311, PD312 and PD322, which has been used with considerable success in Australian perennial-dominated arid vegetation, also fall within this group [32].

The soil brightness index (BI) and the green vegetation index (GVI) based on the contrast between red and green reflectance, was shown to double the sensitivity of vegetation indices, especially in sparsely vegetated areas [33, 34]. Thenkabail *et al*., (1994) proposed six different plant-water sensitive vegetation indices using Aster mid-infrared and shortwave-infrared bands, including the mid-infrared vegetation index (MSVI 1 and 2). They found that these indices were as good or better predictors of yield, leaf area index, wet biomass, dry biomass and plant height than slope-based vegetation indices in corn and soybean fields [35]. Most of the widely used vegetation indices such as NDVI, MND, SAI, PVI-1, PVI-3, RATIO and TVI, that use red and NIR regions in arid and semi-arid rangelands [20, 22, 23, 36].

Richardson and Wiegand, (1997) used PVI, GVI, SBI, DVI, IPVI, IR1, IR2, MIR, RA, WI, VNIR1, VNIR2 and PVI indices and found that DVI and PVI were the best for density and cover assessment [31].

In the present study emphasis was on monitoring showing long term changes of rangelands based on field and digital data to achieve suitable vegetation indices derived from Aster imagery for estimation of vegetation parameters.

MATERIALS AND METHODS

Area or rangelands in Isfahan province of Iran is about 8962 hectares having 360 mm annual rainfall. For this research, seventeen vegetation types in Ghareh Aghach watershed in southern part of province were selected (Figure 1). The region lies within the latitudes of 31°30' 28" and 31°26' 19" N and within the longitudes of 51° 45' 53" and 51° 34' 54" E, covering an area of 8962 hectares.

A full scene of Aster imagery from 15 May 2008 was acquired. The dry summer image minimized the contribution of green ephemeral vegetation, maximised solar irradiance and land surface reflectance and also excluded cloud cover from the scene. In addition, a Digital Elevation Model (DEM) 1:25000 of the site was used. On different slope aspects of each vegetation type six 200 m transects, on the hypothetical circle circumference with GPS centering and a radios about 15 m were placed (60 sampling site). The distance between transects was at least 100 m. Ten quadrates $1m^2$ each, were established alongside of transects. Vegetation cover was measured within the quadrates (Figure 2).

In order to analyze vegetation cover percentages, the data field for each vegetation type was collected by stratified random sampling. In each quadrates the percentage vegetation cover was estimated. ASTER image of corresponding fieldwork data were obtained. Image processing in terms of geometric and atmospheric corrections was done. For reducing error caused by sun angle DN values converted to spectral reflectance (Figure 3).

