Using Remote Sensing data for Vegetation Cover Assessment in Semi-arid Rangeland of Center Province of Iran

Fazel Amiri [A], Tayebeh Tabatabaie [B]

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

[B] Ph.D Student of Islamic Azad University, Department of Energy and Environmental, Research and Science Branch Tehran, Iran. Email: tabatabaie20@yahoo.com

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 images 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

Keywords: rangeland, remote sensing, vegetation cover, production, vegetation index, monitoring.

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 (Amiri, 2008). 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 (Graetz 1987; Tueller 1987; Pickup 1989). 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 (Booth and Tueller 2003; Ošstir et al. 2003; Bastin and Ludwig 2006; Wallace et al. 2006; Jafari et al. 2007). 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 (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 and biomass (Asrar et al. 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 VI are called broadband because they are based on algebraic combinations of reflectance in the red (R), and 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).

Some vegetation indices are simple arithmetic combinations of reflectance measurements, contrasting the high infrared and low red reflectances that characterise 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) 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. 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). Duncan et al. (1994) reported that SAVI, NDVI and PVI indices or even simple band ratios depend on shrub types and phenological 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.

The perpendicular vegetation index (PVI) (Richardson and Wiegand 1997) 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 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 (Arzani 2005). 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 rangelands (Rouse et al. 1974; Boyd et al. 1996; Pearson and Miller 1972; Qi et al. 1994).

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.

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.

Material 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 (Fig. 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.

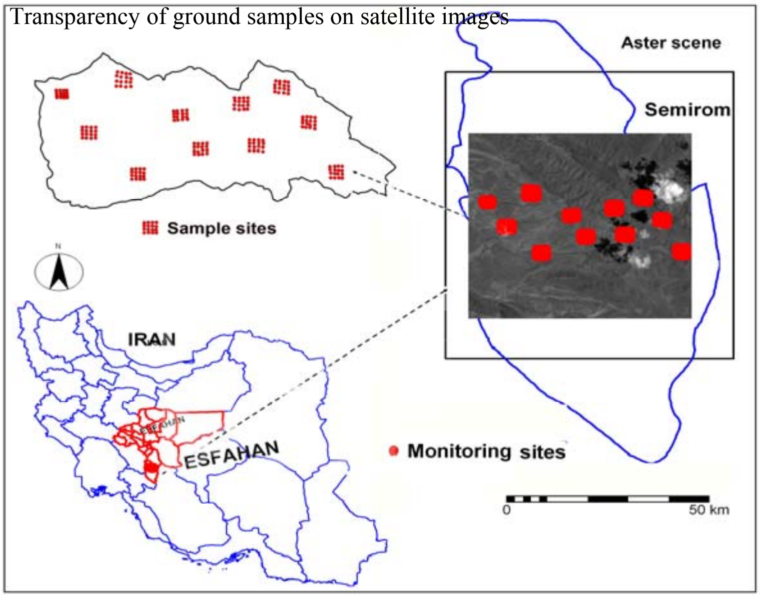

Fig. 1. Location of study area within the Ghareh Aghach District.

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, 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 quadrats 1m^2 each, were established alongside of transects. Vegetation cover was measured within the quadrats (Fig.2)

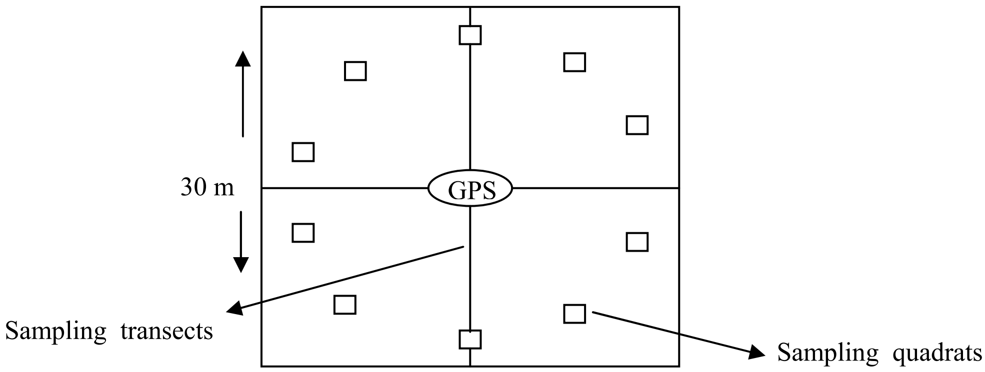

Fig 2. Sampling method in each site

In order to analyze vegetation cover percentages, the data field for each vegetation type was collected by stratified random sampling. In each quadrats the percentage vegetation cover was estimated. ASTER images of corresponding fieldwork data were obtained. Image processing in terms of geometric and atmospheric corrections was done. Based on Richard's (1993) suggestion for reducing error caused by sun angle DN values converted to spectral reflectance (Figure 3).

