

Assessing implications of land use and land cover changes in forest ecosystems of NE Turkey

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Abstract Monitoring land use and land cover change (LUCC) and understanding forest cover dynamics is extremely important in sustainable development and management of forest ecosystems. This study analyzed the spatial and temporal pattern of LUCC in the Yalnızçam and Uğurlu forest planning units which are located in the northeast corner of Turkey. The investigation also evaluates the temporal changes of the spatial structure of forest conditions through the spatial analysis of forest-cover type maps from 1972 and 2005 using geographical information systems and FRAGSTATSTM. As an overall change between 1972 and 2005, there was a net increase of 1,823 ha in forested areas, and cumulative forest improvement accounted for 2.06 %. In terms of spatial configuration, the landscape structure in the study area changed substantially over the 33-year study period, resulting in fragmentation of the landscape as indicated by large patch numbers and smaller mean patch sizes, owing to heavy grazing, illegal cutting, and uncontrolled stand treatments.

Keywords Environment monitoring · FRAGSTATSTM · Spatial analysis · Forest dynamics · Grazing

Introduction

In recent times, land use and land cover change (LUCC) analysis has become a fundamental tool in assessing the environmental and ecological consequences of human activity (Flamenco-Sandoval et al. 2007). In addition to pressures on forest ecosystems, changes in LUCC have had important effects on biodiversity, soil conservation, water quantity and quality, and world climate (Iida and Nakashizuka 1995; Johnson et al. 1997; Chen et al. 2001; Dupouey et al. 2002; Upadhyay et al. 2005; Liu et al. 2006; Park and Stenstrom 2008; Xu et al. 2007; Kadioğulları et al. 2008; Pavón et al. 2003; Karnieli et al. 2008). Main causes of LUCC are influenced by human activities such as population pressure, high population density, increasing demand of land for agriculture, wood production/illegal cutting from forests, and overgrazing (Kennedy and Spies 2004; Wakeel et al. 2005; Cayuela et al. 2006; Çakır et al. 2008). All of these reasons have made LUCC a major topic in the sustainable management of natural resources.

LUCC is shortly defined as conversion from one land cover type to another (Turner and Meyer 1994). Forest cover is one of the land cover types. Forest ecosystem structure refers to the spatial characteristics of ecosystem patches including their size, shape, composition, and spatial arrangement. Depending on these characteristics, forest ecosystems provide several environmental and economic functions such as timber, fuel wood, fodder, water and soil protection, carbon

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sequestration, oxygen production, recreation, aesthetics, biodiversity, and habitat for wildlife species (Köchli and Brang 2005; Keleş et al. 2007; Başkent et al. 2008; Padilla et al. 2010). A sustainable flow of these functions are influenced by forest ecosystem characteristics. Forest dynamics refers to the change of forest structure and function over time (Başkent and Jordan 1995a, b; Kadioğulları and Başkent 2008; Başkent and Kadioğulları 2007). Understanding these factors is critical to the sustainable management of natural resources because LUCC and forest cover change are extremely important factors in an ecosystem's condition and function.

However, it is difficult to understand the historical LUCC dynamics and help design better forest management and environmental policies for a given country without quantifying the rate and amount of land cover change over time. For explaining LUCC dynamics, there are various methods that can be used in the collection, analysis, and presentation of natural resources data. GIS technologies can greatly facilitate the process, and some spatial statistics programs, such as FRAGSTAT, can be effectively used in determining the changes in land use and forest cover. These contemporary tools are important and useful for both visual assessments of LUCC dynamics occurring at a particular time and space as well as quantitative evaluation of land use and forest cover changes over time (Gautam et al. 2003; Sivrikaya et al. 2007; Çakır et al. 2007; Keleş et al. 2008; Kadioğulları et al. 2008).

This study analyses the spatial and temporal pattern of land use/land cover change in two forest-planning units in the northeastern of Turkey, during 1972–2005 period based on forest stand type maps using GIS and FRAGSTATS—a spatial statistics program. The area was chosen as a pilot study site for a number of reasons: (1) the sub-temperate forests, lying in a biogeographic corridor between the Mediterranean and Central Asia, are within the Caucasian hot spot area that is globally recognized as among the most biologically rich areas on Earth; (2) the forests are truly unique where Scots pine grows well up to 2,700 m in elevation with higher wood quality; (3) welfare of the local population is extremely low creating a pressure on forests resources. In this context, the objective of this study is to contribute to the understanding of the patterns of degradation and development in the temperate forests of northeastern Turkey, where indigenous communities play a central role in the creation

of land use/cover pattern. The study focuses on detecting and documenting changes in major land cover type in general and forests patterns in particular, in a representative mountain watershed of a forest management planning unit between 1972 and 2005, and analyzing patterns of changes in landscape during the period by using a few important landscape indices measuring forest fragmentation.

