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Urbanization and forest cover change in regional directorate of Trabzon forestry from 1975 to 2000 using landsat data

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Abstract In this study, forest cover change and urbanization in the borders of Regional Directorate of Trabzon Forestry (RDTF), which is located in NE of Turkey, was investigated during a 25 year period. Spatial and temporal changes in forest cover were also analyzed using Geographical Information System (GIS) and FRAGSTATS™. Forest cover changes were detected from a time series of satellite images of Landsat MSS in 1975, Landsat TM in 1987, and Landsat ETM+ in 2000 using Remote Sensing (RS) and GIS. The results showed a decrease in forest area, productive forest area and degraded forest area. Total forest area decreased in the first period (1975–1987), however increased during the second (1987–2000) period. 36 807 hectares (7% of the study area) mixed forest area converted to conifer forest. During the whole study period, the average annual deforestation rate was 977 ha year^{-1}, equivalent to 0.42% year^{-1} using the compound-interest-rate formula. Total number of forest fragments decreased from 135,039 to 132,839 (1.6%) during a 25 year period. On the other hand, total population lived in the borders of Trabzon City increased from 1975 to 2000 even though the rural population decreased. According to the results, the decrease of forest areas may well be explained by increasing population and urbanization. The decrease of number of patches and degraded forest area can be disclosed by the fact that the decline of rural population has positively affected the development of forest areas.

Keywords Forest cover change · Fragmentation · FRAGSTATS™ · GIS · Landsat · Remote Sensing · Urbanization

Introduction

Human-based disturbances such as forest cover change, air pollution, water pollution, soil erosion, and losses of productive land covers and biodiversity are increasingly threatening ecosystem productivity and health on the local and global scales (Kilic et al. 2004). Land use/land cover (LULC) change can play an important role in environmental changes and contribute to global change and biodiversity loss (Chen et al. 2001; Wang et al. 2006). Changes in land-use and land cover have important consequences for natural resources, especially forest ecosystems, through their impacts on soil and water quality, and climatic systems (Chen et al. 2001). LULC and forest

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cover changes are also the most common cause of loss of biological productivity and biodiversity in aquatic and terrestrial landscapes (Kilic et al. 2004).

LULC change is particularly related to increase of population, urbanization and intensive agriculture (Verburg et al. 1999). Land cover change and conversion are driven by the interaction in space and time between biophysical and human dimensions (Wang et al. 2006; Turner et al. 1993, 1995; Skole and Tucker 1993). Urbanization in the world has been quickening due to population increase, immigrations from rural areas to urban areas. This phenomenon around the world has been an important component of LULC change, and its significance will continue to increase with the majority of the world's population swarming into urban areas (Acar et al. 2007).

Understanding of landscape changes is essential for sustainable management of natural resources and urban areas as it allows decision makers to take a broader view of urban system and its components (Doygun and Alphan 2006). With the awareness of the importance of LULC change on global change, the importance of analyzing LULC changes has become the focus of much scientific and international organization in regional and global scales (Chen et al. 2001). Thus, the LULC change studies based on interpretation of multi-date remotely sensed data have increased in recent years as well as GIS.

Remote sensing with multi-temporal high resolution satellite data has become a strong tool for monitoring aspects such as vegetation cover, forest biomass, soil degradation, urban expansion and more generally for most types of LULC changes (Güler et al. 2007). Studying changes in land-use pattern using remotely-sensed data is based on the comparison of time-sequential data. Change detection using satellite data and GIS can allow for timely and consistent estimates of changes in land-use trends over large areas (Güler et al. 2007; Prakash and Gupta 1998). On the other hand, some spatial statistic programs like FRAGSTATS offer a comprehensive choice of landscape metrics and have been used to

