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Forest cover change and fragmentation using Landsat data in Maçka State Forest Enterprise in Turkey

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Abstract Monitoring forest cover change and understanding the dynamic of forest cover is increasingly important in sustainable development and management of forest ecosystems. This paper uses remote sensing (RS) techniques to monitor forest cover change in Maçka State Forest Enterprise (MSFE) located in NE of Turkey through 1975 to 2000 and then analyses spatial and temporal changes in forest cover by Geographical Information Systems (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 RS and GIS. The results showed that total forest area, productive forest area and degraded forest area increased while broadleaf forest area and non forest area decreased. Mixed forest and degraded forest increased during the first (1975–1987) period, but decreased during the second (1987–2000) period. During the whole study period, the annual forestation rate was 152 ha year^{-1}, equivalent to 0.27% year^{-1} using the compound-interest-rate formula. The total number of patches increased from 36,204 to 48,092 (33%), and mean size of forest patch (MPS) decreased from 2.8 ha to 2.1 ha during a 25 year period. Number of smaller patches (patches in 0–100 ha size class) increased, indicating more fragmented landscape over time that might create a risk for the maintenance of biodiversity of the area. While total population increased from 1975 to 2000 (3.7%), rural population constantly decreased. The increase of forest areas may well be explained by the fact that demographic movement of rural areas concentrated into Maçka City Center. These figures also indicated that decrease in the rural population might likely lead to the release of human pressure to forest areas, probably resulting in a positive development of forest areas.

Keywords Forest cover change · FRAGSTATS™ · Forest dynamics · GIS · Landsat · Remote sensing

Introduction

Forest ecosystems provide to the society important functions from ecological, social and economic perspectives. Greenhouse gas regulation, water supplies and regulation, soil conservation, nutrient cycling, genetic and species diversity as well as recreation are only some examples of the services that forest ecosystems provide (Rao and Pant 2001). Nowadays,

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human-induced disturbances such as land use/cover (LULC) changes, pollution of air, water and soil, and losses of productive lands and biodiversity degradation are increasingly threatening ecosystem productivity and health on the local, regional and global scales (Kilic et al. 2004).

LULC changes may have been important consequences for natural and forest landscapes through their impacts on soil and water quality, biodiversity, and global climatic systems (Chen et al. 2001). Driving forces behind LULC changes mainly include rapid growth rates of population, lack of valuation of ecological services, poverty, and use of ecologically incompatible technologies. Changes in LULC are defined broadly to include the conversion of forested lands into croplands and pastures, the abandonment of agricultural lands, deforestation, reforestation, afforestation, and urban sprawl (Kilic et al. 2004).

LULC changes are the most common cause of loss of biological productivity and biodiversity in aquatic and terrestrial ecosystems. Forest fragmentation due to land use is a major reason for the declining biodiversity and biodiversity erosion in forest ecosystems and widely considered to be a primary threat to terrestrial biodiversity (Harris 1984; Armsworth et al. 2004; Kilic et al. 2004; Pichancourt et al. 2006; Matsushita et al. 2006). The ecological consequences of fragmentation may differ depending on the patterns or spatial configuration imposed on a landscape and how it varies both temporally and spatially (Echeverria et al. 2006; Cayuela et al. 2006). Therefore, an understanding of the relationship between landscape patterns is required by resource managers to provide a basis for making land-use decisions (Cayuela et al. 2006).

The importance of analyzing LULC changes has become the focus of much scientific endeavor and international organizations in regional and global scales (Chen et al. 2001). Thus, the LULC change analysis studies based on interpretation of multi-date remotely sensed data have increased in recent years (Hall et al. 1988, 1991; Sader and Joyce 1988; Iverson et al. 1989; Fearnside et al. 1990; Green and Sussman 1990; Luque 2000). Repeated satellite images as well as aerial photographs are useful for both visual assessments of dynamics of forest ecosystems occurring at a particular time and space as well as quantitative evaluation of LULC changes overtime (Tekle and Hedlund 2000; Gautam et al. 2003). Almost all these studies have focused on rates and patterns of land use and land conversion. There are many applications to illustrate changes of LULC, the effects of LULC on biodiversity, forest loss and fragmentation, changes in spatial landscape characteristics and deforestation (Skole and Tucker 1993; Spies et al. 1994; Turner and Corlett 1996; Luque 2000; Imbernon and Branthomme 2001; Steininger et al. 2001; Sader et al. 2001; Garcı´a-Gigorro and Saura 2005; Kupfer 2006; Echeverria et al. 2006).

The ability to quantify landscape structure is prerequisite to the study of landscape function and change. Most of the efforts to date have been tailored to meet the needs of specific research objectives and have employed user-generated computer programs to perform the analyses. Such user-generated programs allow for the inclusion of customized analytical methods and easy linkages to other programs, such as spatial simulation models, yet generally lack the advanced graphics capabilities of commercially available GIS. FRAGSTATS offers a comprehensive choice of landscape metrics and have been used to quantify landscape structure. FRAGSTATS is a spatial pattern analysis program that was implemented by decision maker 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 Maçka State Forest Enterprise which is the centre of the Black Sea region in Turkey during 1975–2000 period. The satellite images of Landsat MSS in 1975, Landsat TM in 1987, and Landsat ETM+ in 2000 are used for temporal and spatial analysis. The spatial and temporal change patterns of land use are quantified by interpreting spatial data. RS, GIS and FRAGSTATS™ – a spatial statistics program have been used in the collection, analysis and presentation of resource data.

