Forest Extent Mapping Using Fusion of Multi Spectral and PAN Data, Comparison of ETM+ and IRS-PAN Imagery

Mohammad Rashid Amini*, Shaban Shataee**
*Research Centre of Agriculture and Natural Resources Kermanshah Province, Iran
Tel.: +98-0831-8358128, Fax: +98-0831-8351022 Email: rashidamini@gmail.com
**Faculty of forestry, University of agriculture science and natural resources, Gorgan, Iran
Email: shataee@yahoo.com

KEY WORDS: Forest mapping, ETM+, IRS-1C, Data Fusion, Zagros forests

ABSTRACT

Using of satellite imagery and its potentials are new tools in order to managing and mapping forest-covered area. This research compares the potentials of multi spectral and panchromatic imagery of Landsat ETM+ and IRS-1C panchromatic imagery for forest extent mapping and estimation of forest area in the northern Zagros forests, Iran. Also this research is seeking to determine which fusion of multi sensoral and multi spectral data can be improve the results of forest extent mapping. In this research some arithmetic bands such as suitable Rationing transformations, vegetation index, tasseled cap transformation, and principal components analysis were used to classification processes. In addition, the panchromatic images of ETM+ and IRS-1C with multi spectral bands were fused using IHS and automatic statistical PANSHARP techniques. After selecting some pixels as training area, the best band for classification were chosen using separability index and the images were classified with supervised classification to forest and non-forest. Then they were classified to forest, agriculture, garden, rock land, and Settlement area. The results of classifications were assessed trough sample ground truth points gathered using GPS base on a random systematic network. The results showed that ETM+ bands could better classified forest and non-forest areas than other images by maximum likelihood with 81.3% overall accuracy and 0.64 Kappa coefficient. This study explored that automatic PANSHARP technique compare with IHS method could better classify the forest area. This study distinguished the spectral capabilities of ETM+ data is more qualified for forest extent classification than spatial capabilities of ETM+ and IRS-IC panchromatic imagery

1. INTRODUCTION

Remote Sensing (RS) and geographic information systems (GIS) are useful tools for many forestry related applications (Ghayyas ahmad, 2001). Satellite remote sensing is a widely used technique to produce land use and land cover maps and to study vegetation cover (Fung and Chan, 1994). Multi spectral (Hyyppä et al., 1998) and hyper spectral remote sensing (Pu & Gong, 2004) have been used to map structural metrics at moderate resolution and broad scales. Land cover mapping with Landsat data for the entire the world has not yet been achieved, although there are impressive efforts underway to accomplish this massive task in the future (Tomppo et al., 2002). However, this issue has been accomplished in the local scale; for example, forest map of Noor area, Iran was produced using TM images (Shataee, 1996). The principal interest of merging multi resolution image data is to create composite images of enhanced interpretability (Kaczynski et al., 1995). Image fusion is a technique used to integrate the geometric detail of a high-resolution panchromatic (Pan) image and the color information of a low-resolution multi spectral (MS) image to produce a high-resolution MS image. (Konstantinos G. Nikolakopoulos, 2005) In this research images with better spectral and spatial resolution (Panchromatic and Multispectral) were fused for forest extent maping. Another objective was comparing the results obtained by fusing images using different merging techniques. Image merging techniques combines the spectral and spatial information from two different sensors into one image, which has both spectral and spatial resolution. When exactly three MS bands are concerned, the most straightforward fusion method is to resort to an HIS transformation (W. Carper et al., 1990& P. S. Chavez et al., 1991) also a new method of image fusion – a statistics based fusion, currently implemented in the PCI Geomatica software as special module, PANSHARP – shows significant promise as an automated technique.

2. MATERIAL AND METHODS

2.1 Study area

The studied area is located in Kurdistan province, western Iran, between 45° 42′ 16″ to 45° 54′ 3″ Longitude and 35° 47′ 57″ to 35° 57′ 44″ Latitude. The studied area called Armerdeh, with about 19964 ha is a mountain area with elevation between 1120 and 2200 meter above sea level and located in north of Zagros chain (Figure 1).

