ESTIMATION OF FOREST STAND PARAMETERS IN DENSITY CLASSES IN ARID AND SEMI-ARID REGIONS USING LANDSAT ETM+ DATA

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ABSTRACT:

In this investigation the capability of Landsat ETM+ data for estimation of forest stand density and canopy area in National Park of Khabr in Kerman province, Iran in different density classes was evaluated. In a preliminary study, density mapping in the study area was qualitatively implemented and very thin, thin and semi-dense classes were concluded. Measurements made in sample plots in each density class were considered as a reference. Orthorectified satellite data were used to produce different ratios, vegetation indices (VIs), VIs for soil influence decreasing, components of Principal Component Analysis (PCA) and Tasselled Cap transformation features to apply in further analyses together with the original bands. Simple regression between stand parameters and digital values of each synthetic and original band was separately investigated. Ratio3 ((ETM3 – ETM1)/ (ETM3 + ETM1)) showed the highest correlation (R = 0.75 and Adj. R^2 = 0.54) with stand density measurements in sample plots of semi-dense class. Through multiple regression the results of explanation of variability of dependent variables were improved. Utilizing Ratio3 together with Ratio5 ((ETM4 – ETM5)/ (ETM4 + ETM5)) showed the highest ability to model stand density (Adj. R^2 = 0.75) in semi-dense class. Near results achieved from some other bands in this class and the other ones, too. Regression validation showed that the whole models were statistically valid. Higher spatial resolution satellites data such as SPOT5 and IRS are advised to be examined to improve the results.

1. INTRODUCTION

In arid and semi-arid regions, vegetation plays an important role in soil conservation, fluid prevention, underground water nutrition and life continuance. Irregular exploiting of forests and rangelands made serious damages during late time and also treated life cycle.

In order to manage vegetation in these areas it is necessary to gather their correct and updated information. In this relation utilizing different possibilities and techniques such as remotely sensed data is advised.

Satellite data were used in estimation of vegetation vital parameters (Ripple *etal*., 1991; Cohen & Spies, 1992; Chiao, 1996; Xu etal., 2003, Maselli *etal*., 2005; Sivanpillari etal., 2006).
In this study estimation of crown area and density of forest stands in arid and semi-arid regions was investigated. Such studies have been implemented in different areas (Satterwhite & Henley, 1987; Leprieure *etal*., 1996; Hurcom & Harrison, 1998).

2. MATERIALS AND METHODS

This study was implemented in some parts of forest stands (1800 ha) in National Park of Khabr, Kerman, Iran This area was situated between 28° 46′ 00″ to 28° 49′ 30″ northern latitude and 56° 28′ 30″ to 56° 37′ 30″ eastern longitude and 2000 to 2600 meters above mean sea level (figure 1).

Various forest trees and shrubs such as *Pistacia atlantica*, *Pistacia khinjuk*, *Acer monspessulanum*, *Amygdalus* spp. and *Juniperus excelsa* exist in the study area and *Pistacia*, *Acer* and *Amygdalus* types were dominant forest types.

In order to meet the study aim, forest species canopy was qualitatively estimated through strip sampling. In this regard 3 density classes consisting very thin (1-5%), thin (6-25%) and semi-dense (26-50%) were recognized. In each density class, crown area and density of forest species in 30 plots were measured.

Landsat ETM+ data dated 19/May/2000 pre-processed and then orthorectified using 14 GCPs based on Toutin model (Ann., 2001). RMS error was less than half a pixel.

Band ratioing (Hurcom & Harrison, 1998, Leprieur *etal*., 1996), PCA, Tasselled Cap Transformation (Todd & Hoffer, 1998) and band fusion (Darvishsefat, 2002) performed. Based on climatic conditions in the study area, suitable vegetation indices were achieved to reduce soil reflectance (Hurcom & Harrison, 1998; Karteris, 1990). Some of ratios and vegetation indices indicated in table 2 and the whole list is accessible in Naseri, 2002.

Linear and logarithmic regression relations between quantitative values in sample plots and the relevant spectral values in the original and synthetic bands were investigated as the other investigations (Cohen & Spies, 1992, Xu *etal*., 2003, Maselli *etal*., 2005; Sivanpillari *etal*., 2006). Then considering additional sample plots in each density class, regression validation for the models with R^2>0.5 in confidence level of 95% was evaluated (Montgomery & Peck, 1992). When control data locate in prediction distance the regression model is statistically valid.