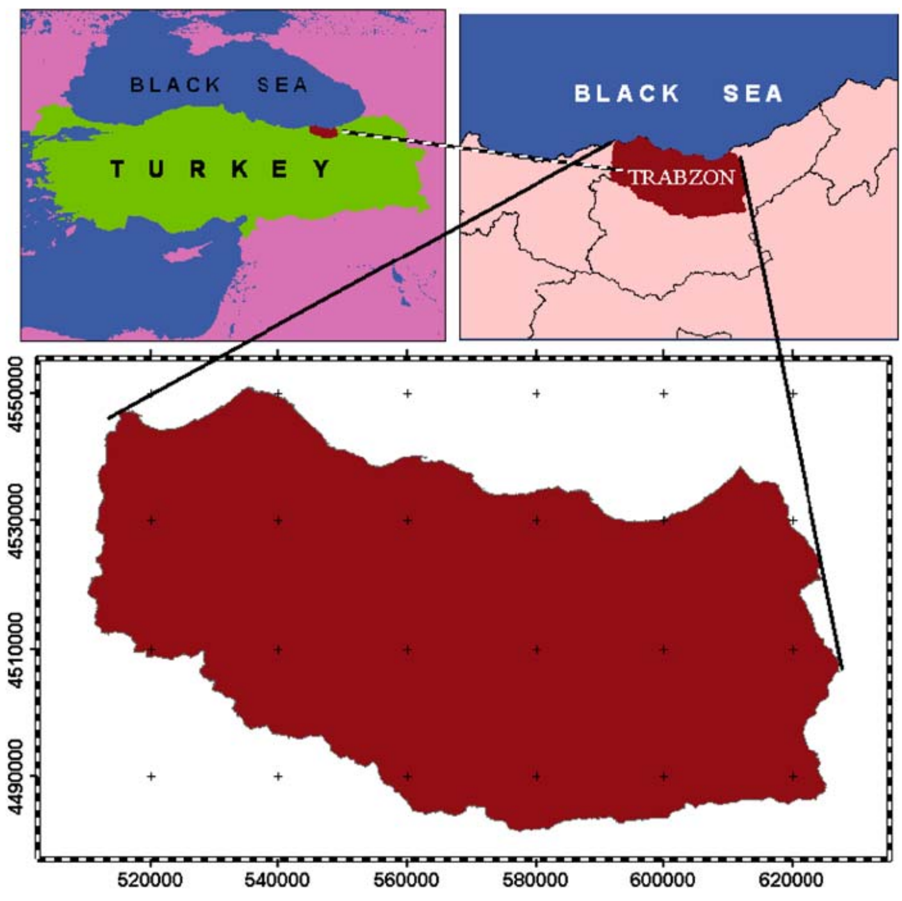


Fig. 1 Location of study area in the province of Trabzon

Table 1 Satellite images used in forest cover classification

Satellite type	Sensor	Number of bands	Pixel resolution (m)	Observation date
Landsat 2	MSS	4	57×57	21 August 1975
Landsat 5	TM	7	28.5×28.5	24 September 1987
Landsat 7	ETM+	8	28.5×28.5	19 September 2000

quantify landscape structure. FRAGSTATS is a spatial pattern analysis program that was implemented by decision maker, forest manager and ecologists to analyze landscape fragmentation describe the characteristics of landscape, components of those landscapes. These statistics facilitate the comparison of landscapes and the evaluation of processes. The advantage of FRAGSTATS is that the calculations are implemented in a fully integrated fashion in a GIS and consequently easy to apply to digitals map (McGarigal and Marks 1995; Raines 2002; Baskent and Keles 2005).

This study analyses the spatial and temporal pattern of forest cover change in RDTF including Trabzon City which is the centre of the Black Sea region during 1975–2000 period based on a time series of satellite images of Landsat MSS in 1975, Landsat TM in 1987, and Landsat ETM+ in 2000. RS, GIS and FRAGSTATS™ – a spatial statistics program have been used to detect and analyze the changes in forest cover.

Study area

The study area is located in the province of Trabzon (in Turkey) that consists of three forest state enterprise (Trabzon, Maçka and Sürmene) and 18 rural directorate of forestry, and covers approximately 529,300 ha of the area. The Trabzon City, which is the centre of the Black Sea region, is door open to Asia for West Black Sea region and Turkey. The second Center of World Trade in Turkey has just been build here. In addition, having an international airport and providing land and sea arrival are some important characteristics of Trabzon City. These features increase the importance of Trabzon, however the city *Trabzon*, has been mostly affected from the economical development. Emerging of shore-trade and consequently, improving commercial activities and activation of regional tourism caused to immigration from surrounding cities or rural areas to Trabzon. In addition to this, increasing population density due to local population-growth caused to changes in urban land-use. All these conditions display a dense housing and commercial area demand in the future (Reis et al. 2003).

The study region is delimited by the Black Sea in the north, by the province of Giresun in the west, by the province of Rize in the east and by the province of Gümüşhane in the south. It is characterized by a dominantly rough and steep terrain with an average slope of 60%. The altitude ranges from sea level up to 3,378 m. It extends along ED 50 datum 37. zone 510000–628000 E, 4481000–4550000 N on the East Black Sea Region of Turkey (Fig. 1). The prevalent climate regime is Black Sea climate characterized by a mild winter and a cool and humidity summer and rainy all season. Average annual temperature reaches a maximum of 20.2°C in the summer, a minimum of 4.5°C in the winter with an average annual temperature of 12.2°C and average annual precipitation of 640.9 mm (Altun 1995). The vegetation type is forest vegetation and the dominant tree species of the vegetation are *Picea orientalis* (L.) Link, *Pinus sylvestris* L., *Abies nordmanniana* (Stev.) Spach subsp. *nordmanniana, Fagus orientalis* Lipsky, *Quercus petraea* (Maattuschka) Liebl. subsp. *iberica* (Steven

Table 2 Landscape metrics used in this study and their brief definitions

Landscape metrics (unit)	Description
CA (ha)	Class area; sum of areas of all patches belonging to a given class, in map units
NP	Number of patches
MPS (ha)	Mean patch size; the average patch size within a particular class
PERCLAND (%)	Percent of landscape
LPI (%)	Largest patch index; % of the landscape comprised by the largest patch
PD	Patch density; number of patches per 100 ha
PSCV (%)	Patch size coefficient of variation
AWMSI	Area-weighted mean shape index, the average perimeter-to-area ratio for a class, weighted by the size of its patches

Table 3 Confusion matrix for the Landsat MSS (1975) image supervised classification

