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# The spatiotemporal forest cover changes in Köprülü Canyon National Park (1965 - 2008) in Turkey

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**Analyzing the historical legacy of forest structure and its temporal changes is paramount to design future forest management interventions in preparing an effective forest management plan in national parks. In this study, forest cover type maps prepared in 1965, 1984 and 2008 were digitized using geographic information systems and spatial database was built for nearly 36000 ha Köprülü Canyon National Park. Spatial data bases for three periods were used to determine temporal and spatial (number, size and spatial distributions of patches) changes of forest resources using FRAGSTATS™ program. The results indicated clear changes in the temporal and spatial dynamics of land cover/forest cover. Mixed forests increased about 151.7% (1570.7 ha) like agricultural and urban areas 39.8% (777.5 ha) and productive forests (crown closure > 10%) increased 21.9% (2838.8 ha) too, while other open lands decreased about 27.5% (1326.3 ha) and 459 ha pure cedar stands entirely converted mostly to the degraded and mixed forests from 1965 to 2008. In terms of spatial configuration, analysis of the metrics revealed that landscape structure in study area has changed substantially over the 43-year study period, resulting in fragmentation of the landscape as the total number of patches increased from 238 to 672 and mean patch size drop from 1615.0 ha to 425.3 ha markedly between 1965 and 2008. Geographic Information Systems (GIS) coupled with fragmentation analysis has a powerful role in analyzing spatiotemporal dynamics of forest landscape for effective national park planning.**

**Key words:** Land cover/ forest cover change, landscape metrics, Köprülü Canyon National Park, forest management plans.

## INTRODUCTION

Biological diversity is the basis of living resources which have an essential place in meeting the basic needs of human beings. It helps speed up the process of decomposition, chemical structure of the atmosphere and the world climate that can be secured through the sustainability of healthy and complex ecosystems. Forest ecosystems satisfy these vital tasks.

Forest ecosystems have also important values from economical and ecological perspectives providing many goods and services such as water and soil protection, carbon sequestration, tourism and recreation and non-wood forest products. To help ensure the sustainability of those forest values over time, forest ecosystems are generally reserved in-situ conservation programs such as

National Parks (NP), Nature Conservation Areas, Nature Parks or Wildlife Development Areas. While the NPs are designated to provide certain level of contributions to global conservation, they seldom meet all the functions for which they were designed for. Land use and spatial forest patterns of NP constantly face the danger of being displaced by rapid population growth, urbanization, over use and illegal cutting (Ruddle and Manshard 1981; Kirdar, 1992).

Protected areas such as NPs need to be designed and managed in a way to provide real benefits to society if they are to survive in a period of increasing demands on natural resources. Generally, changes in land use and forest cover have negative effects on biodiversity, soil and water quality and world climate when forest ecosystems were disturbed or deteriorated (Iida, 1995).

Generally, forest ecosystem structure refers to the spatial characteristics of ecosystem patches including their size, shape, composition and spatial arrangements.

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Ecosystem function encompasses the ecological processes and relationships that exist within an ecosystem quantified by its structural characteristics. Forest dynamics relay the change of forest structure and function over time (Baskent and Jordan, 1995a, b; Başkent and Kadioğulları, 2007; Kadioğulları and Başkent, 2008; Kadioğulları et al., 2008). To help understand the spatio-temporal dynamics of forest ecosystems and functions, it is necessary to quantify the ecosystem structure with certain metrics. In explaining forest dynamics, there are various methods that can be used in the collection, analysis and presentation of natural resources data. The use of remote sensing (RS) and Geographic Information Systems (GIS) technologies can greatly facilitate the process. As well, spatial statistics programs like FRAGSTAT have been effectively used in determining the changes in land use and forest cover.

