Int. J. Environ. Res. 1 (1): 35-41, Winter 2007
ISSN:1735-6865
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Digital Change Detection Using Remotely Sensed Data for Monitoring Green Space Destruction in Tabriz

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Received 27 May 2006; Revised 12 Sep 2006; Accepted 15 Oct 2006

ABSTRACT: Being very dynamic, natural and artificial land features are changing somewhat rapidly in over lifetime. It is important that such changes be inventoried accurately so that the physical and human processes at work can be more fully understood. Change detection is a technique used in remote sensing to determine the changes in a particular object of study between two or more time periods. This research compared three change detection techniques for detecting urban development, spatially spatially physical extension of Tabriz and its influence on destruction of green Space with landsat TM and ETM+ imageries. Based on post classification comparison and products of two classification maps and initial – final matrix during the period 1989 to 2001, 6743 hectares of building block class increases to 9552 hectares and 866 hectares of this class related to decreasing of Green space class.

Key words: Change detection, Green space, Multi temporal remotely sensed data, Post classification

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INTRODUCTION

Change detection is an important process for monitoring and managing natural resources and urban development because it provides quantitative analysis of spatial distribution in the area of interest. There are several urban applications where satellite based remotely sensed data are being applied, namely, urban sprawl/ urban growth trends, mapping and monitoring land use/ land cover, urban change detection and updation, urban utility and infrastructure planning, urban land use zoning, urban environment and impact assessment, urban hydrology, urban management and modeling.

Remote sensing techniques offer benefits in the field of land use/ land cover mapping and its change analysis. One of the major advantages of remote sensing systems is their capability for repetitive coverage, which is necessary for change detection studies at global and regional scales. Detection of changes in land use/ land cover involves use of at least two period data sets. The changes in land use/ land cover due to natural and human activities can be observed using current and archived remotely sensed data. Green space destruction is critically linked to human influences on urban environment. In recent years, physical extension of Tabriz has lead to extensive destruction of green space in it. Considering the availability of multi-date satellite data and temporal resolutions, it is now possible to prepare up-to-date and accurate green space map in less time, at lower cost and with better accuracy. The present work has been undertaken to prepare the multi-date land use/ land cover maps of Tabriz from multi-date satellite data and to monitor the changes in various land use/ land cover classes using digital remote sensing techniques. Tabriz (the area of study) the capital of East Azerbaijan province, is situated at the northwest of Iran. The study area is bounded between the latitudes 38°1'N to 38°9'N and longitudes 46°11'E to 46°23'E. For monitoring the changes in green space of Tabriz, ETM+ digital data of 2nd July 2001 of Landsat satellite along with TM digital data of 30th June 1989 have been used. The path/ row number of TM and ETM+ imagery is 168/ 34. Main reason of using TM and ETM+ data was unavailability of time series of high resolution images and ability of TM and ETM+ data in extracting green area land use that had a large scale change in our study area.

ENVI4.0 image processing software, its GIS analysis capabilities and ArcView GIS 3.2 have been used for the preparation of multi-date land use/ land cover maps and for monitoring the change pattern.

MATERIALS & METHODS

After atmospheric correction and elimination of offset value of satellite data, in order to prepare two or more satellite images for an accurate change detection comparison, it is imperative to geometrically rectify the imagery (Macleod and Congalton, 1998). To lessen the impact of misregistration on the change detection results, geometric registration was performed on a pixel-by-pixel basis. Erroneous land cover change results may result if any misregistration greater than one pixel occurs (Lunetta and Elvidge, 1998). The accuracy of image registration is usually conveyed in terms of Root-Mean-Square (RMS) error. For landsat TM imagery acceptable RMS error is approximately 0.5 pixels (Yuan and Elvidge, 1998). The TM1989 image using 18 ground control points (GCPs) was registered to Tabriz digital topographical map. After this process of image-to-image registration, ETM+2001 was then adopted for the registration of TM 1989 using 18 GCPs. The registration error (RMS) obtained was 0.128 pixel for TM 1989 image and 0.116 pixel for ETM+2001 image. Both images were resampled using the nearest neighbor algorithm. Vector module of ENVI software has been used for building the mask and for obtaining the boundary of study area from the guide map of Tabriz and its environs. By using this as vector mask, TM and ETM+ imageries of the study area have been extracted. There are many change detection techniques from visual comparison to detailed quantitative approaches (Wickware and Howarth, 1981). In this Research, techniques evaluated are: (1) Vegetation index comparison (2) Principal component analysis, (3) Post-classification comparison. In addition, a variety of data exploration techniques were examined such as spectral pattern analysis, bi-spectral plots, derivative band, and divergence analysis, which were used as diagnostics to determine the best combination of spectral bands to be used in the change detection process.