Class	Reference data								
	CF	BF	MF	DF	NFA	W	ND	Total	User. acc.
Conifer forest	28		2					30	93.33
Broadleaf forest	1	28	1					30	93.33
Mixed forest			30					30	100.00
Degraded forest			1	22	5			30	73.33
Non-forest area		1			28			30	93.33
Water	1					28	1	30	96.66
No data	2						28	30	93.33
Total	32	29	34	22	33	28	29	210	192
Prod acc	98.50	96.55	88.24	100.00	84.84	100.00	96.55		
Kappa	0.9025	0.9205	1.0000	0.6962	0.9400	0.9400	0.9765		

Overall classification accuracy 91.42 kappa statistics 0.8915.

ex Bieb.) Krassiln., *Carpinus betulus* L., *Ostrya carpinifolia* Scop., and *Pinus pinea* L. The study area is included by Altındere National Park, East Black Sea Mountains important plant area (IPA) designated by WWF (Özhatay et al. 2003), East Black Sea Mountains important bird areas (IBA) and Karadeniz Technical University Research Forest. Altındere National Park is one of the most important national parks in Turkey having the most diverse flora comprises four vegetation types (stream, forest, subalpine and alpine). The National Park also includes Sumela Monastery (well-known the Meryem Ana, Virgin Mary Monastery) which is an important place for spiritual tourism. Also, recent building of Galyan dam and Çamlıkaya dam for hydroelectrical power generation provides further interest on the vegetation of the areas.

Data sources

Landsat MSS, TM and ETM+ satellite imageries were selected for forest cover change classification of the study area during a 25 year period. The main data used in the research included three Landsat satellite images acquired for the years 1975 (MSS), 1987 (TM), and 2000 (ETM+). A brief description of the satellite images used is given in Table 1. Landsat MSS (1975) and Landsat TM (1987) images were downloaded from the Global Land-Cover Facility site hosted by the Univer-

Table 4 Confusion matrix for the Landsat TM (1987) image supervised classification

Class	Reference data								
	CF	BF	MF	DF	NFA	W	ND	Total	User. acc.
Conifer forest	25		2				3	30	83.33
Broadleaf forest		25	5					30	83.33
Mixed forest			27	2	1			30	90.00
Degraded forest			1	24	5			30	76.67
Non-forest area				2	28			30	93.33
Water	1				1	28		30	93.33
No data	2						28	30	93.33
Total	28	25	35	28	35	28	31	30	
Prod acc	89.82	100.00	77.14	85.71	80.00	100.00	90.32	210	185
Kappa	0.8094	0.8465	0.8732	0.7273	0.9149	0.9640	0.9200		

Overall classification accuracy 88.09 kappa statistics 0.8637

Table 5 Confusion matrix for the Landsat ETM+ (2000) image supervised classification

Class	Reference data								
	CF	BF	MF	DF	NFA	W	ND	Total	User. acc.
Conifer forest	29						1	30	96.66
Broadleaf forest		25	4	1				30	83.33
Mixed forest	3	2	22	3				30	73.33
Degraded forest		1	3	24	2			30	80.00
Non-forest area				1	29			30	96.67
Water						30		30	100.00
No data	1						29	30	96.67
Total	33	28	29	29	31	30	30	210	188
Prod acc	87.88	89.28	75.86	82.75	93.54	100.00	96.66		
Kappa	0.9878	0.7947	0.7021	0.7855	0.9586	1.0000	0.9878		

Overall classification accuracy 89.52 kappa statistics 0.8798

sity of Maryland (http://glcfapp.umiacs.umd.edu). Landsat ETM+ (2000) image was provided by the GISLab at Karadeniz Technical University, Turkey (Reis 2003). Landsat images were acquired during the dry season, which enables us to ensure that the images are cloud free, and also allow us to differentiate forest from non forest areas (mostly fallow agriculture and dry grasslands at this time of the year), with a greater degree of accuracy. The image was the highest quality, being both defect-free and having 10% or less cloud cover. Summer and early fall image data were used for this study, in order to separate the deciduous and coniferous stands through leaf-on canopy differences rather than through the strong seasonal differences in reflection found during leaf-seasons. Landsat MSS, TM and ETM+ data were selected in order to take advantage of the better spectral and spatial resolution for the available dates in the study area. Topographic maps of 1:25,000 scales produced by the General Command of Mapping of Turkey were used for rectification and forest cover type map that were originally generated from both the stereo interpretation of black and white aerial photos with an average 1/25,000 scale and ground survey were used for "ground-truth"

