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Spatiotemporal changes of land use patterns in high mountain areas of Northeast Turkey: a case study in Maçka

Gokhan Sen · Mahmut M. Bayramoglu · Devlet Toksoy

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Abstract High mountain forests (HMFs) have an important significance in forest ecosystems, but the benefits from such ecosystems have been compromised in recent years. In Turkey, HMFs constitute significant portions of Turkish forests because they cover 4 % of Turkey; 15 % of all Turkish forest areas are HMFs. The Eastern Black Sea region has a particular importance for HMFs due to its biological diversity and the rich presence of endemic species. This study analyzes the changes in spatial and temporal patterns of forest cover in HMF from 1973 to 2008 in the town of Maçka, which is located at the center of the Eastern Black Sea region of Turkey. The spatial and temporal change patterns of land use are quantified by interpreting spatial data. Remote sensing (RS), geographical information system (GIS), and a spatial pattern analysis program for categorical maps (FRAGSTATS) have been used for data collection, analysis, and presentation. The results showed that the HMF areas had biphasic growth from 1973 to 2008. Despite a net increase of 200.6 ha in forested areas between 1984 and 2008, there was an overall decrease from 1973 to 2008. The annual percentage of forestation for the forest areas within the study period was 0.04 % in Maçka. The amount of aggregated forest area fragments rose from 388 in 1973 to 711 in 2008. The increase in the HMF of Maçka can be explained to some extent by the change in the demographic structure of Maçka and its plateaus, which contributed to changes in the daily life of the population of Maçka and its villages, such as changes in annual incomes, their lifestyles, decrease in transhumance and stockbreeding, decrease in the time of dwelling on the plateaus, and changes in the traditional architectural style.

Keywords Spatiotemporal analysis · FRAGSTATS · Geographic information system · Land use/cover · Maçka · Turkey

Introduction

Forest ecosystem services include but are not limited to security, carbon sequestration, and climate control. Financial support for underprivileged regions has been increasing quite fast; however, the benefits of these services have been compromised in recent years. The Food and Agriculture Organization reports of the United Nations (FAO) indicate that the loss of forest field over the 1990–2000 and 2000–2010 periods were 16 and 13 million hectares, respectively (FAO 2010). The excessive use of forest ecosystem services resulted in the

G. Sen (✉)
Forestry Faculty Department of Forest Engineering,
Kastamonu University, 37200 Kastamonu, Turkey
e-mail: gsen@kastamonu.edu.tr

M. M. Bayramoglu · D. Toksoy
Forestry Faculty Department of Forest Engineering,
Karadeniz Technical University, 61080 Trabzon, Turkey

M. M. Bayramoglu
e-mail: mahmudtr@yahoo.com

D. Toksoy
e-mail: devlettoksoy@ktu.edu.tr

damage or unsustainable deterioration in 60 % of forests worldwide (Brockhause and Botoni 2009). Developed countries with higher education levels achieve sustainable use of forest ecosystems in a planned manner compared with the developing and underdeveloped countries, which have lower education levels (FAO 2006). In order to achieve such a result, Australia and Switzerland spent approximately €50 million to protect and improve these functions in their high mountain forests. HMFs also provide the cheapest and most esthetic protection against natural disasters such as avalanche (Brauner et al. 2005).

Therefore, HMFs have an important role to play in forest ecosystems. Any mountainous areas over 1500 m are categorized as high mountain areas (mountain, subalpine, and higher Alps) (Tavşanoğlu 1974; Çolak and Pitterle 1999), and forests within this area are known as high mountain forests in mountainous regions. The environmental benefits of these forests vary from widely known practices, such as hunting animals, firelogs, and timber, to the less appreciated such as carbon sequestration, climate control, and protection against natural disasters (Great-Regaway and Kytzia 2007). One of the most important roles of HMFs is their function in protection. Therefore, improvement of the quality of HMFs would prevent the damage that could occur during natural disasters.

In Turkey, HMFs constitute a significant portion of Turkish forest as it accounts for 15 % of all the forest area and 4 % of the total area (Sağ 2002). The Eastern Black Sea region has a particular importance for HMFs due to its biological diversity and the rich presence of endemic species. The Kaçkar Mountains, which are situated in the Eastern Black Sea region, were included in the International Union for Conservation of Nature hotspot list. In order to be listed as a "hotspot," the region had to fulfill two main criteria: first, there had to be over 2000 endemic plants present, and the second, no more than 70 % of natural habitat lost in the region. These hotspot regions have both the largest biologic diversity and the highest risk of species extinction (Anonymous 2009).

