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Monitoring changes in forest and other land use forms in Istanbul

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Abstract: *This study introduces the monitoring system to be established within this project, it aims to determine changes occurring within forested areas, settlement areas and other land use forms located at the peripheral area of Istanbul during consecutive decades. The first phase of the study was completed in 1998 and published, covering the period from 1984 to 1994. This study is the second phase of the first one and implemented to determine land use changes which have occurred on the same site from 1994 to 2000.*

Standard topographic maps with 1/25 000 scale, forest management maps with the same scale, results of the previous study, orthophoto maps of the year 2000 that were produced from aerial color photographs of the site with 1/5 000 scale, and 4-band IRS_LISS III multispectral satellite data for July 2000 were used as data. The changes in land use within the study area occurring during a six year period were studied.

Key words: *Monitoring, Change detection, Remote sensing, GIS, Land use forms.*

Introduction

The horizontal and vertical structuring of the forest is determined mostly by terrestrial surveys and partially by photo interpretation (Koç, 1997). Satellite data and image processing techniques, with their effective and innovative capacity and availability in various application fields especially dealing with natural resources, possess the characteristic of determining the spatial and structural specifications of forest areas and peripheral forest areas of Turkey that have very dynamic feature and rapidly change appearance in the shortest time possible (Koç and Selik, 1996). In combination with geographical information systems, the utilization of both satellite data and image processing techniques provide us with the opportunity to obtain a great deal of information about the surface of the earth in the shortest possible time and in a precise manner and, additionally, allow us to conduct comprehensive spatial analysis with respect to the surface of the earth. Incorporating the geographical information obtained within a geographical information system (GIS) designed to suit the purpose, that is, within a database, tremendous possibilities will be achieved in planning, decision making and administrative procedures, taking into consideration the analytic capabilities inherent in the system.

Istanbul is the most important center of industry and commerce in Turkey. Istanbul accommodates almost one sixth of the population of Turkey and is one of the most densely populated cities of the world with its 11 million inhabitants. Turkey exhibits typical features specific to a developing country. Being the most crowded city of Turkey, Istanbul attracts thousands of our citizens coming from various regions of Turkey. Rapid increase in the number of inhabitant results in haphazard urbanization, the phenomena of shanty houses, and the destruction of green areas as well as in social and economic problems. Such problems give rise to accelerated change in the utilization of the area within and at the periphery of Istanbul. It is very difficult to keep track of this change. This change is so accelerated that it can only be determined via satellite data that enable the compilation of the relevant data effectively in connection with vast areas in the shortest time possible. On the other hand, an individual monitoring system should be established to monitor the forest areas in Istanbul and the changes therein. This is the only way to devise effective measures to protect the forest areas located at periphery of Istanbul in order to leave them to future generations (Yener and Koç, 2002).

In order to conduct a study, monitoring these changes, an area of 360 km^2 was chosen in Istanbul. The area had earlier been monitored to observe changes occurring in forest lands, settlements, and other land use types for a ten year period from 1984 to 1994 and the first study was completed in 1998. The present study is the second step of the project and covers the changes on the same site between 1994 and 2000.

Materials and Methods

Study site and data: The study area covers the city of Istanbul, located at between 28° 52’49’’ and 29º07’27’’ eastern longitudes and 41° 06’00’’ and 41° 15’49’’ northern latitudes. The metropolitan area of Istanbul is subject to very rapid change. Therefore, satellite images are used as a quick and effective data collection method within vast areas. The study has been conducted over approximately an area of 360 km^2.

Data from TM sensor are used for a wide variety of applications including resource management, mapping, environmental monitoring, and change detection. The four LISS-III multispectral bands are similar to Landsat's TM bands 2 to 5 and are excellent for vegetation discrimination, land-cover mapping, and natural resource planning (CCRS, 2001). Technical characteristics of sensors (TM and LISS-III) used in this study are given in Table 1.

Table – 1: Technical characteristics of TM and LISS-III sensors (derived from CCRS, 2001).