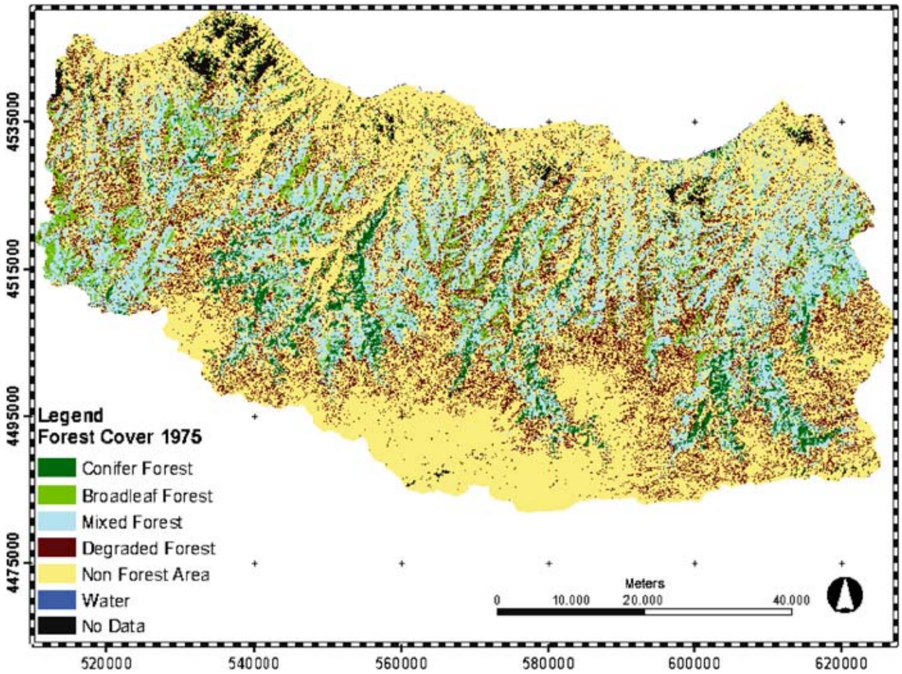
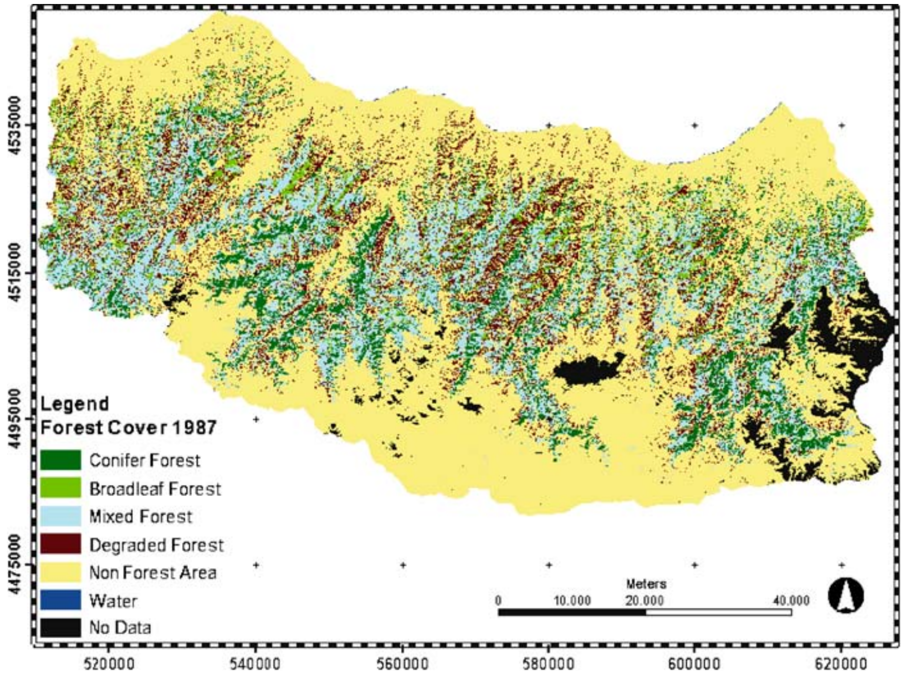


Fig. 2 Forest cover type map of Regional Directorate of Trabzon Forestry in 1975

Fig. 3 Forest cover type map of Regional Directorate of Trabzon Forestry in 1987



information required for classification and accuracy estimation of classified MSS, TM and ETM+ images.

Materials and methods

Geometric correction

Subsets of satellite images were rectified first for their inherent geometric errors using 1:25,000 topographic maps in Universal Transverse Mercator coordinate system (ED 50 datum). Registration was carried out using distinctive features such as road intersections and stream confluences that are also clearly visible in the image. A first-degree rotation scaling and translation transformation function and the nearest neighbor resampling method were applied. This resampling method uses the nearest pixel without any interpolation to create the warped image (Richards 1994). A total of 32 ground points were used for registration of Landsat MSS image sunset with the rectification error of less than 1 pixel. The TM and ETM+ images were registered to the already registered Landsat MSS image through image-to-image registration technique with rectification errors of 0.12 and 0.08 pixels, respectively. Quite high level of accuracy in georeferencing of the images was possible due to the use of digital source as the reference data that allowed zooming to the nearest possible point location (Gautam et al. 2003).

Classification of satellite image

An assessment of forest cover change between 1975 and 2000 was conducted using Landsat satellite imageries. All image processing, classification and GIS analysis were carried out using the ERDAS Imagine™ 8.6 image processing software and ArcGIS 8.3. The possibility of discriminating various land features by digital analysis of satellite data depends upon various factors and methods used in classification. We used supervised maximum likelihood classification method for the classification of all the images. Maximum likelihood classifier assigns a pixel to a particular class based upon the covariance information and a substantially superior performance is expected from this method compared to other approaches (Richards 1994). We gathered ground reference data from more than 78 ground truthing points as signatures. The points were sampled on the cover type (stand) maps of RDTF that are drafted from Ariel Photography and finalized from ground measurements by the State Forest Management Teams. Then classified images were checked to