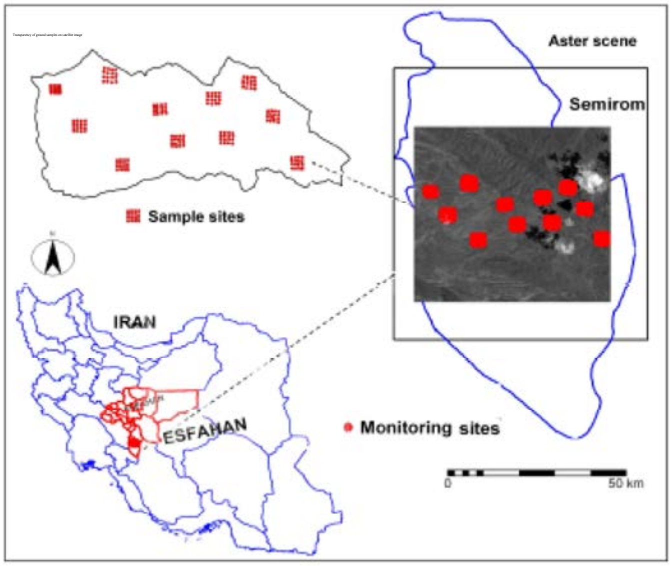

Fig. 1: Location of study area within the Ghareh Aghach District

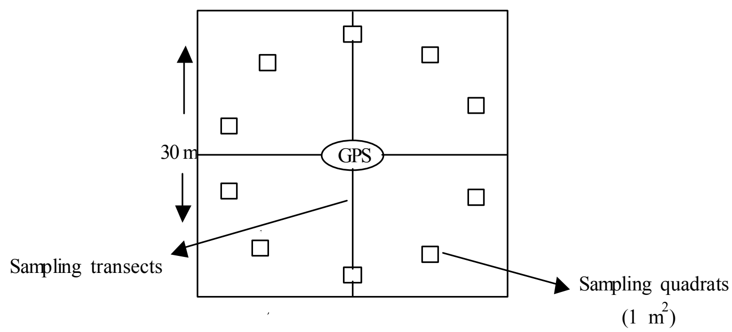

Fig. 2: Sampling method in each site

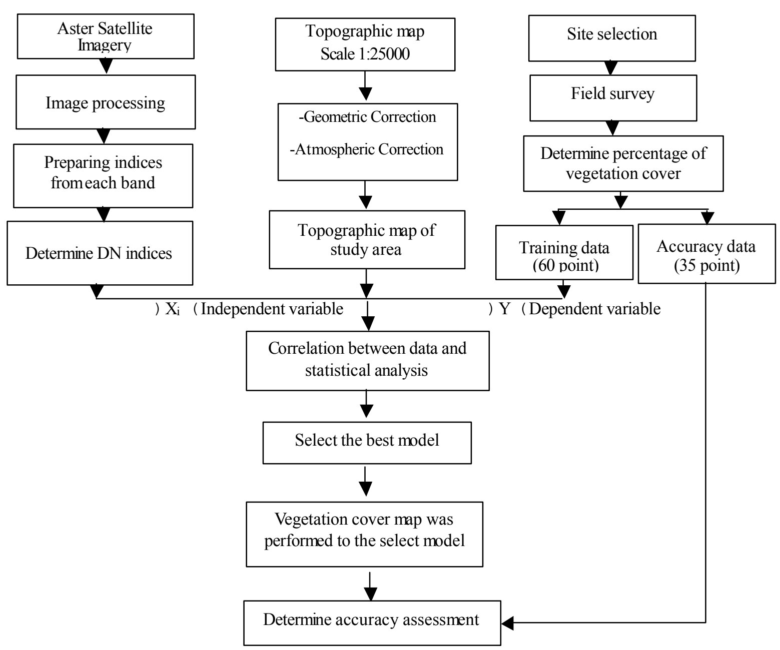

Fig. 3: Model for image processing and integrating ground data with satellite data