There has been a common perception and understanding that the forest resources of the world have been progressively decreasing in terms of both area and quality over the last few decades. However, without quantifying the rate and amount of land cover change over time, it is difficult to understand the historical forest dynamics and design better forest management and environmental policies for the future (Başkent and Kadıoğulları 2007). Land use-cover change processes, which are considered to be changes from any primary dominated land cover into any man-made-dominated one, have largely resulted in desertification, deforestation, habitat fragmentation, biodiversity loss, and ultimately global warming. Remote sensing has been used to map patterns of deforestation and to uncover rates of forest cover change in various regions including the tropics (Lele and Joshi 2009). Various methods can be used in the collection, analysis, and presentation of natural resources data to explain forest dynamics. The use of remote sensing (RS) and geographical information system (GIS) technologies can greatly facilitate the process. Furthermore, spatial statistics programs like FRAGSTATS have been effectively used in determining the changes in land use and forest cover. These contemporary tools are quite important and useful for both visual assessments of forest ecosystem dynamics that occur at a particular time and space, as well as quantitative evaluation of land use and forest cover changes over time (Gautam et al. 2003). The use of these tools to illustrate spatiotemporal dynamics of land use and forest cover has been reported by many researchers during the past decade (Liu et al. 1993; Menon and Bawa 1997; Schmitz et al. 1998; Gaona-Ochoa and Gonzalez-Espinoza 1999; Verburg et al. 1999; Kammerbauer and Ardon 1999; Latorre et al. 2000, Luque 2000; Vasquez et al. 2002; Nagashima et al. 2002; Turner et al. 2003; Wardell et al. 2003; Yuliang et al. 2004; Siddiqui et al. 2004; Kennedy and Spies 2004; Zhang et al. 2004; Wakeel et al. 2005; Liu et al. 2005; Armenteras et al. 2006; Cayuela et al. 2006; Echeverria et al. 2006; Etter et al. 2006; Hayes and Cohen 2007; Fan et al. 2008; Aricak et al. 2014; Aricak 2015). In Turkey, numerous studies have attempted to document the temporal changes in forest ecosystem patterns using GIS and RS techniques (Yıldırım et al. 2002; Alphan 2003; Musaoğlu et al. 2005; Doygun and Alphan 2006; Kılıç et al. 2006; Musaoglu et al. 2006; Atasoy 2007; Çölkesen and Sesli 2007; Reis 2007; Geymen and Baz 2007; Güler et al. 2007; Sivrikaya et al. 2007; Başkent and Kadıoğulları 2007; Kadıoğulları and Başkent 2008; Tunay et al. 2008; Karahalil 2009). However, these studies generally documented the spatial and temporal land use and forest cover changes as well as the factors affecting these processes; the historical dynamics of forest ecosystems, which include ecosystem composition structure (Tunay and Ateşoğlu 2004; Atasoy et al.

2005; Kavzaoğlu and Çetin 2005; Karabulut et al. 2006), have yet to be fully studied.

This study focuses on spatiotemporal changes in forests in general and high mountain forests. This study fills the gap through a large-scale analysis of landscape structure and changes using remotely sensed data, particularly focusing on the Maçka high mountain forests during the 1973–2008 period.

The spatial and temporal change patterns of land use were quantified using interpreting spatial data from RS, GIS, and FRAGSTATS.

Study area

The study area was the town of Maçka, which covers part of the city of Trabzon, located in the Eastern Black Sea Region of Turkey (527,000–567,000 E, 4,480,000–4,530,000 N, UTM ED 50 datum zone) (Çakır et al. 2008) (Fig. 1). Maçka is the largest and best-known town of the Trabzon city.

A geographical property of Maçka province is its very rough and mountainous topography. The main mountains in the area are Zigana, Kulin, and Kuştul (Anonymous 2009). The study area was in the Colchis province of the Euro-Siberian phytogeographical region (Davis et al. 1971). The region is very rich in plant species. For example, the Altindere valley, which was included in our study area, has 384 plant taxons that belong to 61 familia and 190 species of alpine and subalpine flora. Among those, there are 32 endemic (8.3 %) and 9 rare species (2.3 %) (Uzun Palabaş and Anşin 2006). The plant flora of the region consists of

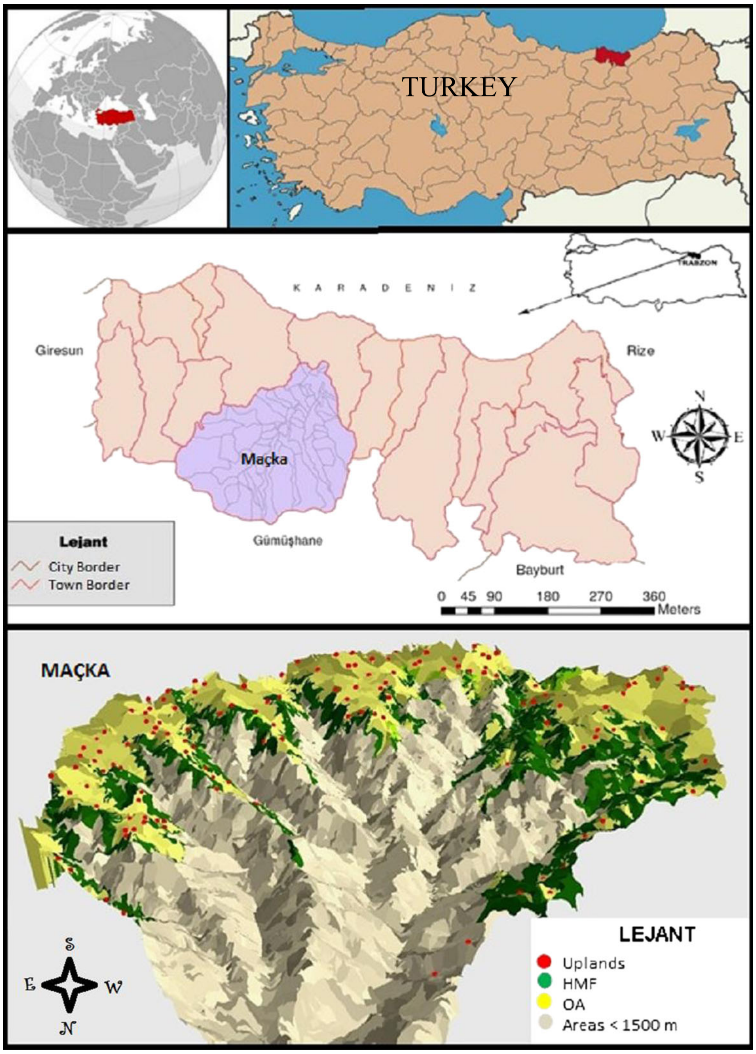

Fig. 1 The geographic location of the study area

mountain and high mountain forests, subalpine and alpine grasses, bush-like plants, and crop plants. The dominant species 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. (Çakır et al. 2008; Uzun and Terzioglu 2008; Güney et al. 2013). The average slope is 57 %. The prevalent climate regime is of a typical Black Sea climate, characterized by a mild winter, a cool summer, and rain throughout all seasons. Annual precipitation is high, ranging from 1000 to 1250 mm, and frost days are between 21 and 40 (Günlü et al. 2008). The average annual temperature reaches a maximum of 20.2 °C in the summer and a minimum of 4.5 °C in the winter, with an average annual temperature of 12.2 °C (Altun 1995).