The Normalized Difference Vegetation Index (NDVI) is strongly correlated to the green leaf biomass (Tucker, 1979) and calculated by $NDVI = \frac{b4 - b3}{b4 + b3}$. The symbols b4 (near infrared) and b3 (red) refer to Landsat 4 to 7.The fact that sums and differences of bands are used in the NDVI rather than absolute values may make the NDVI more appropriate for use in studies where comparisons over time for a single area are involved, since the NDVI might be expected to be influenced to a lesser extent by variation in atmospheric conditions (Mather, 1979). DN values of NDVI images are between –1 to +1.

RESULTS & DISCUSSIONS

In our study, we categorized DN value of NDVI images 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 for evaluation mechanism of cleared green space in Tabriz. Therefore categorized DN value of NDVI imageries were vectored and then transferred to GIS environment. During the period 1989 to 2001, urban developments caused 1280.9 hectares of green space to decrease (Table 1).

Table 1. Changes of NDVI density during the period 1989 to 2001

Density	Pixel Value	Area (Ha) 1989	Area (Ha) 2001
Low	0.1 – 0.2	385.91	536.99
Medium	0.2 – 0.3	303.71	431.85
High	0.3 – 0.4	279.54	224.78
Very High	0.4 <	1560.84	55.54

(Unit: ha)

Comparison of categorized NDVI imageries in related Table and graph indicates that the category of very high density (63%) in 1989 is replaced with category of low density (43%) in 2001. (Figs. 1, 2 and 3). A characteristic of PCA is that the piece of information common to all input bands (high correlation between bands) is mapped to the first Principal Component (PC) whilst subsequent PC accounts for progressively less of the total scene variance. This principle can be applied to multi temporal datasets. If two images covering the same ground area but taken at different times of the year are subjected to PCA, the first PC will contain all of the information that has not changed between the two dates whilst the second PC will contain all the changed information. The areas of greatest change are found in the tails of the image histogram. In This method, produced NDVI Images of TM 1989 and ETM+ 2001 transform to two PC derivatives. First PC’s variance was 82.26% (changes range) and second PC’s variance was 17.74 % (unchanged ranges) (Fig. 6). Displaying first PCs as green layer and second PCs as Red layer of NDVI Images explicate the cleared green space with bright red color (Fig. 6).

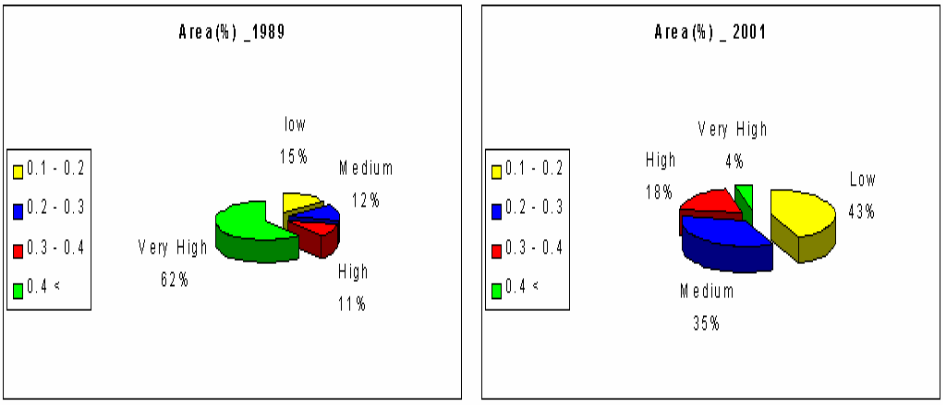

Fig. 1. Changes of NDVI density during the period 1989 to 2001 (%)