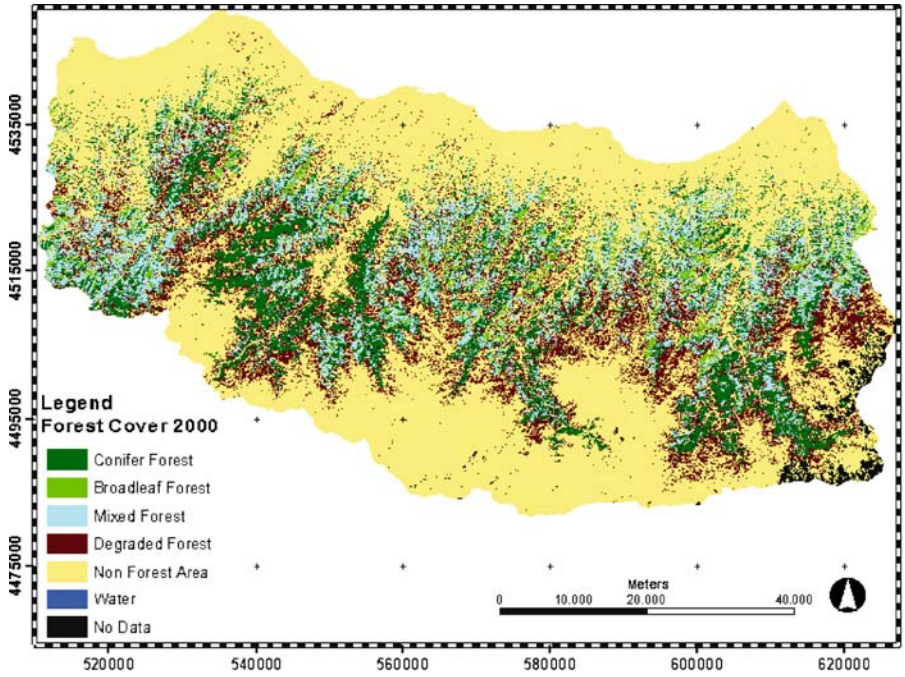


Fig. 4 Forest cover type map of Regional Directorate of Trabzon Forestry in 2000

control the accuracy using ground data points that are not used in the classification process. For producing forest cover maps for 1975, 1987 and 2000 and to investigate changes that occurred between these periods, we defined seven classes of forest cover: (1) conifer forest (CF); (2) broadleaf forest (BF); (3) mixed forest (MF); (4) degraded forest (DF); (5) non-forest area (NFA); (6) water (W); (7) no data (ND). Non-forest area corresponds to agriculture fields, settlements and pasturelands. No data refers the area which was not classified due to cloud.

Accuracy assessment

Accuracy assessment involves identifying a set of sample locations (ground verification points) that are visited in the field. The forest cover found in the field is then compared to that which was mapped in the image for the same location by means of error or confusion matrices. Accuracy Assessment using an error matrix was assessed for the 1975, 1987 and 2000 supervised classification using four measures of accuracy: overall accuracy, user's accuracy, pro-

Table 6 Evolution of selected landscape variables in the study area from 1975 to 2000

Year	1975		1987		2000	
Total area	ha	%	ha	%	ha	%
Conifer forest	30,235.0	5.7	46,813.0	8.9	67,247.6	12.7
Broadleaf forest	23,778.9	4.5	16,238.2	3.1	16,132.8	3.0
Mixed forest	106,820.7	20.2	89,916.3	17.0	59,579.8	11.3
Degraded forest	83,708.5	15.8	56,706.4	10.7	77,167.3	14.6
Non-forest area	273,510.7	51.7	300,766.4	56.8	302,475.9	57.1
Water	69.9	0.0	176.4	0.0	15.1	0.0
No data	11,174.0	2.1	18,683.5	3.5	6,764.8	1.3
Total	529,297.7	100	529,300.2	100	529,383.3	100
Filling land			2.5		83.1	

Table 7 Amount of forest cover that was converted from each of the classes into the rest during the study period

Changed from	Changed to	Percent change during		
		1975–1987	1987–2000	1975–2000
Conifer forest	Broadleaf forest	26.6	45.5	20.8
	Mixed forest	5,756.8	3,243.2	1,465.8
	Degraded forest	206.4	1,821.2	1,366.1
	Non-forest area	5,180.1	6,527.6	6,354.9
	Water	11.0		
	No data	58.8	1,147.7	984.8
Broadleaf forest	Conifer forest	120.2	143.8	475.1
	Mixed forest	6,118.0	2,202.7	7,458.2
	Degraded forest	5,753.1	1,083.5	2,385.7
	Non-forest area	3,886.5	5,336.6	6,251.9
	Water			
	No data	30.3	0.9	3.5
Mixed forest	Conifer forest	22,113.6	25,727.0	36,806.5
	Broadleaf forest	1,191.7	1,470.3	1,541.9
	Degraded forest	2,884.4	11,776.8	10,814.3
	Non-forest area	24,751.1	12,802.3	23,831.7
	Water	50.3		
	No data	391.2	209.8	258.2
Degraded forest	Conifer forest	872.3	698.8	1,862.9
	Broadleaf forest	3,624.9	5,180.8	3,935.6
	Mixed forest	4,737.2	5,328.4	4,269.6
	Non-forest area	50,400.1	28,684.3	49,111.8
	Water	14.5		
	No data	5,185.4	30.1	928.1
Non-forest area	Conifer forest	3,363.2	6,452.8	6,981.6
	Broadleaf forest	3,334.5	1,962.4	3,320.6
	Mixed forest	17,156.3	10,809.3	12,445.6
	Degraded forest	28,426.9	41,307.3	38,699.7
	Water	63.7	2.6	1.0
	No data	12,926.3	2,779.9	4,172.1
No data	Conifer forest	1,348.7	197.4	1,079.1
	Broadleaf forest	190.9	3.1	113.0
	Mixed forest	711.8	66.2	381.7
	Degraded forest	563.4	4,394.4	315.1
	Water	27.1		4.5
	Non-forest area	8,242.1	11,426.1	8,868.3
Water	Non-forest area	67.0	170.1	65.2