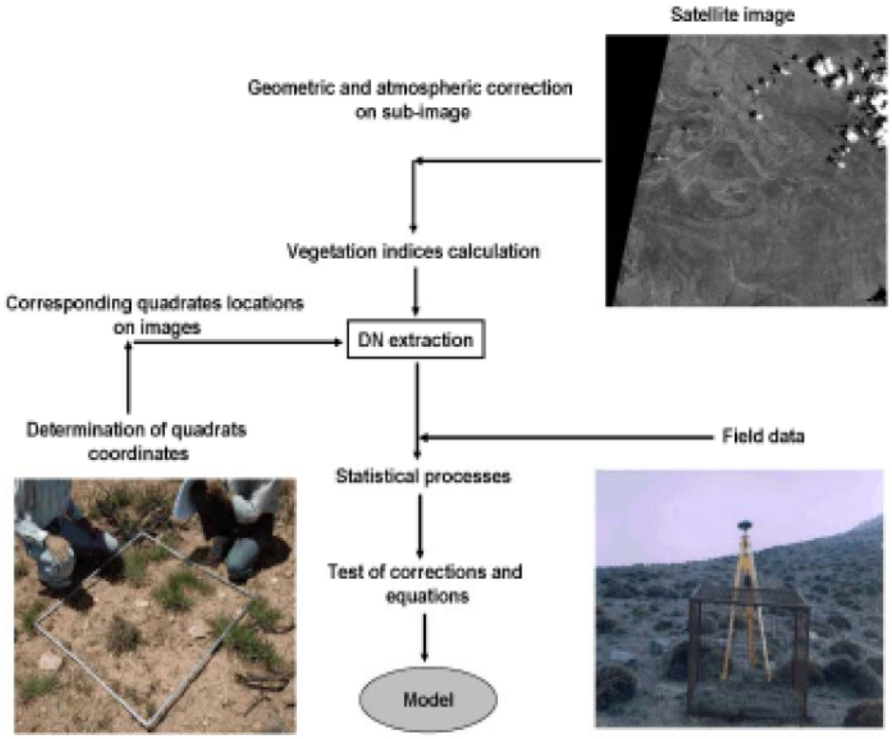

Fig. 4: Model for image processing and integrating ground data with satellite data

Table 1: Vegetation indices compared in this study

Acronym	Author	Formula	Aster bands *
NDVI	Rouse *et al*., (1974) [23]	(NIR-R)/(NIR+R)	$(b_3 - b_2) / (b_3+b_2)$
BI	Kauth and Thomas (1976) [37]	BG+G+R+NIR+MIR+ SWIR	All bands except thermals bands
GVI	Kauth and Thomas (1976) [37]	BG-G-R+NIR+MIR-SWIR	All bands except thermals bands
IPVI	Boyd *et al*., (1996) [36]	[(NIR-R)/(NIR+R)]+1/2	(NDVI+1)/2
IR1	Boyd *et al*., (1996) [36]	(NIR-MIR)/(NIR+MIR)	$(b_3-b_4) / (b_3+b_4)$
IR2	Boyd *et al*., (1996) [36]	(NIR-SWIR)/(NIR+SWIR)	$(b_3-b_7) / (b_3+b_7)$
MIR	Boyd *et al*., (1996) [36]	MIR/SWIR	b_4/b_7
MND	Boyd *et al*., (1996) [36]	[NIR-(1.2*R)/(NIR+R)]	$[b_3-(1.2 \times b_2) / (b_3+b_2)]$
MSVI-1	Thenkabail *et al*., (1994) [35]	NIR/MIR	b_3/b_4
MSVI-2	Thenkabail *et al*., (1994) [35]	NIR/SWIR	b_3/b_7
SVI	Pearson and Miller (1972) [20]	NIR/ R	b_3/b_2
PD311	Pickup *et al*., (1993) [32]	R-1	b_2-1
PD312	Pickup *et al*., (1993) [32]	(R-1)/(R+1)	$(b_2-1)/ (b_2+1)$
PD322	Pickup *et al*., (1993) [32]	(R-G)/(R+G)	$(b_2-1)/(b_2+1)$
PVI	Richardson and Wiegand, (1997) [31]	(SWIR-NIR)/ (SWIR+NIR)	$(b_7-b_3)/(b_7+b_3)$
PVI-1	Qi *et al*., (1994) [22]	$(\beta.NIR\text{-}RED)+ \alpha/ (\sqrt{1+b^2})$	$(\beta.b_3-b_2)+ \alpha/ (\sqrt{1+b^2})$
PVI-3	Qi *et al*., (1994) [22]	A×NIR-B×R, where A is the intercept of soil line and B is the slope of soil line	$A \times b_3 - B \times b_2$
RA	Boyd *et al*., (1996) [36]	NIR/(R+MIR)	$b_3 / (b_2+ b_4)$
RATIO	Boyd *et al*., (1996) [36]	NIR/R	b_3/b_2
SAVI-1	Pearson and Miller (1972) [20]	(MIR×R)/NIR	$(b_4 \times b_2) / b_3$
SAVI-3	Pearson and Miller (1972) [20]	NIR/(R+MIR)	$b_3 / (b_2+b_4)$
SAVI-4	Pearson and Miller (1972) [20]	MIR/(NIR+MIR)	$b_4 / (b_3+b_4)$
TVI	Boyd *et al*., (1996) [36]	(NIR-R)/(NIR+R)+0.5	$(b_3-b_2) / (b_3+b_2)+0.5$
WI	Qi *et al*., (1994) [22]	(G+R+NIR)-MIR-SWIR	$(b_1+b_2+b_3) - b_4 - b_7$
VNIR1	Qi *et al*., (1994) [22]	(NIR-1)/(NIR+1)	$(b_3-1)/(b_3+1)$
VNIR2	Qi *et al*., (1994) [22]	(NIR-2)/(NIR+2)	$(b_3-2)/(b_3+2)$

