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Analysis of land use-land covers changes using normalized difference vegetation index (NDVI) differencing and classification methods

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Over the last decade, the normalized difference vegetation index (NDVI) differencing method and classification method are widely used as a change detection method and provides detailed information for detecting and monitoring changes in land use-land cover (LULC). So in the presented study to raise awareness for the LULC change in Ardakan, Iran, two Landsat ETM+ images of the years 1990 and 2006 have been prepared and used to derive NDVI images and perform image classification. At first stage, differences between two correspondent NDVI images of the area was calculated and threshold to demonstrate the areas with 10% increase or decrease in NDVI values. From the results, the 18.83% of the region's NDVI values have decreased by about more than 10% from 1990 to 2006, while only 1.38% of it has increased at the same time period. At second stage, supervised classification was performed and outputs of the two time periods were compared to derive information on changes that occurred over a period of time. During the study period, urban areas were increased from 10.68% of the total land in 1990 to 17.16% in 2006 whereas, the agricultural lands were decreased from 30.15 to 21.76% in the same period.

Key words: Change detection, normalized difference vegetation index (NDVI), density slice, band math, image classification.

INTRODUCTION

Detection of land use-land cover (LULC) changes is one of the most important factors for management and planning issues. There are so many methods to do it but the common change detection methods include the comparison of land cover classifications, multi-date classification, band arithmetic, simple rationing, vegetation index differencing and change vector analysis (Jomaa and Kheir, 2003).

In general, multi date remote sensing data can be used for detection of the LULC changes (Coppin et al., 2004; Lu et al., 2004). Medium-resolution sensors are intended to provide appropriate scales of information for a wide-variety of Earth-resource applications (Rogan and Chen, 2004). For example, Landsat TM spectral channels are chosen specifically to map vegetation type, soil moisture, and other key landscape features (Jensen, 2000).

Vegetation indices calculated from satellite images can be used for monitoring temporal changes associated with vegetation. The normalized difference vegetation index (NDVI) is developed for estimating vegetation cover from the reflective bands of satellite data. Moreover the created NDVI images could be used to identify the pattern of changes that had occurred between two different dates. Lyon et al. (1998) compared seven

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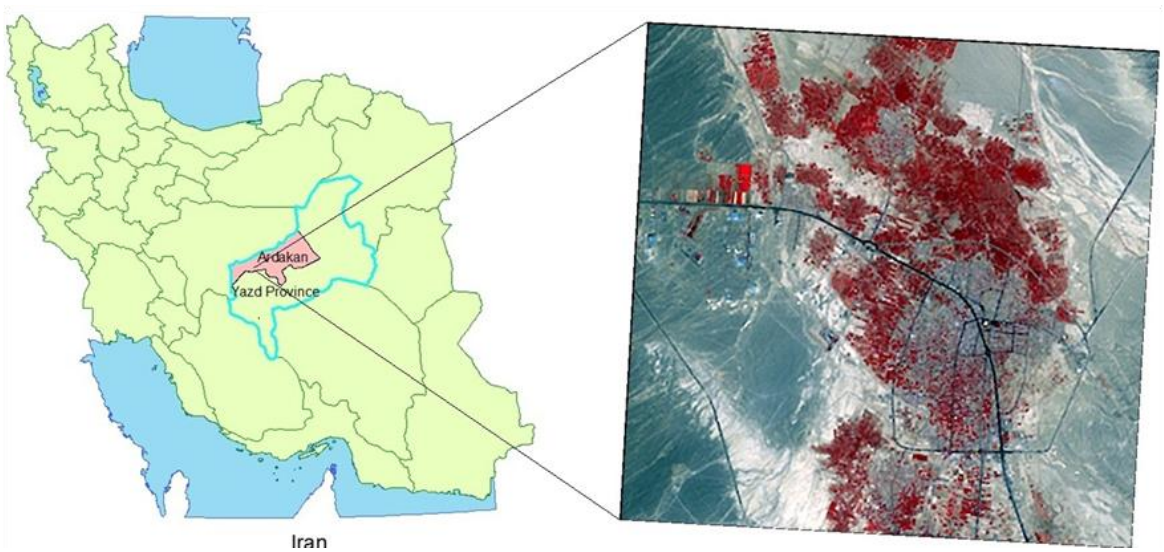

