Operational Monitoring of Vegetative Cover by Remote Sensing in Semi-arid Lands of Iran

Fazel Amiri and Tayebeh Tabatabaie, Iran

Keywords: semi-arid environment, Aster image, rangelands.

SUMMARY

Operational monitoring of vegetative cover by remote sensing currently involves the utilisation of vegetation indices. Vegetation indices are widely used for assessing and monitoring ecological variables such as vegetation cover, above-ground biomass and leaf area index. This study reviewed and evaluated different vegetation indices for estimating vegetation cover in rangelands in Center of Iran. 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. Relationships between various vegetation indices and vegetation cover were compared using simple linear regression. NDVI vegetation index evaluated, using high infrared and low red ASTER bands, consistently showed significant relationships with vegetation cover. Estimation of vegetation cover whit NDVI vegetation index was more accurate and total perennial and ephemeral plant cover was best predicted within rangeland systems. These results provide a strong foundation for use of vegetation indices as an adjunct to field methods for assessing vegetation cover in northern Center Iran.

Operational Monitoring of Vegetative Cover by Remote Sensing in Semi-arid Lands of Iran

Fazel Amiri and Tayebeh Tabatabaie, Iran

INTRODUCTION

One of the influential tools in the study field of pasture and vegetation cover science is technology of remote sensing and satellite data. Satellite data have essential role in preparing needed information for vegetation cover studying. Vegetation cover has been widely recognised as one of the best indicators for determining land condition (Booth and Tueller 2003; Bastin and Ludwig 2006; Wallace et al. 2006; Jafari et al. 2007). Consequently, land condition is often assessed and monitored according to vegetation cover and its variations in time and space. This cover is, therefore, often used as an indicator in the remote sensing of land condition. Remote sensing has developed as a powerful tool in environmental studies (Oˇstir et al. 2003) because it can provide calibrated, objective, repeatable and cost effective information for large areas and it can be empirically related to field data collected by traditional means (Graetz 1987; Tueller 1987; Pickup 1989). One of the most common applications of remote sensing is vegetation monitoring and assessment via vegetation indices which combine reflectance measurements from the bands of sensing instruments (Pickup et al. 1993; Bannari et al. 1995; Purevdorj et al. 1998; Thiam and Eastman 2001).

Vegetation indices derived from satellite data are one of the primary sources of information for operational monitoring of the Earth's vegetative cover (Gilabert et al. 2002). However, most of the widely used vegetation indices are inappropriate in arid and semi-arid environments of Iran where annual and perennial vegetation dominates. These plants often lack the contrast between red and infrared reflectance upon which the common vegetation spectral indices are based, making them difficult to distinguish from red-colored soils. Several alternative multi spectral indices that place less emphasis on vegetation infrared response are more appropriate and have been widely used in arid and semi-arid rangelands (Foran and Pickup 1984; Pickup and Nelson 1984; Pickup and Foran 1987; Pickup et al. 1993; McGregor and Lewis 1996; O'Neill 1996). Approximately, all of the rangelands were grazed by domestic livestock in center part of Iran. The administration of these lands is governed by the Natural Resources Institute (NRI) which aims to ensure sustainable utilisation and resource maintenance and which also provides for effective monitoring of the condition of the lands.

Objective

The aim of this study was to evaluate the suitability of vegetation indices derived from Aster imagery as an adjunct to field methods for assessing and monitoring vegetation cover, and consequently vegetation cover map of Gharah Aghach region, in the center rangelands of Iran. Specifically, we aimed to identify the most suitable image indices for recording vegetation cover in this area, to determine the scales at which they may be applied, and the components of vegetation cover that they best predict for vegetation cover map. Our approach was to determine the relationships between a range of widely used spectral indices and vegetation cover as measured, with the intention to produce image maps that more fully document spatial and temporal variation in vegetation cover.

Vegetation indices

Vegetation indices (VI) derived from satellite data are one of the primary sources of information for operational monitoring of the Earth's vegetative cover. Vegetation indices combine reflectance measurements from different portions of the electromagnetic spectrum to provide information about vegetation cover on the ground (Campbell 1996). 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, biomass, etc. (Asrar, Kanemasu & Yoshida 1985; Baret & Guyot 1991; Gilabert et al. 1996; Richardson et al. 1992). Perry and Lautenschlager (1984) compared 20 VI and found most of them to be functional equivalent. Most of VI is called broadband because they are based on algebraic combinations of reflectance in the red, R, and that in the near infrared, NIR, spectral bands (Bannari et al. 1995; Baret 1995; Elvidge & Chen 1995; LePrieur et al. 1994). 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. Since then, numerous vegetation indices have been proposed, modified, analysed, compared and classified (Huete 1988; Qi et al. 1994; Bannari et al. 1995). Definitions of the indices are provided in Table 1. Some of this vegetation index is simple arithmetic combinations of reflectance measurements, contrasting the high infrared and low red reflectance that characterises photosynthetic vegetation. This contrast has been widely used to generate several vegetation indices such as the simple vegetation index (SVI) (Pearson and Miller 1972), normalised difference vegetation index (NDVI) (Rouse et al. 1974), and soil adjusted vegetation index (SAVI-1,3,4) (Pearson and Miller 1972). Masoud and Koike (2006) in order to prepare the vegetation cover map of the area and with attention to desert situation of area, used SAVI indicator to reduce the afterward influence of soil and they considered soil coefficient 0.5. The NDVI has been widely used in many applications including regional and continental-scale monitoring of vegetation cover (Satterwhite and Henley 1987; Foran and Pearce 1990; Myneni et al. 1997; Wang et al. 2004; Wessels et al. 2004). Others vegetation indices consists of distance-based. These indices have been designed to remove the influence of soil brightness in sparsely vegetated areas; they are more effective at discriminating vegetation from bright soils when the two are mixed within the sensor field of view. These indices take advantage of the fact that most soil-dominated pixels fall along a line in a red/near-infrared bi-spectral plot, with vegetation increasing with distance perpendicular to this line. The soil line can influenced by surface roughness, moisture, texture and colour (Huete et al. 1984; Baret et al. 1993). The perpendicular vegetation index (PVI) (Richardson and Wiegand 1977) 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 (Pickup et al. 1993). The slope-based and distance-based vegetation indices generally use two spectral bands, most usually red and infrared. Orthogonal transformation vegetation indices use multiple spectral bands to derive a new set of image components that are uncorrelated with one another and ordered with respect to the amount of scene variation they capture from the original band set (Kauth and Thomas 1976; Fung and LeDrew 1987).