ducer's accuracy and Kappa coefficient. A total of 30 random points for each class were taken to determine the accuracy of the classification method. Accuracy was assessed in terms of errors of omission (producer's accuracy) and commission (user's accuracy) and Kappa coefficient. The overall map accuracy was calculated by dividing the total correct classified pixels, (major diagonal of the error matrix) by the total number of pixels in the error matrix. Overall accuracy did not take into account the proportion of agreement between datasets and it tends to overestimate classification accuracy (Congalton and Mead 1983). Producer's accuracy indicates the probability of reference pixel being correctly classified and it is a measure of omission error. User's accuracy is the probability of classified pixel actually represents that category on the ground. User's accuracy is a measure of commission error (Jensen 1996). The Kappa Coefficient measures the proportional improvement of classification over purely random assignment to

Table 8 Overview of changes in forest cover type in between 1975 and 2000

Forest Cover	Percent of forest cover in 1975			Net gain/loss (ha)
	Unchanged in 2000	Lost to other classes in 2000	Gained from other classes in 2000	
Conifer forest	20,042.6	10,192.4	47,205.2	37,012.8
Broadleaf forest	7,204.5	16,574.4	8,931.9	−7,642.5
Mixed forest	33,568.1	73,252.6	26,020.9	−47,231.7
Degraded forest	23,600.5	60,108.0	53,580.9	−6,527.1
Non-forest area	207,890.1	65,620.6	94,483.8	28,863.2
Water	4.7	65.2	5.5	−59.7
No data	412.3	10,761.7	6,346.7	−4,415.0

classes. This accuracy measure attempts to control for a chance agreement by incorporating the off-diagonal elements as a product of the row and column of the error matrix (Cohen 1960). After accuracy assessment, all images were clumped, eliminated 3×1 pixels and vectorized in Erdas Imagine 8.6™ programme. These coverages were preprocessed to eliminate areas less than 0.27 ha (corresponding to 3×1 pixel) for faster analysis of spatial pattern.

Spatial and deforestation analysis

The spatial configuration of landscape structure is important as it has important implications to the design and management of the resources (Baskent et al. 2000). The spatial dynamics of the forest landscape refers to the temporal change in the size, number, shape, adjacency and the proximity of patches in a landscape. We used a few metrics or measurements as proxy to quantify and spatially analyze the change in spatial structure as demonstrated by Başkent and Jordan (1995a, b) and McGarigal and Marks (1995).

Choices for appropriate landscape metrics are dependent upon the scale of analysis and objectives of the study (Abdullah and Nakagoshi 2006; Turner and Gardner 1991; Forman 1995; Turner et al. 2003; Farina 2002). Quantification and comparison of the spatial configuration of forest fragments were conducted based on the following landscape metrics selected after reviewing recent forest fragmentation studies (Echeverria et al. 2006; Cayuela et al. 2006; Franklin 2001; Armenteras et al. 2003 Millington et al. 2003; Turner et al. 2003): (a) CA; (b) NP; (c) MPS; (d) PERCLAND; (e) LPI; (f) PD; (g) PSCV; and (h) AWMSI. Brief definitions for the selected metrics are listed in Table 2.

These landscape pattern metrics also represent qualitative aspects of land cover types, expressing the characteristics of the landscape as a whole (Abdullah and Nakagoshi 2006). The selected metrics are used to characterize the spatial heterogeneity, fragmentation, complexity of patch shape, and connectivity for a given landscape. It is noted that number of patch (NP) and mean patch size (MPS) should be used complementarily since high NP and low MPS values reinforce an interpretation of fragmented landscape conditions (Matsushita et al. 2006; Leitao and Ahern 2002). Maps were analyzed using ArcGIS 8.3 to quantify land cover change and forest loss. In order to study forest fragmentation processes, the land cover maps for 1975 and 2000 were used to determine landscape spatial indices. These indices or spatial metrics were computed by FRAGSTATS Version 3.3 (McGarigal et al. 2002) for each of the forest cover class.

Annual deforestation rates were calculated using the compound-interest-rate formula due to its explicit biological meaning (Puyravaud 2003). This is,

$$P = \frac{100}{t_2 - t_1} \ln \frac{A_2}{A_1}$$

where P is percentage of forest loss per year, and A_1 and A_2 are the amount of forest cover at time t_1 and t_2, respectively.

