COMPARING THE CAPABILITY OF ETM+ AND LISS-III IMAGERY IN RIPARIAN FOREST MAPPING: A CASE STUDY OF MAROON RIVER, IRAN

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ABSTRACT

Firoozynejad, M., Torahi, A. A. and Rai, S.C. 2017. Comparing the capability of ETM$^+$ and LISS-III imagery in riparian forest mapping: A case study of maroon river, Iran. Lebanese Science Journal. Vol. 18, No. 2: 226-233.

In order to assess and compare the capability of ETM$^+$ and LISS-III data in the mapping of riparian forests of the Maroon River in Behbahan, Iran, a small window of panchromatic and multispectral images of Landsat-ETM$^+$ and IRS-1D-LISS-III satellite data was selected. The quality of data and radiometric error was checked and geometric correction was implemented using 25 ground control points. Principal component analysis (PCA), tasseled cap transformation and appropriate vegetation indexes (NDVI) were applied to provide the main bands for incorporation in the classification processes. The study also used image fusion by Pansharp (the Gram-Schmidt Spectral Sharpening method) and the HSV method for high spectral and spatial resolution. After selecting the training data, the classification was carried out by choosing seven-class and three-class land-use/cover using a maximum likelihood algorithm. Transformed divergence and Jeffreys–Matusita were used to test the separability of the classes. Considering the results, it can be concluded that IRS1D-LISS-III and landsat 7-ETM+ data have a suitable ability for mapping the Maroon riparian forest as well as the classification of forest to separate landuse. The classification using original bands of ETM$^+$ is better than LISS-III data due to higher spectral resolution. The opposite of these results is only shown in the classification with three user classes. The overall accuracy and kappa coefficient in this method were 98.80 and 0.84, respectively.

Keyword: Behbahan, Riparian forest mapping, LISS-III, ETM+, maximum likelihood.

INTRODUCTION

Riparian zones possess an unusually diverse array of species and environmental processes. They play essential role in water and landscape planning in the restoration of aquatic systems, and in catalyzing institutional and societal cooperation for these efforts (Naiman and Decamps 1997). These forests are important because of their abundant biomass production (forest products), slow decomposition, and impact on natural cycles (Kozlowski 2002). In order to plan for proper management in the future, the sustainable development of human society in riparian forests and the sustained conservation of these ecosystems require an understanding of the properties of these ecosystems as well as evaluation of past changes in these properties. Among the important features and highlights when determining the spatial extent of the riparian forest, mapping and change detection is required. Producing and updating maps for large surfaces is costly and time consuming and in some cases very difficult to reach. Remote sensing can contribute to land-use/cover and forest resources mapping and classification including riparian forests (Darvishsefat and Shataei 1997; Torahi and Rai 2013).

Several studies on the ability of various sensors for forest mapping. Fattahi et al. (2007) studied land-use/cover mapping using ETM$^+$ and IRS sensors and compared different classification methods. An overall accuracy

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of 89.15 was obtained by using a maximum likelihood algorithm. They stated that the results of the vegetation indices were not satisfactory.

Moreover, in the same year Shataei et al. (2008) studied the ability of the same sensors to examine the mapping of a forest area in the Golestan province and they concluded that IRS satellite images have a better ability for forest mapping due to their higher spatial resolution.

Parma et al. (2010) used the multi spectral data of IRS-1D and Landsat imagery for forest type mapping. The results showed that the IRS-1D images were of better quality for the vegetation mapping.

Abdolahi et al. (2010) investigated the ability of IRS and Landsat imagery for density mapping of the forest canopy in Javanrood forests. The highest accuracy was determined using a combination of six bands of the LISS-IV data.

Due to the environmental importance of the Maroon riparian forest, conducting research in relation to vegetation cover mapping and the capabilities of satellite images for suitable management in this area is a high priority. Based on observation, the area has a dense canopy and full cover of shrub which makes field work difficult. The study mainly focused on the evaluation of LISSIII and ETM$^+$ images for mapping in the riparian forest in Behbahan.