Table 1. Vegetation indices compared in this study

Acronym	Author	Formula	Aster bands *
NDVI	Rouse et al. (1974)	(NIR−R)/(NIR+R)	(3 – 2) / (3+2)
BI	Kauth and Thomas (1976)	BG+G+R+NIR+MIR+ SWIR	All bands except thermals bands (10,11,12,13,14)
GVI	Kauth and Thomas (1976)	BG-G-R+NIR+MIR-SWIR	All bands except thermals bands (10,11,12,13,14)
IPVI	Boyd et al. (1996)	[(NIR−R)/(NIR+R)]+1/2	(NDVI+1)/2
IR1	Boyd et al. (1996)	(NIR-MIR)/(NIR+MIR)	(3-4) / (3+4)
IR2	Boyd et al. (1996)	(NIR-SWIR)/(NIR+SWIR)	(3-7) / (3+7)
MIR	Boyd et al. (1996)	MIR/SWIR	4/7
MND	Boyd et al. (1996)	[NIR-(1.2*R)/(NIR+R)]	[3-(1.2 × 2) / (3+2)]
MSVI-1	Thenkabail et al. (1994)	NIR/MIR	3/4
MSVI-2	Thenkabail et al. (1994)	NIR/SWIR	3/7
SVI	Pearson and Miller (1972)	NIR/ R	3/2
PD311	Pickup et al. (1993)	R-1	2-1
PD312	Pickup et al. (1993)	(R-1)/(R+1)	(2-1)/ (2+1)
PD322	Pickup et al. (1993)	(R-G)/(R+G)	(2-1)/(2+1)
PVI	Richardson and Wiegand, (1977)	(SWIR-NIR)/ (SWIR+NIR)	(7-3)/(7+3)
PVI-1	Qi et al. (1994)	(β.NIR-RED)+ α/ ($\sqrt{1+b^2}$)	(β.3-2)+ α/ ($\sqrt{1+b^2}$)
PVI-3	Qi et al. (1994)	A×NIR−B×R, where A is the intercept of soil line and B is the slope of soil line	A×3−B×2
RA	Boyd et al. (1996)	NIR/(R+MIR)	3 / (2+4)
RATIO	Boyd et al. (1996)	NIR/R	3/2
SAVI-1	Pearson and Miller (1972)	(MIR×R)/NIR	(4×2) / 3
SAVI-3	Pearson and Miller (1972)	NIR/(R+MIR)	3 / (2+4)
SAVI-4	Pearson and Miller (1972)	MIR/(NIR+MIR)	4 / (3+4)
TVI	Boyd et al. (1996)	(NIR-R)/(NIR+R)+0.5	(3-2) / (3+2)+0.5
WI	Qi et al. (1994)	(G+R+NIR)-MIR-SWIR	(1+2+3) - 4 - 7
VNIR1	Qi et al. (1994)	(NIR-1)/(NIR+1)	(3-1)/(3+1)
VNIR2	Qi et al. (1994)	(NIR-2)/(NIR+2)	(3-2)/(3+2)

* Band 7 Aster agreement by this formula: Band 7= [1/4 bands (5+6+7+8)] (Pavelka and Svatuskova 2006)

The first component usually represents brightness, often related to soil exposure, and the second component often represents variation in green vegetation cover. These vegetation indices, has been used in numerous environmental studies for vegetation mapping and monitoring land cover changes (Byrne et al. 1980; Ingebritsen and Lyon 1985; Dymond et al. 2002; Price et al. 2002; Jin and Sader 2005). The tasselled cap transformation is the best-known of these indices (Kauth and Thomas 1976): its two first components are the soil brightness index (BI) and the green vegetation index (GVI). The index, based on the contrast between red and green reflectance, was shown to double the sensitivity of vegetation indices, especially in sparsely vegetated areas. The others vegetation indices that include mid and short-wave infrared regions of the electromagnetic spectrum, on the basis that vegetation has lower reflectance than soil in these regions, a contrast that may assist their discrimination (Kimes et al. 1981; Dusek et al. 1985; Baret et al. 1988; Thenkabail et al. 1994). Since it is water content that largely determines plant reflectance in the near infrared, mid and shortwave infrared regions, these have been called plant–water sensitive vegetation indices. 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. 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 lands (Rouse et al. 1974; Boyd et al. 1996; Pearson and Miller 1972; Qi et al. 1994). There more vegetation indices which are studied IPVI, IR1, IR2, MIR, RA, WI, VNIR1, VNIR2 etc. These vegetation indexes are the ratio vegetation index which has been used already for many years. They are widely used expressing ratio between two band values where highest values are those with green and sound vegetation (Pavelka and Halounová 2005).

MATERIALS AND METHODS

Study area

The study area was located in the Ghareh Aghach watershed in the center rangelands of Iran (Fig. 1). The region lies within latitudes 31°30' 28" and 31°26' 19" N and within longitudes 51° 45' 53" and 51° 34' 54" E, covering an area of 8962.25 hectares. The climate in this area includes hot summers and cold–mild winters. Rainfall is highly variable from year-to-year, with average annual totals ranging and Long term mean temperature are 358 and 10.5 degrees Celsius which classifies the site in semi-arid climatic conditions according to Ambergie (Q= 40.7) and Demartin (Ia=17.4) categories. There are about 17 different vegetation types and four major landscapes of mountainous lands, hilly lands, plateau and gravel lands consisting of nine minor land units. The study areas are primarily managed for sheep and goat grazing for wool and meat production (Fazel amiri 2008). We analysed the relationships between vegetation cover and satellite image indices by an Aster scene.