Study area

The study area is located in Maçka State Forest Enterprise that covers part of Trabzon province located in East Black Sea Region of Turkey (527000–567000 E, 4480000–4530000 N, UTM ED 50 datum Zone 37N) (Fig. 1). Maçka State Forest Enterprise consists of five forest district (Maçka, Çatak, Hamsiköy, Meryemana, Yeşiltepe) and covers 101,907 ha of the area. 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 % 57. The altitude ranges from 100 to 3,080 m. The prevalent climate regime is Black Sea climate characterized by a mild winter and a cool 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., *Carpinus betulus* L. and *Alnus glutinosa* Mill. The study area is included by Altındere National Park and Karadeniz Technical University Research Forest. Altındere National Park is one of the most important national park in Turkey having the most diverse flora comprises four vegetation type (stream, forest, subalpine and alpine) and includes Sumela Monastery or as it is well-known, the Meryem Ana (Virgin Mary) Monastery which is an important place for spiritual tourism. Also, recent building of Galyan dam for hydroelectrical power generation along Galyan river adjacent to the edges of the study area 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

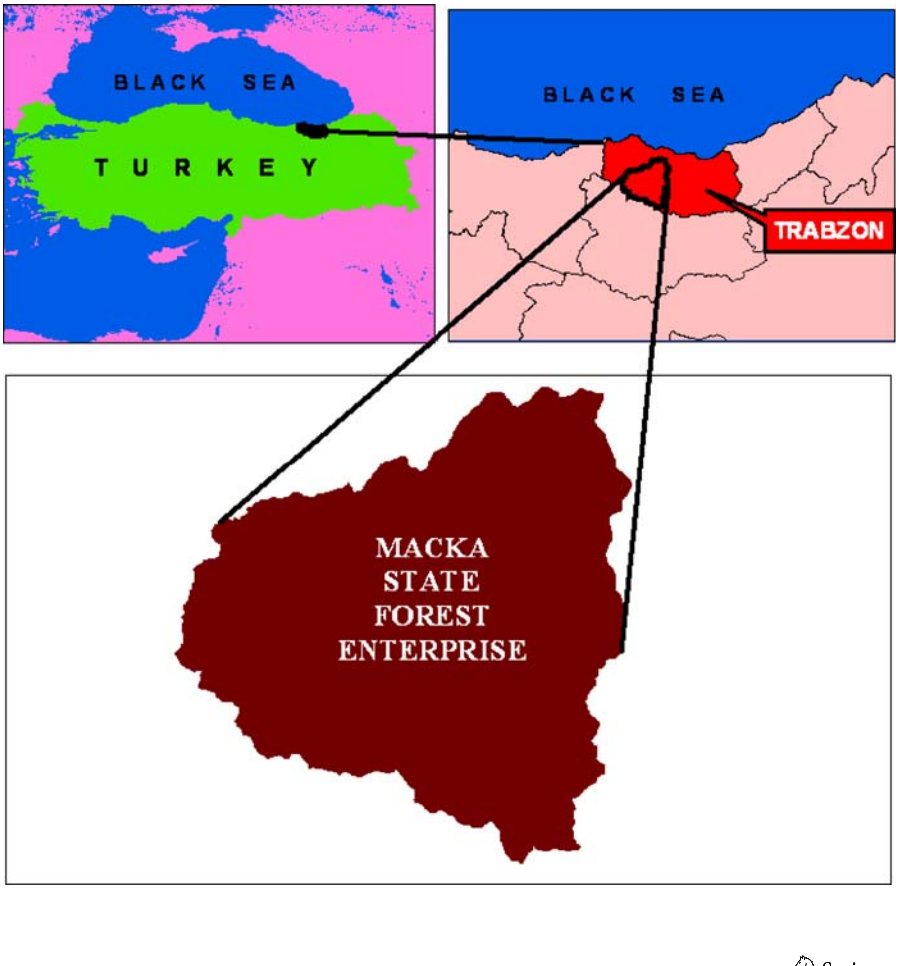

Fig. 1 Location of study area in the province of Trabzon

study area during a period when change in forest cover by human activity has been recognized as an important driver of global environmental change. The main data used in the research included three Landsat satellite image 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 University of Maryland (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 completely cloud free, and also allow us to differentiate forest from non forest areas (mostly agriculture, settlements 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 cloud free. 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 measurements with 300×300 sampling points were used for "ground-truth" information required for classification and accuracy estimation of classified MSS, TM and ETM+ images.

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

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. A very high level of accuracy in georeferencing of the images was possible because of the use of digital source as the reference data that allowed zooming to the nearest possible point location (Gautam et al. 2003).

Image analysis

All image processing, classification and GIS analysis were carried out using the ERDAS Imagine™ 8.6 image processing software and ArcGIS 8.3. We used supervised maximum likelihood classification method for the classification of all the images. Training sites were derived from the satellite images using reference maps. To deliver the appropriate support size of each category the required training set for each class was determine at least 10 times the number of discriminating variables (e.g., wavebands) used in the classified map. 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 Maçka State Forest Enterprise that are drafted from aerial photography with 1/15000–1/20000 and finalized from ground measurements by the State Forest Management Teams. Then classified images were checked to 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, the following six forest cover classes were considered in image classification: (1) conifer forest (CF); (2) broadleaf forest (BF); (3) mixed forest (MF); (4) degraded forest (DF); (5) forest openings (FO); (6) Non-Forest Area (NFA). Non-Forest Area corresponds to agriculture, settlements and pasturelands. A brief description of each of the forest cover classes is given in Table 2.

