ASSESSMENT OF MULTI-TEMPORAL LAND USE / COVER CHANGES USING REMOTELY SENSED IMAGERY, A CASE STUDY : TUZLA REGION IN ISTANBUL, TURKEY

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ABSTRACT

Natural environments are changed due to natural processes, disasters, human and other interventions. One of the major human interventions is the unplanned urbanization. The rapid growth of population and illegal settlements in urban centers and industrial areas have put enormous strains on urban services and amenities, which causes the overgrowing pressure on land resources. To meet the demand for current and accurate data, multi-temporal remotely sensed images are increasingly used as one of the data sources for land use change analysis. The objective of this study was to detect land-cover changes by using 3 Landsat TM imagery in the Tuzla region, Istanbul with different change detection (i.e. image overlay, image differencing, principal component analysis) methods. Each change detection methods used was assessed with their ability to detect specific changes.

1. Introduction

The urbanization is now being accepted as the essential infrastructure for economic development of a region and in index of material progress and prosperity of society. The rapid growth of population and illegal settlements (i.e., slums) in urban centers and new industrial structures have put enormous strains on urban services and amenities, which causes the overgrowing pressure on land resources. One of the major tasks is the acquisition and analysis of latest information upon for the sufficient administration and planning. The conventional methods of urban data collection and analysis can not deliver necessary information in a timely and cost effective fashion [Michalak, 1993]. To meet the demand for current and accurate data, multi-temporal remotely sensed images are increasingly used as one of the data sources of land use change analysis. Data from the Landsat TM, with its synoptic and regular (16 day and year-to-year) coverage offer potential for detection and inventory of disturbances and other changes that occur in land use, cover type and cover condition in areas of interest [Örmeci *et al*, 1994].

In this study, land-cover changes and intense development pressure were analyzed by using the multi-temporal (12 June 1984, 1 September 1990 and 6 September 1992) Landsat TM imagery in the Tuzla region, Istanbul with different change detection methods with their ability to detect specific changes.

2. Study Area

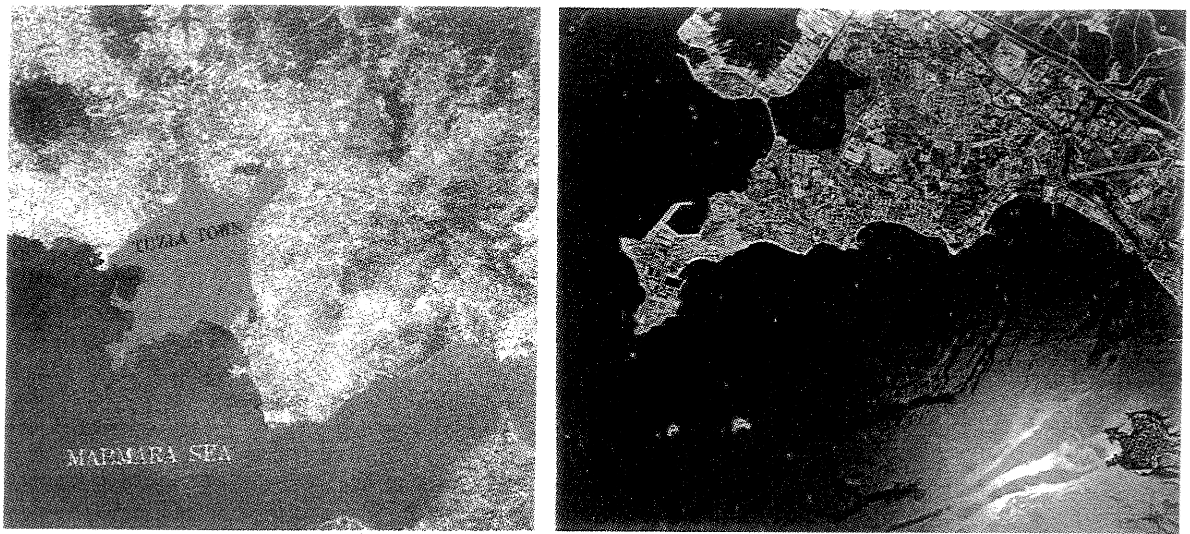
During the last two decades, the urban expansion in Istanbul, biggest city of Turkey, is mostly unplanned and arbitrary which has an encroached upon the agricultural land. In this study, the impacts of the urban growth and land use changes in Tuzla region, located in the east coast line of Istanbul, was evaluated. At the beginning this region has developed as an small village having flat, productive agricultural lands and had a summer residential area characteristic due to its natural beauties, than it showed rapid developments because of the new transportation axes and regional investments. This caused rapid population growth due to migration from the rural areas, and creation of new job facilities and services. The other reason for the rapid growth of the urbanization and land developments in the region was the establishment of new dockyard in 1985. Today, this area and the Lake Kamil Abdus, which is accepted as an natural and archeological site and protection area, are threaten by this unplanned expansion and developments (Figure 1).