MATERIAL AND METHODS

Study Area

The present research work was carried out in the riparian forest of Behbahan in Iran, which is located between latitude 32° to 35º N and longitude 41° to 44° E, with a land area of around 16,998 ha (Fig. 1). The climate in the study area is classified as being semi dry to dry. Minerals such as limestone, marl, gypsum and conglomerates are found in the area (Momenzade et al, 2011). The area is dominated by mixed trees and dense Tamarisk (*Tamarix arceuthoides*) and Populus euphratica Oliv (*Populus euphratica*) with shrub species in some areas (*Lycium shawii*). This creates an area with a beautiful natural environment and ecosystem along the Maroon river.

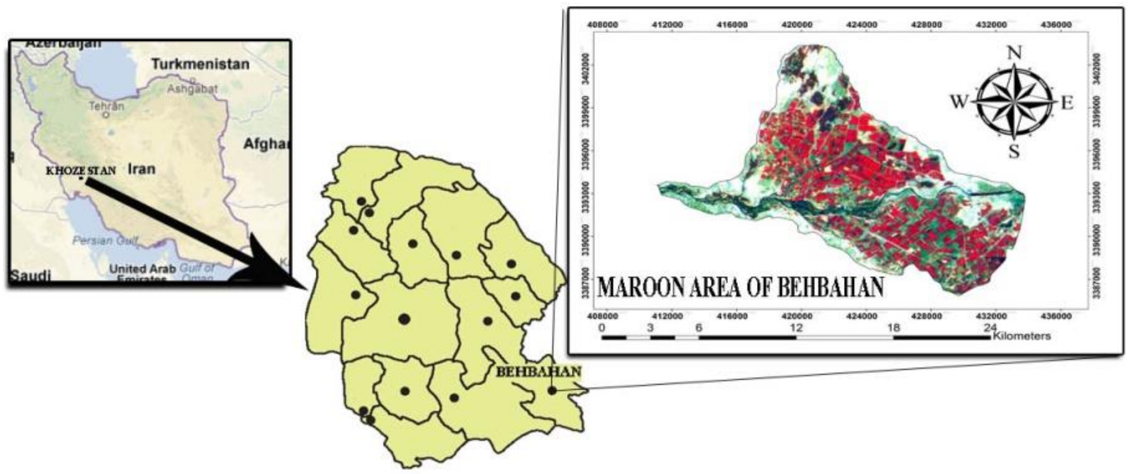

Figure 1. The location of the study area in the Khozestan province of Iran.

Data source

For this research digital topographic maps were used at the scale of 1:25000 and LISS-III data of the IRS-1D satellite (path 68 and row 49) from 11th October 2005 with a spatial resolution of 23.5 m and panchromatic band of 5.8 m (from the Iranian Space Agency) and Landsat ETM$^+$ data (path 164 and row 39) from 21st October 2011 with a spatial resolution of 30 m and panchromatic band of 15 m for generating land-use/cover maps. The software used were: ENVI 4.7, ENVI 4.8, Arc GIS 10, Map source, EXCEL and SPSS.

Pre-processing of satellite images

In the process of using satellite images it was necessary to use pre-processing methods such as atmospheric correction, radiometric correction, geometric correction, and the correction of height difference errors (Parma et al. 2010, Mobasheri, 2010). In this study, geometric correction has been carried out using topographic maps 1:25000 and a polynomial and nearest neighbour re-sampling method with an RMSE of 0.3 pixels. Atmospheric correction of the data was performed using the quick atmospheric correction method (QUAC) (Bernstein et al, 2012). Since the study area has a relatively flat topography, the error correction due to height difference was unnecessary (Jensen et al. 1999).