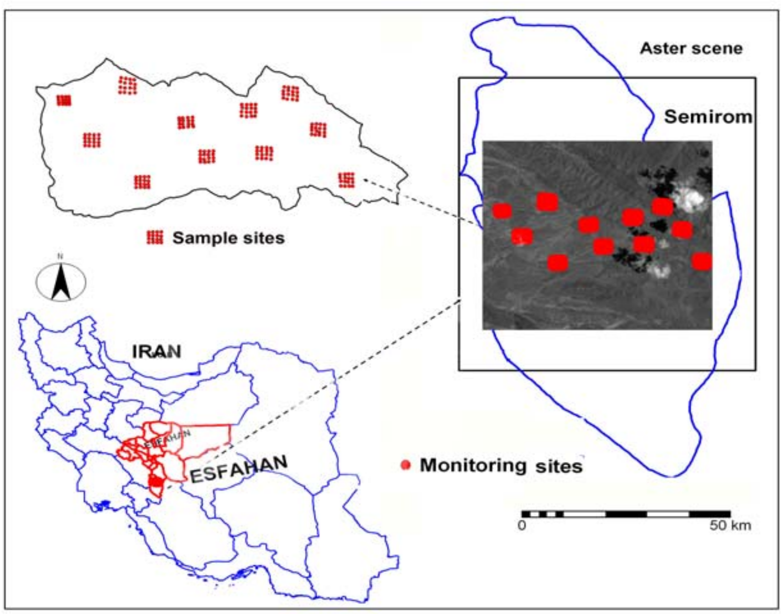

Fig. 1. Location of study area within the Ghareh Aghach District.

Field data

The vegetation cover data used in this study were collected in frequent field visits at all vegetation type in 2008-09: The data were recorded in May and July 2008 and between May and July 2009. Rainfall in the study area was around average during these years (358.06 mm recorded at Semirom station in 2008 and 2009). Monthly rainfall during and immediately preceding the data collection periods was generally low, with some localised falls during January and May 2008 (Fig. 2).

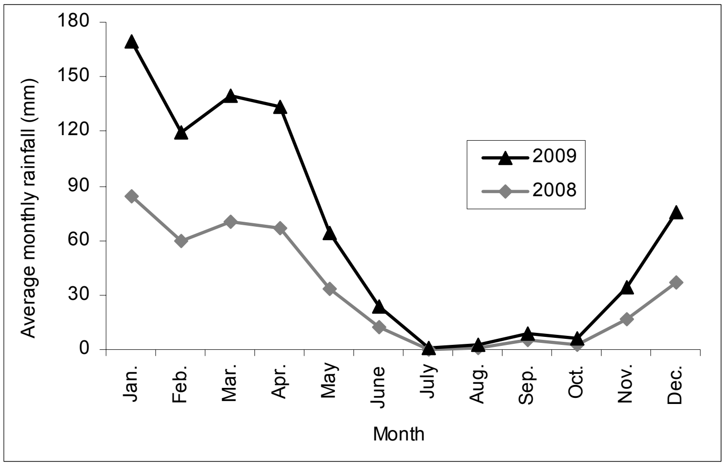

Fig. 2. Monthly average rainfall of 2008 and 2009 recorded at Semirom station within the study area.

Field survey was operated with the following details (Fig. 3).