2.1. Materials and technique of analysis

To evaluate the population growth and unplanned urbanization temporally, 12 June 1984, 1 September 1990, and 6 September 1992 dated 3 LANDSAT TM satellite data (4 bands of each data set) of the study area were used in addition to an earlier mosaic of aerial photographs and field check. The key characteristics of the data used are given in Table 1.

Table 1 . The key characteristics of the data used.

Parameter	LANDSAT TM
Date	12.08.1984 1.09.1990 6.09.1992
No. Bands	7
Wavelength Region	450-12500 nm
Pixel Size	30 m Thermal Band:120 m



(a) (b)

Figure 1. Study area ; (a) 1984 Landsat image (band 3/2/1). (b) Aerial photograph (1994).

2.1.2. Image registration

As a first step all image data set were registered geometrically to each other. A topographic map (1:25 000 scale) is used as a reference grid in the registration process. Linear fit polynomial and cubic convolution interpolation techniques were used to produce the registered output image with a 0.5 pixel registration accuracy.

2.1.3. Change detection techniques

A change in reflectance often indicates a physical change on the ground. The changes in reflectance registered from one area between two points in time provide a key information on land use/cover changes. There are many digital change-detection techniques. The most common used are ; image overlay, image differencing, principal component analysis, and classification comparisons.

1. ***Image overlay*** : The simplest way to produce a change image is a photographic comparison of a single band of data from the two (or more) dates. The image is prepared by making a photographic three-color composite showing the three dates in separate color overlays. The colors in the resulting image indicate the changes in reflectance values between these dates [Virag *et al*, 1987].
2. ***Image difference*** : Another procedure is to prepare temporal difference image by subtracting the **DN**(digital number)'s for one date from those of the other. The difference in the areas of no change will be very small and areas of change will reveal larger positive or negative values [Lillesand *et al*, 1987].
3. ***Principal component analysis*** : Principal Component Analysis can be used to detect and identify temporal change when registered Landsat TM images are merged and treated as a single data set. [Ingebritsen *et al*, 1985] By this method, a new set of coordinate axes was fitted to the image data, choosing as the first new axis or component would account for maximum variance. Subsequent axes (components) would account for smaller portions of the remaining variance. Changes to be anticipated were of two types: (*i*) those that would extend over a substantial part of the scene, such as changes in atmospheric transmission and soil water status; (*ii*) those that were restricted to parts of the scene, such as construction of roads, destruction of green areas.
4. ***Classification comparisons*** : This method involves independently classifying each image, registering the results and locating those pixels that have changed their land cover classification between dates. Successful application of this method requires accurate classifications of both scenes, so that differences between two dates represent true differences in land use rather than differences in classification accuracy [Campbell, 1987].