Figure 1. The location of the study area on the ETM+ image (2006).

vegetation indices from three different dates of Landsat MSS image data for land cover change detection and concluded that, the NDVI differencing technique demonstrated the best vegetation change detection. The NDVI data layer is defined as:

$$NDVI= (NIR-R) / (NIR+R) \quad (1)$$

Where NIR represents the spectral reflectance in near infrared band and R represents red band. The NDVI real values, by definition, would be between -1 and +1, where increasing positive values indicate increasing green vegetation and negative values indicate non-vegetated surface features such as water, barren land, ice, snow, or clouds. Image differencing technique is used in many applications; it can be applied not only to images of two different dates, but also to comparison of vegetation index information derived from multiple dates of imagery. It is a simple process of subtracting the two different times pixel by pixel to create the differentiated image (Yacouba et al., 2009). If there is a land cover change somewhere between two dates, the NDVI differentiated image should have a pixel value greater than or smaller than 0.

Supervised classification has been widely used to detect land use types. In supervised classification, spectral signatures are collected from specified locations (training sites) in the image by digitizing various polygons overlaying different land use types. The spectral signatures are then used to classify all pixels in the image. The supervised classification is generally followed by knowledge-based expert classification systems depending on reference maps to improve the accuracy of the classification process (Berberoglu et al., 2007; Xiaoling et al., 2006).

The main purpose of this study is to evaluate two change detection techniques: an NDVI differencing method and a supervised classification method. Both methods are common and effective in change detection of LULC (Lu et al., 2004). Two Landsat ETM + images were analyzed to detect the LULC changes that have occurred in Ardakan, Iran. Differences between two correspondent NDVI and classified images of the area acquired in the years 1990 and 2006 were calculated and the changes in the vegetation amount and status occurred between the two years were investigated. Supervised classification was performed and outputs of the two time periods were overlaid to derive information on changes that occurred over a period of time in the study area. Moreover, the capabilities of applying ETM+ imageries to provide accurate land use/cover, classification of the study area were investigated.

MATERIALS AND METHODS

The study area is located between Longitudes 53° 55′ 22.9” to 54° 3′ 27.7” E and Latitudes 32° 16’11.3” to 32° 22′ 52.9” N in the southern part of Ardakan, Iran (Figure 1). The study area covers approximately 15760 ha of land with the elevation of 1003 to 10094 m and slope of 0 to 7.8%. The mean annual rainfall of the area is around 80 to 100 mm, while the mean annual temperature is around 30 to 35°C. It is hot in summer and cold in winter.

Two cloud-free Landsat ETM+ images acquired on September 11, 1990 and October 23, 2006 were processed using ERDAS 8.7 and ArcGIS 9.3 softwares.The 1990 image were corrected to remove atmospheric effects and then georefrenced using 35 ground control points derived from the 2006 georefrenced image of the study area. The images were re-sampled to 30 m pixel size for all bands using the nearest neighbor method. All the data were projected to an Universal Transverse Mercator (UTM) coordinate system, Datum WGS 1984, zone 39 North using 1:50 000 topographic map of the study area. At first stage, the NDVI data layer was generated from Landsat ETM+ images in Erdas Imagine 8.7 environment. Band math was then performed on the resulting

Table 1. Change of the NDVI density classes between 1990 and 2006.

NDVI density classes	1990 NDVI classes area		2006 NDVI classes area		Change between 1990 and 2006		Average rate of change	
	ha	%	ha	%	ha	%	Ha/yr	%
Low (0.1-0.2)	1087.56	49.91	453.51	70.80	-634.05	-58.30	-39.63	-3.64
Medium (0.2-0.3)	552.60	25.36	120.56	18.82	-432.04	-78.18	-27.00	-4.89
High (0.3-0.4)	308.52	14.16	41.09	6.41	-267.43	-86.68	-16.71	-5.42
Very high (>0.4)	230.22	10.57	25.40	3.97	-204.82	-88.97	-12.80	-5.56
Total	2178.90	100.00	640.56	100.00	-	-	-	-

NDVI images by subtracting the 2006 image values from the 1990 image values to find the areas where the land cover has changed. The resultant image was threshold based on 10% changes and the areas with 10% increase or decrease in NDVI values were demonstrated. Finally, in order to the investigation of changes in NDVI values, the NDVI-change image was density sliced to the 4 categories included: areas with low, medium, high, and very high NDVI values.