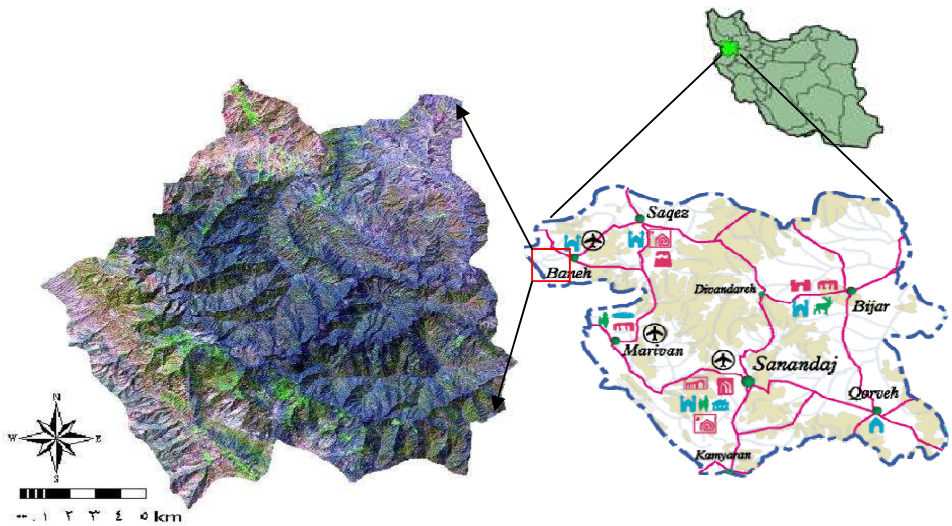

Figure 1. Location of the study area (Armardah, west of Iran), showing false color composite using ETM+ bands 5, 4, 3

2.2 Data and software

Landsat ETM+ (Enhanced Thematic Mapper Plus) and panchromatic band of IRS-1C images of August 2001 with a general resolution of about 28.5 and 14.25 meters for multi spectral and panchromatic Landsat image respectively and 6 meter for IRS-1C panchromatic band, were used to generate the forest extent map. The path/row of ETM+ and IRS-1C images is 168/35 and 64/45 respectively. Thermal band (ETM+6) were not used in this research. Also topographic maps sheets in 1:50,000 scale were used. PCI Geomatica 9.1 was used for image processing like supervised multi spectral classification. In addition ArcGIS 9.1 and IDRISI Kilimanjaro were used to analyze the classification results and accuracy assessment.

2.3 Geometric correction

Remote sensing data, directly acquired from the satellites may contain errors such as instrument error, noise, and geometric distortion. In a preprocessing stage, it is necessary to correct the image mostly if we need the same coordinates and projection on the based maps (Kamal, 1999). The Landsat ETM+ images had ortho rectification correction used in this research. The panchromatic band of IRS-1C geo referenced with 37 control points and digital elevation model by polynomial method, nearest neighbor Resampling algorithm and the RMSe was less than one pixel. The coordinate system assigned to the geo reference had UTM projection, correspond to zone 38; the datum is the Provisional WGS 1984, Area Iran and International ellipsoid.

2.4 Image processing

In order to meet the objectives of this research using mentioned software. Thirty-seven ground control points (GCPs) extracted from a 1:50000 digital topographic map were used for geocoding the image data. Then corrected images were enhanced using contrast enhancement, False Color Composite (FCC), Principal Component Analysis (PCA), Tasseled cap transformation and vegetation indices. Image processing and fusion techniques are shown in flowchart below (Figure 2).