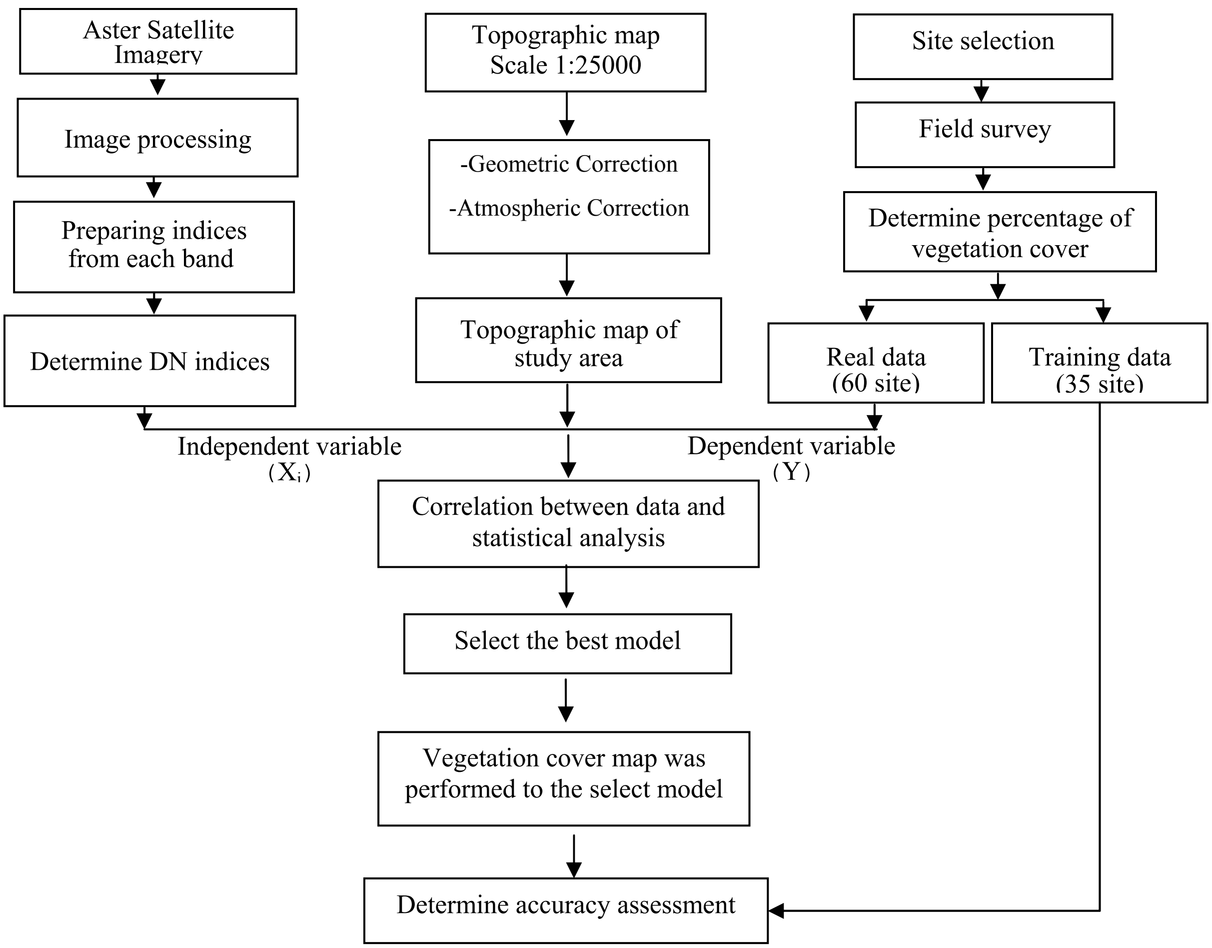

Fig. 3. The process method of field survey

Satellite data

A full scene of Aster imagery from 15 May 2008 was acquired. The dry summer image minimised the contribution of green ephemeral vegetation, maximised solar irradiance and land surface reflectance and also excluded cloud cover from the scene. In addition, the Digital Elevation Model (DEM) 1:25000 of the site was used.

Pre-processing Stage

Geometric correction was done on the data with suitable accuracy and average squares error of lees than 0.8 pixels. In this manner that the most up-dated image was related to topography map of 1:25000 with RMSe, 0.5 pixels and with the use of 30 control spots with suitable dispersion, then ASTER image with the use of 20 joint spots were recorded. With attention to being mountainous of a part of site, the correction of the topography was done with usage of site's DEM and images information. By employing the re-sampled method in this study, the 30-meter bands of 4, 5, 6, 7 and 8 were transformed into 15-meter bands.

Preparing the percentage map of the vegetation cover

In order to preparing the percentage map of the vegetation cover, with the use of existing satellite images, vegetation indicators of Table 1 were prepared. In order to analyze the amount of vegetation cover percentage, the data field in each vegetation type was collected by stratified random sampling method. In each sampling unit, 10 plots were located randomly on perimeter of a supposed circle with about 20 meter radius and then percentage vegetation cover has been estimated on each plot. The average of 10 estimated cover has been considered for each sampling unit. Then, each DN of plots with vegetation indicators, assimilation of simple linear regression was done between plots cover as dependent (Y) variable and same quantities of each plot in vegetation indicator as independent variable (Xi). As a result, strong relationships between vegetation cover and vegetation indices means that image indices have a capability for vegetation cover assessment. Among vegetation indicators, NDVI indicator has the most quantity of percentage map of cover index. So, in order to preparing percentage map of vegetation cover, this indicator was used. Then this equation was then applied to the desired to the desired images in the ERDS software. It is evident that the output resulting from it is a map expressive of the percentage of plant cover in different points. In the next stage, with regard to the plant cover of the region and by the use of re-classification technique, this image was divided into different levels.

Study of the validity of the produced map

The map was checked against the ground data to study its validity. For this purpose, during the visits from the region at the data of receiving satellite data, the validity of the region cover map was determined and with regard to the data from 35 control points, the general validity and Capa factor for this map was calculated.

RESULTS

The regression relationships between fields cover data and vegetation indices at landscape scale, across the Aster scene, are given in Table 2. At this scale, an study area, only NDVI vegetation indices was significantly correlated with field cover data, the strongest relationships, explained 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. These vegetation indices, although explained relatively low proportions or less consistent predictors of the variance of the field data.

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.

The results of stepwise regression on vegetation indices show in Table 3. According to Tables 3, first, each index was entered into the model, but they were removed for the model in next stages and only NDVI index remained in the final model. The equation for this model is as follow:

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

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	0.78
	10801.492	44	245.488	

The distinctive factor for this model is 0.78% and the null hypothesis is rejected at the probability level of 1%. Since there is a linear regression relation between the plant crown cover percentage and the above bands, the model is therefore valid. So, by the use of the map resulted from the above equation, the region ranges under study is divided into 5 separate levels on the basis of the percentage of the plant crown cover. The map resulting from the classification of the ranges is depicted in figure 4. The total validity and the Capa factor for this map are 68.53% and 72.43%, respectively. Moleele et al. (2001) obtained the validity of the plant cover at about 63.5% which conforms to the results obtained in this research.

DISCUSSION

So far, many plant spectral indexes have been introduced for the study of 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 only one index has been used as independent variable. It is successful when the plant cover is highly vigor and turgid and the effect of soil reflection is minimum. Therefore, in drought and semi-drought regions, even in years with suitable raining, one index by itself cannot describe the plant cover of the region. The use of plant cover indexes is therefore more suitable for the study of plant cover of these regions due to the variety produced in the use of the existing data in spectral bands.