The Altındere Valley National Park, which was also included in our study, is one of the most important national parks in Turkey because of its extremely diverse flora, which comprises several vegetation types (forest, subalpine, and alpine), and includes the historical value of Sumela Monastery. The monastery is situated on a rock face 300 m above the deep valley and is an important destination for spiritual tourism and a favorite spot for tourists who travel along the Black Sea coast (Uzun and Anşin 2006; Uzun 2009).

The study area was located over the high mountainous land with close proximity to the Black Sea in which rain and fog frequently occurs. The area is also located north of East Pontid and has volcanic and plutonic rocks such as basalt, spilic basalt, and andesit, and piroclastic rocks, which were determined by petrography examination. Although loamy soils are predominant, clay soils are also common (Günlü et al. 2008).

Data and methods

In this study, spatiotemporal analysis of high mountain forests was performed following three steps. First, the stand-type maps (1973, 1984, and 2008) were digitized and rectified, and a spatial database was built with Arc/Info GIS. Secondly, the spatial and temporal changes, and transitions in cover types, were analyzed with GIS. To complete the analyses, the fragmentation of the study area was evaluated using FRAGSTATS.

The data used in this research were forest cover-type maps at 1/25,000 scale from 1973. Cover-type maps were produced with 1/23,000-scale black-and-white aerial photos in 1984. In 2008, a cover-type map was produced with 1/16,000-scale color infrared aerial photographs by the General Directorate of Forestry (GDF). Aerial photographs of the study area were obtained from the GDF for the years 1973 (panchromatic aerial photographs at 1:23,000 scale), 1982 (panchromatic aerial photographs at 1:15,000 scale), and 2002 (color infrared aerial photographs, at 1:15,000 scale). Stand-type maps, generated through the stereo interpretation of aerial photographs in 1973, 1984, and 2008, were also obtained from the GDF forest management plans (GDF 1973; GDF 1984; GDF 2008). The forest stand-type maps used in this research were first scanned and then entered into a database using 1:25,000-scale topographical maps with Universal Transverse Mercator (UTM) projection (ED 50 datum) using first-order nearest-neighbor rules. Rectified forest stand-type maps were digitized with a 1/3000 to 1/5000 screen-view scale by qualified foresters with substantial GIS experience.

The most significant considerations of landscape evaluation are in which way and by what magnitude landscape changes (Antrop 2000). In this study, land use/cover change was investigated in order to determine in which way and to what extent changes had occurred and different dates were compared. Land use/cover changes were determined by comparing the transition situations from the images taken in 1973, 1984, and 2008. Polygon themes composed of forest cover from 1973, 1984, and 2008 were superposed, and the transformation of each was compared and spatially calculated by using ArcGIS (Çakır et al. 2008).

In this paper, coarse-level classification method was implemented. This classification shows simplified land uses, such as the areas that had land cover and land use types (Karahalil et al. 2009). In total, nine forest cover classes were considered in the analysis (Table 1). For land cover classes, only spatial analysis was conducted.

A number of documents such as forest management plans, silvicultural prescriptions, and harvesting activities were obtained. Field survey data about demographic changes, economic conditions, and living standards of local people were evaluated to determine the socio-economic factors and management interventions that influenced land use changes.

Table 1 Land use/land cover class descriptions

	Land use/cover and forest cover description classes	
Land use/cover classes	Productive forest (PF)	Productive forest with estimated >10 % tree crown cover
	Degraded forest (DF)	Degraded forest with estimated <10 % tree crown cover
	Open Areas (OA)	Agriculture, range land, residence areas, shrub lands and grasslands
	Water	The streams in the study area did not flow continuously throughout the year. Therefore, these seasonal streams were evaluated according to the land use/cover class through which they ran.
Forest cover classes	HW	Pure stands made up of hardwood trees (spruce, Scotch pine, fir)
	SW	Pure stands made up of softwood trees (beech, alder, hornbeam, Acecia, chestnut, poplar, other softwood trees)
	HSW	Mixed stands dominated by hardwood
	SHW	Mixed stands dominated by softwood
	DHW	Degraded pure stands made up of hardwood trees
	DSW	Degraded pure stands made up of softwood trees
	DMW	Degraded mix wood
	OA	Agricultural field, pasture field and settlement area
	C	Coppice

Transition and spatial analysis of land cover types

In addition to analyzing the changes in the amount of land use types, the temporal transitions among the use types were also documented and evaluated to determine the temporal dynamics among various parameters indicative of land use composition and configuration of forest resources. The transitions were evaluated using periodic results of management plans. The land use, development stage, and crown closure polygon themes for 1973, 1984, and 2008 were overlaid, and areas that had been converted from one class to another were computed.

Annual deforestation can be calculated by different methods (Liu et al. 1993; Menon and Bawa 1997; Puyravaud 2003; Armenteras et al. 2006; Lele and Joshi 2009).

In this study, the following formula was used, where r is the 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.

$$r = \left(\frac{1}{t_2 - t_1}\ln\frac{A_2}{A_1}\right)*100 \tag{1}$$

The effects of landscape structure on the management of natural resources and design are as important as the spatial organization of landscape structure (Başkent et al. 2000; Başkent and Kadıoğulları 2007). The forest landscape spatial dynamics include the temporal changes of size, number, shape, proximity of patches, and coverage that occur in landscape fragments. FRAGSTATS was used to evaluate the structure of each land use/cover class of the Maçka high mountain landscape (McGarigal and Marks 1995). FRAGSTATS measures some spatial metrics for all fragments, cover types, and whole landscape. Therefore, in this study, the spatial analysis measurements defined by Başkent and Jordan (1995) and McGarigal and Marks (1995) were used to calculate changes that occurred in the spatial structure. The chosen measurements and the land use in the study area were analyzed.