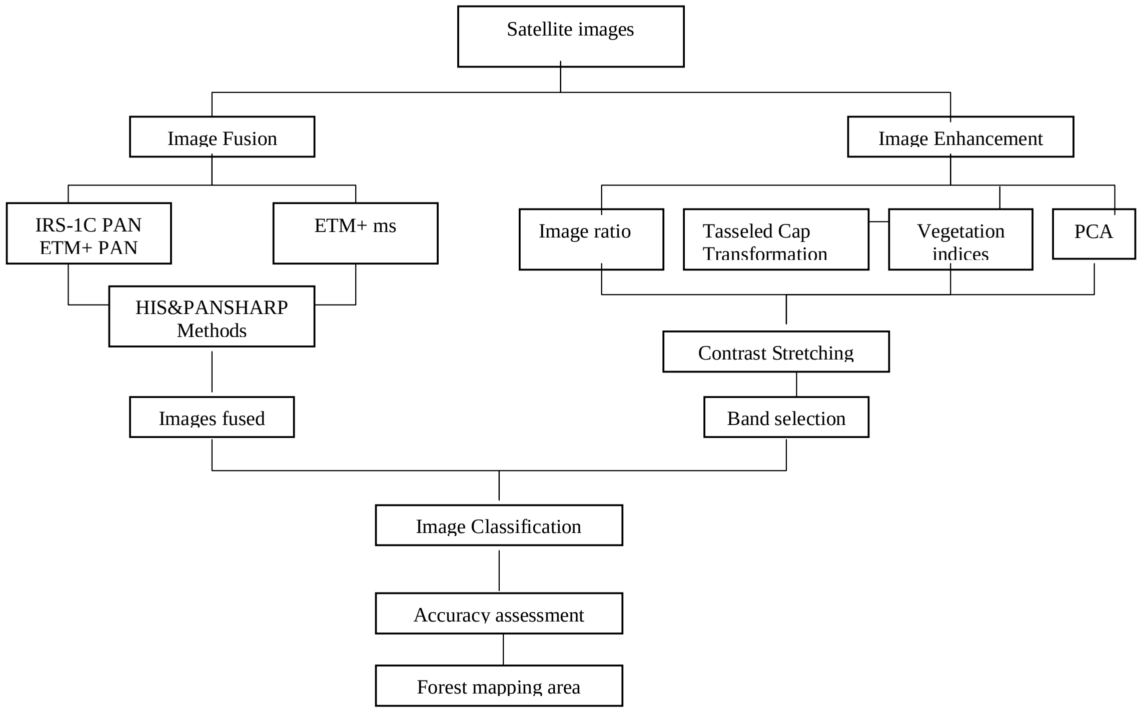

Figure 2. Flowchart of image processing

2.5 Image enhancement

In order to improve information extracted from satellite Image and suitable spectral transformations such as rationing, principal components analysis (PCA), and Tasseled Cap transformation and several vegetation indices were performed on the ETM+ data plus the main spectral bands. Mathematical formulae for calculating Vegetation index and ratios used in this research are given below (equations 1 to 6).

$$NDVI = \frac{NIR - R}{NIR + R} \quad \textbf{(Equ.1)} \qquad SAVI = \frac{(NIR - R)(1 + L)}{NIR + R + L} \quad \textbf{(Equ.2)} \qquad AVI = NIR - R \quad \textbf{(Equ.3)}$$

$$RVI = \frac{R}{NIR} \quad \textbf{(Equ.4)} \qquad ratio1 = \frac{\mathrm{ETM} + b4}{\mathrm{ETM} + b2} \quad \textbf{(Equ.5)} \qquad ratio2 = \frac{\mathrm{ETM} + b5}{\mathrm{ETM} + b2} \quad \textbf{(Equ.6)}$$

NIR= near infra red band, R= red band, ETM+B4= band 4 of landsat7 ETM+ data

The availability of the simultaneous panchromatic bands with the multi spectral bands gives the best opportunity to generate effective multi spectral bands with higher spatial resolution (Darvishsefat and et al., 2000). In addition, the panchromatic images of ETM+ and IRS-1C with multi spectral bands were fused using IHS and automatic statistical PANSHARP techniques. The IHS fusion converts a color image from the RGB (Red, Green, Blue) space into the IHS (Intensity, Hue, Saturation) color space. Because the Intensity (I) band resembles a PAN image, it was replaced by a high-resolution Pan image in the fusion. A reverse IHS transform is then performed on the PAN together with the Hue (H) and Saturation (S) bands, resulting in an IHS fused image (Yun Zhang, 2004). Four compounds of landsat ms bands including 4,3,2; 5,3,2; 5,4,3 and 7,4,2 were fused with panchromatic images of ETM+ and IRS-1C in HIS method. Also all the main bands of ETM+ were fused with panchromatic image at one time in the PANSHARP techniques. Then images were enhanced using contrast stretching and several color composites for better image interpretation and class differentiation.