The magnitude and the direction of changes in landscape are the most important factors relating to landscape evolution (Antrop 2000). Comparison of the change of each forest cover types from 1975, 1987 to 2000 was analyzed by means of the transition from one forest cover to other forest cover. The forest cover polygon themes for 1975, 1987 and 2000 were overlaid using ArcGIS® 8.3 and the area that changed from each of the classes to any of the other classes was computed.

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, producer'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 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 2×1 pixels and vectorized in Erdas Imagine 8.6™ programme. These coverages were preprocessed to eliminate areas less than 0.18 ha (corresponding to 2×1 pixel) for faster analysis of spatial pattern.

The overall accuracy of classification was 85.00% for the 1975 MSS, 84.44% for 1987 TM image, and 85.56% for the 2000 ETM+ image (Tables 3, 4 and 5) and the Kappa Coefficient was 0.8200, 0.8133 and 0.8267 respectively. In terms of producer's accuracy for 1975, all classes were over 85% except non forest area, which was 62%. In other words, all forest cover

Table 2 Forest cover classes descriptions

Forest cover classes	Description
Conifer Forest (CF)	Forest areas with pure conifer trees whose stand crown closure is greater than 10%
Broadleaf Forest (BF)	Forest areas with pure broadleaf trees whose stand crown closure is greater than 10%
Mixed Forest (MF)	Mixed (BF-CF, CF-BF) forest areas whose stand crown closure is greater than 10%
Degraded Forest (DF)	Forest areas whose stand crown closure is less than 10%
Forest Openings (FS)	Treeless and open areas which are being accepted as forest area in Turkey
Non-Forest Area (NFA)	Agricultural lands, settlements areas and pasture lands

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

Class	Reference data							
	CF	BF	MF	DF	FO	NFA	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	2	5	30	73.33
Forest Openings			1		17	12	30	56.67
Non-Forest Area		1			1	28	30	93.33
Total	29	29	35	22	20	45	180	
Prod Acc	96.55	96.55	85.71	100.00	85.00	62.22		153
Kappa	0.9205	0.9205	1.0000	0.6962	05125	0.9111		

Overall classification accuracy 85.00 kappa statistics 0.8200

classes were quite accurately classified except non forest area. In terms of user's accuracy, all classes were over 73% except forest openings, which was 57%. For the classification of 1987 forest cover map, the lowest values of the producer's accuracy (71%) corresponded to mixed forest and the lowest values of user's accuracy (77%) corresponded to degraded forest. 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.

Fragmentation analysis and deforestation

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. These landscape pattern metrics involve the qualitative and quantitative measurements that expressed the characteristics of the landscape as a whole (Abdullah and Nakagoshi 2006). We used some metrics or measurements as proxy to quantify and spatially analysis the change in spatial structure as demonstrated by Baskent and Jordan (1995a, b) and McGarigal and Marks (1995): (a) class area (ha); sum of areas of all patches belonging to a given class, in map units; (b) patch density; number of patches per 100 ha; (c) largest patch index; % of the landscape comprised by the largest patch; (d) number of patches (#); (e) mean patch size (ha); the average patch size within a particular class; (f) PERCLAND; Percent of landscape (%); (g) PSCV; Patch size coefficient of variation (%) and (h) AWMSI; Area-weighted mean shape index, the average perimeter-to-area ratio for a class, weighted by

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

Class	Reference data							
	CF	BF	MF	DF	FO	NFA	Total	User. Acc.
Conifer Forest	25		5				30	83.33
Broadleaf Forest		25	5				30	83.33
Mixed Forest			27	2		1	30	90.00
Degraded Forest			1	23	1	5	30	76.67
Forest Openings				1	24	5	30	80.00
Non-Forest Area					2	28	30	93.33
Total	25	25	38	26	27	39	30	
Prod Acc	100.00	100.00	71.05	88.46	88.49	71.79	180	152
Kappa	0.8065	0.8065	0.8732	0.7273	0.7647	0.9149		

Overall classification accuracy 84.44 kappa statistics 0.8133

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

Class	Reference data							
	CF	BF	MF	DF	FO	NFA	Total	User. Acc.
Conifer Forest	30						30	100.00
Broadleaf Forest		24	4	1	1		30	80.00
Mixed Forest	3	2	22	3			30	73.33
Degraded Forest		1	3	23	1	2	30	76.67
Forest Openings					26	4	30	86.67
Non-Forest Area					1	29	30	96.67
Total	33	27	29	27	29	35	180	154
Prod Acc	90.91	88.89	75.86	85.19	89.66	82.86		
Kappa	1.0000	0.7647	0.6821	0.7255	0.8411	0.9586		

Overall classification accuracy 85.56 kappa statistics 0.8267

the size of its patches). 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 condition (Matsushita et al. 2006; Leitao and Ahern 2002). In order to study forest fragmentation processes, the forest cover maps for 1975, 1987 and 2005 were used to determine scape 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

Changes in forest cover

The forest cover maps for 1975, 1987, and 2000 are presented in Figs. 2, 3 and 4 and the area each forest cover class during the three periods is shown in Table 6. Results showed that the forest area increased from 56,903 ha (55.8% of the study area) in 1975 to 60,865 ha (59.7%) in 2000 during a 25 year period. Productive forest areas (forest areas whose stand crown closure is greater than 10%) increased 1,189 ha (4.2%) even though forest openings (treeless and open areas which are being accepted as forest areas) and degraded forest increased. Productive forest areas increased during the first (1975–1987) period but decreased during the second (1987–2000) period. Degraded forest area (forest areas whose stand crown closure is less than 10%) was declined during the first period, but the trend was reversed during the second period. As an overall change in Maçka, there was a net increase of 3,962 ha (7.0%) in total forested areas. As such, the concept of forestation rate was used instead of deforestation rate. During the whole study period, the average annual forestation rate was 159 ha year^{-1}, equivalent to 0.27% year^{-1} using the compound-interest-rate formula.