Material and methods

Study area

The study area including Yalnızçam and Uğurlu Forest Planning Units is located in Ardahan city in the north-eastern corner of Turkey, UTM European 50 datum 37; zone 268520–307850 E, 4518730–4566880 N. The area consists of primarily high mountain forests and scattered settlements such as villages and upland shelter lands. The altitude varies between 1,800 and 2,920 m with an average slope of 23 % (Fig. 1). Within the Caucasian biodiversity hotspot, the area is surrounded primarily by Yalnızçam Mountains and is partly covered by the important plant area designated by WWF in 2003 with 77 endemic and 43 rare plant taxa (Özhatay et al. 2003).

Naturally, the region is covered by *Pinus sylvestris* L., the most widely distributed species in the world and its two varieties have been recognized such as *P. sylvestris* var. *sylvestris* and *P. sylvestris* var. *hamata* Steven. The variety *hamata* is now recognized as a disjunct regional population distributed in Balkans through N Turkey to the Caucasus Mountains (Frankis 2000). In Turkey, the species is in its most southern site of world distribution. The woody understorey of this unique steppe coniferous forest site is predominantly *Vaccinium myrtillus* L., *Rubus idaeus* L., and *Juniperus communis* L. var. *saxatilis* Pall. From plant geographical point of view, study area is located in transition zone between Colchis sector (in Euxine province of Euro-Siberian region) and Irano-Turanian region of Turkey.

Database development

The spatial database, developed as part of this study, consisted of forest cover type maps. The forest cover type maps of 1972 at 1/25,000 scale cover type map were produced with 1/23,000 scale black and white

