MULTITEMPORAL FOREST CHANGE ANALYSIS

A CASE STUDY : SARIYER REGION

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ABSTRACT

In this study, differentiability of vegetation at Sariyer, an area with rich forest due to its geographical situation and general characteristics, has been analysed through the satellite images used jointly with ground data, and temporal changes which occurred in forest lands have been determined. In order to evaluate multitemporal data sets (June 1984 and June 1997 Landsat TM) Sariyer region, located in the north of Istanbul was selected. In differentiating types of trees through satellite images, classification algorithms have been used by taking as basis the ground measurements carried out at Istanbul University, The Forest of Education and Research of the Faculty of Forestry which was selected as the test area. Firstly uncontrolled classification and then controlled classification algorithms have been applied to the test areas with different dates and to the entire area of study.
Accuracy assessment were made to the classification results and the zonal values obtained were temporally compared.

1 INTRODUCTION

A major role that remote sensing and GIS techniques serve is to inventory and monitor biophysical and man-made features on the surface of the Earth. While some of the data may be static and does not change over time, much of the biophysical and man-made features are dynamic and constantly changing. It is important that such changes be inventoried accurately so that the physical and human processes at work can be more fully understood (Estes, 1992; Jensen and Narumalani, 1992; Ramsey, 2000). In order to maintain his life and in the meantime leave the best for the generations to come, mankind has to utilize the natural resources he has in the most economic manner and protect them. Parallel to the developing technology and increasing scientific researches today, advancements in the science of remote sensing are major helpers of mankind in this field. Changes made on the surface of the earth today are more extensive and occur more rapidly than ever before. Planners and resource managers, need a reliable mechanism to assess these consequences by detecting, monitoring and analysing land use changes quickly and efficiently. To meet the demand for current and accurate data multitemporal remotely sensed images are increasingly used as one of the data sources of land use change analysis.

It is necessary to monitor and know at certain time intervals the amounts and the changes in time of the forest resources in terms of parameters such as tree wealth, growing sites and tree species (Coskun et al., 1998). As the forest inventory to be made by means of ground studies is a time-consuming, costly and difficult task, the studies which have been made show that satellite images provide, for this purpose, sufficient and reliable information in a short period of time.

Satellite data are important sources of information to monitor at a regional scale the use of forests and land (Varjo, 1995; Botkin, 1984; Elijah, 1996). Studies which have been carried out through the satellite data at various dates are being widely used in analysing the use of land as well as the temporal changes in the shorelines and in the forest ecosystem(Peters et al., 1993; Jacobberger - Jellison, 1994; Chavez and MacKinnon, 1994; Johnson, 1994; Dobson et al., 1995; Michener and Houjoulis, 1997). In forestry works and differentiating the types of forest stands, generally 3., 4. and 5. channels of Landsat TM sensor are used. Satellite images, which are widely used in the topics of national forest inventory and monitoring of the periodical changes in forest areas, are combined with aerial photographs to be used in preparing the plans of forest management (Hame and Rauste, 1995).

By applying classification algorithms to satellite images of different dates belonging to Sariyer township, temporal changes of the area were analyzed in this study.

2 STUDY AREA AND TEST SITE

In order to evaluate multitemporal data sets, Sariyer region located on the western part of Istanbul has been chosen (Fig. 1). Sariyer township lies between the co-ordinates of 28° 61' 25" - 28° 61' 25" east, 41° 16' 37"- 41° 04' 55" north and covers an area of approximately 151 square kilometres.

While the total area of Sariyer was covered with forests in ancient times today only the northwest side has remained as a forest. In the forest areas, the vegetation is formed by natural species of *Fagus oriantalis*, *Castania sativa*, *Quercus spp*., *Carpinus betulus*, *Tilia argantena* as well as *Pinus nigra, Pinus maritima, Pinus pinea* and other coniferous species that have been planted, which exist pure or mixed in the forest. Apart from this, shrubbery also flourished in the forest lands. Coniferous species grown by planting generally exist in the north east of the area (Musaoglu and Ormeci, 1999).