Class-level measurements were calculated from the cover-type maps for 1973, 1984, and 2008. The metrics were area of class, percent of landscape (PL), number of patches (NP), largest patch index (LPI), mean patch size (MPS), patch density (PD), and area-weighted mean shape index (AWMSI). The chosen measurements were considered for a particular landscape to indicate spatial inhomogeneous, spatial discontinuity, complicated fragment form, and linking. NP and MPS usage need to be supplementary because large NP and small MPS rates strengthen the spatial discontinuity of landscape (Matsushita et al. 2006; Leitao and Ahern 2002).

Table 2 Evolution of selected landscape variables in the study area from 1973 to 2008

Year	1973		1984		2008	
Class	ha	%	ha	%	ha	%
Productive forest	13,863.3	29.19	11,919.7	25.10	13,883.3	29.24
Degraded forest	816.6	1.72	2334.3	4.92	997.2	2.10
Open areas	32,808.2	69.09	33,234.1	69.98	32,607.6	68.67
Total	47,488.1	100.00	47,488.1	100.00	47,488.1	100.00

Changes in forest structure

The area of each land use/cover class for the three periods studied is shown in Table 2 and Figs. 2, 3, and 4. According to the stand-type maps from the forest management plans, high mountain areas (HMAs) in Maçka cover 47,488.1 ha. This area accounts for approximately 57 % of Maçka province. The total area of HMFs in 2008 was 14,880.5 ha; this area represented 17.8 % of Maçka province and 31.3 % of HMAs.

A total forest increase of 200.6 ha was seen in the HMAs of Maçka between 1973 and 2008, specifically due to the increase seen in forest areas between 1984 and 2008 (626.5 ha). This increase occurred in the areas of both productive forest (PF) and degraded forest (DF).

The results show that the forest area increased from 14,679.9 ha (30.9 % of the study area) in 1973 to 14,880.5 ha (31.3 %) in 2008. Areas of PF decreased in HMAs between 1973 and 1984 by 1943.6 ha (14.02 %) and the total forest (TF) areas decreased by 425.9 ha (2.9 %). However, the areas of DF and open area (OA) increased by 1517.7 ha (185.9 %) and 425.9 ha (1.3 %), respectively. This situation reversed between 1984 and 2008. Compared with 1984, the areas of PF and TF had increased by 1963.6 ha (16.47 %) and 626.5 ha (4.39 %), respectively, by the end of 2008. A decrease occurred in DF areas and OA. The areas of DF and OA decreased by 1337.1 ha (57.3 %) and 626.5 ha (1.9 %), respectively. As an overall change in Maçka HMFs, there was a net increase of 200.6 ha (1.4 %) in total forest areas. The ratio of annual deforestation between 1973 and 2008 was −1.373 % in the areas of PF, −9548 % for DF, and −0.268 % for forest areas in general. Between 1984 and 2008, the percentage change was 0.635 % in areas of PF, −3.544 % in areas of DF, and −0.179 % in general forest areas. The rate of annual deforestation for general forest areas during the study period was 0.04 %.