Satellite image processing

Satellite image processing including different spectral functions, was carried out to facilitate the process of extracting information from images and their classification (Ramadan and Kontny 2004). Processes such as principal component analysis (PCA), tasselledcap, data fusion, vegetation indexes and spectral classification were performed on the original image bands (Parma et al. 2010 and Alavipanah 2003). The first components which resulted from the PCA had the highest variance of spectral data; and consequently were added to the dataset as synthetic bands. In order to obtain a high spectral and spatial resolution image, multispectral bands and panchromatic bands were merged using Pansharp (the Gram-Schmidt Spectral Sharpen method) (Latifi et al. 2007) and the HSV method. Due to sparse standing tree coverage in the study area, there was interference between the spectral reflectance of soil and plant cover. The normalized difference vegetation index (NDVI) was measured for better vegetation cover detection and to enhance the vegetation spectral reflectance and reduce the soil effect (Mobasheri, 2010).

Classification

The spectral classification of images included the selection of training samples, and selecting the best band and operations of classification. To obtain training samples, after checking and identification of images, the training data was selected. For class separation (three and seven classes) Jeffreys–Matusita distance (JM) was used. The JM distance increased class separation like transformed divergence. This method improved classification accuracy. The characteristics of the JM method allow for an easier comparison of class separability between images (Laliberte *et al.* 2012; Gong *et al.* 1996). Data classification was carried out using the maximum likelihood algorithm because this algorithm is reported to be better than mahalanobis distance (Firoozynejad, 2013). For evaluating the ability of sensors and separation of land uses, the study area was classified into 3 classes (forest, rivers and others) to only differentiate forest from others, and 7 classes (roads, rivers, settlements, pastures, fallow, agriculture and forest) for separation of all users. To improve classification the study applied mode filters (3×3, 3×5 and 5×7) (Naseri et al., 2004; Bahadur, 2009). Four standards including overall accuracy, kappa coefficient, producer accuracy and user accuracy were employed to evaluate the classification made (Congalton and Green 1999).

RESULTS AND DISCUSSION

The results of the PCA showed that the first component of LISS-III and ETM^+ images are most of the data with respective rates of 96.82 and 96.60 percent. According to the results, the NDVI index at 95 per cent probability level was a positive correlation with the ground truth map (P<0.05). Finally, the collection of original and synthetic bands was produced, based on transformed divergence and spectral value, selected bands were obtained. Table 1 shows the selected bands for each classification for both sensors with the band used.

Table 1. Band collection of LISS-III and ETM+ sensors for 7 and 3 classes.

	LISS-III	**ETM+**
7 classes	PAN, LISS-III 1,2,3, Pansharp	ETM2,3,4, Brightness, NDVI, Pansharp, PCA1
3 classes	Pansharp, PAN, LISS-III 1,2,3	Pansharp, ETM 2,3,4, NDVI, PCA1

Seven and Three Classes Classification

After the selection of the appropriate bands and determining of the training samples, classifications with the maximum likelihood algorithm were carried out. Tables 2 and 3 show the results of the assessment of classification accuracy. Figures 3 to 8 display the best maps of classified images. Based on the confusion matrix, to classify the users seven classes, overall accuracy of classification was derived from the fusion of the panchromatic band by using the method Pansharp for LISS-III and ETM^+ which was 90.73 and 93.81 %, respectively, and the kappa coefficient for these was 0.63 and 0.89, respectively. The highest classification accuracy for the separation of forest from other areas is obtained from seven-class classification by the maximum likelihood algorithm using the Pansharp method (Table 2). The high kappa coefficient indicates a better matching in the maps with the ground truth map (Congalton and Green, 1999; Congalton, 2001; Congalton and Plourde, 2003).

According to the purpose of this research, which was to separate forest from other land uses, the highest overall accuracy for separating forest from other land uses, was classification with seven classes in fusion bands (with an overall accuracy for ETM+ and LISSIII of 93.81 and 90.73%, respectively). The producer accuracy of the forest was 98.06 and 98.56% for ETM+ and LISSIII, respectively, which showed that the percentage of pixels was correctly classified in ground truth and the remaining percentage of pixels was for other users who found that by mistake. User accuracy of sensors was 98.72 and 99.73%, respectively, which indicated real numbers of forest class pixels as well as forest, and the remaining percentage was users mistakenly classified (Table 2).