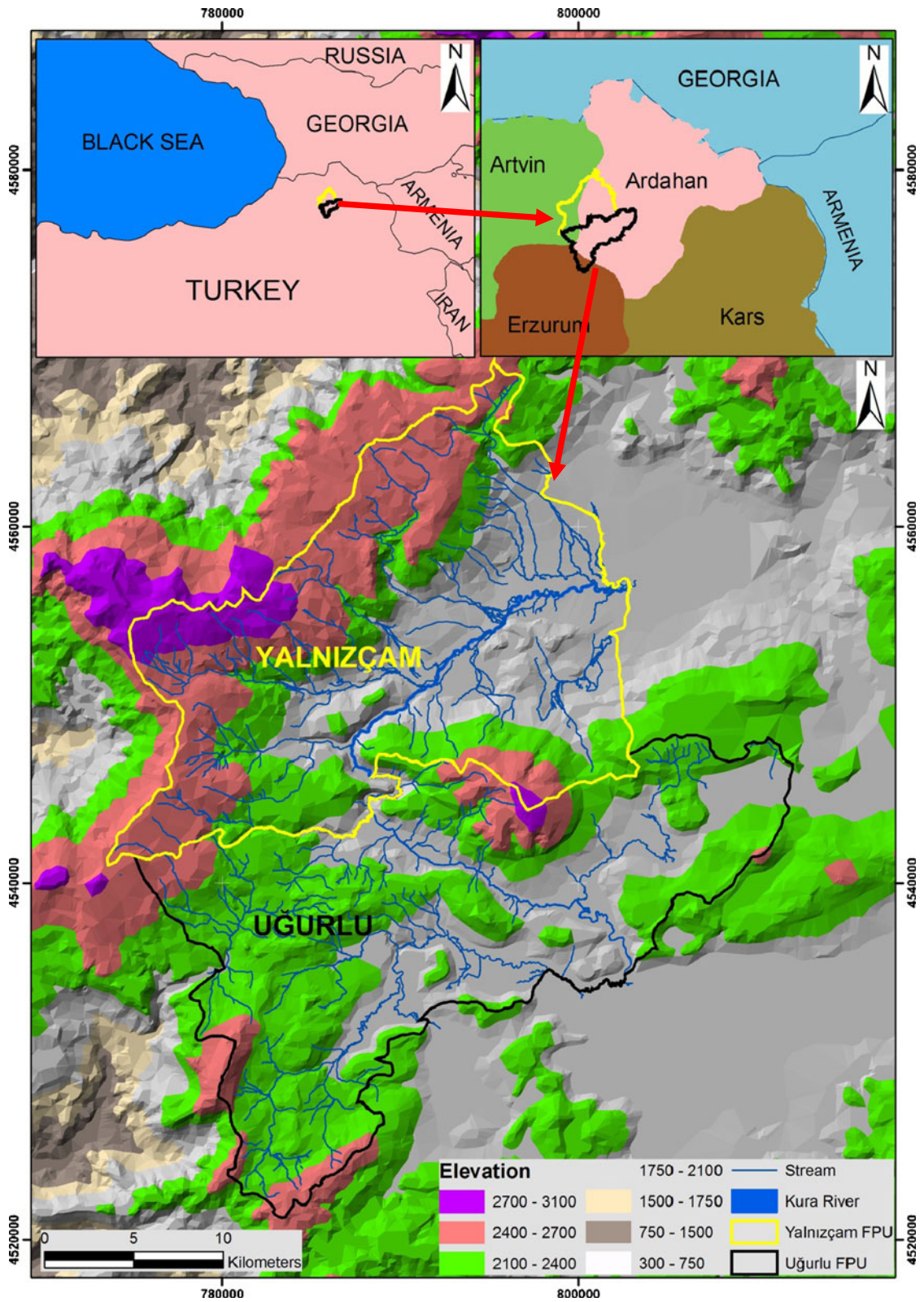


Fig. 1 Map of the study area

aerial photos. The forest stand type maps of 1972 used in this research were first scanned and then georeferenced using 1/25,000 scale topographical maps with UTM projection (ED 50 datum) using first-order nearest neighbor rules. Rectified forest stand type maps were digitized with a 1/3,000 to 1/5,000 screen view scale by a number of qualified foresters with substantial GIS experience. The map of 2005 was derived from the remote sensing data (with 1 m resolution of IKONOS images on August 13, 2005) and field survey in 2005. IKONOS images were obtained from the General Directorate of Turkish Forestry. The forest cover type or stand map was derived from visual interpreting high-resolution satellite images and rectified with field survey data. Systematic sampling accommodated the design of sample points to conduct the field survey. Circular sample plots were generated and distributed over the forest with 300×300-m intervals and located with GPS. The information technologies such as GIS, RS, GPS, and database management system were acquired to establish spatial forest information system necessary for mapping and monitoring spatial and temporal dynamics of forest ecosystem. The spatial database included stand attributes such as species mix, crown closure, and development stages. Previously generated hard copy maps were digitized and processed using Arc/Info version 9.0 GIS with a maximum root mean square (RMS) error below 10 m.

Both landscape and class level spatial statistics for each patch and class in the landscape were calculated using FRAGSTATS. As known, these parameters are approximate or indirect measurements of structural plant diversity in a landscape that quantify both composition and spatial configuration of patches. Diversity measures have been used extensively in a variety of ecological applications and gained popularity as measures of plant or animal species diversity (McGarigal and Marks 1995).

In addition to measuring diversity with a number of measurements, it is also important to understand forest dynamics over time. Here, understanding the dynamics of forest loss is critical for the management and conservation of biodiversity. 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.

Spatial analysis

In addition to analyzing the changes in the amount of land and forest cover types, the temporal transitions among the cover types were also documented and evaluated to see the temporal dynamics through various indicative parameters of both composition and configuration of forest resources (Table 1). The transitions were evaluated using periodic results of management plans. The land use, development stage, and crown closure polygon themes for 1972 and 2005 were overlaid and the area, converted from each of the classes to any of the other classes, was computed using GIS overly commands. 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 measurements as approximately to quantify and spatially analyze the change in spatial structure as demonstrated by Başkent and Jordan (1995a, b) and McGarigal and Marks (1995).

Specifically, we used the FRAGSTATS (McGarigal and Marks 1995) to quantify landscape structure of Ardahan State Forests for each of the land use classes. FRAGSTATS calculates a number of spatial measurements for each patch, for each cover class as well as for the entire landscape. We analyzed selected parameters for the land use class for the landscape. Some class-level metrics were computed for the cover type maps of 1972 and 2005 years. The metrics were: class percent of landscape (PL), class area (CA; sum of the areas of all patches belonging to a given class, in map units), number of patches (NP), largest patch index (LPI; percentage of the landscape comprised by the largest patch), mean patch size (MPS; the average patch size within a particular class), patch density (PD; number of patches per 100 ha), patch size coefficient of variation (PSCV), and area weighted mean shape index (AWMSI; the average perimeter to area ratio for a class, weighted by the size of its patches).

Table 1 Classification of crown closures and development stages

Crown closure types	Criteria (% cover)	Development stages	Criteria (average diameter at breast height (dbh))
0	Regenerated areas	a (regenerated)	<8 cm
Degraded forest	0–10 %	b (young)	8–19.9 cm
1 (low coverage)	11–40 %	c (mature)	20–35.9 cm
2 (medium coverage)	41–70 %	d (overmature)	>36 cm
3 (full coverage)	>71 %		

Results

Changes in land use and land cover

According to the digitized stand type maps from forest management plans between 1972 and 2005 years, there was a net increase of 1,823 ha in forest areas (productive and degraded forest areas). Productive forest areas increased 1,736 ha, degraded forest areas (degraded pure *Pinus silvestris*) increased 87 ha and open areas (agriculture, range land, shrub lands, and grasslands) decreased 1,823 ha (Table 2 and Fig. 2). As an overall change between 1972 and 2005, the percentage of forest cover in the Yalnızçam increased from 14.55 in 1972 to 16.61 in 2005 based on stand type map. Cumulative forest improvement accounted for 2.06 % as a whole (1,823 ha) and 14.13 % of the forested area of the study area from 1972 to 2005. This translates an average of 0.40 % annual rate of forest improvement.