Satellite/ sensor	Channel	Spectral resolution (µm)	Spatial resolution (m)	Radiometric resolution (bit)	Swath width (km)	Revisit period (day) (at equator)
Landsat5/ TM	1	0.45 – 0.52	30	8	185	16
	2	0.52 – 0.60	30	8	185	16
	3	0.63 – 0.69	30	8	185	16
	4	0.76 – 0.90	30	8	185	16
	5	1.55 – 1.75	30	8	185	16
	6	10.4 – 12.5	120	8	185	16
	7	2.08 – 2.35	30	8	185	16
IRS-1C/ LISS-III	1	0.52 – 0.59	23	7	142	24
	2	0.62 – 0.68	23	7	142	24
	3	0.77 – 0.86	23	7	142	24
	4	1.55 – 1.70	70	7	148	24

To determine the size of the forest land, other land use types and changes occurring in these lands between 1994-2000, classified Landsat5_TM images, obtained in the previous phase of the monitoring system in 1994, and 4 bands IRS_LISS III multispectral satellite data for July of the year 2000 were used as data. On the other hand, to classify satellite image obtained in 2000, orthophoto maps produced from aerial color photographs with 1/5 000 scale and the data determined by terrestrial surveys were used to determine the training areas.

Various software, namely, Workstation NT Arc/INFO 8.01, ARC/View GIS Version 3.1, ERDAS IMAGINE 8.4 were used for this purpose.

Preliminary work before classification: Preliminary work undertaken before the classification can be listed as rectification process, image enhancement and formation of the vegetation indices, as shown in Fig. 1.

The purpose of the rectification process is to convert the image elements obtained by the sensing system into image elements organized in conformity with the coordinate system of the country. In this way, the image elements are located on the surface of the earth (Kraus, 1990). 22 different, homogeneously distributed ground control points (GCPs) determined by using standard topographic maps with 1/25000 scales were employed in the rectification of the image obtained in 1994. A 2nd-order polynomial equation was used for the transformation. Finally the images were converted into the UTM (Universal Transverse Mercator) map projection system. Within this last image, each pixel was sampled representing an area of 25 by 25 meters. Nearest Neighbor method was used as the resampling method. Image to image registration method was applied in the rectification of the 2000 image. On the other hand, orthophoto maps with a scale of 1/5000 used in the determination of training areas were scanned and transferred into computer, and they were transformed into the UTM map projection system with a scale of 1/25000. Thus, all these three data set used in this study (Landsat5_TM, IRS_LISS III and orthophoto maps) were converted in to the same map projection system.

Spectral vegetation indices (SVI) are synthesized from spectral reflectance factors using a variety of techniques. A number of SVIs have been proposed in the literature that employs various combinations (differencing, rationing, etc.) of vegetation bidirectional reflectance factors (BRFs) at two or more wavelengths. The most common index is the normalized difference vegetation index (NDVI) (Myneni and Asrar, 1994).

The method of vegetation indices is a kind of image enhancement technique. If the type of vegetation and the vegetation damage are to be classified, then the vegetation indices consisting of rationing of the near infrared and red bands through various formulations (or taking the differences) are used. In such operations, 3 and 4 band values, defined as per TM are used. By this way, the most important information is preserved, although the amount of data decreases to a great extent (Kraus, 1990). Most of the vegetation indices formulas referenced in the literature include ERDAS image processing software.

In this study, five different vegetation indices layers were generated separately for the images of Landsat5_TM and IRS_LISS III (Fig. 1). Then, a new, 10-band image was generated by combining first 5 original bands of Landsat5_TM images together with the images of vegetation indices generated for the image of 1994. Another new, 9-band image was generated by combining the images of five vegetation indices generated for the image of 2000 together with 4 original bands of IRS_LIIS III.

