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Full Length Research Paper

Monitoring land use/cover change and its effects in a higly urbanized district of a metropolitan city Istanbul, Turkey

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The utility of Landsat TM imagery for mapping land use/cover in Istanbul, Turkey is examined in this study. Urbanization has been the dominant demographic trend for the last few decades in Istanbul. The research focused especially to one of the biggest districts of Istanbul (Umraniye), which represents best the growing problems of urban sprawl. Umraniye district is exposed to rapid land use change over last few decades, due to the population growth. Landsat TM data gathered in 1995 and 2005 were used for land use/cover mapping. The changes were monitored by a post classification method. The results suggest that the approach has the potential, particularly for local governments for monitoring land use/cover changes and planning applications. The overall accuracy of the classifications of the data is 80% for both years 1995 and 2005, and the accuracy assessment result shows kappa coefficient agreement of 0.744 and 0.745 for the years 1995 and 2005 respectively. The results revealed that major degradation occurred in the forest and green areas of Umraniye district. The changes from the class of forest and green area to the classes of road, residential and bare land are calculated as 874.17, 483.63 and 1823.31 ha respectively.

Key words: Remote sensing, land use/cover, post classification, landsat TM, urbanization.

INTRODUCTION

Urbanization is one of the main charecteristics of civilization, which is a complex process of change of rural lifestyles into urban ones. Since urbanized landscapes are highly dynamic, complex and multifunctional, detailed inventories of landscape conditions and monitoring of change are needed in order to obtain reliable data for good decision-making especially in metropitan cities (Antrop, 2004).

Identification of existing land use, monitoring the rapid changes in land, record keeping and analyzing these changes are the issues that mankind struggle in that pursuit since the first ages. For this purpose, various techniques have been developed to collect information from different sources. Rapid change in technology and developments in space systems enabled researchers to obtain the information of the earth surface very quickly. In parallel to the developing technology, satellite images that show significant improvements in terms of resolution and accuracy have found wide application areas increasingly. Remote Sensing has been used successfully to map land use/cover and has increasingly been used for mapping the urban development (Barnsley and Barr, 2000; Geoghegan et al., 1997; Gunter et al., 2000; Jantz et al., 2003; Maktav et al., 2005; Masek et al., 2000; Stefanov et al., 2001; Stuckens et al., 2000; Ward et al., 2000). There are many examples in which remote sensing has been used for change detection applications using spatial patterns based on two or more dates of imagery (Balik et al., 2007; Dogru et al., 2009; Franklin et al., 2003; Sachs et al., 1998; Stueve et al., 2007; Wang et al., 2005; Yang and Liu, 2005). Change detection is a computer based process used to identify differences of the state of an object or phenomenon on successive images observed at different times (Singh, 1989). Pre-classification and post classification techniques are the two basic approaches used for change detection. Image differencing, image rationing, vegetation indices or principle components analysis are the algorithms used in pre-classification techniques (Fung and Siu, 2000; Guild et al., 2004; Kwarteng and Chavez, 1998; Mas, 1999;

Figure1. Study area

Masek et al., 2000). Post classification techniques basically use the classification of time series satellite images to produce “from-to” map change information (Jensen, 2004; Yuan et al., 2005). In post classification processes the accuracy of the change maps is dependent on the accuracy of the individual classifications and is subject to error propagation. However classification of each date of imagery builds a historical series that can be more easily updated and used for applications other than change detection. Also not only variations in atmospheric conditions but also vegetation phenology between dates since each classification is independently produced and mapped are compensated by post-classification comparison approach (Coppin et al., 2004; Yuan et al., 1998).

Urbanization has also been the dominant demographic trend for the last few decades in Istanbul. Therefore Istanbul is continuously growing, and while the city expands and its population increases, the need for the new residential areas is increasing. The problems related to the growth of cities and the concentration of human population into large metropolitan areas represents huge challenges for modern societies. First of all the replacement of undeveloped land by residential and commercial areas takes place rapidly without taking precautions for natural resources. This rapid urbanization, which is uncontrolled and illegal in some cases, accompanied by insufficient infrastructure has caused degradation of forest and barren lands in Istanbul (Geymen and Baz, 2008). Since Istanbul is the biggest city with the largest population in Turkey, vast acreages of green areas and agricultural lands have been consumed by unplanned urbanization. Many studies have documented these landcover changes of different districts of Istanbul using remotely sensed data (Dogru et al., 2006; Maktav and Erbek, 2005; Musaoglu et al., 2005).