Generally, due to lower producer and user accuracy for settlements, roads, and sometimes fallow and pasture land, and to evaluate the separation of forest from others, five classes became one class, and the classification was carried out with three classes.

Accordingly, producer accuracy for ETM + and LISS-III was 98.70 and 98.56%, which shows the percentage of pixels that the ground truth map classified correctly, whereas the remaining percentage is pixels classified incorrectly. The lowest accuracy for separation of forest from other areas by three classes for the selected ETM^{+} and LISS-III bands is presented in Table 3. The highest overall accuracy of this research is 98.80% for LISS-III by the Pansharp method with three classes by the maximum likelihood algorithm and also a kappa coefficient of 0.84 (Table 3).

Table 2. The results of confusion matrix for 7 classes using the maximum likelihood algorithm.

	Original bands				**Selected bands**				**Fusion bands**			
	ETM+		**LISS-III**		**ETM+**		**LISS-III**		**ETM+**		**LISS-III**	
	Prod.A	**User.A**	**Prod.A**	**User.A**	**Prod.A**	**User.A**	**Prod.A**	**User.A**	**Prod.A**	**User.A**	**Prod.A**	**User.A**
Road	31.85	88.77	50.00	34.62	88.77	22.65	62.76	30.59	23.90	87.72	37.85	23.65
River	86.89	78.91	25.94	62.97	33.76	14.98	33.93	99.99	94.88	98.99	98.98	96.98
Settlements	83.89	14.84	50.01	59.26	83.96	71.78	25	10	98.99	99.99	50.52	21.05
Pasturage	82.90	52.96	81.16	96.55	97.53	87.13	90.89	97.29	91.75	99.15	88.00	94.07
Fallow	86.49	80.66	80.00	68.57	68.97	93.11	93.37	84.03	93.15	66.71	63.96	97.55
Agriculture	97.69	89.13	99.15	100.00	95.24	95.31	96.61	98.79	97.99	99.91	99.29	96.77
Forest	93.10	84.93	98.02	84.93	93.42	83.83	93.75	93.75	98.06	98.72	98.56	99.73
kappa coefficient	0.86		0.84		0.84		0.88		0.89		0.63	
overall accuracy	89.79		88.50		88.09		87.79		93.81		90.73	

*Prod.A= Producer accuracy
*User.A= User accuracy

Table 3. The results of confusion matrix for 3 classes using the maximum likelihood algorithm.

	Original bands				**Selected bands**				**Fusion bands**			
	ETM+		**LISS-III**		**ETM+**		**LISS-III**		**ETM+**		**LISS-III**	
	Prod.A	**User.A**	**Prod.A**	**User.A**	**Prod.A**	**User.A**	**Prod.A**	**User.A**	**Prod.A**	**User.A**	**Prod.A**	**User.A**
Forest	93.89	83.67	96.55	62.71	96.18	31.66	93.75	51.79	95.59	78.00	97.62	51.1
River	79.07	82.93	96.55	95.45	57.36	90.24	80.00	85.71	95.98	76.02	98.81	99.99
Others	99.40	99.65	92.63	99.92	98.04	99.69	98.55	99.98	97.84	99.99	100	98.01
kappa coefficient	0.88		0.74		0.55		0.15		0.71		0.84	
overall accuracy	98.61		94.01		89.64		90.54		98.70		98.80	

*Prod.A= Producer accuracy
*User.A= User accuracy

The high kappa of maps better indicates the similarity with the ground truth maps (Congalton and Green 1999; Congalton and Plourde 2003 and Congalton 2001). Finally, to estimate area of user in the region, based on the confusion matrix, the best maps were selected and user areas were calculated and presented in Table 4.