Forest cover types transition

A detail of losses and gains among the six forest cover classes over the study period is included in Tables 7 and 8. A broad level analysis showed that about 13,010 ha (12.8% of the study area) forest areas changed into non forest while 16,972 ha (16.7% of the study area) non-forest areas changed into forest areas. One thousand nine hundred forty-six hectares (16.8% of the forest openings) forest openings, 8,297 ha (20.2% of the Non forest area) non-forest area converted to degraded forest. Among the forest cover groups, around 28% of non forest area and 24% of the forest area in 1975 remained unchanged until 2000. Broadleaf forest shrunk by about 977 ha of 1975 area in between 1975 and 2000. Forest lost

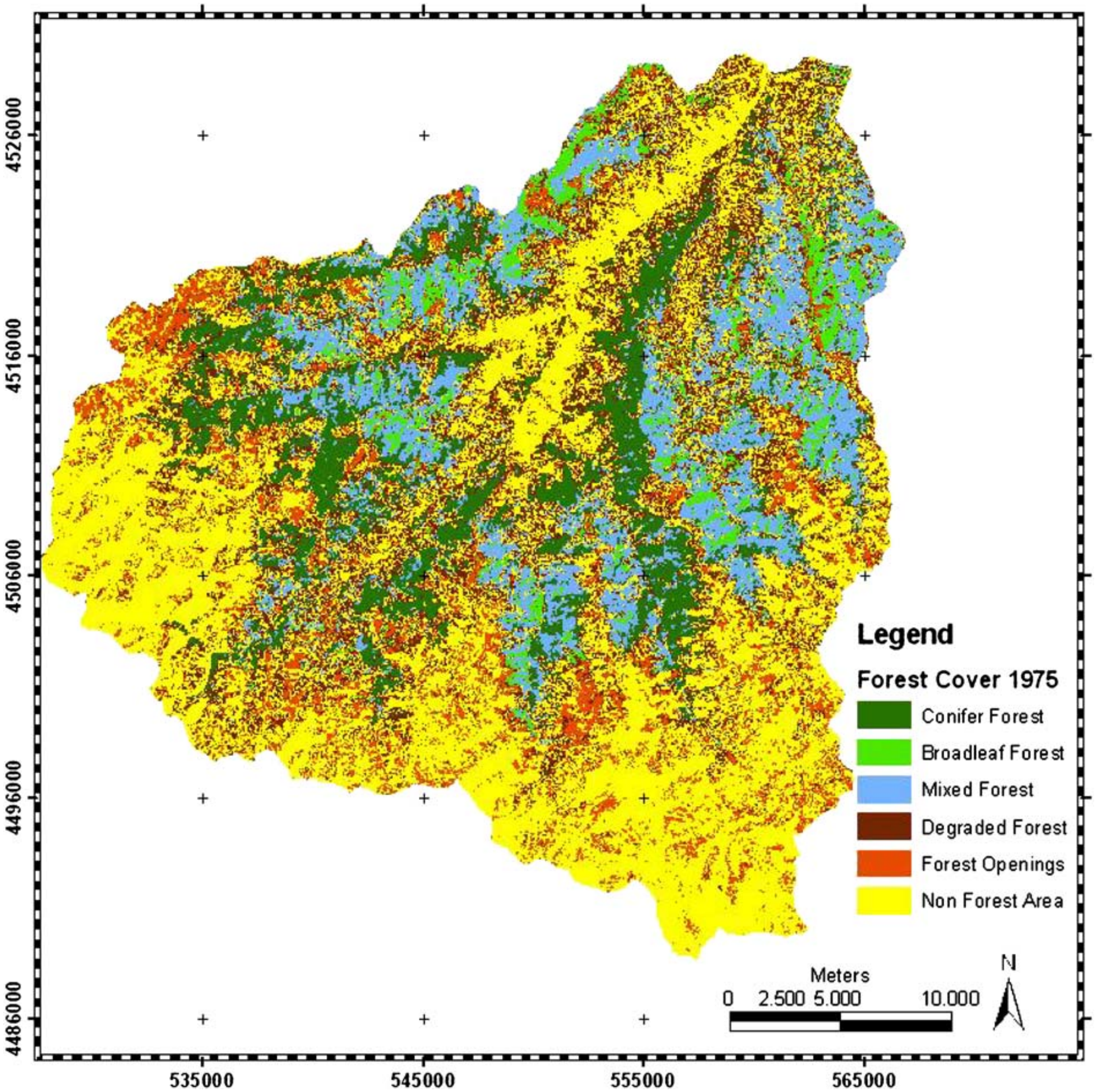

Fig. 2 Forest cover type map of Maçka State Forest Enterprise in 1975

31,792 of its 1975 area to other classes and gained 35,754 from other classes. General analysis showed that there were visible trends in the temporal structure of forest landscape.