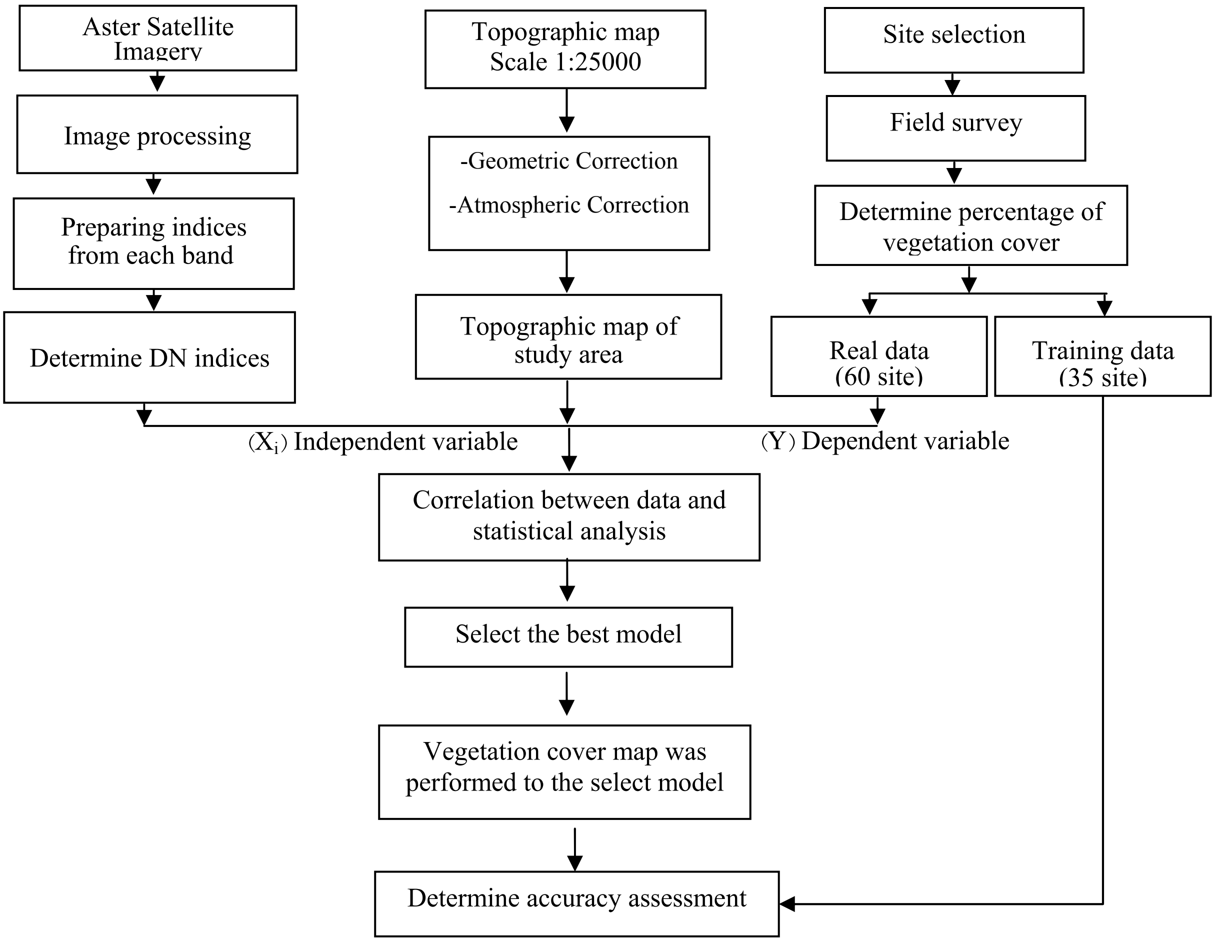

Fig.3. Model for image processing and integrating ground data with satellite data

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 (Fig.4).