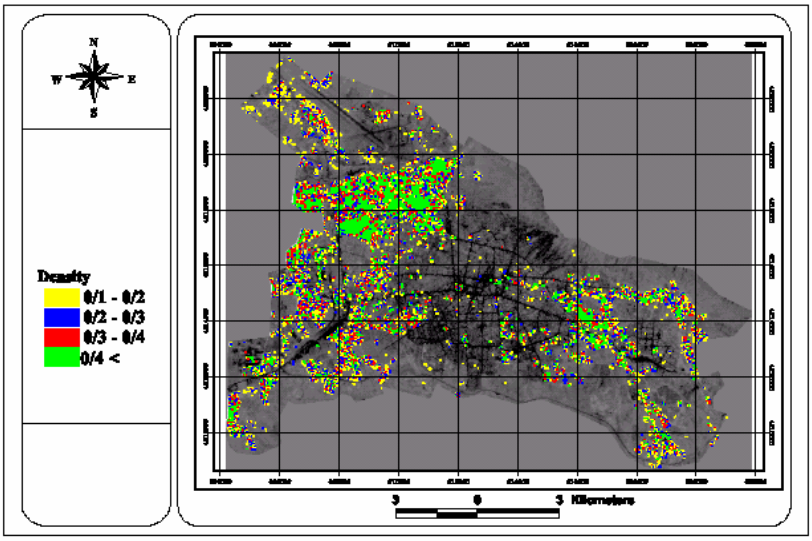

Fig. 2. NDVI density map of TM1989

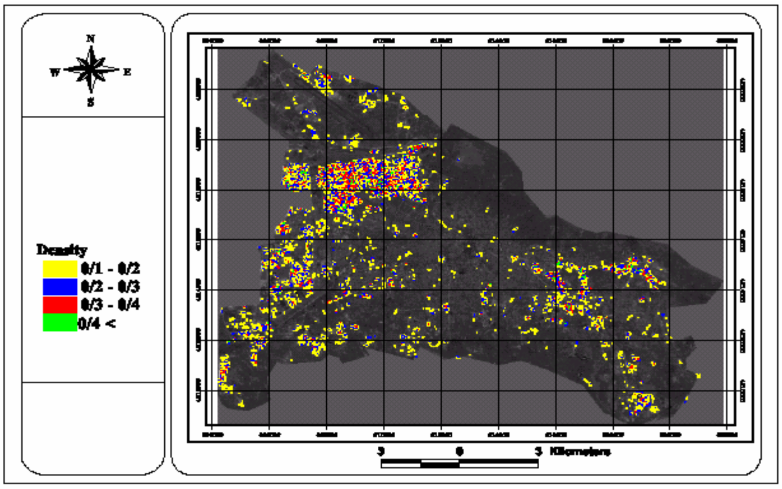

Fig. 3. NDVI density map of ETM+2001

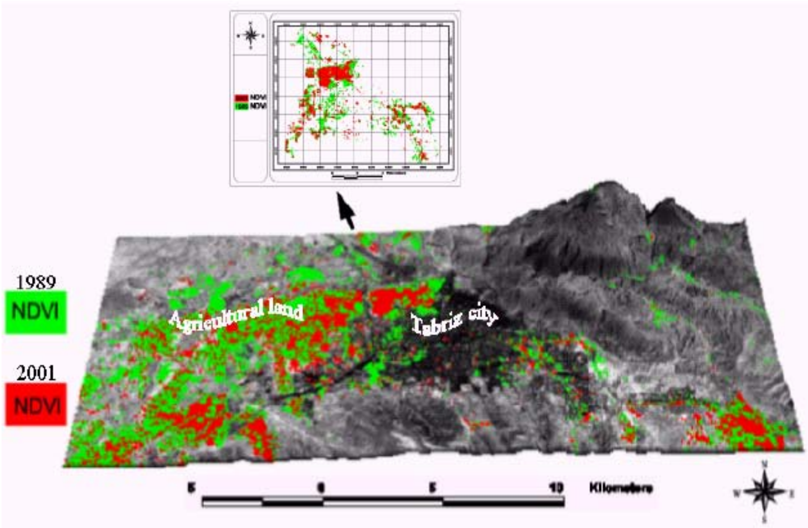

Fig. 4. Overlaid NDVI maps of TM1989 and ETM+2001

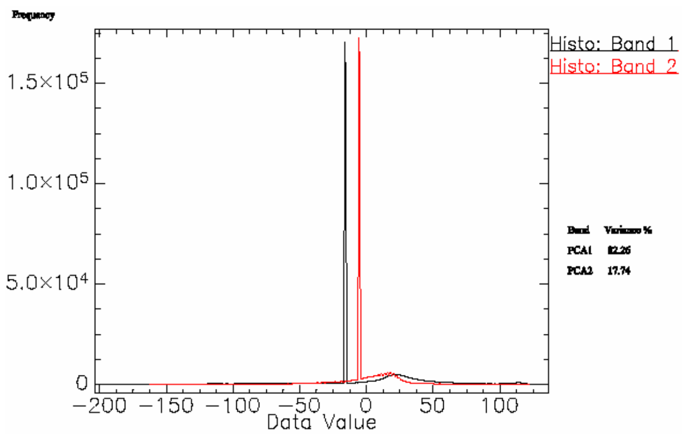

Fig. 5. Histogram PC1 & PC2 of NDVI Images of TM 1989 and ETM+ 2001

Post-classification comparison is used for change detection in this research. This is the most obvious method of change detection that needs comparison of the classification maps, which are independently produced. An algorithm simply compares the two classification maps utilizing class pairs specified by the analyst and generates a map indicating the areas of change. The "from-to" change class information can be detected by comparing to another change detection method, which is not able to detect "from-to" information (Jensen, 1996). Each of two data sets classified separately use decision rule of maximum likelihood. Maximum likelihood classification assumes that the statistics for each class in each band are normally distributed and calculates the probability that a given pixel belongs to a specific class.