Determination of land use class and classification of images: To classify the images obtained in 1994 and 2000 and to detect change, 5 different land use classes were determined. These include many sub-classes. 68 training areas from the image of 1994 and 60 training areas from the image of 2000 were chosen to represent these classes. The reason behind the choice of such a large number of training areas is the size of the project area and the presence of many land use types that

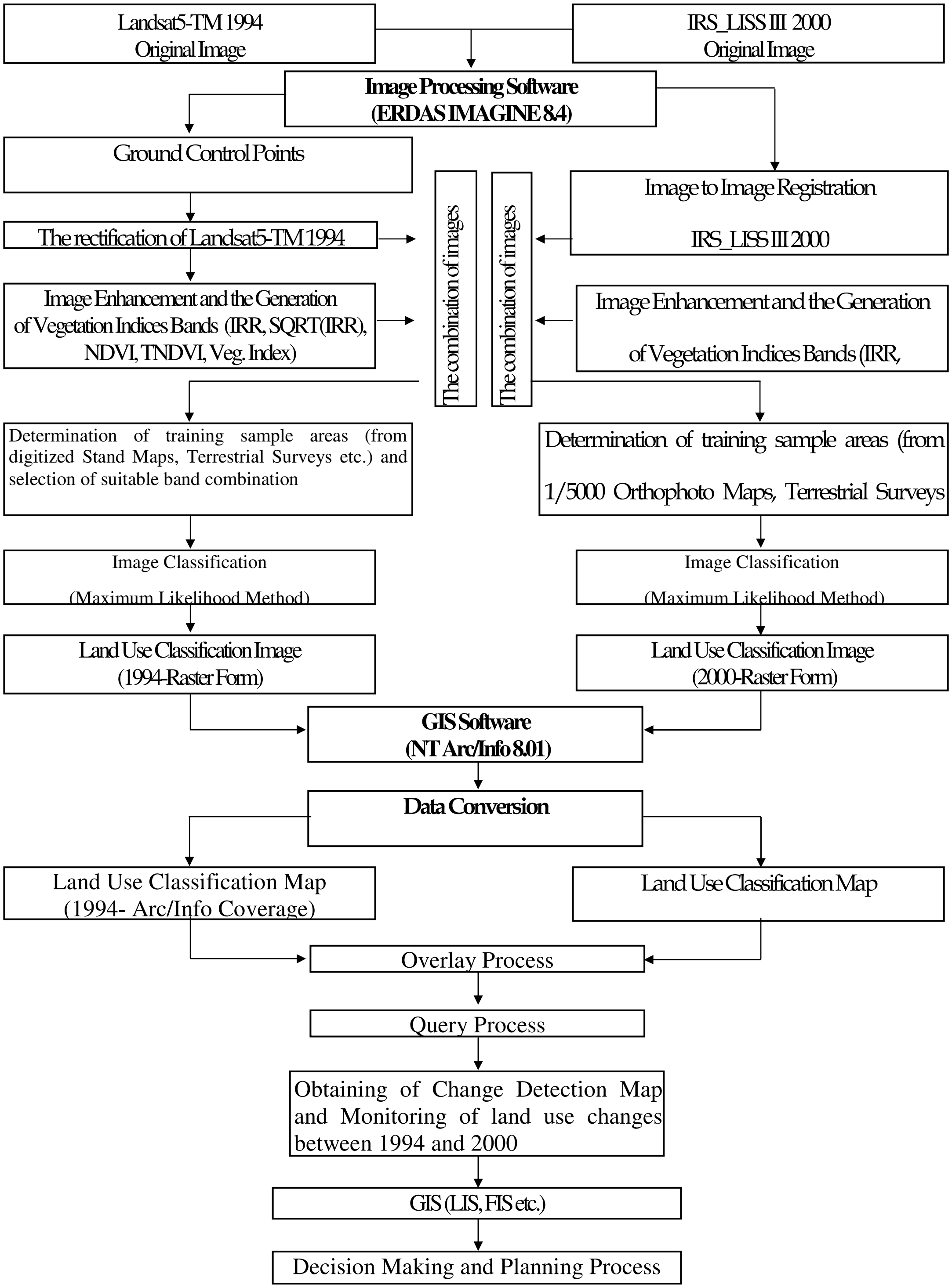

Fig. 1: Flow chart of project.

exhibit great differences with respect to the reflection values. The training areas, each of which was considered as a separate sub-class, were first subjected to signature analysis and an investigation of the brightness values and the relevant curves of these classes was conducted, the sub-classes to be used later in the classification were determined. The decisions were made on the most appropriate band combinations after the investigation of the tables and graphics showing the reflectance values of the training areas belonging to these classes with respect to bands. The combinations determined were third,