At the second stage, in order to investigate the changes in each land cover type, the two images were classified using maximum likelihood classifier in ERDAS Imagine 8.7 environment. The change detection technique, which was employed in this study, was the post- classification comparison. The overlay consisting of LULC maps of 1990 and 2006 were made through ERDAS Imagine software. Then a transition matrix was prepared for the overlaid LULC maps of 1990 and 2006.

RESULTS AND DISCUSSION

Once the choice of change detection taxonomy is determined, decisions on the data processing requirements can be made. Requirements include geometric/radiometric corrections, data normalization, image enhancement, image classification and classification accuracy assessment (Lunetta and Elvidge, 1998). Accurate per-pixel registration of multi-temporal remote sensing data is essential for change detection since the potential exists for registration errors to be interpreted as land-cover-land use change, leading to an overestimation of actual change (Stow, 1999). In this study the 1990 image was georefrenced using 35 ground control points derived from the 2006 georefrenced image and re-sampled to 30 m pixel size for all bands using the nearest neighbor method. The resultant root mean squared error (RMSE) was found to be 0.48 pixels (about 14.4 m on the ground) for the 1990 image. Several authors recommend a maximum tolerable RMSE value of 0.5 pixels (Jensen, 1996), but others have identified acceptable RMSE values ranging from .0.2 pixels to 0.1 pixels, depending on the type of change being investigated (Townshend et al., 1992).

In the present study, DN value of NDVI images are categorized as low density from 0.1 to 0.2, medium density from 0.2 to 0.3, high density from 0.3 to 0.4 and very high density from 0.4 and more.

Table 1 shows the NDVI density classes in the years 1990 and 2006. As it can be seen in this Table and Figure 2, the most important changes have occurred in low and very high density classes. The category of very high NDVI density has reduced from 10.57% in 1990 to about 3.97% in 2006. In contrast, the category of low NDVI density has increased from 49.91 to 70.8%.

The Figures 3 and 4 represent the NDVI density map of the study area in 1990 and 2006 respectively.

Band math was then performed on the resulting NDVI images by subtracting the 2006 image values from the 1990 image values and the resulting image gave the changes in the vegetation amount and status occurred between the two time periods for every image pixels..

As shown in the Figure 2, the NDVI value decreased from 1990 to 2006 for medium, high and very high density classes but increased for the low density classes. Differences between two correspondent NDVI images of the area acquired in two different years were calculated and the resulting image gave the changes in the vegetation amount and status occurred between two different times.

In order to enhance the changes displayed, the 10% change thresholds were fixed on the resulting values. In Figure 5, the areas with gray and light brown colors shows less than 10% increase or decrease represent (some change) , respectively, whereas the green and red colors represent the areas that underwent more than 10% increase or decrease of the vegetation cover, respectively. The percentage change image shows the magnitude of change in the study area from 1990 to 2006. Table 2 represents the change statistics.

In classification process, Supervised Classification method was performed using the maximum likelihood algorithm based on a set of user-defined classes and training areas, by creating the appropriate spectral signatures from ETM+ imageries. Over 50 training areas were repeatedly selected from the whole study area by drawing a polygon around training sites of interests. LULC classes of these training areas were extracted with respect to general knowledge obtained from topographic maps and field visits. Then, supervised classification was performed using the maximum likelihood classifier. Four land use classes as urban areas, bare land, salty clay flats and agricultural lands were identified. The Figures 6 and 7 represent the LULC maps of the study area for 1990 and 2006, respectively.