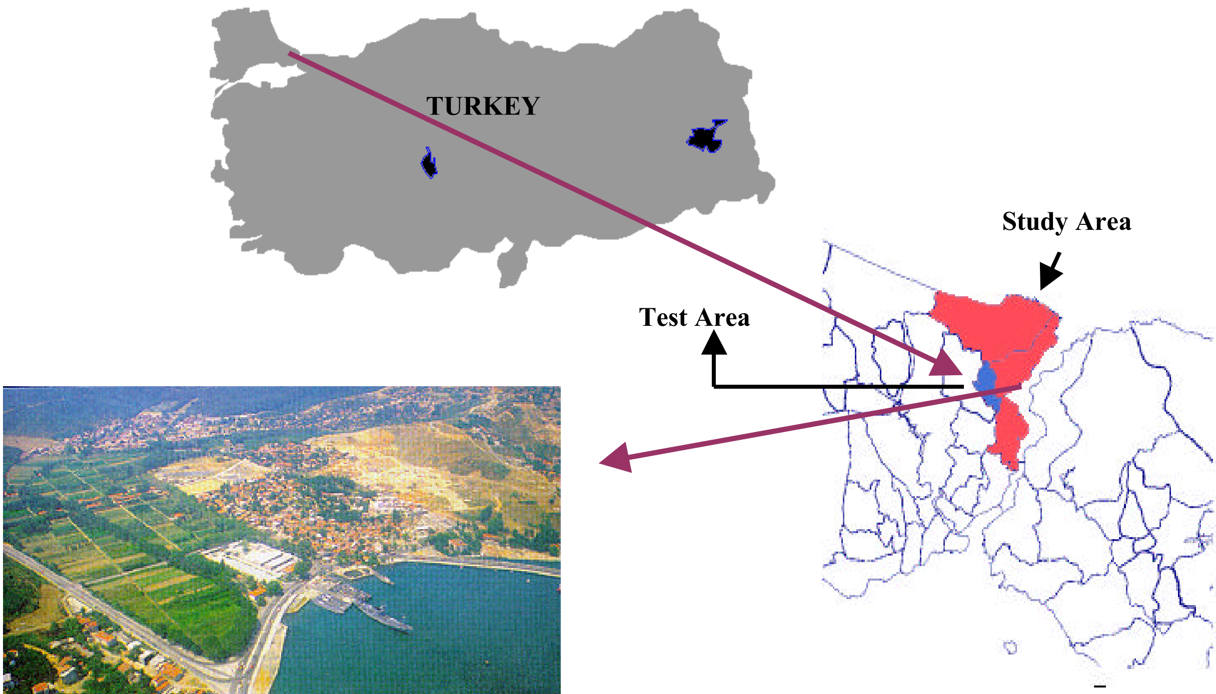


Figure 1. Study Area

2.1 Test Site

In classification, Education and Research Forest of Istanbul University was chosen as the test site. This test site which covers and area of 739.13 hectars, consists of pure and mixed tree species of all ages , especially mixed tree stands such as mainly *Castanea sativa(Cs), Pinus nigra(Pn),Carpinus betulus(Cb), Qercus spp(Qs), Tilia argentena(ta)* as well as *Sorbus domestica(Sd), Fraxinus(F), Arbutus unedo(Au),Cistus spp(Cs),Sorbus torminalis(St),Spartium junceum(Sj) and Laurus nobilis.(Ln)* (Musaoðlu, 1999).

In choosing the test site for classification, tree stand map at 1/5000 scale was taken as the basis. In preparing this map, differentiation of the tree stand species was determined by considering the general characteristics of inaccessible areas due to the thick forest lands and the topography of the area, and it was obtained by combining the species according to density of the tree species. Tree stands map of the test site was digitized and transferred to computer media. Each tree stand was taken as one layer in digitizing (Fig.2).