Forest area by the maximum likelihood algorithm for a Pansharp image of ETM+ and LISS-III was 1399.02 and 1405.64 respectively (Table 4). The calculated area of forest land by LISS-III is closer to the actual area of forest (1441.82 ha). The Maroon River was 12.98 and 11.08 for ETM^+ and LISS-III, respectively.

Table 4. The land use area (ha) of Fusion bands (Pansharp) in LISS-III and ETM+.

	Forest	Agriculture	Fallow	Pasture	Settlements
LISS-III	1405.64	5794.81	3116.99	3592.72	366.89
ETM+	1399.02	6875.81	2375.66	3000.10	174.21

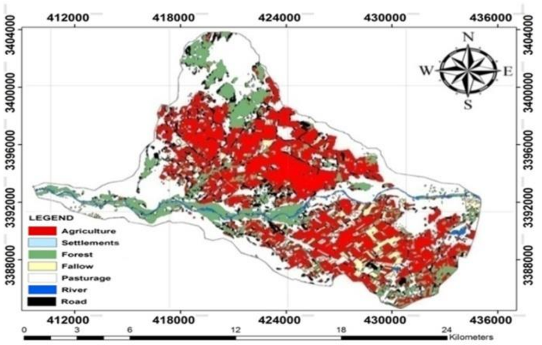

Figure 2. Land use mapping with seven classes by original bands of LISS-III

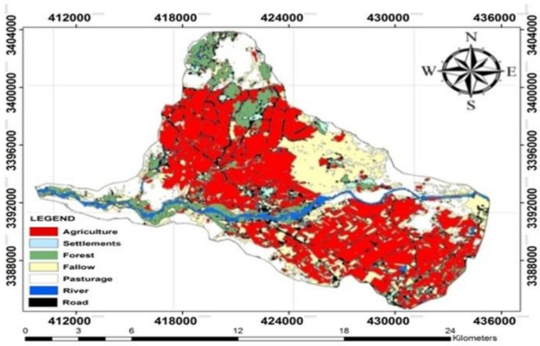

Figure 3. Land use mapping with seven classes by original bands of ETM^+

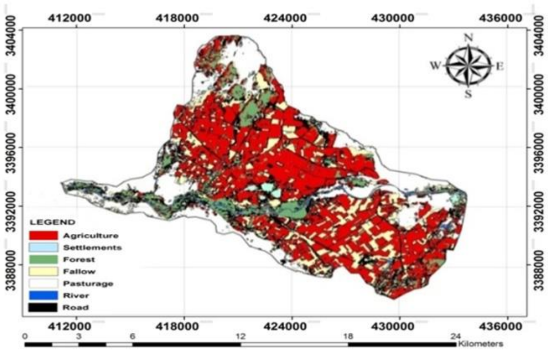

Figure 4. Land use mapping with seven classes by Pansharp method of LISS-III

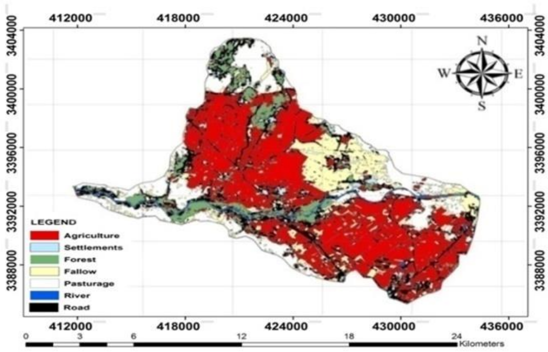

Figure 5. Land use mapping with seven classes by Pansharp method of ETM^+

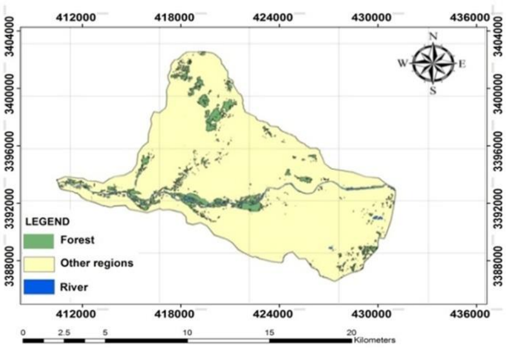

Figure 6. Land use mapping with three classes by Pansharp method of LISS-III

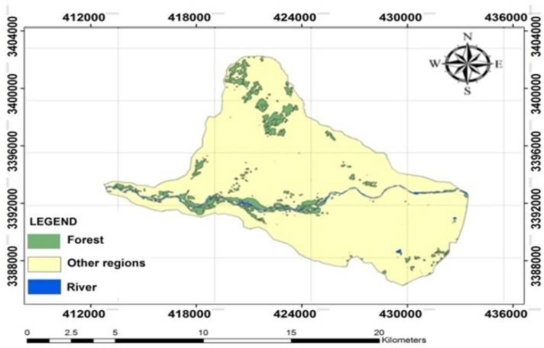

Figure 7. Land use mapping with three classes by Pansharp method of ETM$^+$

The land-use/cover area can be easily quantified from satellite imageries. Therefore, in this study, the forest map is generated using the images of ETM$^+$ and LISS-III. The results showed that the area is often covered with Tamarisk trees and *Populus euphratica Oliv* and within the region the tree types were scattered but dense. Maroon River was narrow in some locations and this caused wrong classification and separation of the river from the forests and other land uses and also reduced overall accuracy, user accuracy and producer accuracy, whereas the spectral overlap between different classes also caused a large difference between the overall kappa accuracy. Simultaneously, a multi-spectral image and panchromatic image were used in the Pansharp method and the data was compared with other classifications.

In the present study, conversely the power of the visual interpretation of satellite data was improved during the fusion operation. Similar to other studies, the higher classification accuracy compared with other classification in this study is an evidence for consistency with the ground truth map (Parma *et al.,* 2010; Latifi *et al.,* 2007; Khorami *et al.,* 2008 and Shataei et al., 2008). The reasons for this could be due to changed spectral/spatial resolution and increased value of spectral resolution by histograms observation.