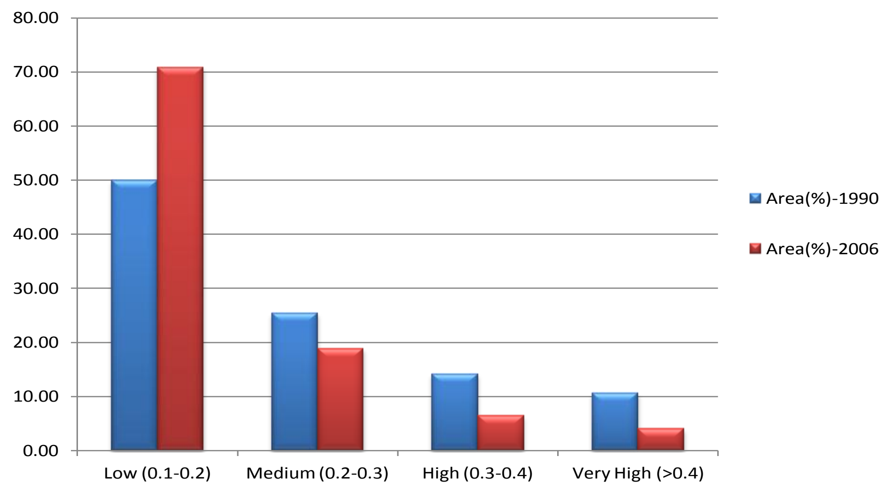

Figure 2. Changes of NDVI density categories during the period of 1990 to 2006 (%).

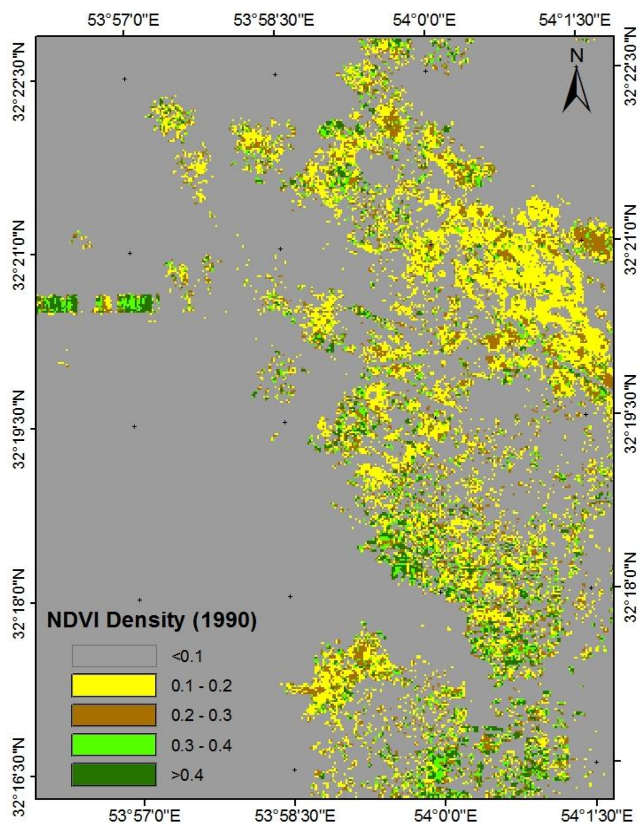

Figure 3. NDVI density map of ETM+ 1990.

To evaluate the accuracy of the classified images, error matrix was used based on random sampling method in which 256 points were automatically selected from classified reference image. In error matrix utility, the reference class values were compared with the classified class values in a cxc matrix, where c is the number of classes. Then, overall accuracy and kappa values were computed by using user's accuracy and producer's accuracy of each class. According to the results, the overall accuracy of classification results were 81.64% (K = 0.73) and 82.81% (K = 0.74) for the year 1990 and 2006, respectively. The total accuracy assessment of the