Some recent applications of these tools have been reported by many researchers to illustrate spatiotemporal dynamics of land use and forest cover changes (Verburg et al., 1999; Kammerbauer and Ardon, 1999; Luque, 2000; Nagashima et al., 2002; Turner et al., 2003; Gautam et al., 2003; Kennedy and Spies, 2004; Zhang et al., 2004; Wakeel et al., 2005; Echeverria et al., 2006; Cayuela et al., 2006; Hayes and Cohen, 2007; Fan et al., 2008). To date, especially recently, there have also been some studies attempting to document the temporal changes in forest ecosystem patterns in Turkey using GIS and RS techniques (Yıldırım et al., 2002; Alphan, 2003; Aksoy and Özsoy, 2004; Tunay and Ateşoğlu, 2004; Musaoglu et al., 2005; Musaoglu et al., 2006; Doygun and Alphan, 2006; Kılıç et al., 2006; Karabulut et al., 2006; Guler et al., 2007; Başkent and Kadioğulları, 2007; Kadioğulları and Başkent, 2008; Keleş et al., 2008a,b; Günlü et al., 2009). Very few similar studies, however, are conducted both at international and national levels to take into account the spatial temporal dynamics of protected areas (Cushman and Wallin, 2000; Hayes et al., 2002; Sivrikaya et al., 2007; Karahalil et al., 2007; Genç and Bostancı, 2007).

These studies generally documented the spatial and temporal land use and forest cover changes as well as the factors affecting the processes. GIS and Remote Sensing techniques (RS) were used in these studies to provide technological infrastructure in examining land use and forest cover changes in any region. There is, however, a strong link between land use/ forest cover changes and social pressure indicated by urbanization, intensive agriculture and over use. For that reason, complex relationships between environmental, ecological and socio-economical factors that induce changes with degradations and historical dynamics including ecosystem composition or structure in land use and forest cover should be documented and understood for effective conservation and sustainable management of NPs.

This study analyses the spatiotemporal changes in land use and forest cover from 1965 to 2008 in a valuable

forest ecosystem of Turkey and assesses the role of various factors affecting these changes. The study covers a large scale analysis of forest ecosystem structure and cover change using spatial database of GIS based on stand type maps (called forest cover type map) focusing particularly on the Köprülü Canyon NP. The objectives of this study are:

- i) To detect and document changes in major land cover types and forest cover type structure in the Köprülü Canyon NP from 1965 to 2008.
- ii) To analyze patterns of changes in landscape of the study area with special focus on forest fragmentation.
- iii) To determine the success rate of Köprülü Canyon as a NP in terms of conservation of natural ecosystems.

## METHODS

### Study area

The study area is the Köprülü Canyon NP surrounding the city of Antalya and Isparta located in the southern Mediterranean Region of Turkey (324500 - 343000 E and 4143000 - 4110000 N, UTM ED 50 datum Zone 36N) (Figure 1). The study region is surrounded by the Sütçüler Forest Planning Unit in the north, the İkizpınar and Burmahanyayla Forest Planning Unit in the west, the Pınargözü and Akbaş Forest Planning Unit in the east and the Karabük Forest Planning Unit in the south.

Köprülü Canyon NP is characterized by dominantly steep and rough terrain conditions with an average slope of 55.7% and an altitude from 200 to 2500 m above sea level with a total area of 35452.8 ha. The vegetation type of the study area is primarily composed of the association of Calabrian pine (*Pinus brutia* (L) Link), Anatolian Black pine (*Pinus nigra* sub. *pallasiana*) and juniper (*Juniperus* sub.) species.

Major forest tree species include Calabrian pine, Anatolian Black pine, juniper, cedar, cypress, fir and oak. Winters are mild and rainy and summers are warm and dry. Mean annual temperature of the study area is 18.3°C, mean annual precipitation is 1140.5 mm and the main soil types are clay, sandy clay loam and sandy loam.

Köprülü Canyon forests, typical Mediterranean ecosystems, provide many goods and services to public, such as water, soil protection, carbon sequestration, recreation and especially the biodiversity. Thus, land-use/land cover changes, especially in forest cover, may have important consequences for all forest functions. The Park has outstanding landscape features such as the typical forest stands of Mediterranean region as unequal and valuable forest stands, habitats for wildlife, valuable sites for culture, interesting phenomena of geomorphology, springs of the Köprüçay River, habitat of wild goats and water fauna. Because of these outstanding features "General Directorate of Nature Conservation and National Parks" of Turkey declared Köprülü Canyon as a NP in 1973 as 15<sup>th</sup> national park of Turkey (Anonymous, 2009a).