Unless you select a probability threshold, all pixels are classified each pixel is assigned to the class that has the highest probability (Richards, 1999). Based on our target we don't classify in detail. We classified 4 classes (building block, barren land, road, and green space) for both TM 1989 and ETM+2001. Accuracy assessment was performed randomly on the entire image for each date. Error matrix for each classification is given in Tables 2 and 3. Also, Kappa coefficient was calculated for measuring the difference between the observed agreement (diagonal element) and the agreement that might be derived by total chance mapping of the maps. We could analyze the changes of land use/land cover based on the two classification maps and initial-final state matrix (Figs. 7, 8 and Table 4).

Table 2. Error Matrix of TM1989

	Green Space	Road	Building blocks	Barren lands	Total	Commission (%)
Green Space	1244	0	0	0	1244	0
Road	0	12	8	0	20	40
Building block	1	0	624	1	626	0.32
Barren land		0	4	1079	1083	0.37
Total	1245	12	636	1080	2973	-
Omission (%)	0.08	0	1.89	0.09	-	-

Overall Accuracy = (2959/2973) = 99.5291%
Kappa Coefficient = 0.9927

Table 3. Error Matrix of ETM+2001

	Green Space	Road	Building blocks	Barren lands	Total	Commission (%)
Green Space	866	0	0	0	866	0
Road	0	15	0	0	15	0
Building block	0	6	577	0	583	1.03
Barren land	0	0	1	586	587	0.17
Total	866	21	578	586	2051	-
Omission (%)	0	28.57	0.17	0	-	-