Transitions among land use and land cover types

The transition among major forest cover types between 1972 and 2005 were determined based on forest

management plans (Table 2 and Fig. 2). A broad level analysis showed that about 966.9 ha productive pine areas changed into non-forest while 2,824 ha non-forest areas changed into productive pine forest areas, with a net increase productive pine areas of 1,736 ha. Open areas change into degraded coppice forest (Poplar) areas was about 192 ha, while degraded pine forest areas change into open areas was about 507 ha. Open areas change into settlement areas was about 633 ha, while settlement areas change into open areas was about 517 ha. Unchanged areas between 1972 and 2005; unchanged open areas 69,970 ha, productive pine 10,610 ha, settlement (residence areas) 1,121 ha (Table 2).

The transition among development stages between 1972 and 2005 were also analyzed using stand type maps. Around 325 ha of areas on young development stages (b) grew naturally into mature stage (c) while 297 ha in d stage converted into a stage possibly through regeneration activities (Table 4). Around 69.7 ha of degraded forests was regenerated (a stage), 1,341 ha of open areas afforestation and developed into “a” stage. The last one shows that afforestation activities are important factors to explain forestation.

Table 2 The transition matrix of land cover/land use change in the study area from 1972 to 2005

1972 land cover/land use type	2005 land cover/land use type						
	Settlement Area (ha)	Degraded coppice Area (ha)	Degraded pine Area (ha)	Open areas Area (ha)	Productive pine Area (ha)	Water Area (ha)	Landscape Area (ha)
Settlement	1,121.7	0.0	0.0	517.9	3.8	0.0	1,643.3
Degraded coppice	0.0	0.0	0.7	0.9	3.0	0.0	4.7
Degraded pine	0.3	0.1	96.5	506.8	268.4	0.0	872.0
Open area	633.7	192.0	228.2	69,970.3	2,874.7	0.0	73,898.9
Productive pine	0.6	15.6	430.9	966.9	10,610.5	0.0	12,024.5
Water	0.0	0.0	0.0	0.0	0.0	197.8	197.8
Landscape	1,756.2	207.7	756.3	71,962.7	13,760.4	197.8	88,641.2