On the basis of the plant indexes, the results of the analysis showed that out of the 26 indexes used in this research 25 indexes did not have a meaningful relation with the percentage of the plant cover of the region and that reason for the lack of the estimation of the cover percentage by these indexes is the high variance among the cover data. NDVI index was the only index with a relatively higher relation with the plant cover percentage of the region which is related to the use of band 2 and 3 in this index. This index had also a correlation of (r=0.28) with plant cover in a study performed by Arzani et al. (1998). The explanation should be searched in the strong reflection of plant cover within the limit of band 3 of Aster gauge. Also, Khajedeen (1995) in his study in Jazmooriyan region introduced the NDVI index as the only suitable index for the study of plant cover in the region (11). The results of Sepehri study (2003) also showed that in regions with high plant cover percentage; this index is correlated with plant cover (5). 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 (9). But in Zahedifard's (2003) study NDVI had a meaningful correlation with the plant cover percentage ($R2= 0.83\%$) although the plant cover rate was low (4). Farzadmehr et al. (2004) in a study performed in Semirroom region estimated the correlation between NDVI index and plant cover data at $<0.5\%$ error.

Moleele et al. (2001) also estimated the correlation between NDVI index and the bush herbaceous biomass in semi-drought ranges of Botswana to be at$<0.5\%$ error. The studies done by Hobbs (1995), Janalog et al. (1998) and also by Tad 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 his studies showed that there was a meaningful correlation between numerical data resulted from 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 are therefore, higher. The results of this research also showed that only 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 Red and NIR regions which is therefore an acceptable result. Due to the effect of high reflection of the background soil and the percentage of annual and perennial graminae in plant composition in drought and semi-drought regions, the correlation indexes between the cover crown percentage and the plant indexes drops (since, on the one hand the direction of the leaves on the stems of this group of plants results in less reflection compared to broad leaves and on the other hand, these plants lack sponge mesophyll). Because of the low percentage of cover crown in the region under study (25%) and 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). The results obtained by Sepehri (2003) also showed that because of the prevalence of spectral reflection 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% (27). The results obtained by Pickup et al. (1993) also showed that in drought and semi-drought ranges 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. Therefore, a plant index should have the capability of being used both in drought and green conditions of the cover (97). Therefore, it can be concluded that by the application of the tested plant indexes, the estimation of plant cover in the region conditions has no desirable result. In a study done by Abdullahe (1997), no meaningful regression relation between the plant indexes and plant cover percentage was obtained. Also, in a study done by Khavaneenzadeh (1999), in Nayeer region of Yazd, none of the indexes had any meaningful relation with the total cover rate the preparation of plant cover percentage map (2 and 6). 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 (Friedel and Shaw 1987; Wilson et al.1987).

CONCLUSIONS

One of the main objectives of this study was to identify vegetation indices that were the best predictors of vegetation cover, and hence vegetation cover map, in the semi-arid of the Gharah Aghach region, in Center of Iran. Criteria that make an image-based vegetation index suitable for regional monitoring are strong relationships with vegetation cover in the vegetation types of the district, ability to predict this cover within semi-arid region. Although simple red-infrared contrast indices, in particular NDVI, have been widely used with success in arid land studies throughout the world, our results confirm that they are the best indices for recording vegetation cover. However, this suggests that NDVI and simple red-infrared indices are useful for general cover monitoring regardless of more localised soil and vegetation variation.

REFERENCES

Amiri, F. (2008). Modeling multiple use of rangeland by using GIS. Ph.D thesis, Islamic Azad University Research and Science Branch, Tehran, Iran. 560 pp.

Apan, A. A. (1997). Land cover mapping for tropical forest rehabilitation planning using remotely sensed data, Int. *Journal of Remote Sensing* **18**, 5. 1029-1049.

Arzani, H. (1998). Using digital Landsat TM image data for estimate production and vegetation cover. *Iranian Journal of Natural Resources*, **50**, 1, 11-21

Asrar, G., Kanemasu, E. T., and Yoshida, M. (1985). Estimates of leaf area index from spectral reflectance of wheat under different cultural practices and solar angle. *Remote Sensing of Environment* **17**, 1–11

Bannari, A., Morin, D., Bonn, F., and Huete, A. R. (1995). A review of vegetation indices. *Remote Sensing Reviews* **13**, 95– 120

Baret, F., Guyot, G., Begue, A., Maurel, P., and Podaire, A. (1988). Complementarity of middle-infrared with visible and near-infrared reflectance for monitoring wheat canopies. *Remote Sensing of Environment* **26**, 213–225. doi: 10.1016/0034-4257(88)90078-8

Baret, F., and Guyot, G. (1991). Potentials and limits of vegetation indices for LAI and PAR assessment. *Remote Sensing of Environment* **35**, 161– 173

Baret, F., Jaquemound, S., and Hanocq, J. F. (1993). The soil line concept in remote sensing. *Remote Sensing Reviews* **7**, 65–82

Baret, F. (1995). Use of spectral reflectance variation to retrieve canopy biophysical character. In F. M. Danson, and S. E. Plumer (Eds.), Advances in environmental remote sensing. Chichester: Wiley (chap. 3)

Bastin, G. N., and Ludwig, J. A. (2006). Problems and prospects for mapping vegetation condition in Australia's arid rangelands. Ecological Management and Restoration **7**, S71–S74. doi: 10.1111/j.1442-8903. 2006.293 4.x

Booth, D. T., and Tueller, P. T. (2003). Rangeland monitoring using remote sensing. *Arid Land Research and Management* **17**, 455–467

Boyd, D.S., Foody, G.M., Curran, P.J., Lucus, R.M. and Klonzak, M., 1996. An assessment of radiance in Landsat TM middle and thermal infrared warebands for the detection of tropical forest rgeneration. Int. *Journal of Remote sensing* **17**, 2, 249-261

Byrne, G. F., Crapper, P. F., and Mayo, K. K. (1980). Monitoring landcover change by principal component analysis of multitemporal Landsat data. *Remote Sensing of Environment* **10**, 175–184. doi: 10.1016/0034-4257(80)90021-8

Campbell, J. B. (1996). 'Introduction to remote sensing.' 2nd edn. (Guilford Press: New York.)