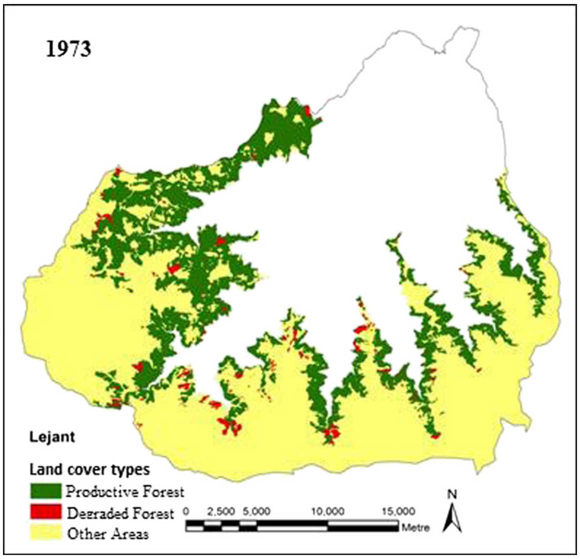

Fig. 2 Condition of land cover/use in Maçka's high mountain areas in 1973

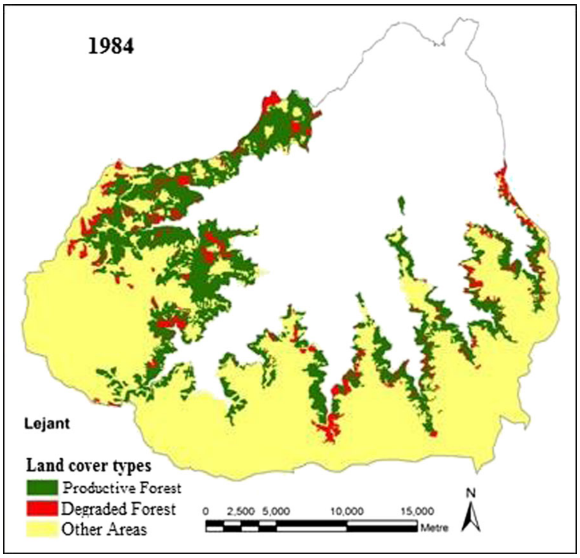

Fig. 3 Condition of land cover/use in Maçka's high mountain areas in 1984

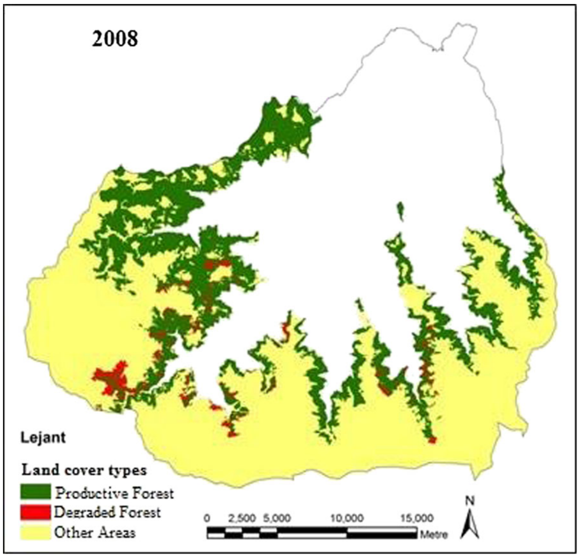

Fig. 4 Condition of land cover/use in Maçka's high mountain areas in 2008

Transition among land use/land cover types

The changeover between all significant land use typologies from 1973 to 2008 was identified from forest management plans. According to the digitized maps, between 1973 and 1984, some 1477.4 ha of 13,863.3-ha (10.66 %) PF had transformed into DF, and 1669.8 ha (12.04 %) transformed into OA. Furthermore, approximately half of DF (816.6 ha) had transformed into OA (423.1 ha) and approximately 5 % of OA (181.3 ha) transformed into forest area. However, the areas of OA, which include open forest areas, ranges, and other open lands including agriculture and settlement areas, increased by 425.9 ha between 1973 and 1984. The highest increase in the same period occurred in DF. The areas of DF showed an increase of 185.9 % (1517.7 ha) between 1973 and 1984 (Table 3).

The 24 years between 1984 and 2008 became a period of recovery for high mountain forests, although transformation from forest area to open area and vice versa continued. During these years, an increase of 1963.6 ha (16.47 %) was seen, to the advantage of PF. This increase happened through the transformation of DFs and open areas into productive forest areas. The total increase in forest area is 626.5 ha.

Between 1973 and 2008, there was a relative increase in HMF area. This increase was seen in both productive and damaged forest areas. From 1973 to 2008, approximately 41 % of damaged forest areas and around 4 % of open areas transformed productive forest areas. The total increase in forest areas was 200.6 ha (Table 3).

Spatial analysis of the change in spatial forest structure

Landscape fabric (pattern) spatial analysis demonstrated that when all types of patches were considered, the overall number of patches (NP) rose from 673 to 947 between 1973 and 2008. During the same period, there was a decline from 326 to 246.3 ha in mean patch size (MPS), i.e., the average fragment size. There was an important alteration of degrade forests' MPS, which reduced from 29.7 to 15.3 ha between 1973 and 2008. The MPS of productive forest fields also fell from 181 to 92.6 ha. A clear reduction of 200.6 ha in patch size and the decrease of 49 patches may have been the cause of the alterations in OA (Table 4). The area-weighted mean

Table 3 The transition matrix of land use/cover changes in Maçka high mountain area from 1973 to 2008

Changed from	Changed to	Percent change during		
		1973–1984	1984–2008	1973–2008
Productive forest	Productive forest	10,716.1	10,715.2	12,157.5
	Degrade forest	1477.4	306.3	402.3
	Open areas	1669.8	898.2	1303.5
Degraded forest	Productive forest	181.3	1569.9	334.6
	Degrade forest	212.2	130.9	84.4
	Open areas	423.1	633.5	397.6
Open areas	Productive forest	1022.3	1598.2	1391.2
	Degrade forest	644.7	560.0	510.5
	Open areas	31,141.2	31,075.9	30,906.5

Table 4 Change of landscape pattern in HMF in Maçka (1973–1984–2008 forest cover-type maps)

Land cover/forest cover classes		Class area (ha)			Number of patches (#) (NP)			Mean patch size (ha) (MPS)			Percent of landscape (%) (PL)		
		1973	1984	2008	1973	1984	2008	1973	1984	2008	1973	1984	2008
PF	HW	9209.7	8858.1	8285.8	105	173	211	87.7	51.8	36.2	19.4	18.7	17.5
	SW	797.9	407.0	706.6	52	72	42	15.4	7.0	18.5	1.7	0.9	1.5
	HSW	1986.2	2237.8	3514.8	50	110	172	39.7	21.2	23.7	4.2	4.7	7.4
	SHW	1869.5	416.8	1376.1	49	59	97	38.2	8.7	14.2	3.9	0.9	2.9
DF	DHW	313.0	1276.1	758.1	40	130	152	7.6	9.0	4.7	0.7	2.7	1.6
	DSW	34.3	160.9	58.0	2	15	13	11.7	4.0	3.7	0.1	0.3	0.1
	DMW	70.3	466.6	181.1	11	35	24	5.5	10.5	6.9	0.1	1.0	0.4
	C	399.0	430.7	–	79	27	–	4.9	12.2	–	0.8	0.9	–
OA		32,808.2	33,234.1	32,607.6	285	182	236	115.3	182.5	138.4	69.1	70.0	68.7
Landscape		47,488.1	47,488.1	47,488.1	673	803	947	326	306.9	246.3	100	100	100
Land cover/forest cover classes		Largest patch index (%) (LPI)			Patch density (number of patch per 100 ha) (PD)			Patch size coefficient of variation (%)			Area-weighted mean shape index (AWMSI)		
		1973	1984	2008	1973	1984	2008	1973	1984	2008	1973	1984	2008
PF	HW	9.5	7.5	5.5	0.2	0.4	0.5	516.8	562.4	565.6	7.0	6.5	5.6
	SW	0.5	0.1	0.2	0.1	0.2	0.1	247.3	159.1	148.2	2.8	2.0	2.4
	HSW	1.0	0.6	1.3	0.1	0.2	0.4	194.1	172.6	266.4	2.6	2.1	2.8
	SHW	1.0	0.1	0.2	0.1	0.1	0.2	195.7	128.5	132.1	2.4	1.9	1.9
DF	DHW	0.1	0.3	0.6	0.1	0.3	0.3	102.2	207.3	461.2	1.5	2.1	3.3
	DSW	0.1	0.0	0.1	0.0	0.0	0.0	130.8	163.4	203.9	1.5	1.9	2.0
	DMW	0.0	0.2	0.1	0.0	0.1	0.1	98.7	162.8	151.4	1.5	1.9	2.6
	C	0.1	0.1	–	0.2	0.1	–	179.9	127.4	–	1.6	2.1	–
OA		44.7	66.4	44.5	0.6	0.4	0.5	1200.6	1279.6	1085.1	6.8	8.6	6.1
Landscape		57	75.3	52.5	1.4	1.8	2.1	2866.1	2963.1	3013.9	27.7	29.1	26.7