3. Results

Image overlay : In the simplest change detection procedure, the single band change image was prepared by color coding TM band **3** from the **1992** data as **red** and from the **1984** data as **green** from the **1990** data as **blue** (Figure 2). Band 3 of the Landsat TM image was selected because it provides the best visual discrimination of rural-to-urban land conversion among the land cover groups in the study area. The industrial complex (***a*** -

planning permission was given in 1990) and also new residential areas (*b*), coded as bright red, can be seen so clearly. The change on vegetation has appeared in the change image as green (*c*). Land undergoing urban development in 1990 and 92 can be identified as magenta color (*d*). However, the success of this method mostly depends on the change end points responses. If the change end points have dissimilar responses in the selected spectral band, than a single band change image may show many changes.

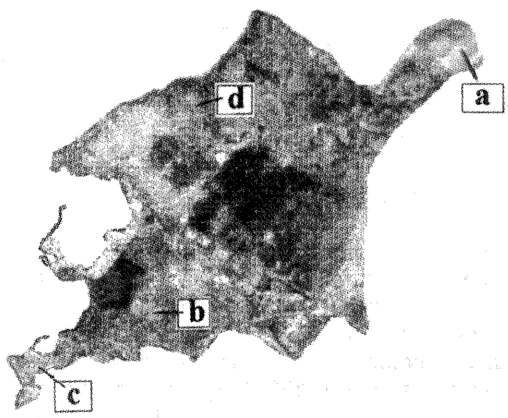


Figure 2. 1984-1990-1992 false color composite of the study area (Band 11/3/7).

Image differencing : Image differencing was carried out on a pair of co-registered images of the study area taken at 1984 and 1992 for band 3 to assess the degree of change that has taken place in 8 years. The difference image is shown in Figure 3 . In Figure 3, areas of no change were represented by a value of 127 while areas that were darker in 1984 than they were in 1992 had values between 128 and 255 (new settlements and industrial complex). Areas that were lighter in 1984 had values between 0 and 126.

Principal component analysis : The standardized principal component analysis (depending on a correlation matrix between the bands) was applied to multidate data set. From analysis of correlation and eigen matrices, it was found that the first four components contain more than 97 per cent of the total scene variance (Table 2).

From the evaluation of the eigen vectors, it was found that PCA 1 image was identical to a total brightness image while PCA 2 were interpreted as attributable to changes in brightness occurred in overall scene between dates. PCA 4 and 5 were also attributable to changes in brightness and greenness (Figure 4). The remaining PCA's were accounted for 1.24 percent for inter-image differences due to atmospheric and sensor variations.

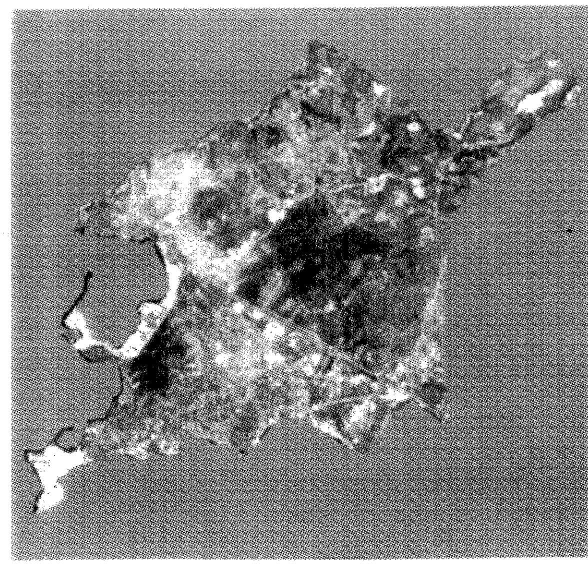


Figure 3. Differenced image result (Band 3 / 1984 and 1992).

Table 2. Eigen Values

	Eigen Values		
	Eigenvalues	Var. %	Total %
1	3002.41	69.40	69.40
2	738.96	17.08	86.48
3	277.10	6.41	92.88
4	183.34	4.24	97.12
5	42.88	0.99	98.11
6	28.07	0.65	98.76
7	21.51	0.50	99.26
8	17.19	0.40	99.66
9	10.15	0.23	99.89
10	2.35	0.05	99.95
11	1.33	0.03	99.98
12	1.01	0.02	100.00