Dusek, D. A., Jackson, R. D., and Musick, J. T. (1985). Winter wheat vegetation indices calculated from combinations of seven spectral bands. *Remote Sensing of Environment* **18**, 255–267. doi:

10.1016/0034- 4257(85)90061-6

Dymond, C. C., Mladenoff, D. J., and Radeloff, V. C. (2002). Phenological differences in Tasseled Cap indices improve deciduous forest classification. *Remote Sensing of Environment* **80**, 460–472. doi: 10.1016/S0034-4257(01)00324-8

Elvidge, C. D., and Chen, Z. (1995). Comparison of broad-band and narrow band red and near-infrared vegetation indices. *Remote Sensing of Environment* **54**, 38– 48

Farzad mehr, H. Arzani, H. Darvish sefat, A. and Jafari. M. (2004). The study of Landsat TM image data for estimate production and vegetation cover in Hanna-Semirom. *Iranian Journal of Natural Resources* **57**, 2, 339-350

Foran, B. D., and Pickup, G. (1984). Relationship of aircraft radiometric measurements to bare ground on semi-desert landscapes in central Australia. *Australian Rangeland Journal* **6**, 59–68. doi: 10.1071/RJ9840059

Foran, B., and Pearce, G. (1990). The use of NOAA AVHRR and the green vegetation index to assess the 1988/1989 summer growing season in central Australia. In: 'Proceedings of 5th Australasian Remote Sensing Conference'. Perth. pp. 198–207. (Committee of the 5th Remote Sensing Conference: Perth.)

Friedel, M. H., and Shaw, K. (1987). Evaluation of methods for monitoring sparse patterned vegetation in arid rangelands. II. Trees and shrubs. *Journal of Environmental Management* **25**, 306–318

Fung, T., and LeDrew, E. (1987). Application of principal components analysis to change detection. Photogrammetric *Engineering and Remote Sensing* **53**, 1649–1658

Gilabert, M. A., Gandı´a, S., and Melia´, J. (1996). Analyses of spectral–biophysical relationships for a corn canopy. *Remote Sensing of Environment* **55**, 11 – 20

Gilabert, M.A. J. Gonza´lez-Piqueras, F.J. Garcı´a-Haro, J. Melia. (2002). A generalized soil-adjusted vegetation index. *Remote Sensing of Environment* **82**, 303–310

Graetz, R. D. (1987). Satellite remote sensing of Australian rangelands. *Remote Sensing of Environment* **23**, 313–331. doi: 10.1016/0034- 4257(87)90044-7

Hobbs. T. J. (1995). The use of NOAA-AVHRR NDVI data to assess herbage production in the arid rangeland of central Australia". Int. *Journal of Remote sensing* **16**, 7, 1289-1302

Huete, A. R. (1988). A soil-adjusted vegetation index (SAVI). *Remote Sensing of Environment* **25**, 295–309. doi: 10.1016/0034- 4257(88)90106-X

Huete, A. R., Post, D. F., and Jackson, R. D. (1984). Soil spectral effect on 4-space vegetation discrimination. *Remote Sensing of Environment* **15**, 155–165. doi: 10.1016/0034-4257(84)90043-9

Ingebritsen, S. E., and Lyon, R. J. P. (1985). Principal components analysis of multitemporal image pairs. *International Journal of Remote Sensing* **6**, 687–696

Jafari,R. M. M. Lewis and B. Ostendorf. (2007). Evaluation of vegetation indices for assessing vegetation cover in southern arid lands in South Australia. *The Rangeland Journal* **29**, 39-49 www.publish.csiro.au/journals/trj

Jianlong, L. (1998). Estimating grassland yield using remote sensing and GIS technical in China .*New Zeland Journal of Agriculture* **41**.31-38

Jin, S., and Sader, S. A. (2005). Comparison of time series tasselled cap wetness and the normalized difference moisture index in detecting forest disturbances. *Remote Sensing of Environment* **94**, 364–372. doi: 10.1016/j.rse.2004.10.012

Kauth, J. R., and Thomas, G. S. (1976). The tasselled cap-A graphic description of the spectral-temporal development of agricultural crops as seen by Landsat. In: 'Proceedings of the LARS 1976 Symposium on Machine Processing of Remotely-sensed Data'. Purdue University, West Lafayette, Indiana. pp. 4B41-44B51. (Committee of the LARS Symposium: West Lafayette.)

Khajeddin. S. J. (1995). A survey of the plant communities of the Jazmorian Iran ‹using land sat Mss data. Ph.D Thesis. University of Reading

Kimes, D. S., Markham, B. L., Tucker, C. J., and McMurtrey, I. J. E. (1981).Temporal relationships between spectral response and agronomic variables of a corn canopy. *Remote Sensing of Environment* **11**, 401–411. doi: 10.1016/0034-4257(81)90037-7

LePrieur, D., Verstraete, M. M., and Pinty, B. (1994). Evaluation of the performance of various vegetation indices to retrieve cover from AVHRR data. *Remote Sensing Reviews* **10**, 265– 284

McGregor, K. F., and Lewis, M. M. (1996). Quantitative spectral change in chenopod shrublands. In: Focus on the future-the heat is on! Proceedings of the 9th Biennial Conference of The Australian Rangeland Society'. Port Augusta, SA. (Eds L. P. Hunt and R. Sinclair.) pp. 153–154. (Australian Rangeland Society: Cottesloe.)