shape index (AWMSI) was 6.8 and this also reduced to 6.1. In addition, from 1973 to 2008, the patch density (PD) value increased from 1.4 to 2.1. This ratio decreased from 0.6 to 0.5 in OA. All these changes show that landscape fragmentation increased and that the forest became more sensitive to external factors between 1973 and 1984. However, after 1984, PF areas increased by 1963.6 ha but DF areas decreased by 1337.1 ha. Together with the decrease in open areas, these data indicated that forest areas recovered between 1984 and 2008 (Table 4).

Although a more homogenous structure occurred in open areas and the classes of coppice between 1973 and 1984, multipartiteness increased in other stand classes and a more heterogeneous structure appeared. In general, the total number of patches with characteristics of productive and damaged forest in HMA significantly increased from 388 in 1973 to 711 in 2008, and especially disintegration with the characteristic of DF became greater and more effective (from 132 in 1973 to 321 in 2008). In non-forest areas, the number of patches decreased and the lost forest areas enabled the disintegrated spaces to integrate. These areas were evaluated within the other classes because the operation of coppice was abolished during the latter half of 1984–2008. In this period, the transformation of some stand classes into a more homogenous structure was an indicator for the recovery of the forests, together with the occurrence of a more partite structure in the areas of OA. Degraded and extremely degraded stands decreased and productive forests increased during the same period (Table 4).

Demographic development

In order to protect and manage biodiversity, it is important to understand the dynamics of forest loss and human factors of which that contributes. Understanding these dynamics will also help various organizations and development projects that focus on protecting forests (Puyravaud 2003; Lele and Joshi 2009). With human interference, dominant plant flora and/or its use may transform into a completely different flora and/or use, which in turn may lead to deforestation, desertification, habitat splitting, loss of biodiversity, and even global warming. Ultimately, this may also lead to a decrease in natural services (Lele and Joshi 2009).

The main reason for environmental deterioration in many rural and urban areas is population increase (Otu Judith et al. 2011; Johnson and Libecap 1982). There are 57 villages in our study area, Maçka. This area is within the borders of the Maçka Department of Forestry, which consists of six Chiefdom of Forestry Operations that are managed by six chiefs of operation and one chief manager. In this high mountain area, there are 157 settlements on the plateau within the forest and on alpine meadowlands (Fig. 1). The settlements are of high density when compared with other settlement areas closeby in the study area. Therefore, due to their density, these settlements have a sizeable impact on the forest. These plateaus are generally used by those who live in villages that are dependent on the town of Maçka. The plateaus are located in areas within the forest boundary and areas that cross the forest boundary at altitudes of 1400 m and over. Fifty-seven villages with a population of 6262 inhabitants are excessive for sustainable HMA management.

Similar to the other developing countries, the rural population in Turkey is high and it made up 61.5 % of the total population in 1973. This decreased to 25 % in 2008 (TÜİK 1979; TÜİK 2008). Relative to the decrease in the rural population, a decrease also occurred in the population of forest villages. The total population of forest villages was 7.9 million in 1973, which then increased to 10.1 million in 1980. Afterwards, it decreased to 9.1 million in 1990, 7.6 million in 2000, and 7.1 million in 2008 (UNECE 2000; Konukçu 2001, URL-1 2010).

Turkey has experienced a significant demographic movement over the past 35 to 40 years, and consequently, the demographic structure of Maçka significantly changed between 1970 and 2008. These changes were mostly dominated by the migration of the rural population to urban centers both within and outside of the district between 1970 and 2008 (Table 5) (TÜİK 2008). In this period, the population of Maçka decreased by 66.7 %, from 40,641 to 26,984. The rural population decreased from 38,330 to 10,653 (72.2 %) between 1970 and 2008. During the same period, the urban population increased by 271 %, from 2311 to 6262.

Table 5 Demographic change in Maçka (number of inhabitants)

Years	Urban	Rural	Total	Urban (%)	Rural (%)
1970	2311	38,330	40,641	5.7	94.3
1975	3076	37,966	41,042	7.5	92.5
1980	3989	37,219	41,208	9.7	90.3
1985	4614	33,066	37,680	12.2	87.8
1990	7673	34,651	42,324	18.1	81.9
2000	11,060	31,497	42,557	26.0	74.0
2008	6262	20,722	26,984	23.2	76.8

Discussion and conclusion

Turkey has significant biodiversity and is rich in endemic species. Areas in which biodiversity is most dense are called hotspots. The Eastern Black Sea region is one of the most significant hotspots both in Turkey and the world with its high ratio of biodiversity. Migration from rural areas to the cities has been the most important reason for the changes in the forest areas, particularly over the last 50–60 years. Migration from rural to urban areas in Turkey is an important problem in terms of the changes in the use of soil and also for forest cover. These changes are mostly negative in urban areas but may be positive in rural areas.