This study focused on Umraniye district of Istanbul which has not been investigated solitarily before. It is one of the districts of Istanbul which has been subject to a border change in 2009 due to rapid urbanization. The main objective is to determine land use changes in Umraniye district of Istanbul using multi-temporal Landsat TM data for the period of 1995 to 2005, which covers the previous administrative borders of the province. Land use patterns have been dramatically changed in the basin since the 1940s especially with regard to urbanization as a result of growing population. A comparison will be made between land use patterns in different years (1995 and 2005) in view of the urbanization.

STUDY AREA

Istanbul is the biggest city of Turkey with the largest population. It is offering best economic opportunities, and because of these economic reasons urban population is growing with the rate of 3.8% per year. It consists of 39 districts with the new administrative regulations in 2009. It is surrounded by the Black Sea in the north and the Sea of Marmara in the south. It is divided in to two parts by The Bosphorus Strait to be one in Asia and one in Europe. The study area, Ümraniye district of Istanbul, is located in the Asian part of the city. Its central geographical coordinates are at a longitude of 29º 05' east and a latitude of 41º 01' north (Figure 1).

Umraniye, remained as a village until 1960s, has been subject to intense migration after being proclaimed as an Organized Industrial Zone in 1963. It is an interesting example of urbanization as having the most rapidly increasing population and urban sprawl and meanwhile preserving its local village traditions. It became a district in 1987. In 2009, because of the growing urbanization and its high population (Table 1) a part of the district was separated to join a new planned district. In this study, the previous administrative units were taken into consideration.

Table 1. Population of district by year (http://tr.wikipedia.org).

Years	1935	1940	1945	1950	1955	1960	1965	1970
Population	570	501	573	885	1781	7224	14800	22969
Years	1975	1980	1985	1990	1997	2000	2007	2009
Population	38730	71954	131495	242091	498952	605855	897260	573265

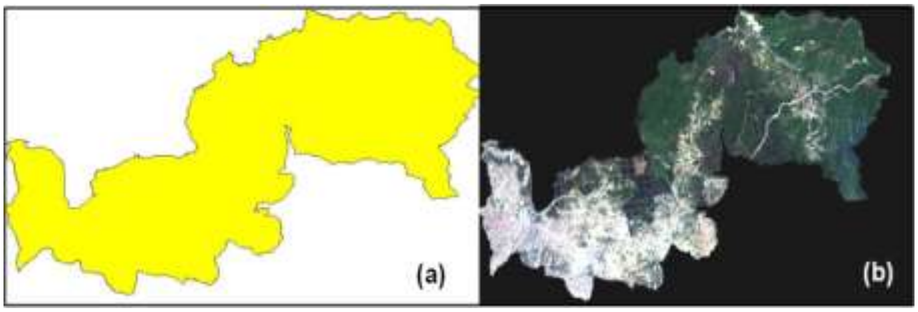

Figure 2. Area of interest as a vector file (a) and clipped image (b)

On the other hand, Istanbul has two bridges on the Bosporus and a new bridge is planned for transportation. The existing bridges caused a dramatic land use/cover change in Istanbul. The third bridge on the route of the transition will take place in this district boundary which is expected to trigger the urbanization dramatically in the area. Thus monitoring the study area by means of remote sensing in the further years is also an important need for the administration of the district.