Spatial pattern analysis

One of the basic indications of forest fragmentation is the increase in number of smaller patches. In the Maçka State Forest Enterprise considerable changes were found in the distribution of forest patch sizes between time intervals (Table 9). While the total number of forest fragments increased from 27,692 to 31,754 (14.6%) during the first (1975–1987) period and also total number of forest fragments increased from 31,754 to 36,427 (14.7%) during the second (1987–2000) period. By 1975, 74% of the forest area was concentrated in small patches between 0 and 100 ha; the remaining forest area occurred in isolated patches of larger than 100 ha, nine patches are bigger

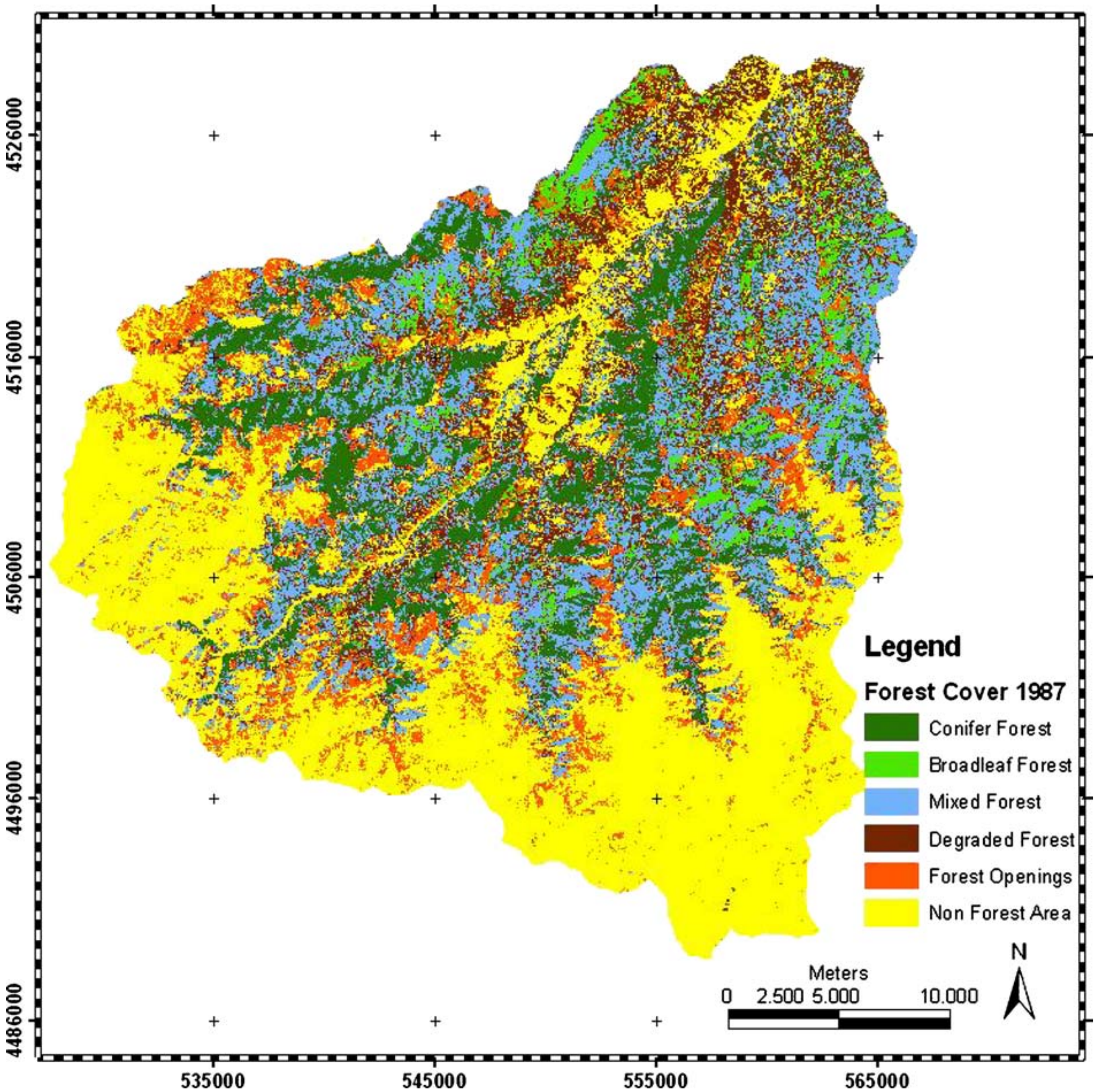

Fig. 3 Forest cover type map of Maçka State Forest Enterprise in 1987

than 5,000 ha. In 2000, 79% of forested areas occurred in patches of less than 100 ha. Due to fewer patches larger than 5,000 ha, forest may become more fragile and fragmented.

Mean forest patch size (MPS) decreased from 2.8 ha in 1975 to 2.1 ha in 2000 (Table 10). This rapid decline in MPS was associated with a rapid increase in the patch density (PD) (35.5–47.2) and a substantial reduction in the size of the largest forest patch (25.1%–13.0%) during a 25 year period. PSCV value increased from 4,896 to 6,199 during the first (1975–1987) period and the trend was reversed during the second period (1987–2000). Area Weighted Shape Index value decreased from 16.4 to 10.9 indicating a more regular shape. Patch shape changed to more regular one (close to circle with straight lines, no