Masoud, A. A. and Koike, K. (2006). Arid Land Sanitization Detected by Remotely-Sensed Land Cover Changes: (A Case Study in the Siwa Region NW Egypt). *Arid Environment* **66**, 151-167

Myneni, R. B., Keeling, C. D., Tanser, C. J., Asrar, G., and Nemani, R. R. (1997). Increased plant growth in the northern high latitudes from 1981 to 1991. Nature 386, 698–702. doi: 10.1038/386698a0

Moleele, N. S., Ringose. W. Arnberg. (2001). Assessment of Vegetation Indices Useful for Browse [forage] prediction In Semi-arid rangelands. *INT. J. remote Sensing*. **22**, 5,741-756

O'Neill, A. L. (1996). Satellite-derived vegetation indices applied to semi-arid shrublands in Australia. Australian Geographer **27**, 185–199

Oˇstir, K., Veljannovski, T., Podobnikar, T., and Stanˇciˇc, Z. (2003). Application of satellite remote sensing in natural hazard management. *International Journal of Remote Sensing* **24**, 3983–4002. doi: 10.1080/ w0143116031000103826

Pavelka, K. and Lena Halounová. (2005). Using of TM data and VHR data for reclamed areas monitoring using vegetation indeces. The International Archives of the Photogrammetry, *Remote Sensing and Spatial Information Sciences* 34, Part XXX

Pearson, R. L., and Miller, L. D. (1972). Remote sensing of standing crop biomass for estimation of the productivity of the shortgrass prairie, Pawnee national grasslands, Colorado. In: 'The 8th International Symposium on Remote Sensing of the Environment'. Ann Arbor, MI. pp. 1355–1379. (Committee of the Symposium: Ann Arbor, MI.)

Perry, C. R., and Lautenschlager, L. F. (1984). Functional equivalence of spectral vegetation indices. *Remote Sensing of Environment* **14**, 169–182

Pickup, G., and Nelson, D. J. (1984). Use of Landsat radiance parameters to distinguish soil erosion, stability, and deposition in arid central Australia. *Remote Sensing of Environment* **16**, 195–209. doi: 10.1016/0034- 4257(84)90064-6

Pickup, G., and Foran, B. D. (1987). The use of spectral and spatial variability to monitor cover change on inert landscapes. *Remote Sensing of Environment* **23**, 361–363. doi: 10.1016/0034-4257(87)90046-0

Pickup, G. (1989). New land degradation survey techniques for arid Australia: problems and prospects. *Australian Rangeland Journal* **11**, 74–82. doi: 10.1071/RJ9890074

Pickup, G., Chewings, V. H., and Nelson, D. J. (1993). Estimating changes in vegetation cover over time in arid rangelands using Landsat MSS data. *Remote Sensing of Environment* **43**, 243–263. doi: 10.1016/0034- 4257(93)90069-A

Price, K. P., Guo, X., and Stiles, J. M. (2002). Optimal Landsat TM band combinations and vegetation indices for discrimination of six grassland types in eastern Kansas. *International Journal of Remote Sensing* **23**, 5031–5042. doi: 10.1080/014311602101 21764

Purevdorj, Ts., Tateishi, R., Ishiyama, T., and Honda, Y. (1998). Relationships between percent vegetation cover and vegetation indices. *International Journal of Remote Sensing* **19**, 3519–3535. doi: 10.1080/014311698213795

Qi, J., Chehbouni, A., Huete, A. R., Kerr, Y. H., and Sorooshian, S. (1994). A modified soil adjusted vegetation index. *Remote Sensing of Environment* **48**, 119–126. doi: 10.1016/0034-4257(94)90134-1

Richardson, A. J., and Wiegand, C. L. (1977). Distinguishing vegetation from soil background information. Photogrammetric *Engineering and Remote Sensing* **43**, 1541–1552.

Richardson, A. J. Wiegand, C. L. Wajura, D. F. Dusek, D. and Steiner, J. L. (1992). Multisite analyses of spectral– biophysical data for sorghum. *Remote Sensing of Environment* **41**, 71–82

Rouse, J. W., Haas, R. W., Schell, J. A., Deering, D. W., and Harlan, J. C. (1974). Monitoring the vernal advancement and retrogradation (greenware effect) of natural vegetation. Greenbelt, MD, USA, NASA/GSFCT, Type 3, Final Report

Sadeghi, Sh. (2009). The study of vegetation cover of Kalahrud region using ASTER data. M.Sc thesis, Department of Natural Resources, Isfahan University of Tecnology

Satterwhite, M. B., and Henley, J. P. (1987). Spectral characteristics of selected soils and vegetation in northernNevada and their discrimination using band ratio techniques. *Remote Sensing of*

Environment **23**, 155–175. doi: 10.1016/0034-4257(87)90035-6

Schmidt, H. and Karnieli, A. (2001). Sensitivity of vegetation indices to substrate brightness in hyper-arid environment: the Makhtesh Ramon Crater (Israel) case study. *International Journal of Remote Sensing* **22**, 17, 3503-3520

Sellers, P. J., Berry, J. A., Collatz, G. J., Field, C. B. and Hall, F. G. (1992). Canopy reflectance, photosynthesis, and transpiration. III: A reanalysis using improved leaf models and a new canopy integration scheme. *Remote sensing of environment* **42**, 187-216

Seperhi, A. (2003). Using Vegetation indices for estimate rangeland vegetation cover in Jahan nama refuge, *Iranian Journal of Natural Resources* **55**, 2, 20-31

Thenkabail, P. S., Ward, A. D., Lyon, J. G., and Maerry, C. J. (1994). Thematic Mapper vegetation indices for determining soybean and corn growth parameters. *Photogrammetric Engineering and Remote Sensing* **60**, 437–442

Thiam A., and Eastman J. R. (2001). 'Vegetation indices in IDRISI 3.2 release 2, guide to GIS and image processing.' Vol. 2. (Clark University: Worcester, MA.)