* Band 7 Aster agreement by this formula: Band 7=]1/4 bands $(b_5+b_6+b_7+b_8)$[(Pavelka and Haloundova 2006) [38]

Coordinates of ground samples were determined using two Promark Xcm GPS based on paired method, i.e. simultaneous application of GPS in the field and in a bench mark (Figure 4).

Based on coordinates a layer of points of ground samples was made using Mstar software. Several ratios or indices were examined which have been illustrated by (Table 1).

Then values of indices relative to ground data as suggested by [33, 34] were extracted from image for two years. Correlations between vegetation indices and band ratios with cover and yield data were evaluated. For each vegetation community, indices with higher significant correlations ($P<0.01$ and $P< 0.05$) were selected. Equations of regression between indices as independent variables and cover as dependent variables were calculated. Then equations were tested in witness quadrates using paired ANOVA and T- test analysis.

Study of the Validity of the Produced Map: The map was validated against field data on the ground. This was done by visiting the regions corresponding to the remotely sensed satellite data and matching the data from 35 control points in each vegetation type, with the interim map of vegetation data, so that the reliability of the map and its Capa coefficient could be determined.

RESULTS

Significant correlations between digital data and quantitative measurements of cover in all vegetation types were observed. Rate of correlations and equations obtained between vegetation indices and vegetation cover parameter have been illustrated by Table 2.

At this scale, a study area, only NDVI vegetation indices were significantly correlated with field cover data ($P<0.05$), the strongest relationships explaining relatively 78% of the variance in the field measurements ($R^2 = 0.38$). Other vegetation indices were not significantly related to vegetation cover percentage of the field data.

The results of using stepwise regression to establish relationship between field cover and different vegetation indices are shown in Table 3. Each of the indices were first entered into the model, but they were subsequently removed in the subsequent stages of running the stepwise regression until only the NDVI index remained in the final model. The equation for this model is as follows:

$$Y = 10.08+86.55\ NDVI \quad (1)$$

Given the goodness of fit between the NDVI index and vegetation cover (Table 3) the null hypothesis was rejected at the probability level of 1%.

Table 2: Relationships between field cover and vegetation indices in the study area values are R

Vegetation index	Correlation coefficient with cover (%)	Vegetation index	Correlation coefficient with cover (%)	Vegetation index	Correlation coefficient with cover (%)
NDVI	0.62**	MSVI-2	-0.07	RATIO	-0.05
BI	0.30	SVI	0.08	SAVI-1	0.22
GVI	-0.31	PD311	0.12	SAVI-3	0.06
IPVI	0.07	PD312	-0.12	SAVI-4	0.05
IR1	0.05	PD322	0.05	TVI	-0.08
IR2	0.23	PVI	0.22	WI	-0.17
MIR	0.26	PVI-1	-0.12	VSVI1	0.23
MND	0.10	PVI-3	0.07	VSVI2	0.14
MSVI-1	0.16	RA	0.04	-	-

* Correlation is significant at the 0.05 level

** Correlation is significant at the 0.01 level

Table 3: ANOVA analysis between NDVI index and vegetation cover (%)

Index entered into the model		Sum of Squares	df	Mean Square	Sig.
NDVI		3559.263	20	177.963	0.05
--		10801.492	44	245.488	
Mean along transect	Actual value	8.81±21.07	-	-	
	Estimated value	2±22.61	-	-	