Results and discussion

Accuracy assessment

The overall accuracy for 1975 MSS, 1987 TM and 2000 ETM+ were 91.42, 88.09 and 89.52% respec-

Table 9 Selected landscape metrics of Regional Directorate of Trabzon Forestry in 1975 and 2000

Forest cover type	CA		NP			MPS				PERCLAND		
	1975	1987	2000	1975	1987	2000	1975	1987	2000	1975	1987	2000
CF	30,235.0	46,813.0	67,247.6	10,786	18,241	15,712	2.8	2.6	4.3	5.7	8.9	12.7
BF	23,778.9	16,238.2	16,132.8	10,305	10,198	8,582	2.3	1.6	1.9	4.5	3.1	3.0
MF	106,820.7	89,916.3	59,579.8	19,087	31,915	24,984	5.6	2.8	2.4	20.2	17.0	11.3
DF	83,708.5	56,706.4	77,167.3	57,704	40,375	42,990	1.5	1.4	1.8	15.8	10.7	14.6
NFA	273,510.7	300,766.4	302,475.9	29,086	31,541	38,369	9.4	9.5	7.9	51.7	56.8	57.1
W	69.9	176.4	15.1	177	152	5	0.9	1.7	3.0	0.0	0.0	0.0
ND	11,174.0	18,683.5	6,764.8	7,894	888	2,197	1.4	21.0	3.1	2.1	3.5	1.3
Total	529,297.7	529,300.2	529,383.3	135,039	133,310	132,839	3.9	4.0	4.0	100.0	100.0	100.0

tively (Tables 3, 4 and 5) and the Kappa Coefficient for these maps was 0.8915, 0.8637 and 0.8798 respectively. According to the accuracy assessment results using supervised classification for 1975, non forest areas had the lowest producer's accuracy of 84.84% and degraded forest had the user's accuracy of 73.33%. All classes were classified over 85% producer's accuracy meaning quite accurately classification. In addition to the accuracy assessment results for 1987, mixed forest had the lowest producer's accuracy of 77.14% and degraded forest had lowest the user's accuracy of 76.67%. For the classification of 2000 forest cover map, the lowest values of the producer's accuracy (76%) corresponded to mixed forest and the lowest values of user's accuracy (73%) corresponded to mixed forest. Mixed forest was classified the lowest producer's accuracy in both 1987 and 2000. The reasons of misclassifications are more evident for the lower resolution ETM+, TM and MSS satellite imagery (Cayuela et al. 2006).

Temporal change in forest cover

The forest cover maps for 1975, 1987, and 2000 are presented in Figs. 2, 3 and 4. Area of each forest cover class during the three periods is shown in Table 6. Results showed that the forest area decreased from 244,543 ha (46.2% of the study area) in 1975 to 220,128 ha (41.6%) in 2000. Both productive and degraded forest areas decreased from 1975 to 2000. Total forest and degraded forest areas decreased during the first (1975–1987) period, but increased during the second (1987–2000) period. Important changes in forest cover is in mixed forest that it decreased from 106,821 ha (20.2% of the study area) in 1975 to 59,580 ha (11.3%) in 2000, a net decrease of 47,241 mixed forest. As an overall change in Trabzon, there was a net decline of 24,416 ha (4.6%) in total forest areas. Study area was 529,298, 529,300 and 529,383 ha in 1975, 1987 and 2000 respectively. Case study area increased from 529,298 to 529,383 (85 ha) during a 25 year period. Planning unit change has emerged along the shore through the years 1960–2000 and area is getting bigger. The reason of that difference is that it has been struggled to gain some land by filling the sea in order to meet public requirements such as green areas, recreation areas, roads (Reis et al. 2003).

The observed trends of decreasing forest areas and increasing non forest areas in the Trabzon could be explained by the following main reasons. First, among the general and main causes of deforestation are human population pressure and an increasing demand of land for agriculture and timber products from forests. In Trabzon, there is an important change in population of Trabzon over 30 years. Total population increased from 659,120 to 975,137 (nearly 48%) inhabitants in the period 1970–2000. However, rural population increased during the first period (1970–1985) and also forested area decreased from 244,543 to 209,674 ha. On the other hand, rural population decreased from 546,641 to 496,183 during the second period (1985–2000) and forested area increased from 209,674 to 220,128 ha. These results supported the idea that the change in human population was extremely important in increasing or decreasing forest areas. Second, urbanization causes forest degradation and loss of biodiversity. Important application raised after 1990s have considerable effect on the growing areas of the city (Reis et al. 2003).

LPI			PD			PSCV			AWMSI		
1975	1987	2000	1975	1987	2000	1975	1987	2000	1975	1987	2000
0.3	0.2	0.6	2.0	3.5	3.0	738.7	667.2	1,056.0	3.6	3.7	5.6
0.1	0.0	0.0	1.9	1.9	1.6	490.2	336.2	335.0	2.6	2.4	2.5
1.3	0.7	0.3	3.6	6.0	4.7	1,330.9	1,306.8	695.2	7.8	7.7	4.4
0.0	0.0	0.4	10.9	7.6	8.1	272.8	338.1	864.2	2.2	2.8	4.4
19.1	24.5	26.5	5.5	6.0	7.3	7,915.6	10,272.5	11,222.2	56.7	55.0	49.3
0.0	0.0	0.0	0.0	0.0	0.0	111.6	136.2	103.4	1.6	2.2	1.8
0.1	1.5	0.1	1.5	0.2	0.4	1007.8	1388.5	714.5	2.6	7.2	3.3
19.1	24.5	26.5	25.5	25.2	25.1	8843.5	12023.7	11941.2	31.6	33.5	30.1

Third, instead of intensive harvesting activities conducted for maximum wood production from 1972 to 2005, light silvicultural prescriptions and harvesting activities were carried out in the research area.