DATA AND METHODOLOGY

Today, there is a wide range of satellite-based remote sensing data providing very high temporal and spatial resolution (approximately 1 to 100 m) that is suitable for detecting and monitoring land cover changes. Generally, investigators are interested in monitoring land dynamics using moderate spatial resolution imagery such as Landsat, SPOT and ASTER etc. In this study, two different Landsat Thematic Mapper (TM) images acquired in 1995 and 2005 were used to determine the land use land cover changes. The reason for the selection of Landsat TM images is that Landsat TM sensors allow monitoring land use/cover change consistent with the grain of the land management. Data is also most commonly utilized for trajectory-based analysis of land use/cover change due to its spatial and spectral qualities (Gillanders et al., 2008). Besides, Landsat TM sensor provides a big archive of over 30 years with the orbital revisit periods of 16 days. Furthermore, the United States Geological Survey (USGS) populates and maintains the Landsat archive and also provide data at no cost (Woodcock et al., 2008). Hence applicants or researchers have the opportunity of using data for their projects or studies without cost limitations. Landsat TM data have spatial resolutions of 30 m and 7 spectral bands. TM bands 1 to 3 represent visible electromagnetic radiation with the wavelengths of 0.45 to 0.52, 0.52 to 0.60, and 0.63 to 0.69 µm respectively. Band 4 represents near infrared with wavelengths of 0.76 to 0.90 µm, and bands 5 and 7 represent mid-infrared with frequencies of 1.55 to 1.75 µm and 2.08 to 2.35 µm, respectively. Band 6 represents the thermal band which has 120 m. spatial resolution. The radiometric resolution of all the data was 8 bits with 256 levels of brightness (Musaoglu et al, 2005).

In the study, image processing techniques including geocorrection and classification were performed using ERDAS IMAGINE version 9.1 software. The cloud free Landsat images were rectified using 1/25,000-scale standard topographic maps and specified a 30 m output cell size. Image- to-map was done firstly for the image of 1995, and then this registered image was used to perform image-to-image rectification for the image of 2005. Images were georefrenced to the common Universal Transverse Mercator (UTM) projection system (zone 36, ED50 datum) using first order polynomial method. For the rectification process, 40 GCPs (Ground Control Points) distributed homogeneously by manual control point selection over the images were used. Accurate rectification is essential for change detection because misregistration of images leads to over estimation of actual land use change (Stow, 1999). Since the change detection analysis is performed on pixel by pixel basis in this research, any misregistration greater than one pixel will cause a deviating result of that pixel. To eliminate this problem root mean square errors (RMSE) of rectified images were not exceeded 0.4 and 0.3 pixel for Landsat TM images of the years 1995 and 2005 respectively. The registration of each image was performed using the nearest neighbour resampling algorithm to avoid altering the original pixel values of the images. The accuracies of the image rectification process were within the acceptable limits. An additional processing step such as radiometric correction was used.

Prior to the classification process, to classify exactly the same area in both images the area of interest is defined using the border of the district. Multiple date rectified images belonging to the same area were clipped using this vector file (Figure2).

Image classification

Classification is a process of grouping pixels, which have similar spectral values, to transfer data into information for determining the earth resources. Multispectral classification is one of the most often used methods for information extraction (Jensen, 2004). Since Landsat data are suitable only for level I land use/cover mapping according to the land use and land cover classification system developed by Anderson et al. (1976) and Jensen and Cowen

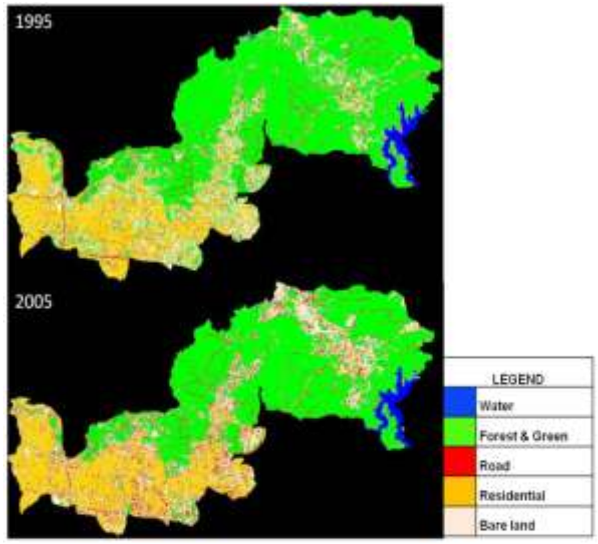

Figure 3. Land use/cover maps of Istanbul-Umraniye region for the years of 1995 and 2005

Table 2. Classification results.