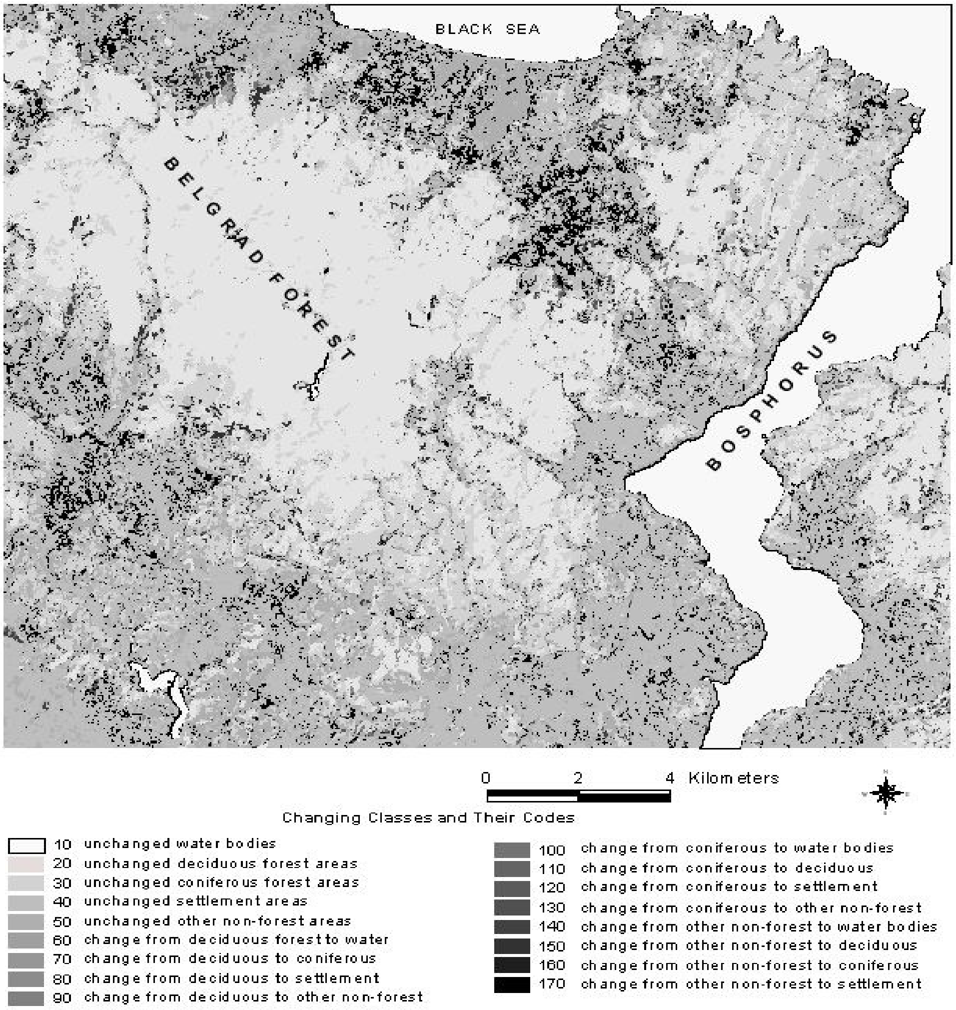

Fig. 2: Thematic map for the changes occurring in land use forms between 1994 and 2000.

fourth, and fifth bands of TM with NDVI and Veg. Index bands from vegetation indices bands for the image of 1994, and 4 original bands of IRS_LISS III with NDVI and Veg. Index bands from vegetation indices bands for the image of 2000. Afterwards, the classification of the sub-classes and the band combination were determined and the classification of the images of 1994 and 2000 was done using the “Maximum Likelihood” method.

Following the classification operation, a recoding operation was performed via Raster GIS Module of ERDAS IMAGINE 8.4 software, in connection with main classes defined in conformity with the purpose of this project. The main classes determined and code values assigned to each land use class are given in Table 2.