Todd. S. W., R. M. Hoffer, D. G. Milchunas. (1998). Biomass estimation on grazed and ungrazed rangelands using spectural Indices. Int. *Journal of Remote sensing* **19**, 3, 427-438

Tueller, P. T. (1987). Remote sensing science applications in arid environment. *Remote Sensing of Environment* **23**, 143–154. doi: 10.1016/0034-4257(87)90034-4

Wallace, J., Behn, G., and Furby, S. (2006). Vegetation condition assessment and monitoring from sequences of satellite imagery. *Ecological Management and Restoration* **7**, S31–S36. doi: 10.1111/j.1442- 8903.2006.00289.x

Wang, J., Rich, P. M., Price, K. P., and Kettle, W. D. (2004). Relationships between NDVI and tree productivity in the central great plains. *International Journal of Remote Sensing* 25, 3127–3138. doi: 10.1080/0143116032000160499

Wessels, K. J., Prince, S. D., Frost, P. E., and Zyl, D. V. (2004). Assessing the effects of human-induced land degradation in the former homelands of northern South Africa. *Remote Sensing of Environment* **91**, 47–67. doi: 10.1016/j.rse.2004.02.005

Wilson, A. D., Abraham, N. A., Barratt, R., Choate, J., Green, D. R., Harland, R. J., Oxley, R. E., and Stanley, R. J. (1987). Evaluation of methods of assessing vegetation change in the semi-arid rangelands of southern Australia. *Australian Rangeland Journal* **9**, 5–13. doi: 10.1071/RJ9870005

Zahedifar, N. (2002). Provision land use map by using satellite data in Bazoft watershed, M.Sc thesis, Department of Agriculture, Isfahan University of Technology

BIOGRAPHY AND CONTACTS

Fazel Amiri Faculty Member of Scientific Board, Islamic Azad University Bushehr Branch, Iran.

Address:
Fazel Amiri,
Department of Natural Resources,
Islamic Azad University Bushehr Branch,
Iran.
P.O. Box: 751494433
Bushehr-Iran,
Tel: +989131102025.
Corresponding Author's: famiri@na.iut.ac.ir or famiri@iaubushehr.ac.ir

Tayebeh Tabatabaie,

Faculty of Yang Research Club,
Islamic Azad University Bushehr Branch,
Iran.

Email: tabatabaie20@yahoo.com

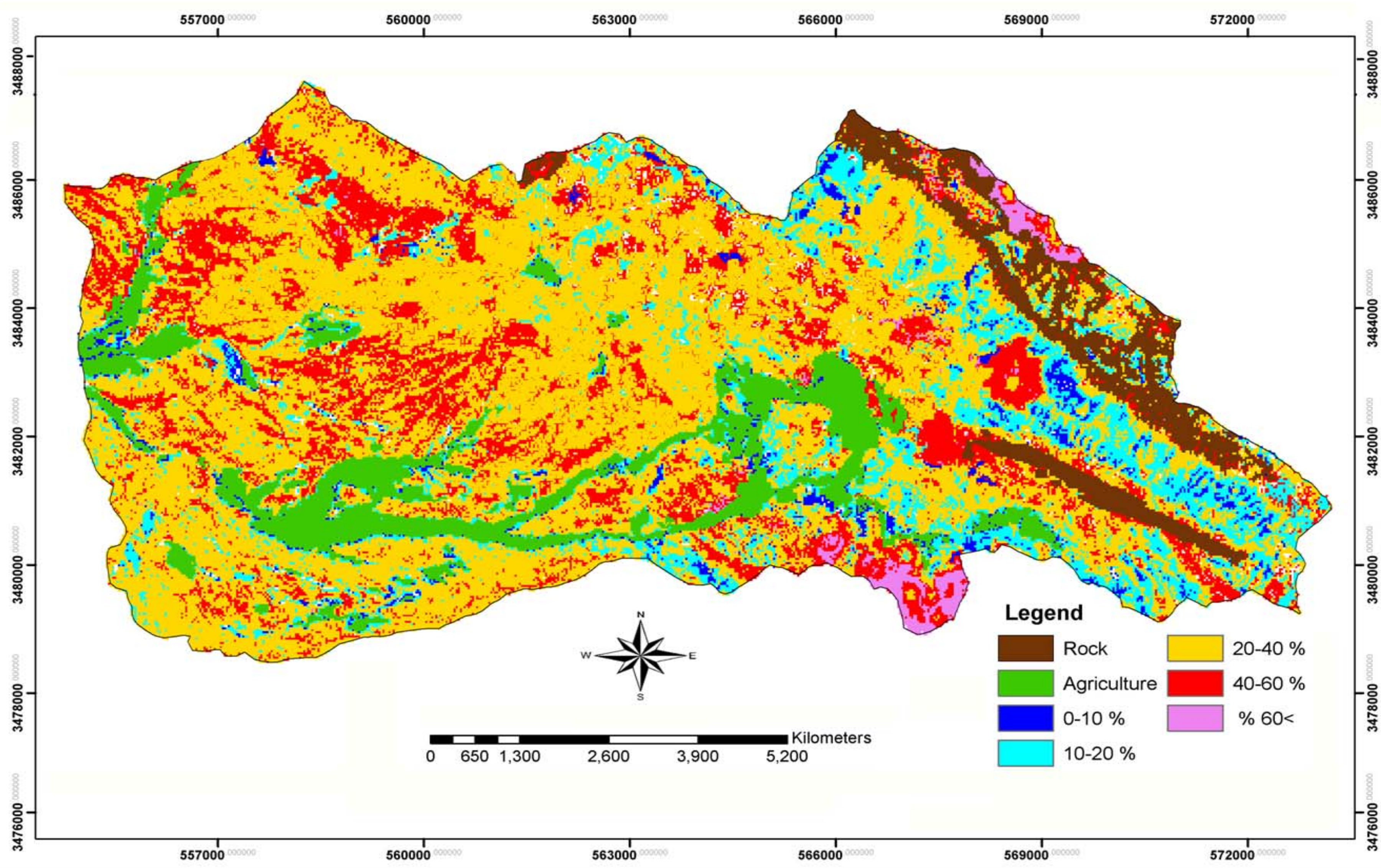

Fig 4. Vegetation cover (%) mapping of Ghareh Aghach rangelands