The NP contains 950 plant taxon including 230 endemics, 32 mammals, 123 birds and 21 reptiles. Nearly 600 ha pure and mixed cypress forest is a unique vegetation habitat in the world (Anonymous, 2009b). The area also includes Köprüçay creek as an ecotourism potential with an ongoing rafting and canoeing activities in the lower part of the creek, starting from the ancient Oluk Bridge and finishing at the lower part of the Beşkonak village. There is also an important ancient city of Selge covering theatre and bazaar in the study area. The Park is thus exceptional in terms of vegetation cover, historical structure, aesthetics, eco-tourism and social aspects.

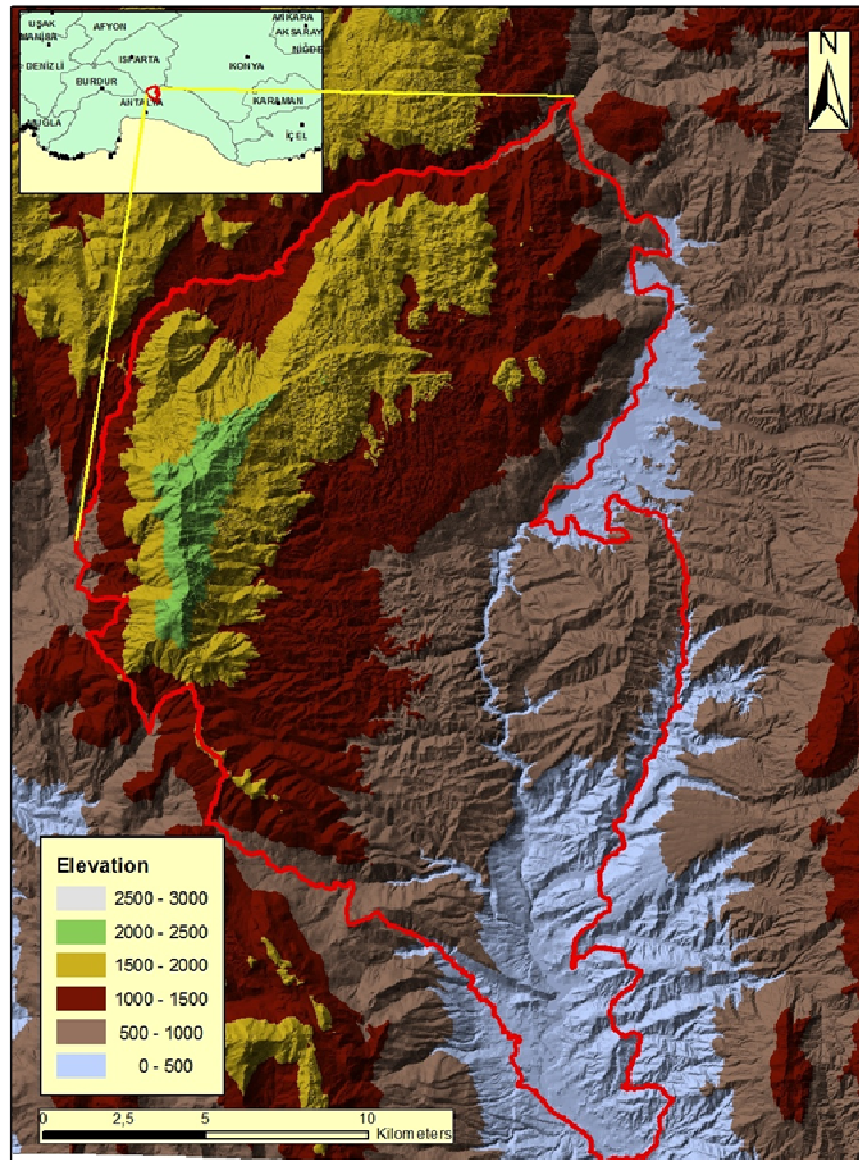


Figure 1. Location of the Köprülü Canyon National Park.

### Data acquisition and methods

GIS and RS techniques are used to acquire, build and manage spatial database of the study area. The database accommodates both forest stand type maps derived from RS data (aerial photographs and satellite images) and attribute data acquired from field survey. Aerial photographs of the study area were obtained from the General Directorate of Forestry (GDF), for the years 1963 (panchromatic aerial photographs at 1:20 000 scale), 1982 (panchromatic aerial photographs at 1:15 000 scale), 2004 (a meter resolution IKONOS images) and 2005 (color infrared aerial photographs, at 1:15 000 scale). Stand type maps, generated through the stereo interpretation of aerial photographs and field survey data in 1965 and 1984, were obtained from the GDF forest management plans (GDF, 1965; GDF, 1984; GDF, 2008). The 2008 stand type map was derived from interpreting aerial photographs, high-resolution satellite images and field survey. 656 sample plots were taken to generate the final stand type map.