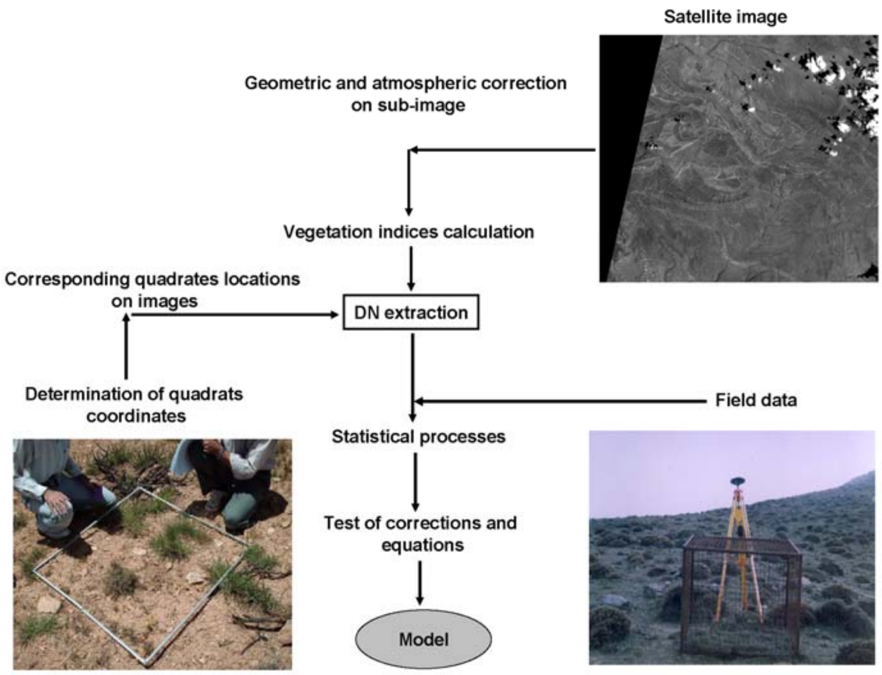

Fig. 4. Model for image processing and integrating ground data with satellite data

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).

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, (1997)	(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)

Then values of indices relative to ground data as suggested by (Arzani et al. 2005) 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 quadrats 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, an study area, only NDVI vegetation indices were significantly correlated with field cover data, 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.

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 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:

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

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	
Mean along transect	Actual value	8.81±21.07	-	-	
	Estimated value	2±22.61	-	-	

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%. 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% which conforms to the results obtained in this research.

Discussions

Estimations of vegetation parameters of three major plant groups from Aster images 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 images 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 (O'Neill 1996). 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 plant 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 establishthis index. This index was correlated with plant cover (r=0.28) in a study performed by Arzani (1998). 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. 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. 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. But in Zahedifard's (2003) study NDVI had a meaningful correlation with the plant cover percentage ($R2= 0.83\%$) even though the plant cover rate was low. Farzadmehr 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. 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), Jianlong (1998) and also by Todd 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 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 by (Arzani 1994). Band red is also sensitive to brightness of soil surface and is able to accurate estimation of cover (Graets 1987). Arzani (2005) investigated on ability of some vegetation indices and had been proved the real ability indices that has been created based on middle infrared band.

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). 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%. 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. 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 (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 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 confirm that they are the best indices for recording vegetation cover in sem-arid regions. However, this suggests that NDVI and simple red-infrared indices are useful for general cover monitoring regardless of more localised 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 (Fig. 6).

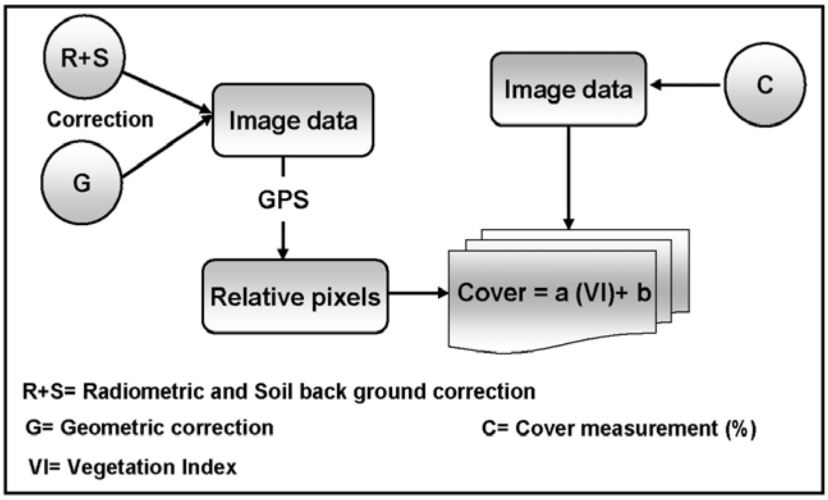

Fig.6. Model for estimating cover from satellite data

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*

References

1. 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.

2. 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

3. Arzani, H. (1994). Some aspects of estimating Short – term and long-term rangeland carrying capacity, PhD Thesis. University of New South Wales. Australia

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

5. Arzani, H. (2005). Vegetation indices for vegetation parameters measurements using remote sensing data in arid areas. First Conference Remote Sensing in Kuwait, 26-28 sep.

6. 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

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

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

9. 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)

10. 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

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

12. 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

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

14. Duncan, J. D. Stow, J. Franklin, & A. Hope (1993). Assessing the relationship between spectral vegetation indices and shrub cover in the Yornada Basin, New Mexico. *Int. J of Remote sensing* 14: 3395-3416.

15. 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

16. 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

17. 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.)

18. 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

19. 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

20. 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

21. 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

22. 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

23. 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

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

25. 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

26. 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

27. 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

28. 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

29. 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

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

31. 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

32. 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.)