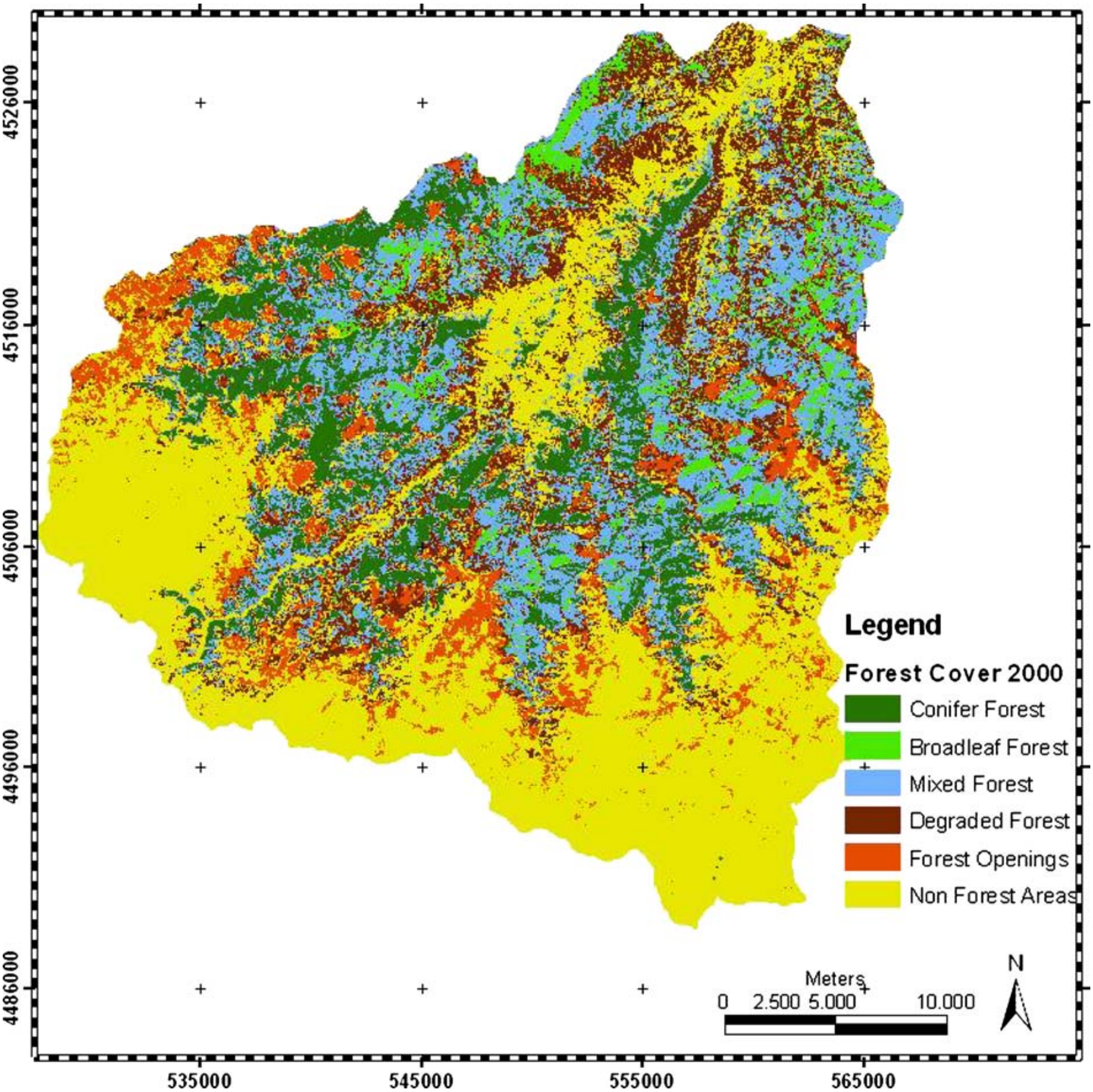

Fig. 4 Forest cover type map of Maçka State Forest Enterprise in 2000

meandering). Variant of patch size and patch density increased. These changes show that landscape fragmentation increased, posing a management challenge for the control of forest landscape.

Demographic development

Forest cover changes are particularly related to increase of population, urbanization and intensive agriculture (Verburg et al. 1999). On the other hand, demographic and socio-economic considerations also play a vital role in LULC and landscape pattern (Kammerbauer and Ardon 1999). The local economy is currently based on traditional sustainable subsistence of agriculture, hazelnut and livestock for their livelihood in Maçka. A range of different crops are cultivated on sloping lands and the study area is also grazed by local cattle. With 49 villages in Maçka State Forest Enterprise, demographic changes of Maçka have been considerably varied between 1970

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	11,150.5	10.9	12,319.2	12.1	12,143.5	11.9
Broadleaf forest	4,252.8	4.2	4,149.2	4.1	3,276.1	3.2
Mixed forest	12,649.0	12.4	19,167.6	18.8	13,821.7	13.6
Degraded forest	18,439.3	18.1	14,981.8	14.7	20,072.0	19.7
Forest openings	10,411.6	10.2	9,505.4	9.3	11,551.6	11.3
Non Forest Area	45,003.9	44.2	41,783.9	41.0	41,042.2	40.3
Total	101,907.1	100	101,907.1	100	101,907.1	100

and 2000 (Table 11) (Republic of Turkey, State Institute of Statistics). This table showed that there is no important changing in population of Maçka over 30 years. Human population increased from 40,641 to 42,557 (nearly 4.7%) inhabitants in the period 1970–2000. However, human population decreased during the first (1970–1985) period but reversed during the second (1985–2000) period. While urban population