We analyzed changes in the use of soil and forest cover between 1973, 1984, and 2008 using digitized stand maps using GIS and FRAGSTATS. The results of the study have shown that there have been changes in terms of types of soil usage and forest cover within the study period in the HMA of Maçka.

There were positive changes in HMA of Maçka. There was a net increase of 200.6 ha of HMF areas between 1973 and 2008. Though this amount seems negligible, it should be considered that a significant decrease in forests occurred between 1973 and 1984, before increasing again after 1984 by 626.5 ha (4.4 %). Other studies show similar results to those of this study. In another study in Maçka, the forest area increased from 56,903 ha (55.8 % of the study area) in 1975 to 60,865 ha (59.7 %) in 2000 was calculated. In spite of the growth of forest gaps and destruction, a rise of

1189 ha (4.2 %) was experienced in efficient forest lands (Çakır et al. 2008).

Maçka experienced total growth of 3962 ha (7.0 %) in entire forested fields (Çakır et al. 2008). In another study by Çakır that was conducted in Trabzon, forest area decreased from 244,543 ha (46.2 % of the study area) in 1975 to 220,128 ha (41.6 %) in 2000. The amount of efficient and destroyed forest lands declined between 1975 and 2000. In contrast to the growth experienced in the second period (1987–2000), the total amount of forest and destroyed forest lands reduced between 1975 and 1987. There was a significant alteration in mixed forest when 106,821 ha (20.2 %) of study field in 1975 declined to 59,580 ha (11.3 %) in 2000; there was a decrease of total forests of 24,416 ha (4.6 %). A decrease of 24,416 ha (4.6 %) was reported to have been experienced in entire forest fields in Trabzon as a total alteration (Keleş et al. 2008). In a study of forest planning also by Keleş, a net decline of 300 ha in forest openings between 1972 and 2002 was documented, as opposed to the net increase of 409 ha in settlement and agricultural areas in Artvin, which is also located in the Eastern Black Sea region. The area of broadleaf forest and mixed forest rose to 110 and 105 ha, respectively, and areas of conifer forest and damaged forest fell to 144 and 222 ha, respectively. As an overall change, there was a net decrease of 450 ha in total forested areas (Keleş et al. 2008).

Similar results have been found in studies conducted by Kadıoğulları and Başkent (2008). In a study conducted in Gümüşhane, which shares borders with Maçka, the percentage of forest cover decreased from 23.67 % in 1971 to 23.14 % in 1987, based on stand-type maps. The percentages of accumulated forest damage in the entire Gümüşhane forested and forest-industry area (2271 ha) between 1971 and 1987 were 0.52 and 2.22 %, respectively. According to supervised categorized Landsat maps, an increase of around 24.5 % occurred in the forest cover of Gümüşhane forest industry in 1987, and in 2000, this percentage changed to 26.1 % (6928 ha). The percentage of the accumulated forest development (6928 ha) of Gümüşhane between 1987 and 2000 was 1.6 % and 6.54 % for Gümüşhane forested area (Kadıoğulları and Başkent 2008).

Based on stand-type map, forest cover in the Inegol forest industry increased from 33.7 % in 1972 to 37.0 % in 1993 and forest cover in Inegol forest industry increased from 34.1 % in 1987 to 40.9 % (12,097 ha). Cumulative forest improvement comprised 3.3 % of the Inegol forest industry (5836 ha) and 9.73 % of the forested area of the Inegol from 1972 to 1993, which meant an average 0.44 % annual rate of forest improvement. A subsequent analysis of stand-type maps of Inayet and Yenice forest planning units showed that forest cover in this area increased from 29.8 % in 1972 to 36.9 % in 2004 (Başkent and Kadıoğulları 2007). Locational analysis conducted between 1987 and 2010 in Tunceli showed that the forest area increased to 151,005 from 106,229 ha on a class area basis.

Open areas and areas covered with water were shown to have decreased in the region at rates of 5.5 and 0.3 %, respectively (Kadıoğulları 2012). Moreover, according to Karahalil's study of stand pattern maps, a decline of 5.6 % in the stands in Köprülü Canyon occurred between 1965 and 1984. The NPs in the entire area provided an accumulated forest expansion of 1.9 % (548.7 ha). The annual forest expansion was also 12.7 ha (Karahalil et al. 2009). According to a study carried out in India, the rate of deforestation was high in Tripura (0.9 %), Mizoram (0.63 %), and Meghalaya (0.62 %) between 1972 and 1982. The rate of deforestation was high in Nagaland (0.11 %) from 1987 to 1989. There was a parallel tendency in disintegration from 1989 to 1993. The rate of deforestation grew in entire states and the highest amount of 0.3 % was seen in Assam, followed by Mizoram. In accordance with new developments in categorization approaches, digital forest cover map categorization was used by the FSI between 1993 and 1999 and small fragments of forests could then be described. The increased sensitivity meant that the deforestation proportion was different and the highest rate was 0.49 % in Nagaland, followed by Mizoram at 0.43 %. Open forests had risen and a growth was seen in forest cover, especially in Assam and Tripura (Lele and Joshi 2009). According to a study undertaken by the Ballıbucak Planning Department, which is part of Köprülü Canyon NP, there was around 0.5 % (63.6 ha) growth in damaged forests and an 850 % (37.4 ha) increase in urban fields. Contrary to this, there was a 3.2 % (97.5 ha) decline in open fields and a 0.4 % (18.8 ha) fall in effective forest lands between 1965 and 2004 (Karahalil et al. 2007).