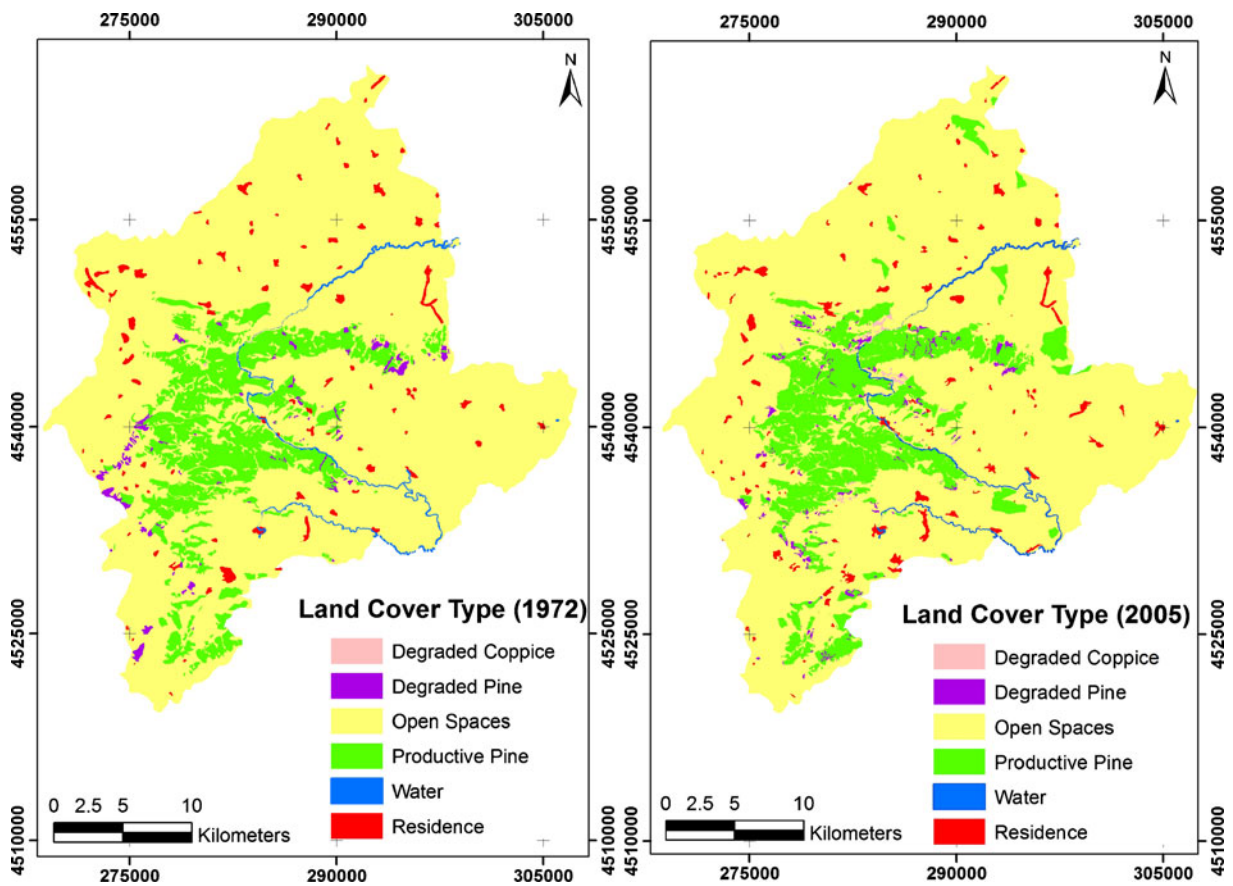


Fig. 2 Land use/cover map of the study area in 1972 and 2005

Further temporal dynamics or transition among crown closure between 1972 and 2005 stand type maps were analyzed subsequently. Nearly 2,035 ha of areas with full closure were thinned into medium

coverage, 952 ha of fully closed areas heavily thinned into low coverage, 2,726 ha of medium covered areas change into low covered areas and 385 ha medium covered areas developed into fully covered areas (Table 3).

Table 3 The transition matrix of crown closure classes in the study area from 1972 to 2005

1972 crown closure classes	2005 crown closure classes						
	1 Area (ha)	2 Area (ha)	3 Area (ha)	Degraded coppice Area (ha)	Degraded pine Area (ha)	Open areas Area (ha)	Total Area (ha)
1	382.1	45.8	10.9	3.6	122.4	209.3	774.1
2	2,726.7	2,932.2	385.2	7.6	226.2	465.6	6,743.5
3	952.6	2,035.3	1,139.6	4.5	82.3	292.5	4,506.9
Degraded coppice	0.0	3.0	0.0	0.0	0.7	0.9	4.7
Degraded pine	216.3	43.8	8.3	0.1	96.5	507.1	872.0
Open areas	2,217.4	535.8	125.3	192.0	228.2	72,441.3	75,740.0
Total	6,495.2	5,596.0	1,669.3	207.7	756.3	73,916.7	88,641.2

Patterns of forest structure

The stand type maps were further analyzed to see any changes in forest structure. In terms of crown closure change, between 1972 and 2005 years, stands with the crown closure 3 (>70 %) decreased about 3.20 % of landscape, crown closure of 1 (11–40 %) increased about 6.45 % of landscape, crown closure of 2 (41–70 %) decreased about 1.29 % of landscape, and crown closure of degraded forest (<10 %) increased about 0.10 % of landscape. Generally, changes of crown closures show that, between 1972 and 2005 years, 2 and 3 crown closure areas decreased, 1 crown closure areas increased, degraded forest increased and quality of forest structure is decreased (Table 3).

Another parameter to analyze the change in the quality of forest structure is the developmental stages of forest ecosystems. According to stand type maps, the forest in 1972 were mostly subdivided into b (young), bd (mature), db (mature and overmature), and d (overmature) development stages with the areas of 1,538, 3,661, 4,321, and 2,409 ha, respectively (Table 4). In 2005, the forest is generally concentrated into a (regenerated), cd (mature and overmature), and d (overmature) development stages (Table 4). This change shows that regenerated areas are adequate for sustainable forestry because of the increased of a stages. The rest of the area was left to grow into older development stages. Overall implication is that the forest is developing to older stages.