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	14.6	8.8	14.9
	Mixed forest	2,226.2	2,429.4	2,366.8
	Degraded forest	587.5	579.1	722.1
	Forest openings	45.3	18.5	28.6
	Non Forest Area	124.3	416.2	439
Broadleaf forest	Conifer forest	22.1	17.4	36.6
	Mixed forest	905.2	262	715.3
	Degraded forest	933.8	483.1	627.2
	Forest openings	285.1	413.9	338.7
	Non Forest Area	229	1,010	901.2
Mixed forest	Conifer forest	2,331.1	2,250	2,025.4
	Broadleaf forest	568.2	492.2	673.4
	Degraded forest	1,826.1	4,354.9	2284
	Forest openings	90.5	163.3	106.8
	Non Forest Area	272.7	3,492.4	1,648.5
Degraded forest	Conifer forest	1,164.4	765.1	1,498.7
	Broadleaf forest	718.1	523.4	423
	Mixed forest	4,306.3	2,206.2	2,510.5
	Forest openings	2,438.4	866.3	2,030.3
	Non Forest Area	4,336.7	5,143.9	5,781.3
Forest openings	Conifer forest	14	25	40.8
	Broadleaf forest	431.5	211.7	247.8
	Mixed forest	235	135.1	144.7
	Degraded forest	826.8	3,339.9	1,946.4
	Non Forest Area	6,215	1,906.9	4,239.9
Non Forest Area	Conifer forest	635	218.7	962.9
	Broadleaf forest	539.4	77.2	283.2
	Mixed forest	3,934.7	374.1	2,173.6
	Degraded forest	5,332.2	5,837.9	8,296.8
	Forest openings	3,956.9	6,202.8	5,255.2

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	7,579.1	3,571.4	4,564.4	993.0
Broadleaf forest	1,633.8	2,619.0	1,642.3	−976.7
Mixed forest	5,910.8	6,738.1	7,910.9	1,172.8
Degraded forest	6,195.5	12,243.8	13,876.5	1,632.7
Forest openings	3,792.0	6,619.6	7,759.6	1,140.0
Non forest Area	28,032.3	16,971.7	13,009.9	−3,961.8

constantly increased from 1970 to 2000, rural population decreased in this period. Small farms were abandoned followed by rapid urbanization as more and more people left the rural areas to become resident in urban centers. Decrease in the urban population might likely lead to the release of human pressure to forest areas, probably resulting in a positive development of forest areas (Karanth et al. 2006; Sivrikaya et al. 2007a).

Discussion and conclusion

As an overall change, there was a net increase of 3,962 ha (7.0%) in total forested areas. The observed trends of increasing forest and decreasing non forest areas in the Maçka could be explained by the following four 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 (Cayuela et al. 2006). In Maçka, human population (rural and urban) increased from 40,641 to 42,557 (nearly 4.7%) inhabitants in the period 1970–2000. However, there is no important changing in population of Maçka over 30 years. While human population decreased during the first (1970–1985) period, forest area increased from 56,903 to 60,123 (5.7%). However, population reversed during the second (1985–2000) period and forest area increased lower percentage (1.2%) than first period. It is important thing that both rural human population and the percentage of rural human population decreased during the 30 years. The increase of forest areas may well be explained by the fact that demographic movement of rural areas concentrated into Maçka Centrum. Many villages were abandoned and more people left the rural areas to become resident in urban centers. Furthermore, abandoned areas were covered by young trees resulted from seeds of near forests. These areas were seemed as degraded forests because these stands had no enough crown closure. This situation is the reason of increasing degraded forest area. In Turkey, besides inequity in land ownership, low productivity in agriculture and the domestic net income per person was far below the threshold to keep the rural communities in their homeland, allowing the urban population to increase (Yüceşahin 2003). The demographic movement indicated that the rate of rural population decreased from 94% in 1975 to 74% in 2000, indicating much faster population growth in urbanization than that in rural areas. During the whole study period, the annual forestation rate was 152 ha year^{-1}, equivalent to 0.27% year^{-1} using the compound-interest-rate formula. The quantitative evidences of forest cover patterns showed that human activities have affected the forest cover type changes. Second,

Table 9 Variation of forest area and number of patches over patch size classes

Patch size (ha)	Area (ha)			Number of patches		
	1975	1987	2000	1975	1987	2000
0–100	41,869.5	42,350.9	47,748.3	27,644	31,686	36,369
100–500	7,866.3	11,239.3	8,823.2	39	59	53
500–1000	5,480.5	5,201.8	1,945.6	8	8	3
1000–2000	1,686.7	1331.0	2,346.7	1	1	2

Table 10 Selected landscape metrics of Maçka in 1975 and 2000

Forest cover type	CA			NP			MPS			PERCLAND			LPI			PD			PSCV			AWMSI		
	1975	1987	2000	1975	1987	2000	1975	1987	2000	1975	1987	2000	1975	1987	2000	1975	1987	2000	1975	1987	2000	1975	1987	2000
Conifer forest	11,150.5	12,319.2	12,143.5	1,726	2,914	3,344	6.5	4.2	3.6	10.9	12.1	11.9	1.7	1.3	1.1	1.7	2.9	3.3	829.3	877.9	852.2	4.9	5.6	5.2
Broadleaf forest	4252.8	4149.2	3276.1	1642	2284	1936	2.6	1.8	1.7	4.2	4.1	3.2	0.3	0.3	0.3	1.6	2.2	1.9	445.1	488.1	539.4	2.9	3.0	3.0
Mixed forest	12,649	19,167.6	13,821.7	3,605	7,638	7,818	3.5	2.5	1.8	12.4	18.8	13.6	0.7	0.6	0.3	3.5	7.5	7.7	858.1	692.2	505.7	6.2	5.8	4.9
Degraded forest	18,439.3	14,981.8	20,072.0	12,769	12,185	16,886	1.4	1.2	1.2	18.1	14.7	19.7	0.1	0.9	0.2	12.5	12.0	16.6	279.4	935.4	462.9	2.6	5.6	3.8
Forest openings	10,411.6	9,505.4	11,551.6	7,950	6,733	6,443	1.3	1.4	1.8	10.2	9.3	11.3	0.5	0.4	1.2	7.8	6.6	6.3	542.3	536.6	1001.9	2.7	3.5	5.5
Non Forest Area	45,003.9	41,783.9	41,042.2	8,512	6,968	11,665	5.3	6.0	3.5	44.2	41.0	40.3	25.1	31.2	13.0	8.4	6.8	11.4	5,339.6	6,386.8	4,398.5	32.1	26.2	20.2
Total	101,907.1	101,907.1	101,907.1	36,204	38,722	48,092	2.8	2.6	2.1	100	100	100	25.1	31.2	13	35.5	38	47.2	4,895.6	6,198.7	3,639.1	16.4	13.8	10.9