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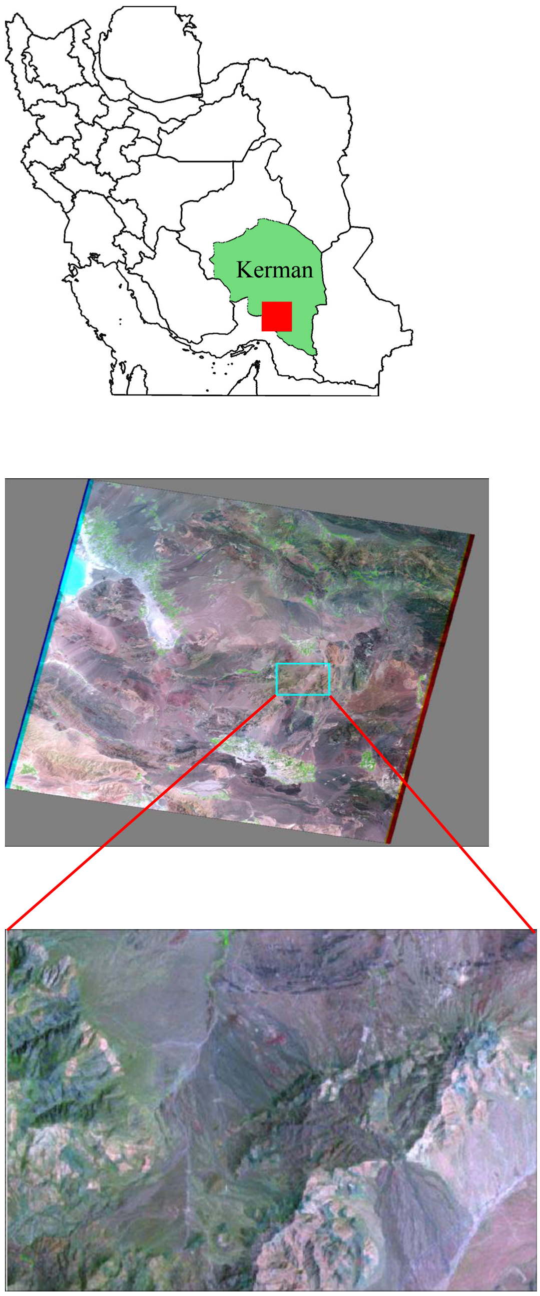

Figure1. Situation of the study area in Iran and in a satellite image frame

3. RESULTS

The best results from simple and multiple regression models possessing the most correlation and determinant coefficients indicated in tables 3 and 4 respectively.

Original / synthetic band	Details
ETM8	ETM+ Pan band
Ratio1	ETM3-ETM2
Ratio2	ETM5/ETM7
Ratio3	(ETM3-ETM1)/ (ETM3+ETM1)
Ratio4	(ETM4-ETM1)/ (ETM4+ETM1)
Ratio5	(ETM4-ETM5)/ (ETM4+ETM5)
SAVI	((ETM4-ETM3) / (ETM4+ETM3+L))(1+L) L = 0, 0.5, 1 for rich, medium and poor vegetation, respectively
PCA1(1,2,3)	First component of PCA for visible bands
PCA1(4,5,7)	First component of PCA for infrared bands
FusionIHS5	Band5 achieved from pan and multispecral bands fusion using Intensity, Hue, Saturation Method
FusionR3	Band3 achieved from pan and multispecral bands fusion using Spectral Response Method

Table2. Synthetic and original bands

Density class	variable	regression model	R	Adj. R^2	Sig. level
Very thin	NT	NT = -32.225 * LRatio3 + 158.210	0.484	0.207	ns
	CA	CA = - 25.793 * LRatio2 + 149. 826	0.072	0.006	ns
Thin	NT	NT = 100.214 * Ratio4- 448.010	0.651	0.403	*
	CA	CA = 224.088 * Ratio4 – 1023.715	0.320	0.070	ns
Semi-dense	NT	NT = - 1.970 * Ratio3 + 255.910	0.748	0.543	**
	CA	CA = 4.535 * Ratio3 - 350.274	0.494	0.217	*