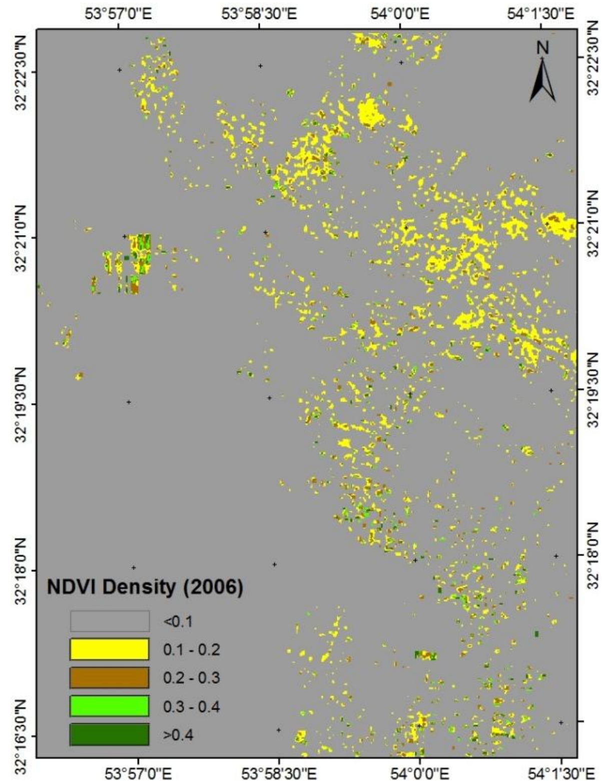

Figure 4. NDVI density map of ETM+ 2006

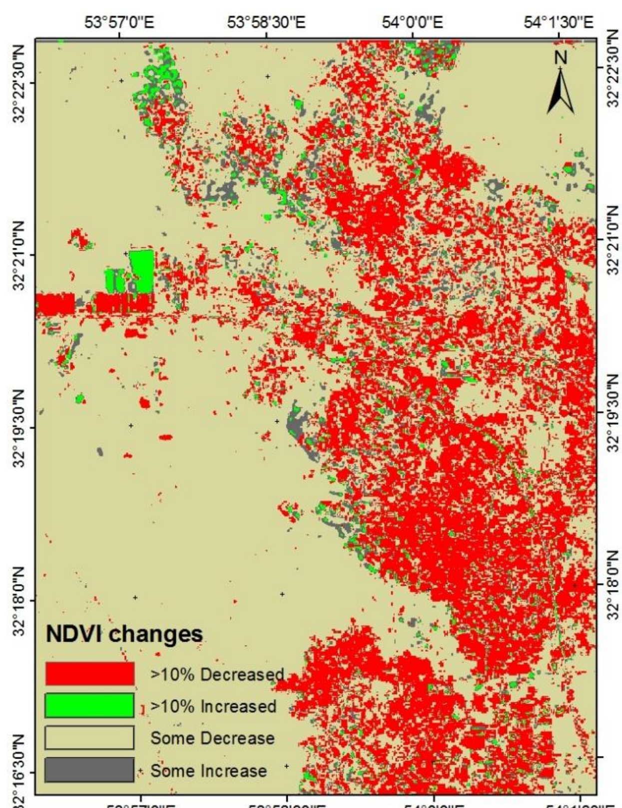

Figure 5. Threshold NDVI difference map.

Table 2. NDVI changes during the 16-years period.

NDVI changes	NDVI changes	Percentage
Some decrease	11956.42	75.87
Some increase	619.87	3.93
10% decrease	2966.89	18.83
10% increase	216.9	1.38
Total	15760.08	100.00