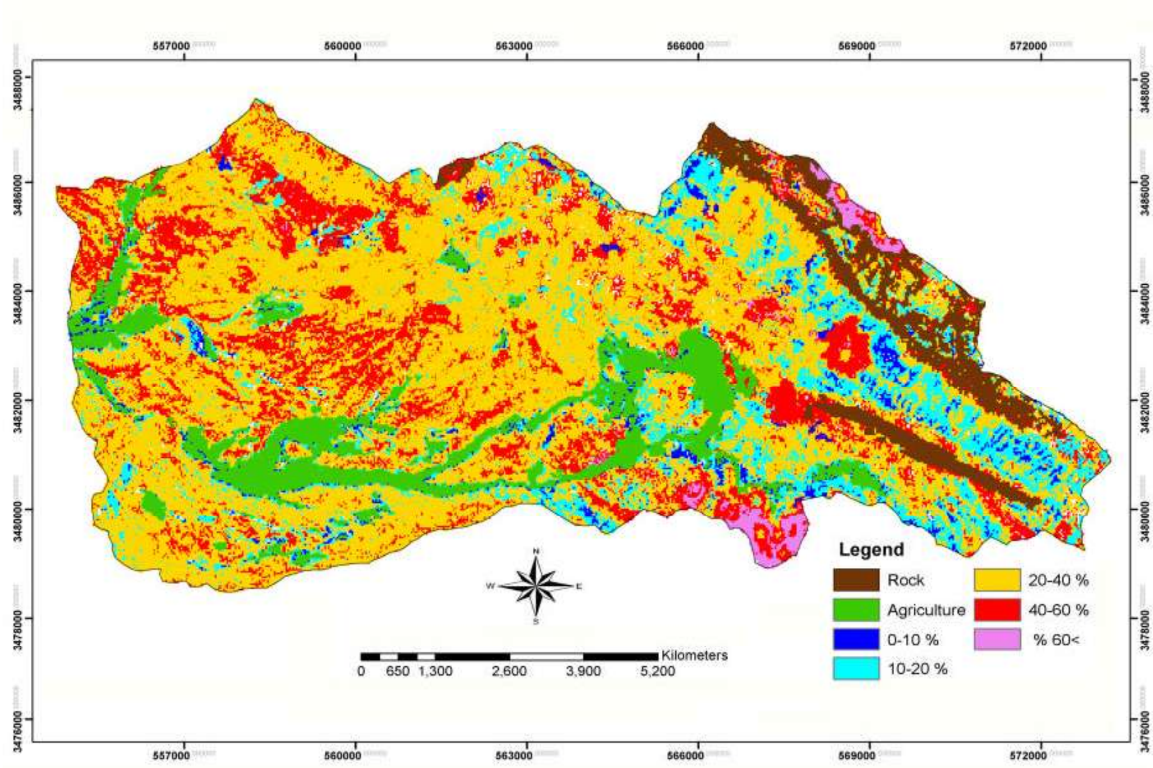

Fig. 5: Vegetation cover (%) map of Ghareh Aghach rangelands

Since a significant linear relationship existed between the plant crown cover percentage and the above spectral bands, the validity of the model was established. In the resultant map, depicted in Figure 5, the region was subdivided into 5 separate levels based on the percentage of plant crown cover. The total validity and the Capa coefficient for this map are 68.5% and 72.4%, respectively. Moleele *et al*., (2001) obtained the validity of the plant cover at about 63.5% [39] which conforms to the results obtained in this research.

DISCUSSIONS

Estimations of vegetation parameters of three major plant groups from Aster image were examined. Vegetation cover included a combination of green and brown canopy reflectance in rangelands. For better estimation of cover single band ratios or vegetation indices (combination of bands) were used. The vegetation indices and ratios that had positive correlation with relative vegetation parameters and which had negative correlations with relative vegetation parameters showed higher and lower values for image of good conditions respectively at all sites. So far, many plant spectral indexes have been introduced for studying the quality and quantity specifications of plant cover. Selection the best index for quantitative analysis of plant cover is one of the most important problems for users to address [40]. In most similar researches only one index has been used as an independent variable. It is successful when the plant cover is associated with highly vigorous growth and turgid plant leaves and any deleterious effects of soil reflection are minimal. Therefore, in drought and semi-drought regions, even in years with sufficient rain for plant growth, one index by itself cannot describe the plant cover of the region. The use of plant cover indices is therefore more suitable for studying plant cover in such regions due to the variety of information produced by using existing data from different spectral bands.