A number of documents such as draft master plan, forest management plan, silvicultural prescriptions, harvesting activities, fire records, demographic change, economic conditions and living standards of local people were obtained and evaluated to determine socio-economic factors and management interventions influencing land use changes.

Coarse level classification approach was used in the study area. The classification refers to broad simplification of land covers with major land use types using stand types described by species composition and crown closure as well as non-forested lands (Table 1).

### Digitizing and geometric correction of stand type maps

The stand type maps used in this research were first scanned and then registered to the 1:25000 scale Topographical Maps with UTM projection (ED 50 datum) using first order nearest neighbor rules

**Table 1.** Land use/ land cover classes.

Land Cover/ Forest Cover Classes	Description
Juniper	Pure juniper stands with estimated > 10% tree crown closure
Anatolian B. Pine	Pure anatolian black pine stands with estimated > 10% tree crown closure
Calabrian Pine	Pure calabrian pine stands with estimated > 10% tree crown closure
Cedar	Pure cedar stands with estimated > 10% tree crown closure
Cypress	Pure cypress stands with estimated > 10% tree crown closure
Mixed	Mixed softwood areas and 400 ha pure oak stand
Degraded	Degraded stands with estimated < 10% tree crown cover
Open areas	Open forest lands, ranges, shrub lands and grasslands, water, sand, erosion lands and timber yards
Agriculture	Agriculture and settlement areas

with a maximum root mean square (RMS) error under 10 m. using GIS (ArcGIS 9.3). Rectified stand type maps were digitized with a 1:3000 to 1:5000 screen view scale. Afterwards, associated attribute data were entered into the computer to create the spatial database of the area.

#### Transition of land cover/ forest cover types

Both the changes in terms of selected land cover and forest cover types and the temporal transitions among the cover types were documented and evaluated to see the temporal dynamics among various parameters, indicative of both composition and configuration of forest resources. The land use and land cover class polygon themes for 1965, 1984 and 2008 were overlaid on top of each other and then the area of each unchanged or converted classes to any of the other classes was computed.

#### Changes in landscape patterns and spatial analysis

The spatial structure of the landscape is very important as it has implications for the design and management of forest resources besides non-spatial compositions (Başkent et al., 2000). The spatial dynamics of the forest landscape refers to the temporal change in size, number, shape, adjacency and the proximity of patches in a landscape. In this study we used a few metrics or measurements as proxy to quantify and spatially analyze the change in spatial structure as demonstrated by Başkent and Jordan (1995a,b) and McGarigal and Marks (1995). The Shape Complexity Index (SCI) is useful indicator especially in forested areas (Equation 1).

$$SCI = b/d \quad (1)$$

Where *SCI* is shape complexity index (m/ha), *b* is average perimeter (m) and *d* is average area of the patches (ha).

Higher *SCI* ratios indicate more irregular patch forms. Besides, the most important indicators of fragmentation are the number of patches and the increase in the number of smaller patches (Kammerbauer and Andon, 1999; Rao and Pant, 2001; Southworth et al., 2004; Echeverria et al., 2006). In order to study forest fragmentation processes, the land use/ forest cover maps for 1965, 1984 and 2008 were used to determine the number of forest patches, their perimeters and areas. The case study area was analyzed from the point of view of both land cover types (forest, agriculture, open areas) and forest cover types (pure forests, mixed forest and degraded forest). Forest patches are represented as stand types, characterized according to tree species, development

stages and crown closures. Non-forested areas have also been found in forest cover type maps and represented in the form of polygons.

We used FRAGSTATS (McGarigal and Marks, 1995) to quantify landscape structure of Köprülü Canyon NP for each of the land use classes. FRAGSTATS calculates a number of spatial metrics for each patch, for each cover class as well as for the entire landscape. We analyzed selected metrics for the land use class for the landscape. Some class-level metrics were computed for the cover type maps of 1965, 1984 and 2008 years. The metrics were: class Percent of Landscape (PL), Number of patch (NP), Largest Patch Index (LPI), Mean Patch Size (MPS), Patch density (PD) and Area Weighted Mean Shape Index (AWMSI).