Classes	1995		2005	
	ha	Percent	ha	Percent
Water	438.80	2.06	471.69	2.22
Forest& Green	12025.50	56.11	10455.70	48.78
Road	1254.35	5.85	1956.78	9.13
Residential	3615.75	16.87	4009.23	18.70
Bare Land	4096.26	19.11	4537.26	21.17
Total (ha)	21430.66	100	21430.66	100

(1999), US Geological Survey Level I was referred to for the classification system in this study. The study area was classified into five classes such as water, forest and green, residential, road, and bare land (Figure 3). A supervised Maximum Likelihood classification technique was used. All the channels except thermal band of Landsat images were used for the classification process. However training and testing data were collected using a false color composite image (red = band 4, green = band 3, blue = band 2 for Landsat TM) which helps visualizing land use types without any enhancement processes. Statistical results of the classifications are given in Table 2.

Accuracy assesement analysis

The accuracy assesment was performed for 1995 and 2005 land use maps (Table 3). The overall accuracy and a Kappa analysis were used to perform the classification accuracy assessment based on an error matrix analysis. The overall accuracy is calculated by summing the number of pixels classified correctly and dividing them by the total number of pixels.

Kappa analysis is a discrete multivariate technique of use in accuracy assessment (Foody 2002, Lillesand and Kiefer, 2000). Kappa statistics gives how much better our classification compared to one where we randomly assigned class values to each pixel (Verbyla, 1995).

Error matrices were used to assess the classification accuracy for the two-period Landsat TM images. For the 1995 land use map, the accuracy assessment result shows an overall accuracy of 80% and a kappa coefficient agreement of 0.7440. For the 2005 land use map, the accuracy assessment result shows an overall accuracy of 80 % and a kappa coefficient of the agreement of 0.7450.

CHANGE DETECTION AND RESULTS

Following the classification process of individual images, a postclassification change detection algorithm was used to determine pixel-by-pixel differences between the years 1995 and 2005 (Figure 4). This method compared thematic information derived from time series satellite imagery. The classified lands cover information comprising of five classes for the year of 1995 and 2000 were combined into a single map and change dynamics were analyzed from attribute table. The 1995 image was classified first followed by the 2005 image according to the classification procedures described in the classi-fication section. The classification for each year with the highest overall accuracy was used in the change detection

Table 3. Accuracy assesment of classified images.

Class name	Reference	Classified	Number correct	Producer accuracy (%)	User accuracy (%)
Water	20	20	20	100.00	100.00
Forest and green	22	20	20	90.91	100.00
Road	20	20	12	60.00	60.00
Residential	20	20	14	70.00	70.00
Bare Land	18	20	14	77.78	70.00
Total	100	100	80		
1995	Overall classification accuracy = 80.00				
	Overall kappa statistics = 0.7440				
Water	20	20	20	100.00	100.00
Forest and green	20	20	18	90.00	90.00
Road	24	20	16	66.67	80.00
Residential	18	20	14	77.78	70.00
Bare Land	18	20	12	66.67	60.00
Total	100	100	80		
2005	Overall classification accuracy = 80.00				
	Overall kappa statistics = 0.7450				

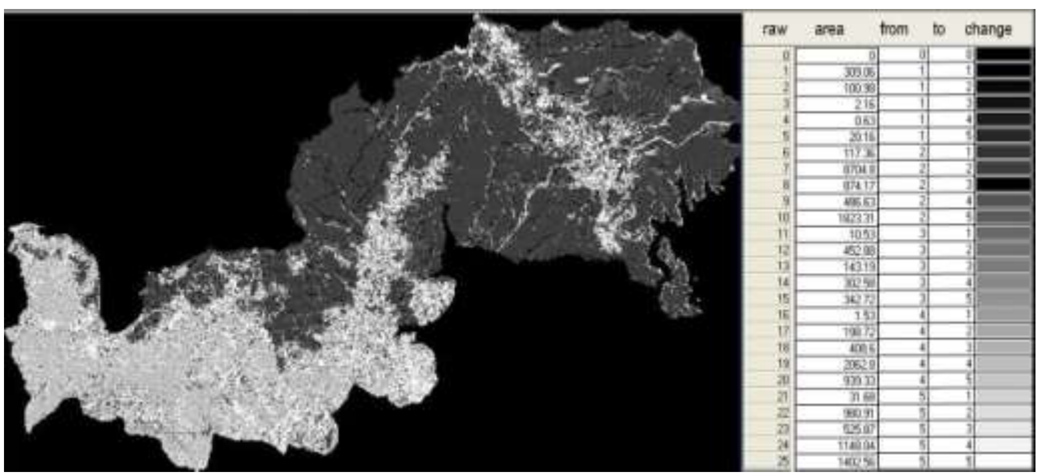

Figure 4. Map of the post classification result and the areas that changed from 1995 to 2005 (Code of classes: (1) Water, (2) Forest and green, (3) Road , (4) Residential ,(5) Bare land).