Overall Accuracy = (2044/2051) = 99.6587%
Kappa Coefficient = 0.9948

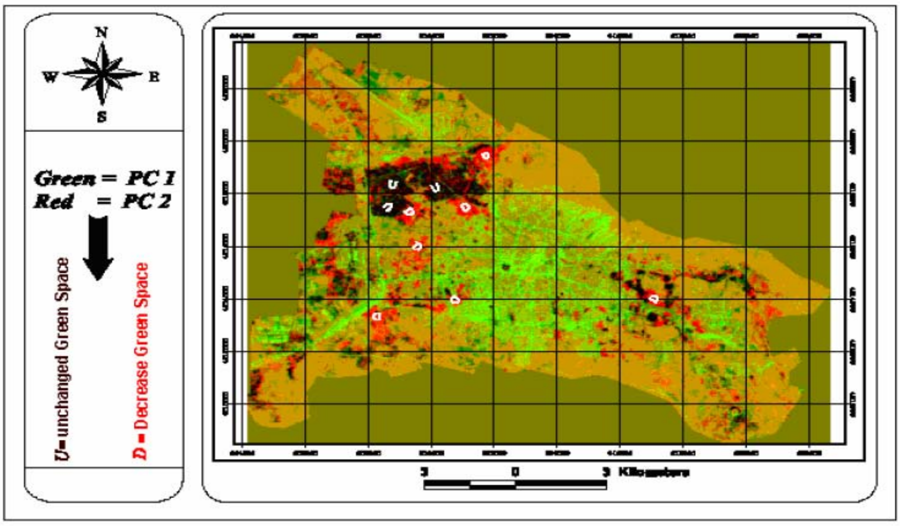

Fig. 6. Visual composite PC1 & PC2 of NDVI Images of TM 1989 and ETM+ 2001

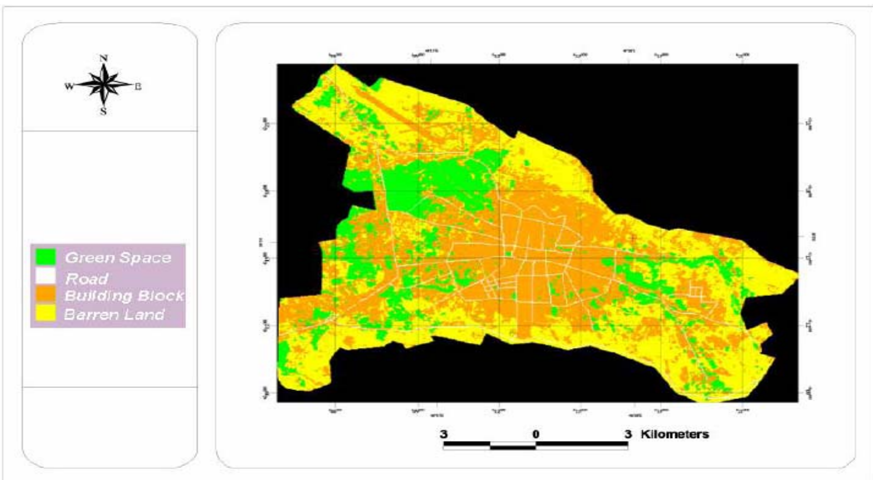

Fig.7. Classified TM 1989

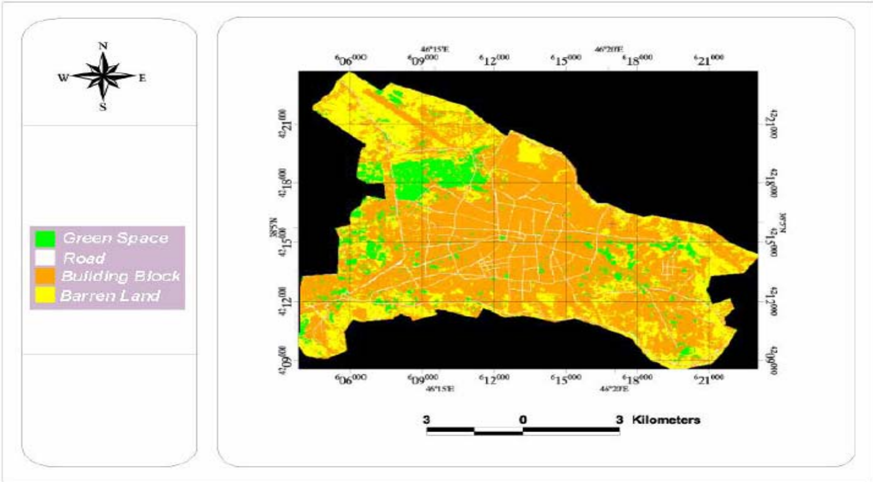

Fig. 8. Classified ETM+2001

Table 4.post-classification compaction in the study area

	Green Space	**Barren Land**	**Building Block**	**Road**	**Row Total**	**Class Total**
	ha	ha	ha	ha	ha	ha
Green Space	984.44	118.01	133.12	5.6	1241.19	1245.09
Barren Land	624.94	2567.84	596.67	12.3	3801.73	3820.74
Building Block	866.67	2732.97	5756.7	184	9540.6	9552.7
Road	32.16	94.05	250.17	189	565.48	565.89
Class Total	2509.9	5533.45	6743.5	391	-	-
Class changes	1525.5	2965.6	986.8	202	-	-
Image Difference	-1264.8	-1712.71	2809.2	175	-	-

(Unit: ha)
The Class Total row indicates the total number of pixels in each Initial State Class and the Class Total column indicates the total number of pixels in each Final State Class.
The **Row Total column** is simply a class-by-class summation of all Final State pixels that fell into the selected Initial State classes.
The **Class changes row** indicates the total number of Initial State pixels that have changed classes.
The **Image Difference row** is simply the difference in the total number of equivalently classed pixels in two images, computed by subtracting the Initial State Class Totals from the Final State Class Totals. An Image Difference that is positive indicates that the class size has been increased.

Physical extension of Tabriz could be an indicator of decreasing vegetation. The purpose of this study examines the role of Tabriz physical extension in destruction green space during the period of 1989 to 2001. Preliminary results from the NDVI density map indicate that 49.37% of green area is decreased between 1989 and 2001. Also, comparing of categorized NDVI imageries specifies the replacement of category very high density from first grade in 1989 to fourth grade in 2001(Figs. 2, 3 and 4). The initial interpretation of visual composite