The classification was confirmed to make sure that the classification is valid. To this effect, verification of the accuracy of the classification with respect to 1994 and 2000 was checked by the Overlay method and the Accuracy Assessment method. In order to implement the accuracy analysis of the classifications for 1994 and 2000, randomly selected 100-ground control points (GCPs) belonging to each of the two classifications were used.

In the event that the ratio of the accuracy of the estimations to be obtained through remote sensing is equal or above 80%, the classification is assumed as accurate and reliable. Within this project, the precisions of the classifications for both years are above this ratio. The ratio of accuracy of the classifications for all classes belonging to 1994 and 2000 are 90,0% and 91,0%, respectively. In accordance with these results, the sufficient accuracy level and reliability are reached in the classification performed. The reliability of these results, as it has been already mentioned, were also verified through overlaying of the image data classified with the original images.

Findings:

Determination of changes in land use forms: For the purpose of determining changes in land use forms, priority was given to the raster-vector conversion to analyze the classified images recoded under 5 main land use classes within Arc/INFO media. As a result of these operations, two different geographical information layers were generated, which consisted of land

Table – 2: Major land use classes and codes.

Code	Major land use classes
10	Water bodies
20	Deciduous forest
30	Coniferous forest
40	Settlement
50	Other non-forest areas

use data for 1994 and 2000. In order to perform the change detection, it was necessary to overlay the geographical information layers containing land use data belonging to 1994 and the geographical information layers containing land use data belonging to 2000. This operation ensured the identification of the intersections and combinations between the two geographical information layers, as well as the combination of the geographical databases of the geographical information layers for both years. A new geographical database was thus generated to facilitate the investigation of the changes within the project area during a period of six years.

Within the new geographical information layer obtained by the overlay operation, a new attribute class (item), so called CHANGE was created for Change Detection. The codes that specify any change occurring in land use data within the project during this six year period were entered in this attribute class. These were in the form of numerical data.

In order to determine the changes which had occurred in land utilization classes during this 6 year period, the relevant query is obtained on the results gained by overlaying geographical information layers. At the end of the 6 year period between 1994 and 2000, the extent of change occurring in land use forms within the project area were investigated mainly in two ways. One was an investigation perform of the overall areal changes within the project area. The areal changes within the project area, the land use and the areal changes obtained for 1994 and 2000 are given in Table 3. The other was the spatial analysis of the changes between the classes.

An investigation of the real changes within the project area is only possible through spatial analysis and the implementation of such an analysis is possible only within GIS media. To conduct the analysis of changes in the class with respect to the location, the information obtained after the query performed within GIS media is given in Table 4, together with the code values that have been explained before.

Table – 3: A comparison of land use classes between 1994 and 2000.

Class	Land use in 1994 (ha)	Land use in 2000 (ha)	Change (difference) (ha)	Change (percent) (%)
Water bodies	4418.4377	4666.6802	+ 248.2425	+ 0.69
Deciduous forest	10274.9375	10222.7600	- 52.1775	- 0.14
Coniferous forest	7570.0000	7338.7300	- 231.2700	- 0.64
Settlement	7416.7500	9136.9000	+ 1720.1500	+ 4.76
Other non-forest areas	6424.7850	4739.8400	- 1684.9450	- 4.67
TOTAL	**36104.9102**	**36104.9102**		

Table – 4: Changes occurring in land use classes between 1994 and 2000.

Changing codes	Land use classes in 1994	Land use classes in 2000	Area (ha)	Percent %
10	Water bodies	Water bodies	4418.4377	12.24
20	Deciduous forest areas	Deciduous forest areas	9863.0875	27.32
30	Coniferous forest areas	Coniferous forest areas	6917.4050	19.16
40	Settlement	Settlement	7416.7500	20.54
50	Other non-forest areas	Other non-forest areas	4291.3475	11.89
60	Deciduous forest areas	Water Bodies	82.58	0.23
70	Deciduous forest areas	Coniferous forest areas	143.6125	0.40
80	Deciduous forest areas	Settlement	55.3000	0.15
90	Deciduous forest areas	Other non-forest areas	130.3575	0.36
100	Coniferous forest areas	Water bodies	28.1300	0.08
110	Coniferous forest areas	Deciduous forest areas	42.7200	0.12
120	Coniferous forest areas	Settlement	263.6100	0.73
130	Coniferous forest areas	Other non-forest areas	318.1350	0.88
140	Other non-forest areas	Water bodies	137.5325	0.38
150	Other non-forest areas	Deciduous forest areas	316.9525	0.88
160	Other non-forest areas	Coniferous forest areas	277.7125	0.77
170	Other non-forest areas	Settlement	1401.2400	3.88
Total			**36104.9102**	**100**