The spatial analysis of the landscape pattern indicated that the total NP increased from 469 to 650 between 1972 and 2005 as all patch types were taken into account. Mean patch size decreased from 189 to 136.4 ha. The MPS of degraded pine areas changed significantly from 11.2 to 5.0 ha between 1972 and 2005. Similarly, the MPS of open areas changed from 754 to 557 ha. Reasons for these changes in open areas probably relate to the net decrease of 1,823 ha in patch size and a net increase of 31 patches (Table 5). However, beside the number of patches increased from 152 to 165 in 33 years, MPS of productive pine areas increased 79.1 to 83.4 ha. Reasons for these changes in productive pine areas probably relate to the net increase of 1,823 ha in patch size and also this changed areas not adjacency to old forest areas. Similarly, area weighted shape index value increased from

Table 4 The transition matrix of development stages in the study area from 1972 to 2005

	1972 development stages										2005 development stages										Total Area (ha)		
	a	bc	c	c/a	cd	cd/a	d	d/a	degraded pine	degraded poplar	Open areas	a	bc	c	c/a	cd	cd/a	d	d/a	degraded pine		degraded poplar	Open areas
A	0.0	0.0	0.3	0.0	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1
b	28.5	7.1	325.1	115.7	821	9.6	89.3	4.0	24.1	2.2	111.8	1,537.9	111.8	7.8	89.3	2.2	111.8	4.0	24.1	2.2	111.8	1,537.9	1,537.9
bc	0.0	0.0	18.4	0.0	55	0.0	8.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	89.3
bd	19.6	21.9	331.8	0.0	2,532	0.0	368.4	28.3	109.8	5.2	244.6	3,660.9	244.6	7.8	89.3	5.2	244.6	28.3	109.8	5.2	244.6	3,660.9	3,660.9
d	110.9	0.0	67.1	0.0	525	0.0	856.2	279.6	220.0	6.3	343.7	2,409.1	343.7	7.8	89.3	6.3	343.7	279.6	220.0	6.3	343.7	2,409.1	2,409.1
d/a	0.0	0.0	2.6	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0
db	186.1	5.0	101.2	0.0	2,691	0.0	869.2	131.5	77.1	2.0	258.2	4,321.2	258.2	7.8	89.3	2.0	258.2	131.5	77.1	2.0	258.2	4,321.2	4,321.2
Degraded coppice	0.0	0.0	0.0	0.0	3	0.0	0.0	0.0	0.7	0.0	0.9	4.7	0.9	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7
Degraded pine	69.7	0.0	7.2	13.8	115	0.0	56.0	6.5	96.5	0.1	507.1	872.0	507.1	7.8	89.3	0.1	507.1	6.5	96.5	0.1	507.1	872.0	872.0
Open areas	1,341.4	5.5	84.9	52.3	919	1.1	334.5	139.6	228.2	192.0	72,441.3	75,740.0	72,441.3	7.8	89.3	192.0	72,441.3	139.6	228.2	192.0	72,441.3	75,740.0	75,740.0
Total	1,756.2	39.4	938.5	181.8	7,662	10.7	2,582.1	589.4	756.3	207.7	73,916.7	88,641.2	73,916.7	7.8	89.3	207.7	73,916.7	589.4	756.3	207.7	73,916.7	88,641.2	88,641.2

Table 5 Change of landscape pattern in the study area (1972–2005 forest cover type maps)

Land cover/land use type	Class area (ha)		Number of patches (no.)		Mean patch size (ha)		Percent of landscape (%)		Largest patch index (%)		Patch density (number of patches per 100 ha)		Patch size coefficient of variation (%)		Area-weighted mean shape index	
	1972	2005	1972	2005	1972	2005	1972	2005	1972	2005	1972	2005	1972	2005	1972	2005
Settlement	1,643.3	1,756.2	103	121	16.0	14.5	1.85	1.98	0.13	0.10	0.12	0.14	111.3	116.1	1.5	1.7
Degraded coppice	4.7	207.7	1	48	4.7	4.3	0.01	0.23	0.01	0.03	0.00	0.05	0.0	138.3	1.1	1.9
Degraded pine	872.0	756.3	78	150	11.2	5.0	0.98	0.85	0.09	0.04	0.09	0.17	136.6	127.9	1.8	2.4
Open areas	73,898.9	71,962.7	98	129	754.1	557.9	83.37	81.18	55.96	54.08	0.11	0.15	732.9	835.9	9.0	9.8
Productive pine	12,024.5	13,760.4	152	165	79.1	83.4	13.57	15.52	3.72	7.59	0.17	0.19	425.4	652.4	4.8	7.7
Water	197.8	197.8	37	37	5.3	5.3	0.22	0.22	0.17	0.17	0.04	0.04	472.9	472.9	22.8	22.8
Landscape	88,641.2	88,641.2	469	650	189.0	136.4	100.00	100.00	55.96	54.08	0.53	0.73	1,343.9	1,539.6	8.2	9.2

8.2 to 9.2. However, patch density value increased from 0.53 to 0.73 and PSCV (%) value increased from 1,343.9 to 1,539.6 between 1972 and 2005 years. All these changes showed that landscape fragmentation increased and the forest has become more susceptible to harsh disturbances.