analysis. The results of the post-classification change-detection was a new classification with "from" and "to" identifiers. For example, if the best 1995 classification distinguished a pixel as "green and forest" areas and the best 2005 classification distinguished the same pixel as "bare land", then the result of the new classification would describe the pixel as "from green and forest to bareland". Post classification comparison is the most commonly used quantitive method of change detection, which shows the change trajectories through the time series. It is proved to be the most effective approach for change detection, because it requires comparison of rectified individual classification results, hence minimizing the problem of normalizing for atmospheric and sensor differences between the two dates (Dobson et al., 1995; Jensen, 2005). Since the postclassification approach provides ‘‘from–to’’ change information associated with land use transformations that have occurred, it requires high classification accuracy (Rutchey and Velcheck, 1994).

While doing the postclassification process, a cross tabulation analysis was carried out to analyze the spatial distribution of the different land use/cover classes and land use/cover changes. For 5 land use/cover classes, 25 land use/cover changes were calculated (Figure 4). Then the areas for the individual land use/cover changes were calculated to do the statistical analysis. Post classification comparison of the classified images and statistics depicts that the major damage occured on the forest and green area of the district (Figure 5). Forest and green area

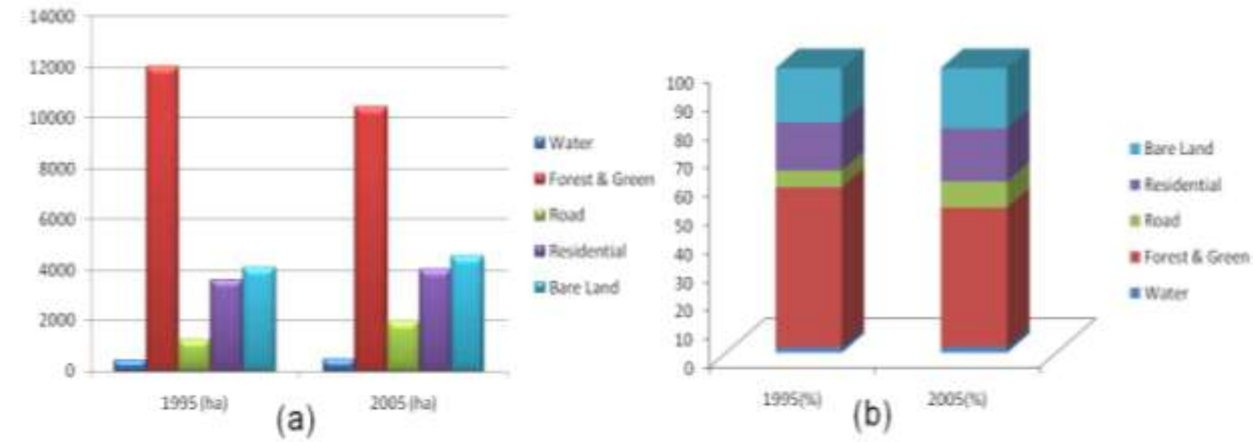

Figure 5. Classification results acording to years **a**) area of classes **b)** percentages of classes