Out of the 26 vegetation indices used in this research, 25 were not meaningfully related to the percentage of the plant cover of the region, due to the high variance in the cover data. The NDVI index was the only index that was closely related to the percentage plant cover of the region, using spectral bands 3 and 4 of TM to establish this index. This index was correlated with plant cover (r =0.28) in a study performed by Arzani (1998) [34]. The explanation should be searched in the strong reflection of plant cover within the limit of band 3 of the Aster gauge. Khajedeen (1995) in his study in the semi-arid rangelands found that the NDVI index was the only suitable index for studying plant cover in that region [41]. The results of a study by Sepehri (2003) study in regions with high plant cover percentage also found this index to be correlated with plant cover [42]. Apan *et al*., (1997) in their study believed that the reason for the reduction of NDVI correlation with the cover crown percentage was the effects of the background soil on the plant cover [43]. But in Zahedifard's (2002) study NDVI had a meaningful correlation with the plant cover percentage ($R^2 = 0.83\%$) even though the plant cover rate was low [44]. Farzad Mehr *et al*., (2004) in a study performed in the Semirom region estimated that the correlation between NDVI index and plant cover data was significant at $P<0.5\%$ error [45]. For the preparation of the plant cover map of Kalahurd, Sadeghi (2009) employed the Aster Satellite data [46]. The results of his studies showed that there was a meaningful correlation between numerical data resulting from the Aster gauge and the plant cover crown percentage and among the spectral bands, the correlation in plant indexes generated from the combination of bands 2 and 3 was therefore higher. The results of this research also showed that only the NDVI index had a meaningful relation with the plant cover crown percentage. The meaningfulness of the relation of the total cover crown with bands 2 and 3 of the gauge can be attributed to the high reflection of plant cover in the Red and NIR spectral regions which is considered an acceptable result. NDVI index had strong correlation with total cover. The image was belonging to vegetative growth stage when those plants were green and active. In combination of this band also band of middle infrared was used which has been found suitable for cover estimation [33]. Band red is also sensitive to brightness of soil surface and is able to accurate estimation of cover [2]. Arzani (1994, 1998) investigated on ability of some vegetation indices and had been proved the real ability indices that has been created based on middle infrared band [33, 34]. Because of the low percentage of cover crown in the region under study (25%) and the prevailing effect of the background reflection as well as the nonlinear nature of relations between spectral reflection and pant specifications, the correlation relations have practically lower justification coefficients. This was supported by Schmidt and Karnelli (2001) as well as Sellers *et al*., (1992) [47, 48]. The results obtained by Sepehri (2003) also showed that because of the prevalence of spectral refection of the soil, estimation of plant cover (<40%) is difficult and there should be other data such as the type of the soil, color and leaf surface indexes to be included in the model for the estimation of plant cover less than 40% [42]. The results obtained by Pickup *et al*., (1993) also showed that in arid and semi-arid range except for rainy seasons and a few days after, most of the time the plant cover is not green and its reflection specifications are near to the soil specifications [32]. Therefore, a plant index should have the capability of being used both in drought and green conditions of the cover. Therefore, it can be concluded that by applying tested plant indexes, the estimation of plant cover in the region conditions has no desirable result. Other cases resulting in error in the evaluation of plant cover in the region are, slight mismatch between the precise area sampled in the field and the pixels extracted from the imagery could also potentially reduce the strength of relationships between the two datasets. Finally, the field measurements were made by several different field workers, adding another source of variation to the data. For example, it has been shown that there may be up to 20% difference in measurements of plant cover made by experienced field workers, using objective methods similar to those made at the pastoral lease monitoring sites [49, 50].