2.6 Fieldwork design

To determine the training samples points we applied simple random sampling. A grid over the study area was designed to devote each area to each point. After the field observations, the coordinates of sample points were introduced to the GPS to recognize and locate points in the field. To define the land cover category, each point of area with tree cover >10% was supposed as forest, therefore the other areas were supposed as non-forest. The non-forest areas were defined five land use classes including rangeland, agriculture, garden, rock land and man-made installation. Also a 550*550m grid based on systematic random sampling was used to produce ground control map of study area.

2.7 Channel selection

The best band set for image classification to forest and non-forest classes in first stage and rangeland, agriculture, garden, rock land and manufactured installation in second stage were chosen using statistic characteristics of mentioned classes Spectral Signatures. Therefore, two set bands selected including seven bands for mentioned classification in two stages.

2.8 Classification

Training samples were used to determine the land cover classes on the ground and then train a supervised classification of the satellite image. After selecting some pixels as training area for forest and non-forest area in first time and other features such as rangeland, agriculture, garden, rock land and man-made installation in second time, The images including image fusion and the best set bands were classified with supervised classification to forest, non-forest by maximum likelihood, parallelepiped and minimum distance algorithms. In addition, the mentioned images were classified by forest, rangeland, agriculture, garden, rock land, and manufactured installation in second time. Then the non-forest classes of the all maps that were classified to 6 classes were merged into one class. Finally, 66 maps of forest and non-forest cover were produced. The Majority Filter was applied for smoothing the classification result. The classified maps were assessed with sample ground truth and created a confusion matrix. The classified cover map was evaluated using overall accuracy, user and producer accuracies, and Kappa coefficient.

3. RESULTS AND CONCLUSION

The best set bands for images classification to forest and non-forest classes in first time and rangeland, agriculture, garden, rock land and man-made installation classes was chosen in second time according to table 1.

The result of this band selection showed that near infrared band (ETM+4) and red visible band (ETM+3) are chosen for each selection set bands. It indicates that using of two mentioned bands is very effective for produce forest map using satellite data. In this research, two classes include forest and non-forest separated in first step and six classes include rangeland, agriculture, garden, rock land and manufactured installation were separated in second step from satellite images. Also separation between applied classes was identified by means of the Bhattacharyya and transformation divergence index. The Bhattacharyya and transformation divergence index for forest and non-forest classes were 1.45 and 1.86 respectively.

Table 1. the chosen set bands for image classification to 2 and 6 classes

Input bands	Chosen bands for 2 classes	Chosen bands for 6 classes
$ETM+_1$	$ETM+_1$	$ETM+_3$
$ETM+_2$	$ETM+_2$	$ETM+_4$
$ETM+_3$	$ETM+_3$	Ratio 4/2
$ETM+_4$	$ETM+_4$	AVI
$ETM+_5$	RVI	RVI
$ETM+_7$	Ratio 4/2	Greenness
RVI	NDVI	PCA_1
AVI		
Ratio 4/2		
Ratio 5/2		
Brightness		
Greenness		
NDVI		
SAVI		
PCA_1		
PCA_2		

In addition, results showed that there is little spectral interference between forest and garden classes in some area. This subject was true for soil in open forests too. Therefore, this subject was caused results of accuracy assessment to be lower. Sixty six maps of forest area were obtained from supervised classification of selected set bands and fused images. To assess the capability of mentioned images to discriminate forest area, the results of the classification were compared pixel by pixel to the ground truth. Therefore, confusion matrix was produced; then overall accuracy, user and producer accuracies, and the Kappa coefficient were derived from the confusion matrix. Some results of classified images with their accuracy assessment are shown in the table 2.