When fusion results were compared to the original bands, LISS-III was better than ETM+ due to a lower spatial resolution panchromatic band of the ETM+ sensor compared to LISS-III. The present study used the NDVI index to estimate vegetation biomass and our findings were very much similar to other studies (Zarine *et al*., 2012; Dolati 2007; Abdi and Ghaderi, 2005; Farzadmehr *et al*., 2005 and Kuhnell 1996).

After the classification of images obtained from the Pansharp method, it can be seen that the classification of original bands had the highest accuracy compared to selected bands. This suggests that images of original bands are better for accurate maps than selected bands. It must be noted that this applies to both ETM$^+$ and LISS-III. A higher accuracy of ETM$^+$ than LISS-III was observed in the classification of the original bands, which is in agreement to what was reported by Fatahi *et al.* (2007). In other studies such as those of Hosseini *et al.* (2004), Latifi (2005) and Dolati (2007), classification with 3 classes showed higher accuracy. This could be due to the merging of land use classes that were causing spectral interference with each other and where it would be inappropriate to use separation. After merging classes, there was improved overall accuracy, but this created a map with fewer details. Scattering strands of forest, could be due to spectral interference of forest and non-forest and this will reduce the overall accuracy and kappa coefficient, as reported earlier by Abdolahi and Shataei (2012).

Based on the results obtained, ETM$^+$ showed a better separation of land uses than LISS-III because it has a higher spectral resolution. Thus, the mapping of the riparian forests of Maroon, and the separation of land uses by using Landsat ETM$^+$ and LISS-III images, was possible. However, the classification with original band multi-spectral bands of Landsat-ETM$^+$ was better than IRS-1D- LISS-III. Only in the classification with three user classes, opposite results were obtained.

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