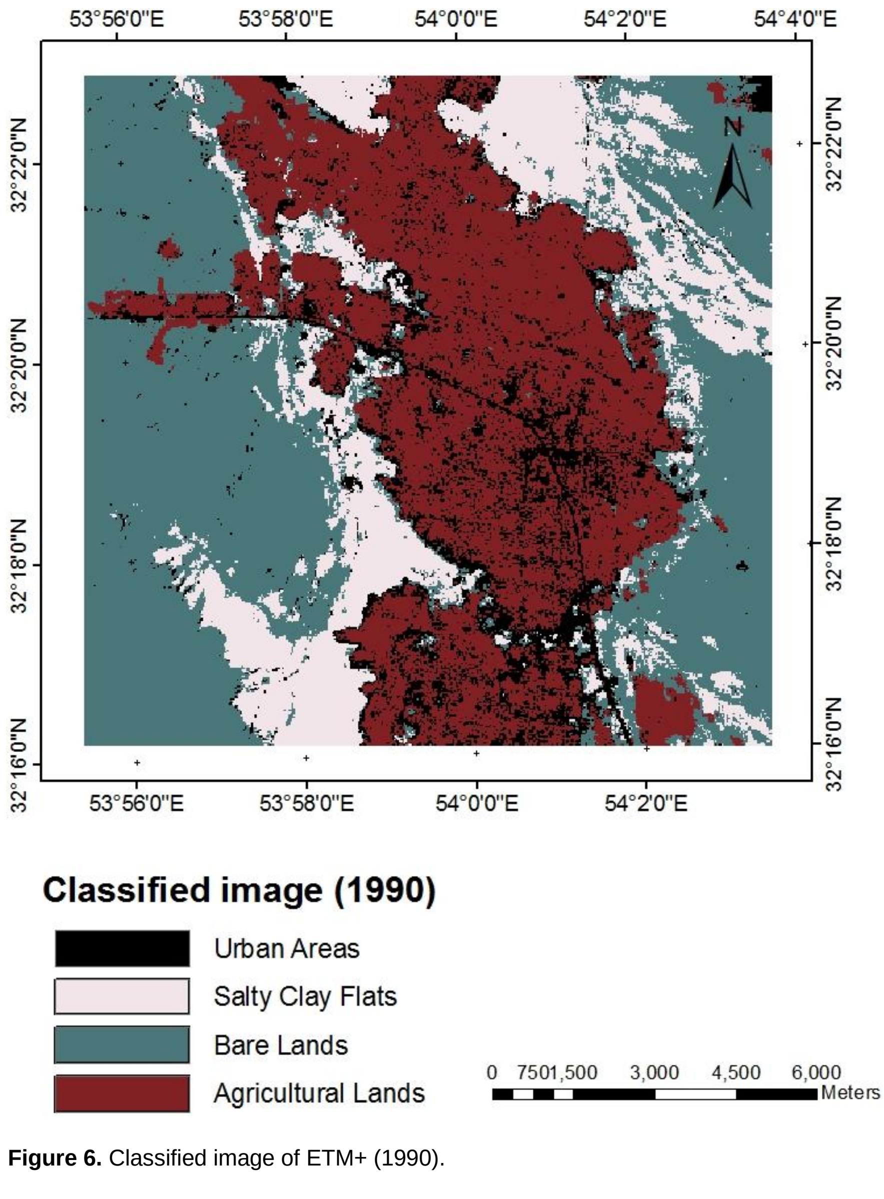

Figure 6. Classified image of ETM+ (1990).

years 1990 and 2006 is given in the Tables 3 and 4, respectively.

The pattern of the changes between 1990 and 2006 are presented in Table 5 and Figure 8. The spatial extent of agricultural lands and salty clay flats are significantly decreased until 2006 but the urban areas and bare lands are increased almost in same extent reversely. After 1990 the agricultural lands are decreased which may be replaced by the urban area. The urban areas were accounted for 10.68% of the total land in 1990 which was increased by 17.16% until 2006 whereas the agricultural lands were decreased from 30.15 to 21.76% in the same period. Urban areas and bare lands were expanding at an average rate of 3.79 and 1.18% per annum respectively,

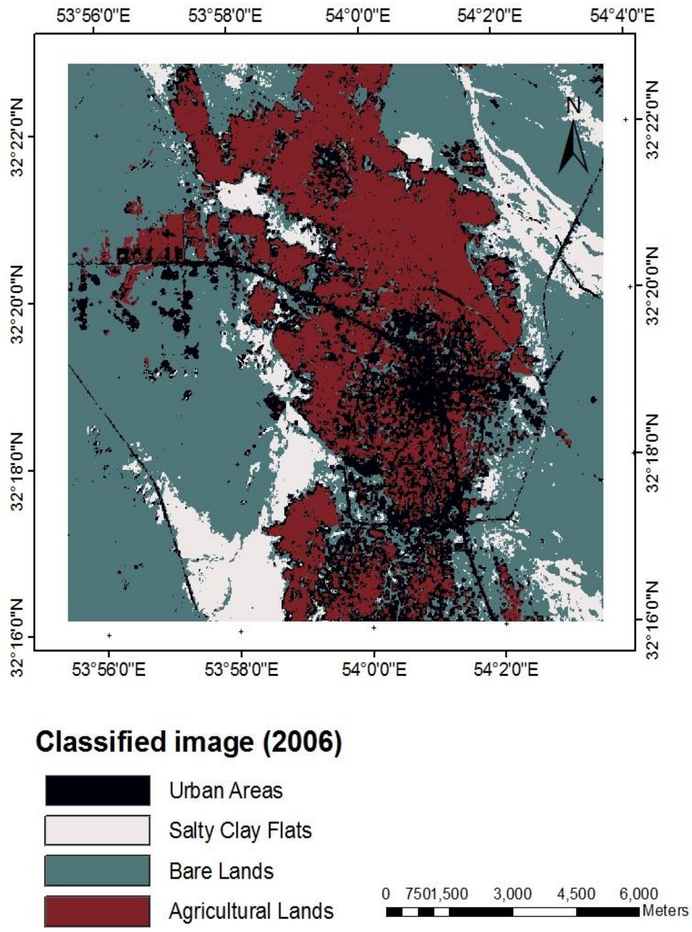

Figure 7. Classified image of ETM+ (2006).