Development of socio-economic factors

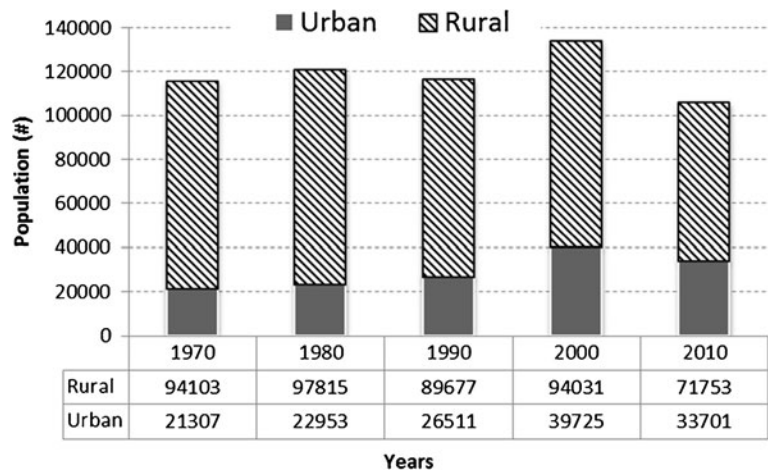
Aside from the natural resources management, socio-economic considerations also play a role in landscape pattern (Sivrikaya et al. 2007). Demographic changes in Ardahan City have been considerably varied between 1970 and 2010 (Fig. 3). This figure shows that there is no important changing in total population of Ardahan City over 40 years. However, while urban population increased (58 %) from 1970 to 2010, rural population decreased (23 %) in this period. In one hand, small farms were abandoned followed by urbanization as many people left the rural areas to become resident in urban centers for better job opportunities. On the other hand, increase in the urban population has not changed the human pressure to forest areas, probably resulting in a negative development of forest ecosystems.

The income of the local people is extremely below the average national GDP (Fig. 4) and their livelihood depends only on animal husbandry and forestry activities. The forest ecosystems are heavily influenced by over grazing (Fig. 5), land conversion to agriculture and rangeland, and cutting of the forest for firewood (Fig. 6). Forests are, however, important natural resources for local communities who graze the areas, clear them for agriculture, and cut them for firewood. Squeezed by the dilemma, the forests are overexploited, degraded, and fragmented generating additional problems such as increased soil erosion, deregulated water resources, and decreased productivity of grazing and agricultural land. As a result, a cycle of increased rural poverty and degraded natural resources are created that persuade migration of local people from the region.

Discussion and conclusion

This study analyzed the spatial and temporal pattern of land use/land cover change in a forest ecosystem covering Yalnızçam and Uğurlu forest management

Fig. 3 Human population change in Ardahan State between 1970 and 2010



planning units in the northeastern Turkey. The digitized stand maps from periodically renewed forest management plans from 1972 to 2005 with GIS and FRAGSTATS were used to analyze land use/land cover and the spatial configuration of forest resources. The quantitative evidences of land use/land cover dynamics presented here showed that there were drastic changes in the temporal and spatial patterns of land use/land cover classes, especially on forest resources in the study area.

The results showed that the total forested areas (degraded coppice, degraded pine, and productive pine) increased from 12,901 ha (14.6 %) to 14,724 ha (16.6 %) during the 33-year period. In other words, almost 4.5 % of open areas existing in 1972 had been replaced by forested areas by 2005. The observed trends of increasing forest and decreasing open areas in the study area could be explained by

the following two main reasons. First, plantation of degraded forestlands and open areas by the forest department has contributed to the increase in forest area. Second, effective protection operations helped the conversion of open areas to forests. The quantitative evidences of land use patterns also showed that human-based pressure such as heavy grazing and illegal cutting increased the degraded forest area from 875 to 964 ha.

In other words, cumulative forest improvement accounted for 2.06 % as a whole (1,823 ha) and 14.13 % of the forested area of the study area from 1972 to 2005. This translates an average of 0.40 % annual rate of forest improvement. Similar results from some important studies in Turkey are also shown. A research by Kadioğulları et al. (2008) in the same region of Turkey stated that the percentage of forest cover in the Torul forest enterprise increased from 42.95 in 1984 to



Fig. 4 An example of rural residential area from the case study area



Fig. 5 An example of livestock grazing from the case study area



Fig. 6 An example of illegal cutting from the case study area

51.20 in 2005 based on stand type map. This translates to an annual rate of forest improvement of 0.92 %. Besides, the same researchers in another study showed that the percentage of forest cover in İnegöl forest enterprise increased from 33.7 in 1972 to 37.0 in 1993 based on stand type map. Cumulative forest improvement accounted for 3.3 % of the İnegöl forest enterprise as a whole (5,836 ha) and 9.73 % of the forested area of the İnegöl from 1972 to 1993. This translates to an average 0.44 % annual rate of forest improvement (Baskent and Kadioğulları 2007).