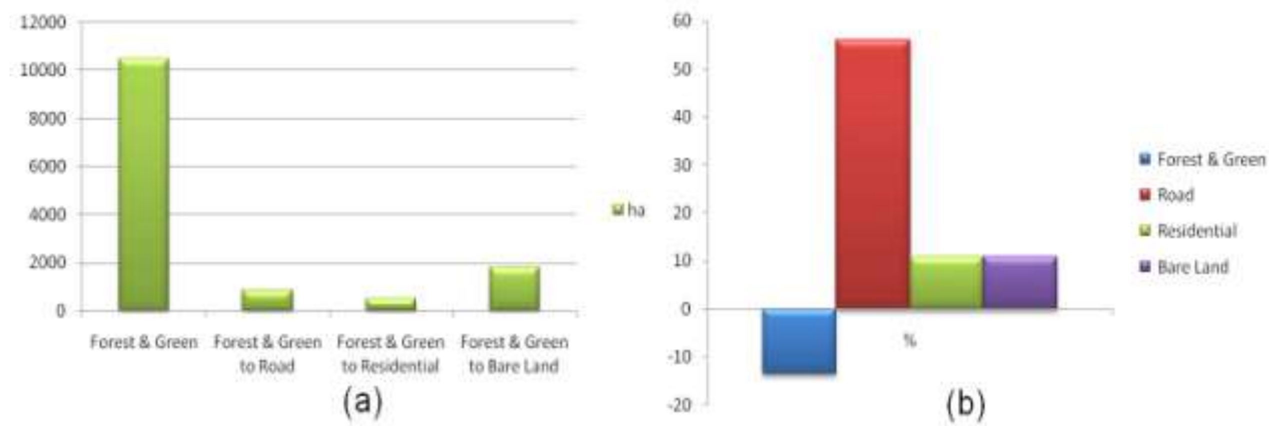

Figure 6. a) Changes of forest and green areas to other classes b) percentages of changes

includes agricultural lands, pastures, green areas such as parks and trees. It was found that 874.17, 483.63 and 1823.31 ha areas changed from forest and green areas to road, residential and bare lands respectively as a result of heavy population and uncontrolled urbanization between the years 1995 and 2005 (Figure 6).

The post classification results give an explanation on the question, in which part of the district land use/cover changes have occured. An example of the visual interpretation given in Figure 7 shows the forest areas in 1995 turned in to roads in 2005.

In Figure 8, a part of the change detection map corresponding to residential areas of Umraniye is demonstrated. It is a dramatic example that shows trajectory of changes to urban areas from forest in Umraniye district of Istanbul. This district was demolished with construction of buildings without taking into account the sustainability of forest areas as a natural resource. Figure 9 is also depicting the areas which were changed to baren lands from forest areas.

DISCUSSION AND CONCLUSIONS

This paper uses a post-classification comparison for land use/cover change detection in a very highly urbanized district of Istanbul metropolitan city by using Landsat TM imagery gathered in 1995 and 2005. Since this study focused on defining the effect of urbanization on natural resources, five land use/cover classes, which were defined a priori, used in the classification process were water, forest and green area, road, residential area and bare land. Individual classifications were employed for both Landsat images belonging to 1995 and 2005. Maximum Likelihood classifier was used in the classification process as a supervised classification technique. Image pairs of the consecutive dates were compared by using “from-to” analysis of the post classification method.