image of PC1 and PC2 derived of NDVI images of TM 1989 and ETM+2001, suggests that the bright red regions represent vegetation which has been cleared in north west, south west and east of the city. Based on the two classification maps and initial – final matrix during the period of 1989 to 2001, 6743 ha of building block class were increased to 9552 ha and 866 ha of this class is related to decreasing of green space class (Figs. 7, 8 and Table 4).

CONCLUSION

In this study, three change detection techniques were evaluated: (1) Vegetation index comparison, (2) Principal component analysis and (3 Post-classification comparison. All were performed using Landsat TM and ETM+ data from 1989 to 2001 to detect environmental changes, spatially physical extension of Tabriz and its influence on destruction of green space. This study provided an application of landsat Thematic Mapper(TM) to detect land use change and the methodology for comparing change detection techniques using standard accuracy assessment procedures. Performing the change detection analysis on Tabriz allowed for the monitoring of decreasing green space over time. This change detection study provides beneficial insight into the extent and nature of change that has taken place in Tabriz from 1989 to 2001, and lays the foundation for further research to be conducted. This research can also be used as a model for other regions encountering development and vegetation change by illustrating the importance of satellite imagery.

In future research, we will perform several change detection in the same study area but different intervals, different periods and high-resolution images. Consequently, we can monitor the trend of changes of land cover and changing location.

ACKNOWLEDGEMENT

Author wishes to thank Dr. Russell G. Congalton and Dr. Peter Sean Tardie in Department of Natural Resources of New Hampshire, Durham University for their ideas and co-operation.The comments and suggestions received from two reviewers greatly helped to improve the quality of this paper.

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