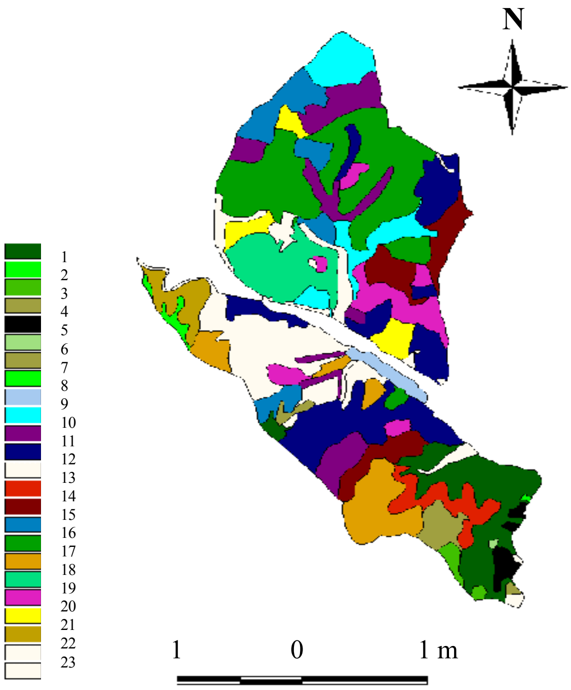


Figure 2. Test site

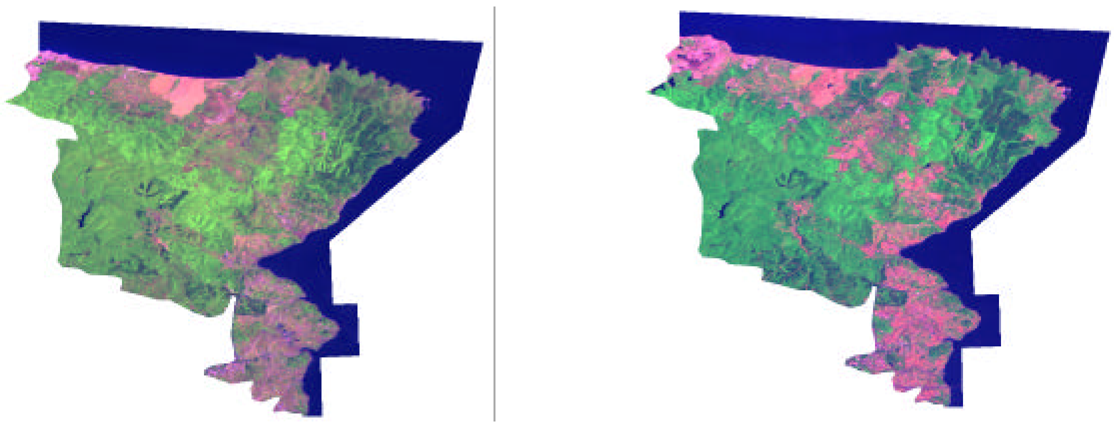
3 METHOD

In this study, Landsat TM images dated 12th June 1984 and 18th July 1997 were used. First of all , boundaries of the area of study were determined by applying geometric correction to the satellite images. Then, correction analyses were made to the classification results by applying controlled and uncontrolled classification algorithms to the images and temporal changes were examined.

3.1 Geometric Correction

Geometric errors that can be corrected using sensor characteristics and ephemeris data include scan skew, mirror-scan velocity variance, panoramic distortion, platform velocity, and perspective geometry. Errors that can only be accounted for by the use of ground control points (GCP) include the roll, pitch, and yaw of the platform and/or the altitude variance (Bernstein, 1983).

In the first stage of the study, satellite images were transformed into Universal Transverse Mercator (UTM) co-ordinate system by using 1/25000-scale standard topographic maps (Fig.3). In selecting the GCP's to be used for transformation, care was shown in homogeneous distribution of the sharp points and net differentiation on the map and satellite image (roads, shores, etc.) and transformation equations were selected as a first-degree polynom. For the geometric transformation, cubic convolution method was used. Co-ordinate transformation was done with ± 0.5 pixel root mean square (RMS).