*, ** indicates 1% and 5% significance level, respectively and ns means not significant.
CA= Crown Area (m^2 per plot), NT= Number of Trees and shrubs (density), L= Natural logarithm, R= Correlation Coefficient, Adj. R^2= Adjusted Determinant Coefficient

Table3. The best simple regression models

Density class	Dependent variable	regression model	Adjusted R^2	Significance level
Very thin	NT	NT = 0.097128 * FusionIHS5 - 0.31421 * FusionR3 + 43.789 * LETM8 – 182.79	0.7284	*
Thin	NT	NT = - 0.295 * Ratio1 + 1.203 * Ratio3 - 1.061 * Ratio5 + 7.170	0.7316	*
Semi-dense	NT	NT = - 126.46* LPCA1(1.2.3) + 137.45 * LPCA1(4.5.7) – 184.78 * LSAVI + 796.13	0.7409	**
	LNT	LNT = 4.167 * LRatio3 – 15.082 * LRatio5 + 54.525	0.7504	**

*, ** indicates 1% and 5% significance level, respectively and ns means not significant.
NT= Number of Trees and shrubs (density), L= Natural logarithm, R^2= Determinant Coefficient

Table4. The best multiple regression models

Since determinant coefficients of simple regression models were less than 0.5, except for 1 model, validation was only performed for multiple regression models (table 5).
Based on the results achieved, the whole regression models were statistically valid.

4. CONCLUSIONS

Based on the results, among crown area and species density, as the two favoured parameters, the best regression models were concluded for the second one. Multiple regression in comparison with simple regression improved the results and the relations between measured parameters in sample plots and their spectral values in ETM+ data were some significant and some highly significant.
Reflection of forest species is mainly related to trees crown. In this research as in the other ones (Dewulf & Goosens, 1990; xu *etal*., 2003) when canopy was increased, significant relations were increased too.
On the other hand, reflection is indirectly related to species density. Hence it is expected that regression models are more significant for crown area rather than for species density. Irregularly, in this research, as in a similar one (Danson, 1987) the opposite result was achieved. In this regard it can be said that in dense forests, only the upper part of trees crowns observed by sensor. On the other hand, a large number of trees in lower strata not observed. Thus, it is possible that a significant relation between density (no. of trees) and reflection is not obtained.

Density class	Estimated parameter	Control plots no.	Prediction distance for confidence coefficient of 95%	Estimated value	Measured value
Very thin	NT	1	-0.629 : 5.997	2.3903	2
		2	1.199 : 7.891	4.1898	3
		3	1.668 : 8.354	5.0742	7
		4	5.012 : 11.876	8.4335	9
		5	3.435 : 10.080	6.4667	9
Thin	NT	1	-3.483 : 12.929	4.6000	6
		2	-1.679 : 14.225	6.1400	4
		3	10.272 : 33.593	21.8000	20
		4	0.136 : 23.216	11.5600	13
		5	-0.552 : 17.290	8.2450	14
Semi dense	NT	1	-1.091 : 19.481	7.7200	9
		2	5.561 : 25.570	14.2400	16
		3	12.169 : 43.219	25.7600	29
		4	19.487 : 49.342	33.5600	30
		5	23.142 : 46.604	34.0600	32
	LNT	1	1.834 : 2.998	2.3696	2.485
		2	1.646 : 2.821	2.1510	2.302
		3	2.495 : 3.638	2.9635	2.890
		4	2.674 : 3.830	3.1562	3.296
		5	2.843 : 4.109	3.3432	3.466

NT= Number of Trees and shrubs (density) L= Natural logarithm

Table5. Validation results for multiple regression models

In contrast, in areas such as the study area with sparse forests, not only the upper parts of trees but also most of the parts of them are observed by sensor. Therefore, it seems that crown area may not show the whole reflection. Also each of the trees separately is at the field of view of the sensor. So it can be concluded that increasing in species density makes increasing in foliage observed and reflection achieved and consequently significant relations between forest species density and spectral values in satellite data may be deduced.

Based on the results, ETM+ data showed a relative potential for estimating forest species density in the study area. Different similar researches indicated capability of satellite data in estimating vegetation quantitative parameters (Cohen & Spies, 1992; Chiao, 1996; Xu *etal*., 2003). In This regard, using satellite data with better spatial resolution such as spot5 and IRS is advised.

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