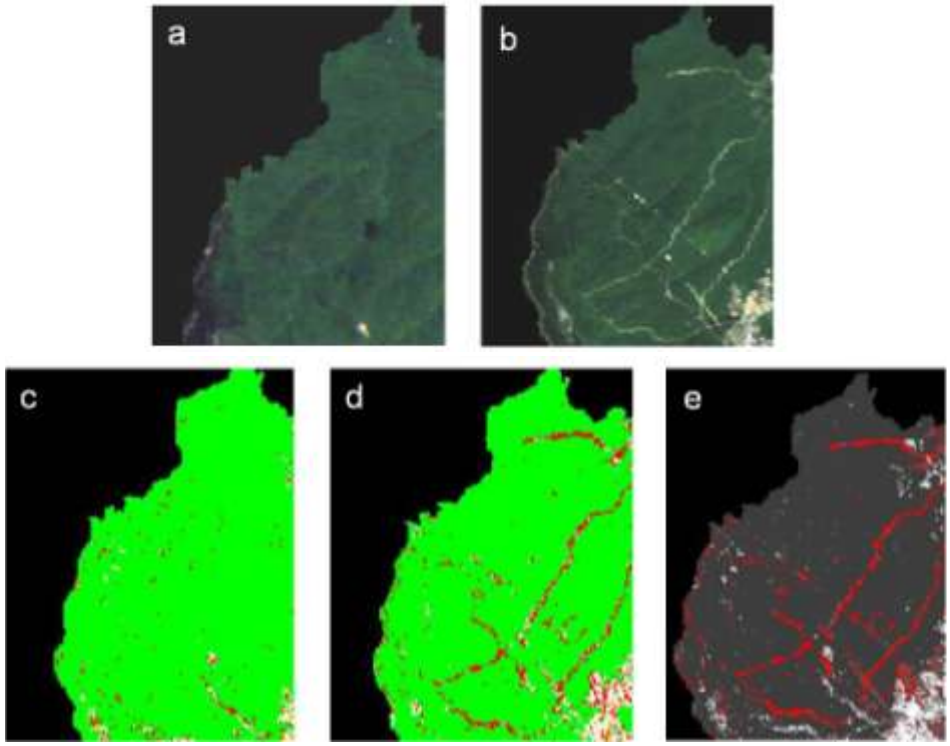

Figure 7. Changes from forest and green area to road: ***a*** and ***b*** are Landsat TM images of 1995 and 2005 respectively, ***c*** and ***d*** are classified Landsat TM images of 1995 and 2005 respectively, ***e*** is the change map.

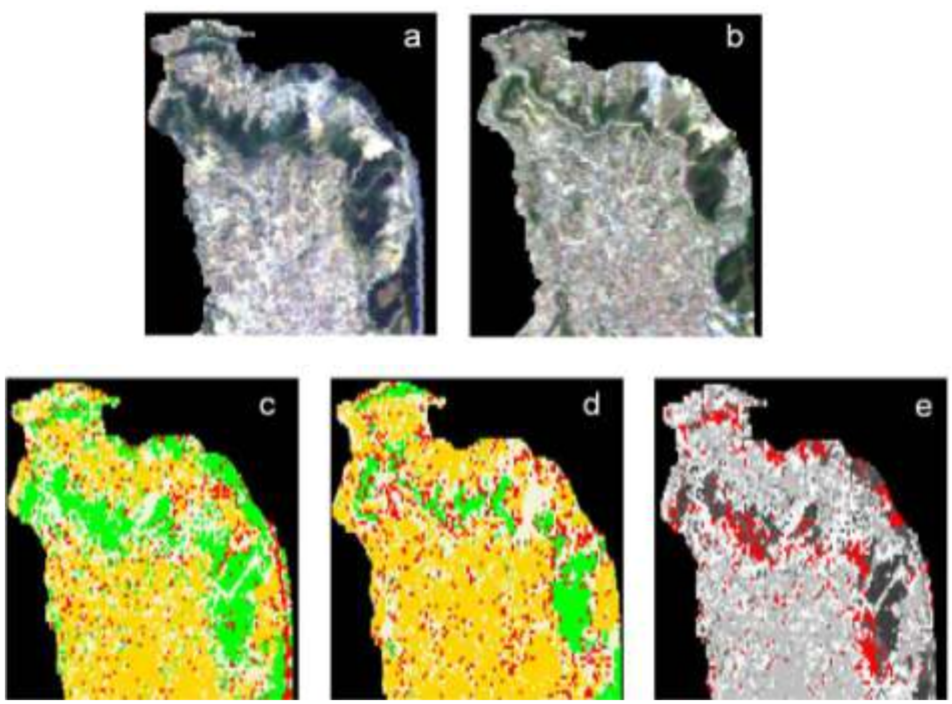

Figure 8. Changes from forest and green area to residential areas: ***a*** and ***b*** are Landsat TM images of 1995 and 2005 respectively, c and d are classified Landsat TM images of 1995 and 2005 respectively , and ***e*** is the change map.