Table 3. The results from the accuracy assessment process for the image classification of the year 1999.

Class name	Reference total	Classified totals	Number correct	Producers accuracy (%)	Users accuracy (%)	Kappa index
Agricultural lands	76	102	74	97.37	72.55	0.6096
Salty clay flats	50	43	40	80.00	93.02	0.9133
Bare lands	115	94	86	74.78	91.49	0.8455
Urban areas	15	15	9	60.00	60.00	0.5751
Totals	256	254	209	-	-	-

*Overall classification accuracy = 81.64%, *overall Kappa statistics = 0.7302.

Table 4. The results from the accuracy assessment process for the image classification of the year 2006.

Class name	Reference total	Classified totals	Number correct	Producers accuracy (%)	Users accuracy (%)	Kappa index
Agricultural lands	61	59	53	86.89	89.83	0.6096
Salty clay flats	34	22	21	61.76	95.45	0.9133
Bare lands	122	132	111	90.98	84.09	0.8455
Urban areas	39	39	27	69.23	69.23	0.5751
Totals	256	252	212	-	-	-

*Overall classification accuracy = 82.81%, *overall kappa statistics = 0.7414.

Table 5. Comparison of areas and rates of changes in LULC classes between 1990 and 2006.

LULC type	1990 LULC area		2006 LULC area		Change between 1990 and 2006		Average rate of change	
	ha	%	ha	%	ha	%	Ha/yr	%
Agricultural lands	4751.37	30.15	3429.94	21.76	-1323.41	-27.81	-82.59	-1.74
Salty clay flats	2742.48	17.40	1801.69	11.43	-940.79	-34.30	-58.80	-2.14
Bare lands	6582.60	41.77	7823.96	49.64	1241.36	18.86	77.59	1.18
Urban areas	1683.63	10.68	2704.48	17.16	1020.85	60.63	63.80	3.79
Total	15760.08	100.00	15760.08	100	-	-	-	-

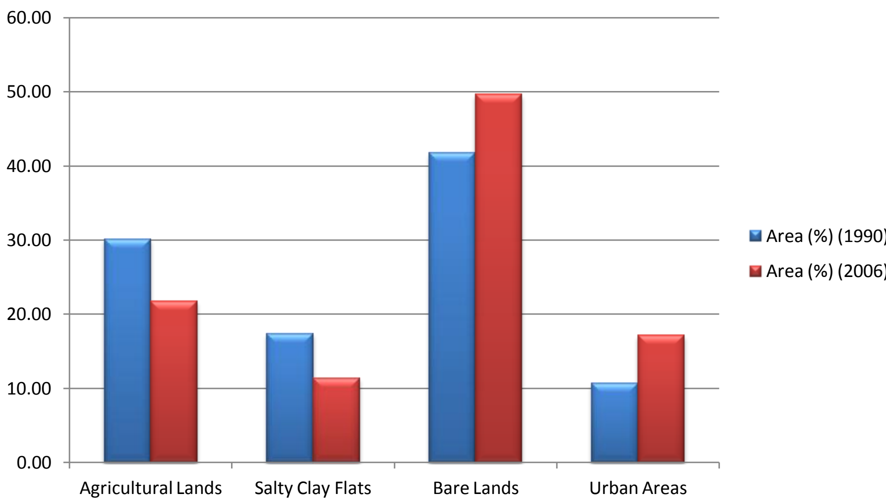

Figure 8. Changes of the land cover categories during the period 1990 to 2006 (%).

while agricultural lands and salty clay flats were respectively, receding at rates of 1.74 and 2.14% per annum over the 16 years period. It indicates the encroachment of urban areas towards the agricultural lands.