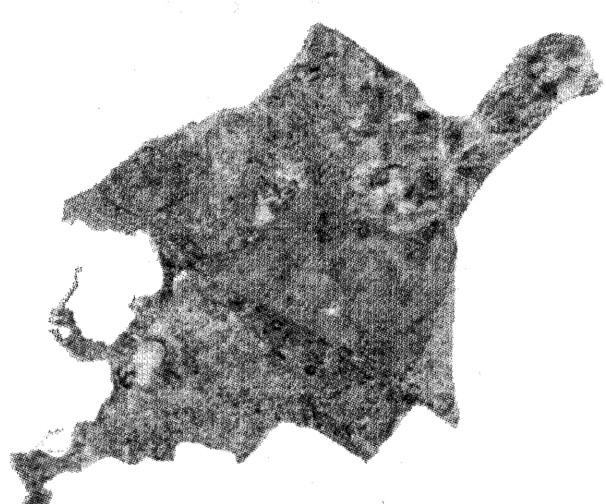


Figure 4. Color composite of PC 5/2/4.

Classification comparisons : The range of cover types and absence of efficient ground data (especially for 1984) caused to use the classification method based on an interactive ISODATA (ERDAS Ver.7.5) approach. From an examination of the data with ancillary data (aerial photographs, topographic maps and merged Landsat TM + Spot P image (Figure 5)), both spectrally and spatially, 35 clusters (5 main land use category; *urban area, lake, unproductive area, green area, industrial-commercial structures and road/construction*) were separated initially. Statistics from the clustering were than used as input to the Maximum likelihood classification algorithm.

The following assessments were obtained from the classified images :

- Changes in land development (both in urban areas and industrial/commercial structures) were easily separated
- Green areas (destructed and/or changed due to atmospheric effects) were also mapped
- Open space was led to confusion due to insufficient ground data.
- Changes in lake and environments were readily seen.

Figure 5. Merged image of the study area.