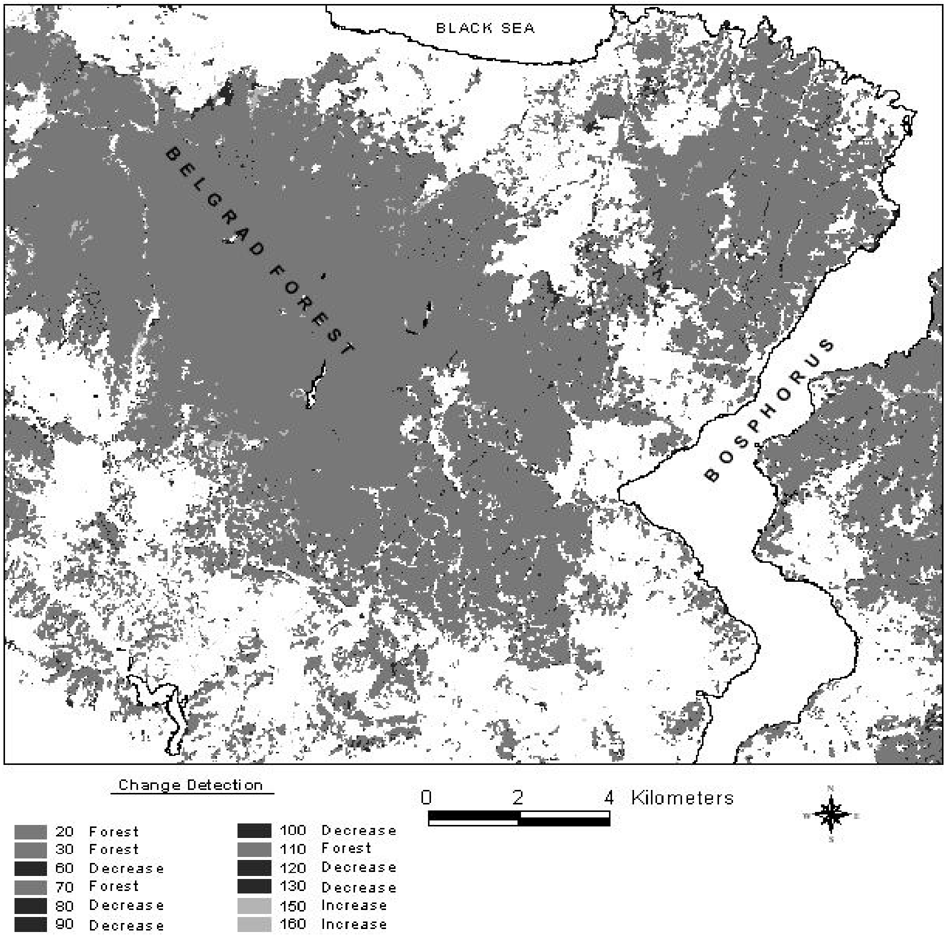

Fig. 3: General trend of the changes occurring in the forest areas between 1994 and 2000 (inreases and decreases).

In Table 4, codes between 10 and 50 show the areas that remained unchanged between 1994 and 2000. However, the codes from 60 to 170 indicate inter-class changes occurring in the land use class during the 6 year period. In order to visualize the changes that are given as tabular values, the thematic map, together with the change codes are given in Fig. 2.