Transitions among forest cover types

The magnitude and the direction of LULC changes in landscapes are the most important factors relating to landscape evolution (Antrop 2000). Besides analyzing the changes in the amount of forest cover types, the temporal transitions among forest cover types are also documented and evaluated to see the intertemporal dynamics of forest cover types. A detail of losses and gains among the seven forest cover classes over the study period is included in Tables 7 and 8.

A broad level analysis showed that about 87,725 ha (16.6% of the study area) forest areas changed into non forest while 61,448 ha (11.6% of the study area) non-forest areas changed into forest areas. There is a net decrease of 47,241 ha (8.9% of the study area) mixed forest during a 25 year period and 36,807 ha (7.0% of the study area) mixed forest converted to conifer forest. Among the forest cover groups, 84,416 ha forest area and 207,895 ha non forest area in 1975 remained unchanged until 2000. Conifer forest increased by about 37,013 ha of 1975 area in between 1975 and 2000. Forest lost 160,127 of its 1975 area to other classes and gained 135,739 from other classes. Overtime, mixed stand types were destroyed exactly and converted to conifer forest cover. The removal of broadleaf overstorey can easily be attributed to the ongoing retrogressive succession of conifer taxa and insect (*Ips typographus, Ips sexdentatus* and *Dendroctonus micans*) defoliation.

Spatial change in forest cover

One of the basic indications of forest fragmentation is the increase in number of smaller patches (Echeverria et al. 2006). In RDTF, there were no important changes (approximately a decrease of 1.6%) in the number of forest patches between time intervals (Table 9). During the whole study period, the average annual deforestation rate was 977 ha year^{-1}, equivalent to 0.42% year^{-1} using the compound-interest-rate formula. The qualitative aspect of the forest resources based on natural composition and configuration of forest landscape seem to provide an expected environment for maintenance of biodiversity due to

Table 10 Demographic change in regional directorate of Trabzon forestry

Years	Urban	Rural	Total	Urban (%)	Rural (%)
1970	138,435	520,685	659,120	21.0	79.0
1975	171,570	547,438	719,008	23.9	76.1
1980	186,580	544,465	731,045	25.5	74.5
1985	239,553	546,641	786,194	30.5	69.5
1990	303,612	492,237	795,849	38.1	61.9
2000	478,954	496,183	975,137	49.1	50.9

decreasing number of patches. The configuration of the area changed positively overtime, providing favorable situation for use of forest values.

Mean forest patch size (MPS) increased from 3.9 ha in 1975 to 4.0 ha in 2000 (Table 9). This smooth increase in mean patch size was associated with especially two reasons. First one is a decrease in the patch density (PD) during a 25 year period (25.5–25.1). The second one is a substantial increase in the size of the largest forest patch, from 19.1% of the total study area in 1975 to 26.5% in 2000. PSCV value increased from 8,844 to 12,024 during the first (1975–1987) period, however the trend was reversed during the second period (1987–2000). Area Weighted Shape Index value decreased from 31.6 to 30.1 indicating a more regular shape. Patch shape changed to more regular one (close to circle with straight lines, no meandering) and number of patches and patch density decreased. These changes showed that landscape fragmentation decreased, positive effect for biodiversity in forest and improve quality of landscape. The decrease of number of patches and degraded forest area can be disclosed by the fact that the decline of rural population has positively affected the development of forest areas.

Demographic development and urbanization

In most cases, land use and forest cover changes are attributed to the human population growth and urbanization processes (Wakeel et al. 2005). Changes in forest landscape patterns are generally known to be affected by socio-economic factors and are being increasingly identified as critical factors influencing environmental change (Abdullah and Nakagoshi 2006; Nagendra et al. 2004). Many landscape ecological studies have shown that socio-economic factors (Zhao et al. 2003), forestry expansion (Nagashima et al. 2002), urbanization (Doygun and Alphan 2006) and agricultural use patterns (Hietala-Koivu 1999; Mander et al. 1999) impact on the landscape.

Rural people in the region are primarily dependent on arable agriculture and livestock rising for their livelihood. The fishery is an important livelihood for the local people living in the rural parts because of Black Sea and several rivers. The local economy is currently based on traditional sustainable agriculture including hazelnut, corn and tea. Also, the cement factory in the city is among the most important industrial investments in the region. Furthermore, the rural area is also grazed by local cattle. This high variability in the ecological and socio-economic conditions makes the study area an appropriate site to study forest cover dynamics and factors associated with it.

Demographic changes of Trabzon have been considerably varied between 1970 and 2000 (Table 10) (Republic of Turkey 1970–2000; State Institute of Statistics). This table showed that there was an important change in population of Trabzon over 30 years. Human population increased from 659,120 to 975,137 (nearly 48%) inhabitants in the period 1970–2000. However, rural population increased during the first (1970–1985) period, but reversed during the second (1985–2000) period while total human population and urban population constantly increased from 1970 to 2000. Percentage of rural population decreased in this period and small farms were abandoned followed by rapid urbanization as more and more people left the rural areas to become resident in urban centers.

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