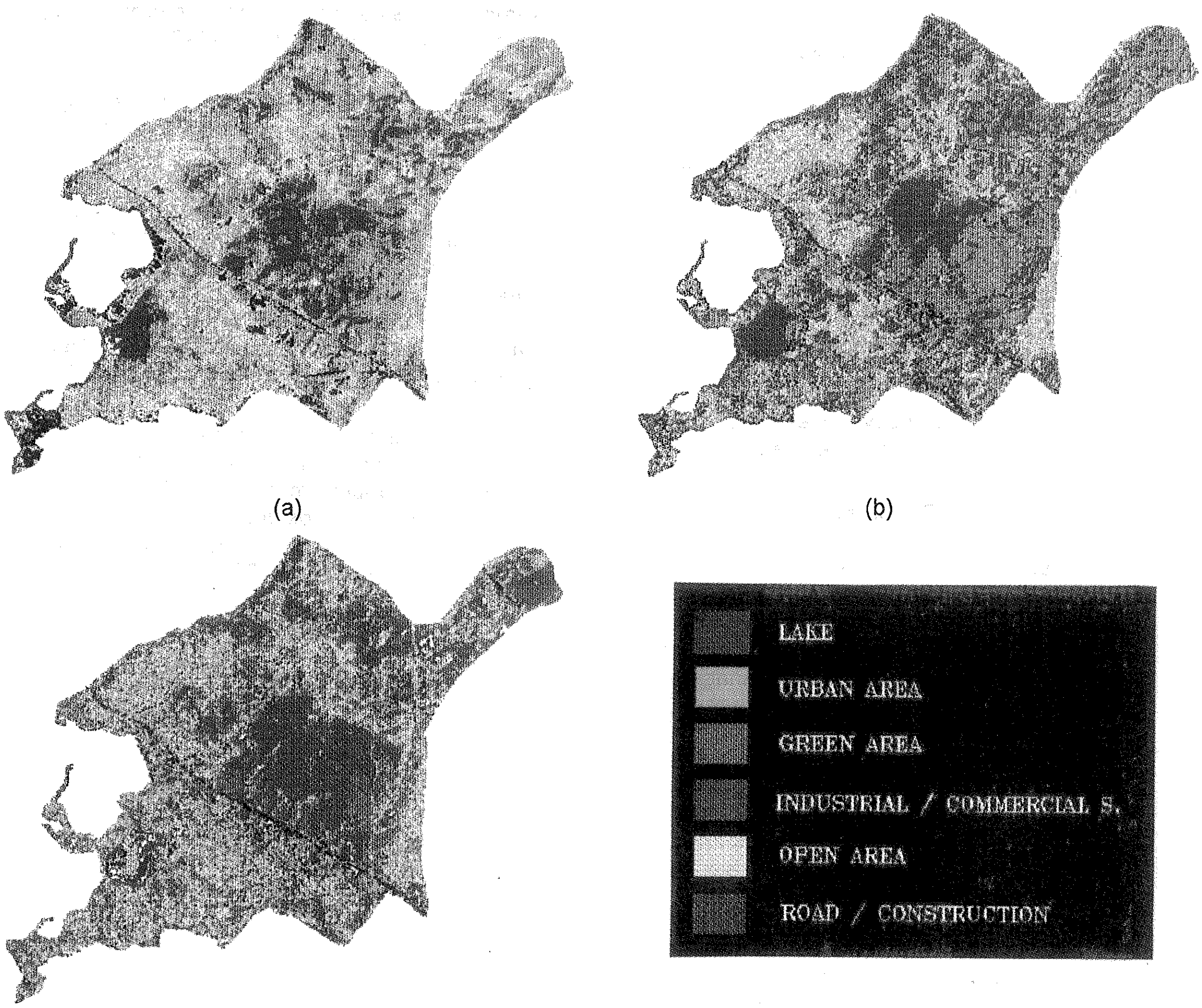


Figure 6. Classification results (a) 1984 Landsat TM (b) 1990 Landsat TM (c) 1992 Landsat TM.

The classification accuracy were calculated by comparing the results obtained from a digital classification to the known identity of land cover in test areas (75 randomly selected test pixels were used) derived from an reference area. Due to the effect of the high percentage of mixed pixels in urban and suburban classes, the overall classification accuracy's for each date were obtained 84%, 84% and 85% respectively.

In Table 3, the areal context of the changes in urban and green area obtained from the classified 3 data set were given. In Figure 7, the land cover changes as per the years are shown.

Table 3. Land Use/Cover Change Assessment.

Land Use/Cover	1984 (hectares)	1990 (hectares)	1992 (hectares)
Urban A.	319.59	416.34	558.63
Green A.	4850.73	4561.92	4273.92

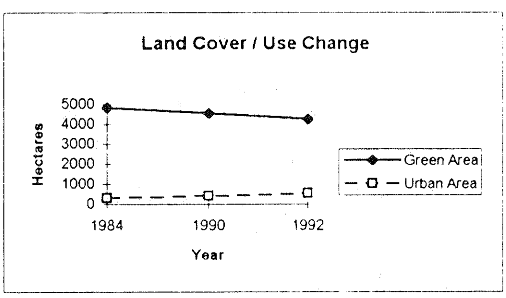


Figure 7. Land cover/use changes as per the years.

4. Conclusion

Land use patterns change over time in response to economic, social and environmental forces. Type of any change in the use of land resources is essential information to proper planning, management and regulation of the use of land resources.

As shown in this study, multi-temporal remotely sensed images are capable for identifying and delineating the changes occurred in land use e.g. new logging areas or new land developments such as settlements, industrial complex and roads etc. by comparing two (or more) Landsat scenes taken on different dates, pixel by pixel and than updating the land use map of the study area. It is possible to use many change-detection techniques. The procedure that is most appropriate to use in a given situation depends on the specific application (type of environment, targets of interest), the amount of detail required and an extensive knowledge of the area to be studied and the logical and spectral interrelationships between land use classes.

As a result, it was concluded that since the spatial structures of the Tuzla region became more rigid and planning alternatives were narrowed, the considerable progress must be made in the creation of environmental awareness and implementation of effective legislation.

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