These results are quite comparable to similar other research results. As known, annual disturbance rates for many other temperate forests have been generally higher. Our results are generally in line with Status et al. (2002) showed that forested areas decreased nearly 4.7 % with an annual rate of forest disturbance of only 0.53 and 0.57 % and yet forest fragmentation increased. However, Gautam et al. (2003) who presented a 5.2 % increase in forest of landscape between 1976 and 2000 years in Nepal. In the Sikhote-alinskiy Biosphere Reserve region of the Russian Far East, Cushman and Wallin (2000) showed 18.3 % reduction in

conifer forest cover between 1972 and 1992 and 7.4 % reduction in hardwood forests; fire played a major role in these totals. Zheng et al. (1997) reported 1.12 % annual rate of forest disturbance outside of the Changbai Biosphere Reserve in China. In a portion of the Central Oregon Cascades, Spies et al. (1994) reported annual forest disturbance rates of 1.2 % on public, non-wilderness lands, 3.9 % on private lands, and 0.2 % in wilderness. The Tillamook Bay watershed of mid coastal Oregon showed an annual forest disturbance rate of 1.0 % (Strittholt and Frost 1995).

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. Forest degradation in the study area is shown 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 heavy grazing of pastureland adjacent to forest areas, illegal use of forest resources, and ecosystem dynamics. The impacts are loss and conversion of some natural forest types, increase of productive forests because of regeneration activities in open areas, and exposure of some lands to soil erosion and carbon emission to the atmosphere.

The NP and their sizes are relatively good indices of fragmentation (Southworth et al. 2004; Echeverria et al. 2006). The general trend in the study area was towards an increase in the number of fragments and isolation of patches and a decline in the mean patch size. Therefore, the landscape progressed towards more fragmented structure as indicated with the increase in the number of forest patches and decrease in MPS and LPI. Mean patch sizes of almost all land use/type classes decreased from 189 to 136 ha. This rapid decline in MPS might be associated with a rapid increase in PD for the same period (0.53–0.73) and a substantial reduction in the size of the largest patch from 56 to 54 %. Area weighted shape index value increased from 8.2 to 9.2 indicating fragments with more irregular shape. Such trend signals a danger for the sustainability of forest resources and the resilience of the ecosystem mainly for biodiversity and to a lesser extent timber production.

The possible reasons for the increased fragmentation of the study area could be related to heavy grazing, illegal cutting, uncontrolled stand treatments, and natural breakdown forest structure. Indeed, it is not

possible to say that the population growth or urbanization has affected the dynamics of the forest structure because the total population (especially rural population) in the study area has decreased during the study period. There has also been a marked decrease in the rural population (who are generally blamed for forest degradation or depletion in most regions of the world).

Furthermore, in examining the changes in crown closure between 1972 and 2005 in forest management planning units, the results showed that fully covered areas were changed in favor of less covered areas. Some development stages was left to grow older development stages while some of the them changed to lower development stages as a result of potential reforestation activities of some open areas.

In terms of spatial configuration, the landscape structure in Yalnızçam and Uğurlu forest management planning units changed substantially over the 33-year study period, resulting in fragmentation of the landscape as indicated by the increase of patch numbers, smaller mean patch sizes, and the decrease of fully cover areas.

There are numerous factors behind the change of spatial landscape structures. There is a continuous social pressure of low-income local communities on forest resources. They fail in meeting their essential needs and earning sufficient income from forests. Rural community development projects, programs, and means are not sufficient. Participation of stakeholders is not adequate in sustainable management of forest ecosystems. There is a poor communication and collaboration among state forestry organization, forest villagers, local NGOs etc.

Also, solo timber-oriented forest management practices, uncontrolled and unplanned grazing of livestock, illicit harvesting, and fuel-wood utilization are among the causes of deforestation, forest degradation, and fragmentation. Last but not the least, there is a lack of sufficient knowledge, information, awareness, and interest about the biodiversity and other values of the forest ecosystems among the local communities and stakeholders.

Fragmented habitats are a major threat to the important ecosystems. In this context, developing as well as conducting conservation-based plans and programs should be promoted since they are vital tools to control the development of forest ecosystems over time. Restoration is an indispensable action that should be sustainably designed and implemented in the upcoming

forest management plans to connect fragmented patches and ameliorate degraded forest patches through forestation. An appropriate grazing plan is to be urgently prepared and conducted for organized livestock rising in the range land. An effective self- or auto-control mechanism is desirable to control the activities in the areas. Community development projects are needed to help halt the social conflicts and lessen the social pressure to forest resources.

Finally, there is a strong link between land use/forest cover changes and social pressure. For that reason, complex relationships between environmental, ecological, and socio-economical factors that induce changes and degradations in land use and forest cover should be studied and understood among the first priorities of sustainable development and management of forest resources.

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