Table 2. Subset of images classified that had been high accuracy

Bands combination	classification type	algorithm classifier	overall Accuracy	Kappa coefficient	forest P.A	no-forest P.A	forest U.A	non-forest U.A
Selected 7 bands set	2 classes	ML	81.3	0.64	86.95	78.95	83.45	76.34
Pansharp IRS-PAN with ETM+-ms	2 classes	ML	80.53	0.59	80.54	80.50	87.43	71.46
Pansharp ETM+-PAN with ETM+-ms	2 classes	ML	79.75	0.57	81.03	77.59	85.90	70.83
Pansharp ETM+-PAN with ETM+-ms	6 classes	ML	79.13	0.56	79.06	79.25	86.52	69.20
Pansharp IRS-PAN with ETM+-ms	2 classes	PPD	78.83	0.52	81.62	56.57	74.21	67.32
Selected 7 bands set	2 classes	PPD	78.52	0.49	81.85	76.21	83.96	68.54
Pansharp IRS-PAN with ETM+-ms	6 classes	PPD	78.36	0.55	77.34	80.08	86.74	67.72
Pansharp IRS-PAN with ETM+-ms	6 classes	ML	77.59	0.53	76.35	79.67	86.35	66.66
IHS ETM+-PAN with ETM+4,3,2	2 classes	ML	77.59	0.52	80.54	72.61	83.20	68.89
IHS ETM+-PAN with ETM+4,3,2	6 classes	ML	73.42	0.46	71.18	77.17	84.01	61.39
IHS ETM+-PAN with ETM+4,3,2	6 classes	PPD	73.26	0.45	70.93	77.18	83.96	61.18
Pansharp IRS-PAN with ETM+-ms	2 classes	MD	71.21	0.35	70.50	76.47	79.36	54.98
IHS ETM+-PAN with ETM+4,3,2	6 classes	MD	70.79	0.40	70.93	70.54	80.22	59.02
IHS IRS-PAN with ETM+5,3,2	2 classes	MD	69.86	0.39	67.73	73.44	81.12	57.47
Selected 7 bands set	2 classes	MD	63.83	0.29	57.64	74.27	79.05	50.06

The accuracy of the classified maps was measured through confusion matrices. As shown in the table 2 the results of accuracy assessment indicate that using of the best selected ETM+ bands could better classified forest and non-forest areas than other images by maximum likelihood algorithm with 81.3% overall accuracy and 0.64 Kappa coefficient. The produced mentioned map is shown in figure 3.