(a) (b)

Figure 3: Satellite images of study area a) 1984 Landsat TM b) 1997 Landsat TM

3.2 Classification

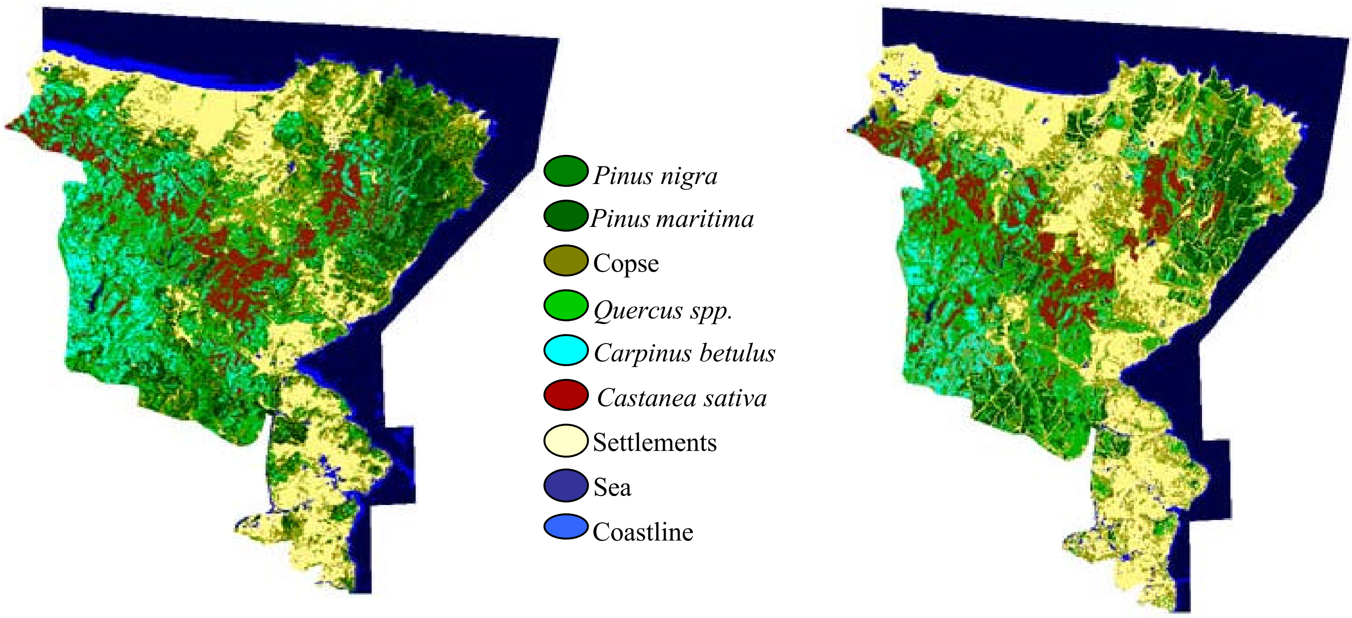
In multispectral data analyses, spectral excess is formed due to the correlation made up of the similarities among spectral channels, therefore, differentiability of topographic features is decreased. This correlation arises out of the similarities in reflections of objects, proximity among the spectral channels and the topographic effects, indicating that the spectral bands are proximate visually and digitally (Lillesand and Kiefer, 1987). Use of low correlation channels in classification of satellite images enhances the differentiability of topographic features of the earth and positively affects the classification accuracy.

For the purpose of determining the suitable channel combination before classification, firstly spectral curves in different vegetation cover types were drawn on two different dated satellite images, then variance and covariance analysis was made to calculate the correlation among the channels. When the correlation coefficients obtained as a result of such analyses were examined, it was found out that the lowest correlation were obtained in 4^{th} and 5^{th} channels. In Landsat TM data, low correlation of 1^{st} and 2^{nd} channels with 4^{th} and 5^{th} channels and of 3^{rd} channel with 4^{th} channel, were considered and assessed jointly with the blank areas and areas covered with water in the area of study . As a result, it was decided that 1^{st}, 2^{nd}, 3^{rd}, 4^{th} and 5^{th} channels were to be used (Musaoglu, 1999).