Between 1973 and 1984, the annual deforestation rates were 1.4 % in PF, 9.6 % in DF, and 0.3 % in total forest areas (HMFs) in the town of Maçka, and from 1984 to 2008, it was 0.6 % in PF, 3.5 % in DF, and 0.2 % in total forest areas. The annual rate of forestation for the general forest areas within the study period was 0.04 %.

This rate is very low when compared with others. Despite this, Achard et al. (2002) estimated an annual deforestation rate of 0.38 % of humid tropical forest in Latin America. According to a study that was carried out in the Colombian Amazon (Armenteras et al. 2006), the loss of natural ecosystems was 28 % in 2001 and 68.57 % in Macarena in Alto-Putumaya, which is close to the Andes and the largest transformation area. Moreover, the yearly highest mean of natural ecosystem fall was seen in these places. The yearly highest value of loss of 3.73 % was in Putumayo, the second was seen in Macarena (0.97 %), and the third was in Mitu (0.31 %), and other values were 0.23 % in Inı'rida-Matave'n and 0.01 % in Pure. Lele and Joshi (2009) separated the areas as dynamic and non-dynamic in terms of the change in forest cover. According to Lele's field investigation, the reason for the loss of 40 % in dynamic fields was the sudden alteration in forest cover. This was approximately 97,875 km^2. The percentage of less dynamic fields was 23 % and more dynamic fields 17 % of all dynamic fields. It is also known that 60 % of the area is categorized as non-dynamic because no alteration has occurred since 1972 (Lele and Joshi 2009). Zheng et al. (1997) found that the yearly amount of damage to forests was 1.12 % in the outer spaces of the Changbai Biosphere Reserve in China.

In a study for the Maçka Department of Forestry, the annual forestation rate of Maçka was calculated to be 152 ha year^{-1}, equivalent to 0.27 % year $^{-1}$ (Çakır et al. 2008). In another study in Trabzon, between 1975 and 2000, the average annual deforestation rate was calculated to be 977 ha year^{-1}, equivalent to 0.42 % year^{-1} (Keleş et al. 2008). The annual forestation rate has been calculated as 1.52 % between 1987 and 2010 in a study conducted in Tunceli (Kadıoğulları 2012).

The amount of NP in the study field rose to 388 and 711 in the respective years of 1973 and 2008. It can be understood that forest landscape was broken into pieces, and this affected biodiversity and the ecosystem in a negative manner while considering the rise of the amount of fragments and the decrease of MPS (from 210.7 to 107.9 in the same period) (Günlü et al. 2009). In response to this, the decrease in the values of LPI (from 12.3 to 8 in the same period) and MPS stems from the open areas being terminated by the areas that show a tendency for forestation as a result of the decrease in the pressure on forest areas. For this reason, when the whole area is evaluated, it can be said that the area takes a partite structure with the effect of forestation (Kadıoğulları 2012).

There are a few reasons for the increase in the HMFs of Maçka. The first of these is the change in the demographic structure in Maçka and the plateaus and the reflections of this change on daily life. The plateaus that neighbor HMFs are an important part of rural life. Generally, they are the settlement places that are seasonally used, especially during the summer for the purpose of grazing, by forest villagers who receive a very small share of the gross national product. Human-sourced activities such as cutting and opening (illegal cutting of trees and to illegal deforestation for new field and new house land), which may cause the areal losses and structural deformations in HMFs, still continue in these areas. In the 1970–2008 period, the demographic structure of Maçka significantly changed and increased by 66.7 %. Despite the 72.2 % decrease in the population of rural areas, an increase of 271 % occurred in the populations of city centers. Relative to this change, there was also a 27.4 % decrease in the number of the families that moved to the plateaus between 1973 and 2008. Although 90.5 % of the villagers who came to the plateau in 1973 lived in villages, this decreased to 62.1 % in 2008; economic reasons formed 60.8 % of the factors behind this migration. The annual mean income per person of those who came to the plateaus in 2008 was 3718 USD. This is much lower than the mean 9881 USD of Turkey for the same year (Anonymous 2010). Of those who came to the plateaus, the annual income of those officially living in villages was 2318 USD, that of those living in town was 3476 USD, that of people living in a city was 6908.8 USD, and that of those living abroad was 9211 USD. This created a pressure-decreasing effect on HMFs by changing the intentions of those coming to the plateaus, giving opportunities for the use of alternative energy sources and meeting the need for wood from the city or town. Relative to the migration experienced in the region and the changing life styles, the use of wood also decreased with the decrease in transhumance and stockbreeding. Due to the decrease in stockbreeding and inspections from authorities, the decrease in the number of the goats that fed in the region also decreased the pressure on HMFs and contributed to the increase in forest areas.

Together with the expansion of the use of durable consumption goods, the use of different energy sources as a substitution for wood became more common, for example, the use of gas bottles for cooking and heating water. Moreover, coming and going from plateaus became easier with the use of private cars and transportation vehicles. It became easier for those going to the plateaus to bring the wood they gathered from their gardens in the valley or bottled gas. All these developments became elements that decreased the pressure on forests.

Also, the duration of the stay in dwellings on the plateaus changed in parallel with the change in socio-economic life; there was a net decrease in the duration of the stay in dwelling in plateaus. The mean duration of stay in dwellings on the plateaus between 1973 and 2008 decreased per year from 125 to 94 days, and the amount of wood consumed also decreased.

The amount of insulation on the plateaus is low, and the change from the traditional stone or wooden architectural style to concrete-reinforced structures is another factor that decreased the use of wood. Between 1973 and 2008, while the number of wooden and stone houses decreased at rates of 20 and 10 %, respectively, the rate of concrete-reinforced houses increased at a rate of 30 %.

Consequently, observation and evaluation continues to be important. Observations and evaluations of land use and forest cover are especially important for an efficient management of the ecosystem.

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