Investigation of changes in the forest areas: One of the main purposes of this study is to determine forest areas and changes occurring in forest areas at a peripheral area of Istanbul. Preliminary investigations conducted for this purpose aimed mainly at determining the enlargement and shrinkage of forest areas. The spatial enlargement and shrinkage of the forest areas are given in Fig. 3 which depicts the general trends of change in forest areas. In order to express the figures introduced quantitatively, it is necessary to go over the information given in Table 3. The amount of enlargement and shrinkage in forest areas during this 6 year period is determined for the coniferous and deciduous forest areas in 1994 and 2000 separately. As a result of the areal comparison, it can be concluded that the overall size of the forest areas in 1994 and 2000 are very close to each other.

Another investigation made within the scope of this study was an assessment of the enlargement and the shrinkage of forest areas spatially, and then an attempt was made to determine the reasons for these changes. Taking Fig. 3 and Table 4 together:

- The enlargement of the forest areas occurred in the form of inclusion into the forest areas from Other Non-Forest Areas class. From a quantitative point of view, the overall enlargement amounted to 594.665 ha, with the inclusion of 316.9525 ha Deciduous Forest class and of 277.7125 ha Coniferous Forest class from Other Non-Forest Areas.
- When the nature of the shrinkage of the forest areas was investigated, it was seen that there were mainly three type of shrinkage. The first type of shrinkage is in the form of shifting to the Settlement class from the classes belonging to Deciduous or Coniferous Forest Areas. The loss of the forest areas in this type amounted to 318.91 ha, which consisted of a shift of 55.30 from Deciduous Forest class to Settlement class and 263.61 ha from Coniferous Forest class to Settlement class. The conversion of these areas back to forest areas is practically impossible. This shows that the loss of real forest areas within the scope of this project area was actually larger. The second

type of shrinkage of Forest areas was in the form of shifting to Other Non-Forest Areas class from forest areas. The loss of forest areas of this type amounted to 448.4925 ha, a shift of 130.3575 ha from Deciduous Forest class and 318.1350 ha from Coniferous Forest class. Another type of shrinkage of forest areas is seen in the form of shifting to the class of water bodies. The loss of forest areas in this type amounted to 110.71 ha, of which 82.58 ha was from deciduous forest class and 28.13 ha from coniferous forest class.

After the investigation of these changes, it can be concluded that they originated from mainly five reasons.

1. Increase in the coniferous forest areas mainly originated was from the plantation areas. The enlargement of deciduous forest areas was the result of increase in canopy closure where forest openings existed in 1994.
2. The destruction of vegetation due to surface mining operations in the areas close to the shore of the Black Sea altered the topographic structure of the area and resulted in the establishment of artificial water bodies.
3. Forest fires,
4. Provisional cases due to forestry operations,
5. Destruction of the forest in an attempt to obtain real estate (Destruction)

The shrinkage of forest areas originating from the second, third and fourth causes given above is provisional in nature, and can eventually be reversed. However, the shrinkage of forest areas originating from the fifth cause incorporates permanent elements that cannot be eliminated easily. In some cases, complicated legal proceedings are required to convert these areas back into forest areas, however, in most cases the areas opened up to settlement are permanently lost and are eventually converted into settlement areas.

Discussion and Conclusion

Data with a high degree of accuracy can be obtained via remote sensing over vast areas, and the evaluation of data compiled within geographical information systems facilitates various types of spatial analyses. In this way, it is possible to determine changes, especially with respect to spatial and temporal dimensions. Such analysis (Change Detection) is mainly performed via the Monitoring System, by the use of image processing systems aimed at the processing of satellite data in combination with geographical information systems. The Monitoring System is not only considered in connection with the spatial analysis with respect to the temporal dimension, it also includes the implementation of the necessary measures and the orientation of the monitored area in regard to the targets established. The present study aims at providing the necessary information that would enable such an orientation as well as the orientation or restructuring itself.

The results of this study show that among the land use classes, the largest increase took place in settlement areas (1720.15 ha-4.76 %) whereas the greatest decrease occurred in the other non-forest areas (1684.9450 ha-4.67 %) rather than in forest lands for the six year period. Looking at Table 4, about 81.46 % of the enlargement in settlement areas originated mainly from other non-forest areas, and 18.54 % of it from forest lands. This result shows that the forest lands were not properly protected from the pressures of society, rapid population increase, and migration from rural areas to urban areas. It also shows that irregular settlement is the biggest problem facing the city of Istanbul.

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