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

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

35. 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

36. 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

37. 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

38. Richards, J. A. (1993). Remote sensing Digital Image Analysis an Introduction. 2nd Ed., Springer-Verlag, New York.

39. Richardson, A. J., and Wiegand, C. L. (1997). Distinguishing vegetation from soil background information. Photogrammetric *Engineering and Remote Sensing* **43**, 1541–1552

40. 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

41. 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

42. 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

43. 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

44. 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

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

46. 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

47. 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

48. 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

49. 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

50. 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

51. 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

52. 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

53. Zahedifar, N. (2003). Provision land use map by using satellite data in Bazoft watershed, M.Sc thesis, Department of Agriculture, Isfahan University of Technology

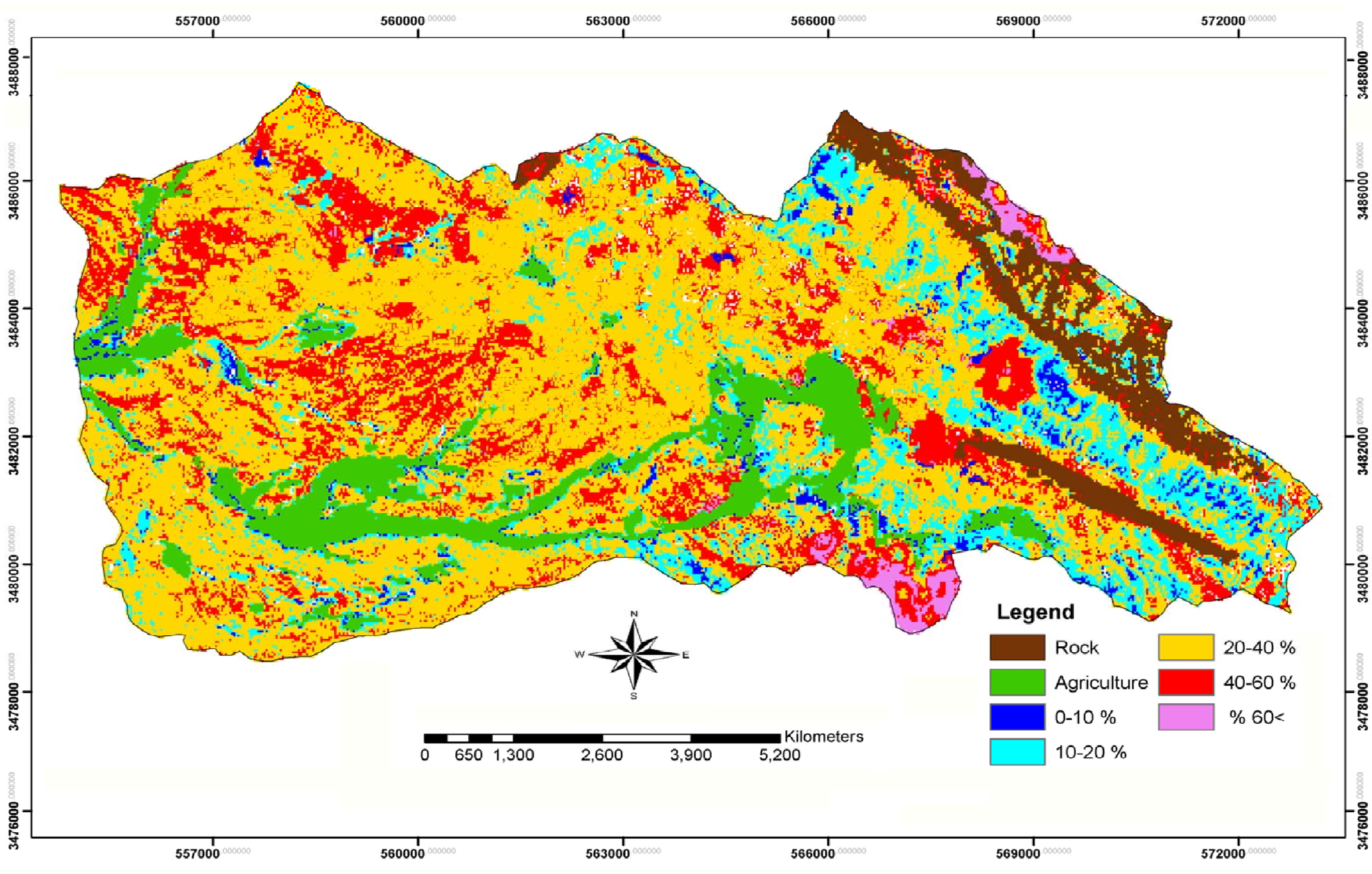

Fig 5. Vegetation cover (%) map of Ghareh Aghach rangelands