plantation by the forest department has contributed to the increase in forest area. Third, effective protection measurements due to being National Park and Karadeniz Technical University Research Forest in study area helped halt the decrease of productive forest and accelerate the conversion of agriculture-settlement areas and forest openings to forests. Fourth, Insects that primarily attack individual species have an effect similar to selective cutting on a multi-species stand within a forest. Insect infestation may or may not cause significant change in species composition (i.e., associated plant and animal species) and forest-stand structure. A lot depends on the diversity, site conditions and overall health of the original stand (Binelli et al. 2000). Instead of intensive harvesting activities conducted for maximum wood production from 1975 to 2000, light silvicultural prescriptions and harvesting activities due to insect attack were carried out in the research area. The positive changes in forest cover provide some evidences of ecological sustainability of the resource.

To understand forest dynamics and successfully manage forest ecosystems, managers need to understand spatial and temporal configuration of forest landscape. Biodiversity conservation is associated with both landscape configuration and composition and also forest management activities directly affect both components. Improvement of biodiversity is one of the key objectives of forest management. Forest cover changes are the most common cause of loss biodiversity (Armsworth et al. 2004; Harris 1984; Kilic et al. 2004). Moreover, forest fragmentation, habitat loss, urbanization due to forest cover change is a major reason for the declining biodiversity and biodiversity erosion in forest ecosystems. The most important indicators of fragmentation are the number of patches and the increase in number of smaller patches (Echeverria et al. 2006; Southworth et al.

Table 11 Demographic change in Maçka State Forest Enterprise

Years	Urban	Rural	Total	Urban (%)	Rural (%)
1970	2,311	38,330	40,641	5.7	94.3
1975	3,076	37,966	41,042	7.5	92.5
1980	3,989	37,219	41,208	9.7	90.3
1985	4,614	33,066	37,680	12.2	87.8
1990	7,673	34,651	42,324	18.1	81.9
2000	11,060	31,497	42,557	26.0	74.0

2004; Kammerbauer and Ardon 1999). Fragmentation may effect isolation of habitats, endangered species' population dynamics and species richness. The composition and the configuration of forest resource are considerably changed in Maçka. While the forest area increased during a 25 year period, number of patch, smaller patch and patch increased resulting in fragmentation of the landscape. Forest ecosystem positively affected in point of view quantity of forest area however forest configuration more fragmented that may affect negatively biodiversity and forest values.

A forest patch is a spatially independent, contiguous and homogenous area that has spatial and aspatial characteristics distinct from its surroundings (Baskent and Jordan 1995a, b; Forman 1998). A variety of patch sizes is important for wildlife (Wei and Hoganson 2005). Impacts of forest patch sizes on wildlife differ by wildlife species. Species affected by the size of habitat patches are referred as area sensitive (Freemark and Collins 1992). Human activities generally cause patch sizes to decline, which is harmful to some wildlife species (Bender et al. 1998). Careful planning can help achieve more desirable distribution of patches (Baskent and Jordan 2002). Patchiness in forested area is of special importance because it serves as an important indicator of natural habitat fragmentation (Kammerbauer and Ardon 1999). Other basic indication of forest fragmentation is the increase in number of smaller patches (patches in 0–100 ha size class) that increased from 27,644 to 36,369 (32%) between 1975 and 2000 in forested area. The general trend was towards an increase in the number of fragments and isolation of patches and a decline in the mean patch size. Therefore, the landscapes progressed towards more fragmented structure as indicated with the increase in the number of forest patches, patch density and decrease in MPS and LPI.

The possible reasons for increased fragmentation of Maçka State Forest Enterprise could relate the followings. First, degraded forest, forest openings and non forest area converted to forest cover types whose areas ranged from 0.18 to 100 ha, increased patchiness. Second is an insect attack on spruce stands. Furthermore, roads have increased throughout forested areas in many parts of the world, in addition to the human settlement and land conversion to non-forest uses, and have negative effects on biodiversity and ecological processes (Kennedy and Spies 2004). Third is the road construction. The total road length in Maçka State Forest Enterprise was increased due to transportation and harvesting activity. Fourth, urbanization causes forest fragmentation. Urban population of research area was increased during the 25 years.

Overall, while the forested areas increased slightly, the qualitative aspect of the forest resources based on natural composition and configuration of forest landscape deteriorated or fragmented due to increase in number of patches, in number of smaller patches, MPS and PD. Forest degradation in the study area has developed in the form of total removal of some forest types, partly deterioration of existing forest areas, isolation of forest fragments or changing the natural composition of habitats. The causes are mainly mismanagement, heavy grazing of pasture land adjacent to forest areas, illegal use of forest resources and insect attacks and ecosystem dynamics. The impacts are loss and conversion of some natural forest types, increase of productive forests, exposure of some lands to soil erosion and carbon emission to the atmosphere (Sivrikaya et al. 2007b).

In conclusion, monitoring the implications of past, present and future both composition and configuration of forest ecosystem is increasingly important in forest management and applied ecology for forest values and especially biodiversity. This kind of studies makes a contribution to forest manager, monitoring biodiversity and sustainable forest management.

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