The change detection technique, which was employed in this study, was the post- classification comparison. The overlay consisting of LULC maps of 1990 and 2006 were made through post classification comparison. Then, a transition matrix was prepared for the overlaid LULC maps of 1990 and 2006. Figure 9 shows the thematic map of LULC change during the study period.

Conclusions

The NDVI differencing method and classification method are the most common procedures for detecting and monitoring LULC changes. The NDVI differencing method is relatively easy to implement and simple to interpret, but it cannot provide complete matrices of change directions (Lu et al., 2004) and the index differencing is also subject to registration error (Gong et al., 1992). Comparing, two NDVI statistics shows the notably change in agricultural lands area percentage from 1990 to 2006. According to the results, the agricultural lands area decrease from 2178.90 ha in the year 1990 to about 640.56 ha in 2006. In fact the green areas (agricultural lands) have been decreased from approximately 14% of the whole area to about 4% during the 16 year period.

Moreover, the classification of satellite imagery data is a proper tool to derive land cover-land use maps and statistics. Comparing between classified images of two different years provide the basis to discern those areas that depict changes of land cover-land use during the study period. Results of this study indicate that, supervised classification provided satisfactory results in terms of distinguishing urban areas, bare land, salty clay flats and agricultural lands. Furthermore the roads in the study area could be distinguished during the classification process. The main change observed for the time period of 1990 to 2006 was the decrease of agricultural areas due to urbanization from 30.15 to 21.76%. Both procedures indicate the decrease rate of about 10% in green areas.

Several factors have significant impact on LULC changes observed during the study period. In this regards, loss of valuable land resources, water deficiency,

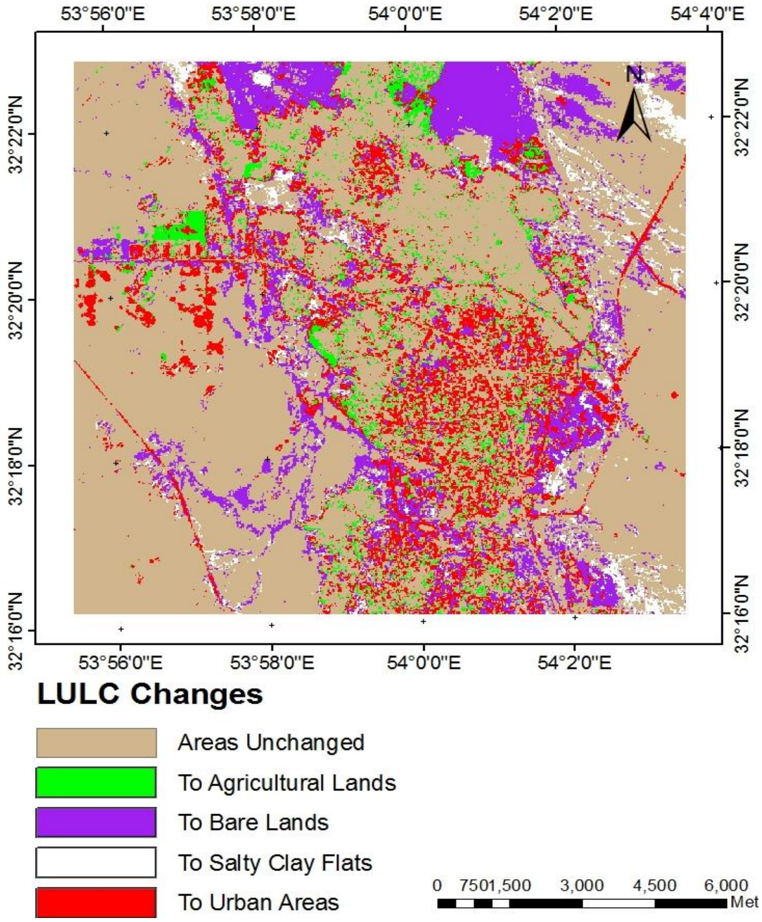

Figure 9. Land use/land cover change map (1990-2006).

population growth and urban area expansion are the major factors behind the LULC changes observed in the study area.

Hence, the results of this study confirm that, change detection procedures including NDVI and supervised classification using LANDSAT ETM+ data offer a good potential tool for characterizing and understanding LULC changes occurring in transitional areas like Ardakan, Iran.

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