Classification of satellite images was done in 2 stages. In Stage 1, for the purpose of having preliminary information about the region, ISODATA uncontrolled classification algorithm was applied to all the satellite data and 30 groups were obtained for each data. Data group obtained as a result of uncontrolled classification were compared with tree stand maps, land use plans and other data, followed by elimination of some groups and combination of some others to use as sample area in controlled classification.

In Stage 2, Maximum Likelihood controlled classification algorithm was applied to all the satellite data. In controlled classification, 20 sample zones were determined on each satellite image. In determining the sample zones and controlling the classification results, tree stand maps, ground data, orthophotos, regional photographs and personal contacts were utilized.

In selecting the sample area in test sites, the accepted basis consisted of 1/5000 scale tree stand map, digitized to be transferred into computer media, of Education and Research Forest of Faculty of Forestry of Istanbul University and field measurements done on the spots . It was found out that 10 groups whose accuracy had been determined by analysing as a result of uncontrolled classification and 10 sample areas selected from the tree stand maps have provided adequate differentiation in the test site . Then, together with 20 classes, Maximum Likelihood controlled algorithm was applied to the satellite images dated 1984 and 1997. While the color attributions were being made to the images obtained as a result of classification, groups with similar characteristics were given the same colors and number of classes was decreased (Fig. 4).



(a) (b)

Figure 4 : Classified images a) 1984 b) 1997

During classification, non-forest areas (settlements, roads etc.) were combined under the heading of settlements class. Areas covered with water were roughly allocated into 2 groups, being sea and shore. In forest areas, badly deformed tree stands were combined with mixed woods (copse) class as they had similar characteristics. In this class, there were also various tree stands such as *Carpinus betilus, Qercus spp, Castanea sativa* as well as maquis areas.

3.3 Accuracy Assessment

Determining the accuracy of the classification results obtained from the satellite images ensures assessment of quality and usability of the maps obtained from remote sensing data (Stehmen, 1996).

In the remote sensing field, the accuracy of an image classification refers to the extent to which it agrees with a set of reference data. Most quantitative methods to assess classification accuracy involve an error matrix built from the two data sets (classifications are read across the rows and reference data down the columns). The percentage agreement uses only the main diagonal elements of the error matrix, and, as such, it is a relatively simple and intuitive measure of agreement. On the other hand, because it does not take into account the proportion of agreement between data sets that is due to chance alone, it tends to overestimate classification accuracy (Congalton and Mead, 1983; Congalton et al., 1983; Rosenfield and Fitzpatrick-Lins, 1986; Zhenkui and Redmond, 1995). For this purpose, pixels were selected during classification or over the classified data followed by examinaton of compatibility of these pixels with reference data.(Treitz et al. 1992, Skidmore et al., 1996) . Random selection of pixels prevents the user from having the possibility of obtaining preliminary information about the accuracy to be obtained. In order to determine ± 5 % accuracy of a class, more than 250 pixels to be selected from classified data is needed (Congaltan, 1991).

The Kappa coefficient has come into wide use because it attempts to control for chance agreement by incorporating all marginal distributions of the error matrix (Cohen, 1960; Congalton, 1991). Kappa coefficient is calculated by using the total of rows and columns of error matrix and diagonal elements and receives a value between 0 to 1.

Classification accuracy in remote sensing is indeed determining how compatible are the reference data with classified data (Ma,Z., Redmond,L.R., 1995). For this purpose, different dated 50 pixels classified depending on the size of the used data groups, and 400 random pixels in area of study were selected, then the compatibility of these pixels with ground data were examined. In controlling the selected pixels; works of ground facts, tree stand maps, topographic maps, land use maps, photographs of the area, orthophotos and contacts with people were utilized. For the purpose of examining the accuracy (A) obtained from classification results, statistical analysis was made and Kappa coefficient (K) values too were calculated. Values belonging to satellite images dated 1984 and 1997 are shown in Table 1 and Table 2. Furthermore, misclassified pixels as a result of classification were calculated too. As these pixels were small in number and located mainly in areas covered with sea, they were ignored.