CONCLUSIONS

One of the main objectives of this study was to identify vegetation indices that were the best available predictors of vegetation cover, which could then be used to construct a vegetation cover map, in the semi-arid range lands, in the center of Iran. Generally based on the results of this research, there were significant correlations between quantitative vegetation characteristics and ASTER data in period of study in the sites of Ghareh Aghach watershed (Grassland and Shrub land). Suitable indices for each vegetation community were differed based on vegetation composition. So it is possible to evaluate rangeland vegetation using ASTER data for sustainable utilization. Due to complexity of range ecosystem it is too difficult to show all changes with one quantitative model. However suitable indices and ratios obtained from different vegetation communities in this study can provide accurate estimations from vegetation parameters. Criteria that make an image-based vegetation index suitable for regional monitoring are strongly related to vegetation cover in the vegetation types of the district and an ability to predict this cover within semi-arid regions. Although simple red-infrared contrast indices, in particular NDVI, have been widely used with success in arid land studies throughout the world, our results

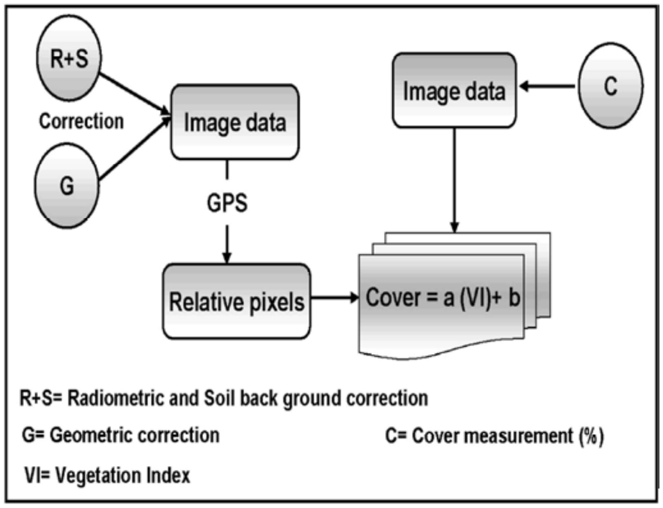

Fig. 6: Model for estimating cover from satellite data

confirm that they are the best indices for recording vegetation cover in semi-arid regions. This suggests that NDVI and simple red-infrared indices are useful for general cover monitoring regardless of more localized soil and vegetation variation.

The procedures described in this paper can be considered as a simple rangeland remote sensing analysis model and can be used elsewhere to frequently provide efficient monitoring of the quantity of cover which are a prerequisite to effective management and planning decision, for safe utilisation of rangelands (Figure 6).

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Appendix: Vegetation type in study area

Ag.tr	Agropyron trichophoum
Ag.tr-As.pa	Agropyron trichophoum-Astragalus parroaianus
Ag.tr-As.ca-Da.mu	Agropyron trichophoum- Astragalus canesens- Daphne macronata
As.ad-Ag.tr-Da.mu	Astragalus adsendence-Agropyron trichophoum-Daphne macronata
As.pa-Ag.tr	Astragalus parroaianus-Agropyron trichophoum
As.ly-Ag.tr-Da.mu	Astragalus lycioides-Agropyron trichophoum-Daphne macronata
As.ca-Br.to-Co.cyl	Astragalus canesens-Bromus tomentellus-Cousinia cylianderica
As.br-Br.to-Da.mu	Astragalus brachycalyx-Bromus tomentellus-Daphne macronata
As.go-Co.cyl	Astragalus gossipianus-Cousinia cylanderica
As.pa-Co.cyl-Da.mu	Astragalus parroaianus-Cousinia cylanderica-Daphne macronata
As.cy-Fe.ov	Astragalus cyclophylus-Ferula ovina
Br.to-As.pa	Bromus tomentellus-Astragalus parroaianus
Co.ba-As.go	Cousinia bachtiarica-Astragalus gossipianus
Co.ba-Sc.or	Cousinia bachtiarica-Scariola orientalis
Fe.ov-Br.to-As.za	Ferula ovina-Bromus tomentellus-Astragalus zagrosicus
Ho.vi-Po.bu	Hordeum bulbosum-Poa bulbosa
Br.to-Sc.or	Bromus tomentellus-Scariola orientalis