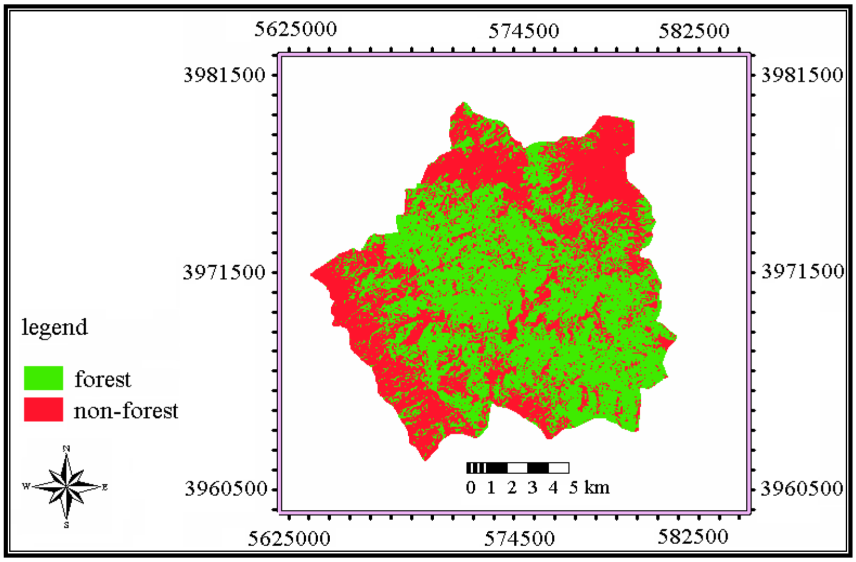

Figure 3. Produced forest and non-forest map of the best selected ETM+ bands

The main purpose of this study is estimate of the potential of the Landsat7- ETM+ data and IRS-1C panchromatic band for forest area mapping in Zagros forests of Iran. Results from this study demonstrate the feasibility of using multi spectral Landsat7 ETM+ data to extend forest mapping. Also the results of image fused accuracy assessment showed fusion of ETM+ multi spectral bands with IRS-1C panchromatic band had improved the classification results compared with ETM-pan. This study determined that automatic PANSHARP technique could better classify the forest and non-forest area comparing with IHS method because of using of all ETM+ multi spectral bands for image fusion. Also fusion of ms bans 4, 3 and 2 and pan images had a high capability to classify the forest and non-forest area, comparing with other band compounds. The produced forest extent map showed that studied area has about 12690 ha forest. Also the results of this investigation demonstrates using of maximum likelihood algorithm for image classification improved the classification results compared with parallelepiped and minimum distance classification algorithms. Similar conclusion was reported by shataee (2003) and Yuan and et al (2005).

Reference:

Darvishsefat, A., P. Fatehi., A. Khalil Pourb. & A. Farzanehb, 200x. Comparison of spot5 and landsat7 for forest area mapping.

Erkki Tomppo et al, 2002. The role of remote sensing in global forest assessment. A remote sensing background paper for Kotka IV expert consultation 01.07-05.07.2002, Kotka, Finland. 31-52

Fung, T. and K. Chan. 1994. Spatial composition of spectral classes: a structural approach for image analysis of heterogeneous land-use and land cover types. Photogrammetric Engineering and Remote Sensing. 60, 173-180.

Ghayyas ahmad, 2001. mapping a dry shrub forest for biodiversity conservation planning (A case study in the Salt range of Pakistan, using remote sensing), Msc Thesis, ITC, Netherlands.

Hosseini, S. Z., S. J. Khajeddin, H. Azarnivand and S. A. Khalilpour, 2004. Land use mapping using ETM+data (Case study: Chamestan area, Iran), XXth ISPRS Congress ,Istanbul ,Turkey

Hyyppä, J., Hyyppä, H., Inkinen, M., & Engdahl, M. (1998). Verification of the potential of various remote sensing devices for forest inventory. Proceedings of IEEE geosciences and remote sensing society (pp. 1812–1814). Pasadena, CA: California Institute of Electrical and Electronics Engineers.

Kamal M. 1999. An assessment of multi data fusion in foret resources management, for the Northern of Selangor, Malaysia. Unpublished Master of Science in Geoinformation for Forest and Tree Resource Management, International Institute for Aeroesace Suevey and Earth Sciences (ITC). Enschede.

Konstantinos G. Nikolakopoulos. 2005. Eight different fusion techniques for use with very high-resolution data (Proceedings Paper), Image and Signal Processing for Remote Sensing XI, Lorenzo Bruzzone, Editors, 598205.

Pu, R. L., & Gong, P. 2004. Wavelet transform applied to EO-1 hyperspectral data for forest LAI and crown closure mapping. Remote Sensing of Environment, 91(2), 212–224.

P. S. Chavez, S. C. Sides, and J. A. Anderson, "Comparison of three different methods to merge multiresolution and multispectral data: Landsat TM and SPOT panchromatic," Photogramm. Eng. Remote Sens., vol. 57, no. 3, pp. 295–303, 1991.

W. Carper, T. Lillesand, and R. Kiefer, "The use of Intensity-Hue-Saturation transformations for merging SPOT panchromatic and multispectral image data," Photogramm. Eng. Remote Sens., vol. 56, no. 4, pp. 459–467, 1990.

Yuan, F. K. E. Sawaya, B. C. Loeffelholz, M. E. Bauer. 2005. Land cover classification and change analysis of the Twin Cities (Minnesota) Metropolitan Area by multitemporal Landsat remote sensing. Remote Sensing of Environment(95), pp: 317 – 328.

Zhang, Y., and Hong, G., 2004, An HIS and wavelet integrated approach to improve pan-sharpening visual quality of natural colour IKONOS and Quickbird images. University of New Brunswick, New Brunswick, Canada E3B 5A3.