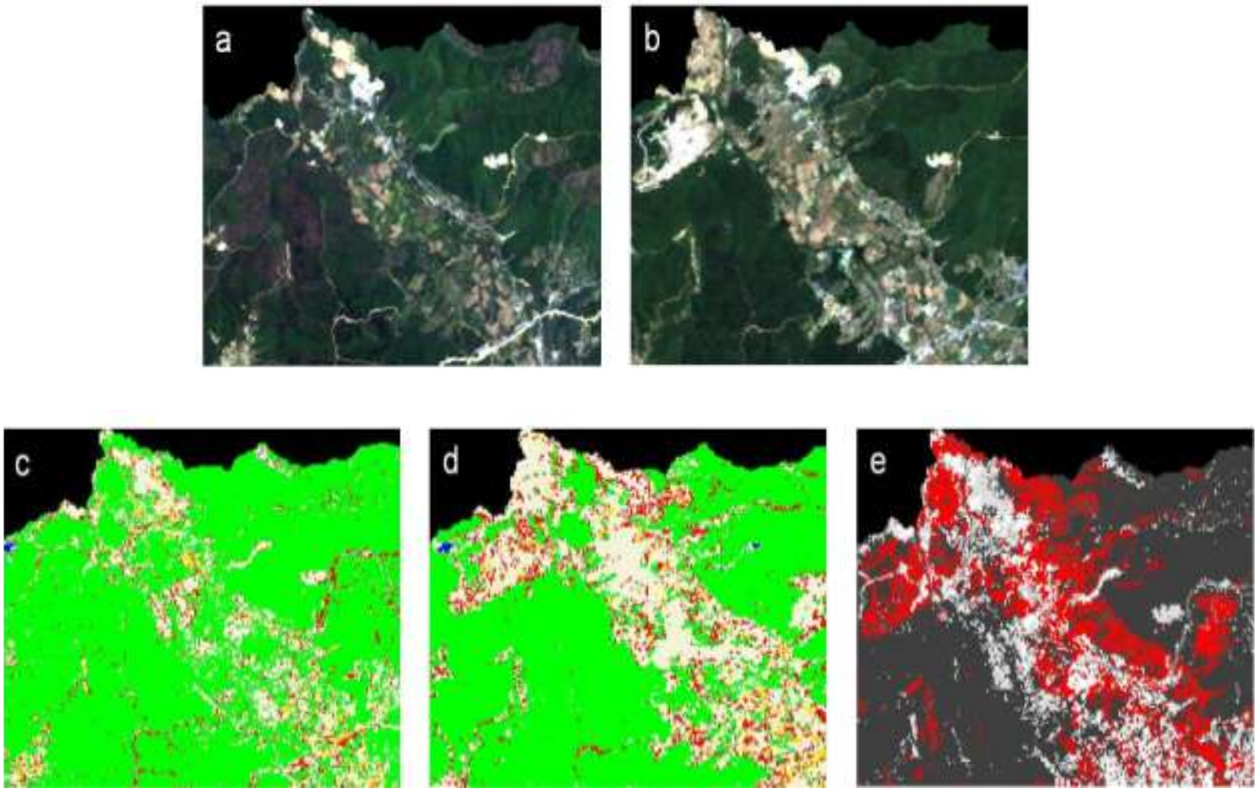

Figure 9. Changes from forest and green area to bare lands: ***a*** and ***b*** are Landsat TM images of 1995 and 2005 respectively, ***c*** and ***d*** are classified Landsat TM images of 1995 and 2005 respectively , and ***e*** is the change map

It was observed that the urbanization and the expansion of roads as a result of the urbanization were the major reasons for the dramatic land use/cover changes. It was determined that over 10 years period 80% growth in the population resulted in approximately 13.06% decrease in the forest and green area, 56.01% increase on the total area of the roads, 10.88% increase on residential areas, and 10.77% increase on the barren land. The amount of conversions from forest and green area to road, residential area and bare land are 874.17, 483.63 and 1823.31 ha respectively. It was demonstrated that a severe environmental degradation occurred in previous administrative borders of Umraniye district of Istanbul as a result of land use change and human activities especially on the forest areas from 1995 to 2005. Unless the growing population is oriented to the pre-planned areas, the life resources such as forest and agricultural areas can be degraded easily. Precautions should be taken to keep the sustainability of the resources. Such studies aim to contribute managers, decision makers and urban planners on land use /cover changes for a certain period in interest. Thus against the uncontrolled urban sprawl or consuming of natural resources that are driven by uncontrolled population migration, they would be able to define a policy to protect the district.

The results presented proved that Landsat can provide accurate information to map and analyze in land cover and land use investigations. Results of the analysis can be used for urban and natural resource management. Using Landsat images provides quick monitoring of large areas with no cost data, however using higher resolution images for monitoring urban areas will provide more accurate results for applications.

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