Class	Sea	Coastline	Pm	Pn	Copse	Qs	Cb	Cs	Settlement	Σ	A (%)	K
Sea	94									94		
Coastline		15								15		
Pm.			6							6		
Pn.			5	42	2					49		
Copse					40	3			1	44		
Qs.			1		13	54	3	6		77		
Cb.						5	18			23		
Cs.					1		1	28		30		
Settlement									62	62		
Σ	94	15	12	42	56	62	22	34	6387	**400**	**89**	**0.87**

Table 1 : Accuracy assessment of 1984 dated Landsat TM.

Class	Sea	Coastline	Pn	Pm	Settlement	Copse	Qs	Cb	Cs	Σ	A (%)	K
Sea	96									96		
Coastline		9								9		
Pn			29	1						30		
Pm				2						2		
Settlement					90					90		
Copse			2			51	5		1	59		
Qs						8	47	4	7	66		
Cb			1			1	3	11		16		
Cs					1	1	3		27	32		
Σ	96	9	32	3	91	61	58	15	35	400	**90**	**0.87**

Table 2 : Accuracy assessment of 1984 dated Landsat TM.

From the accuracy analysis made, the desired accuracy was reached and zonal values of each class were calculated from the classification results (Table 3).

CLASS	**Area (Hectare)**	
	Landsat TM 1984	**Landsat TM 1997**
Castanea sativa	2105.06	1677.24
Carpinus betulus	1027.24	849.81
Qercus spp	3870.01	3419.54
Copse	2884.66	2600.28
Pinus nigra	1948.70	2173.95
Pinus maritima	267.20	249.67
Settlement	3313.65	4824.00
Sea	5911.83	5579.16

Table 3 : Areal distrubition of classes

4 RESULTS

When the classification result of the test site belonging to the year 1984 is examined, especially the stands of *Castanea sativa* is significantly differentiated from the other tree stands as it has got wider leaves and displays quick growth . As stands of *Castanea sativa* are flourishing species in terms of wealth, they are mixed with the *Quercus spp.* of the same age, the dominance being held by stands of *Castanea sativa.* As there is more growth especially in the riverbeds and the thickness of diameter is increased rapidly, stand of pure *Carpinus betulus* is clearly distinguished.

When the classification result of the test site belonging to the year 1997 is examined, it can be seen that especially stands of pure *Carpinus betulus* and at certain locations pure *Quercus spp.* are clearly distinguished. As a result of the classification, it was seen that chestnut trees encroached into the areas of oak trees and woods. Stands of *Castanea sativa* show quick growth and have richer properties than *Quercus spp.,* therefore, have more dominant character than *Quercus spp.* also in terms of biological mass.

When the results of classified images were jointly evaluated, it has been determined that temporal changes occurred both in the forest types of the area and the use of land, that the leafed trees being the natural flora of the area were replaced by coniferous trees trough forestation works in time, and that the Black Sea coastline in particular moved towards the sea (Table 3). Tree cutting in forest management in the shaving manner is carried out at 20-year intervals in the woods fit for cutting and in the areas where artificial regeneration process is to be applied. This situation may lead to errors in assessing the classification results of the satellite data. Although some areas where trees were cut for the purpose of new plantations existed within the classification results of the year 1997, it was found out, in the checks made, that most of the areas that appeared as non-forest were transformed into either mining sites or settlement areas. Another reason of the change in vegetation cover in 1997 is the modification of natural vegetation of the area because of reforestation works carried out in many places.

Monitoring the temporal changes of the forest lands which are among the natural resources that are very difficult or sometimes even impossible to retrieve will enable us to find solutions to the potential environment problems on time. Furthermore; accurate, fast and low cost data/information can be obtained in the studies aimed at determining the potentials of forests, monitoring their temporal changes and updating relevant information by using remote sensing data with spectral range fit for the purpose and spatial resolution that are supported from the field check.

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