## RESULTS

### Changes in land cover/ forest cover types

Area of each land use/ cover class for three periods is shown in Tables 2, 3, 4 and Figure 3. The land use/forest cover maps for 1965, 1984 and 2008 are also presented in Figure 2. According to the stand type maps from forest management plans, there was a net decrease of 1629.6 ha area in forested lands including pure, mixed and degraded stands. On the other hand, there was an increase area of 4906.6 ha between 1984 and 2008.

Open areas including open forest areas, ranges, water and other open lands including agriculture and settlement areas increased about 1629.7 between 1965 and 2008. These land classes decreased 2178.4 ha between 1984 and 2008. As an overall change between 1965 and 2008, there was a net increase of 1.9% of forested areas or stands (Table 4).

Pure Anatolian Black pine forests decreased 1241.3 ha (33.3%) between 1965 and 2008. Calabrian pine increased considerably 414.9 ha, but 459 ha. Cedar stands disappeared in the same period. Cypress stands, having a great value, decreased from 425.8 ha to 369.4 ha between 1965 and 1984 and then fell to 195.5 ha in 2008. Another case with a worth of attention is the increase of 1570.7 ha (151.7%) mixed forests between 1965 and 2008.

**Table 2.** The transition matrix of land cover/ forest cover change in Köprülü Canyon NP from 1965 to 1984.

1965 Forest cover/ land cover type	1984 Forest cover/ Land cover type									
	Juniper	A. Pine	C. Pine	Cedar	Cypress	Mixed	Degraded	Open	Agricul.	Total
Juniper	3.0	2.4	0.0	0.0	0.0	0.0	228.2	0.8	0.0	234.4
Anatolian Pine	0.6	1681.5	197.1	22.7	0.0	1183.2	497.0	105.5	33.3	3720.9
Calabrian Pine	0.0	62.5	5372.8	16.6	54.1	112.6	902.1	187.3	378.4	7086.5
Cedar	0.0	25.3	0.0	131.6	0.0	128.9	116.0	57.1	0.0	459.0
Cypress	0.0	0.0	56.3	7.2	301.7	0.0	47.7	0.0	2.9	425.8
Mixed Forests	0.0	248.6	36.9	90.3	0.0	408.1	202.3	48.9	0.0	1035.0
Degraded	0.0	115.9	1477.2	25.2	3.7	301.0	11494.0	1877.9	435.9	15730.8
Open areas	1.5	49.9	431.4	21.4	0.0	89.2	366.1	3431.2	419.2	4809.9
Agriculture	0.0	17.8	185.2	0.0	0.0	0.0	336.0	81.5	1330.1	1950.7
Total	5.1	2203.9	7756.8	315.1	369.4	2222.8	14189.5	5790.3	2599.9	35452.8

**Table 3.** The transition matrix of land cover/forest cover change in Köprülü Canyon NP from 1984 to 2008.

1984 Forest cover/ land cover type	2008 Forest Cover/Land Cover Type									
	Juniper	A. Pine	C. Pine	Cedar	Cypress	Mixed	Degraded	Open	Agricul.	Total
Juniper	0.0	0.5	0.0	0.0	0.0	0.0	1.1	3.5	0.0	5.1
Anatolian Pine	0.3	1489.7	111.5	0.0	0.0	300.4	269.3	21.8	10.9	2203.9
Calabrian Pine	0.0	85.7	6169.3	0.0	10.2	183.9	878.8	82.7	346.1	7756.8
Cedar	0.0	83.4	3.8	0.0	12.4	87.2	116.0	12.2	0.0	315.1
Cypress	0.0	0.0	49.7	0.0	153.2	112.2	54.3	0.0	0.0	369.4
Mixed Forests	0.0	399.2	54.3	0.0	0.0	1290.5	424.9	50.2	3.6	2222.8
Degraded	286.7	362.5	821.9	0.0	19.6	558.0	11619.2	182.8	338.7	14189.5
Open areas	2.9	52.9	81.1	0.0	0.0	71.5	2457.6	3027.2	97.1	5790.3
Agriculture	0.0	5.7	209.7	0.0	0.0	2.1	347.4	103.2	1931.8	2599.9
Total	289.9	2479.6	7501.4	0.0	195.5	2605.7	16168.8	3483.6	2728.2	35452.8

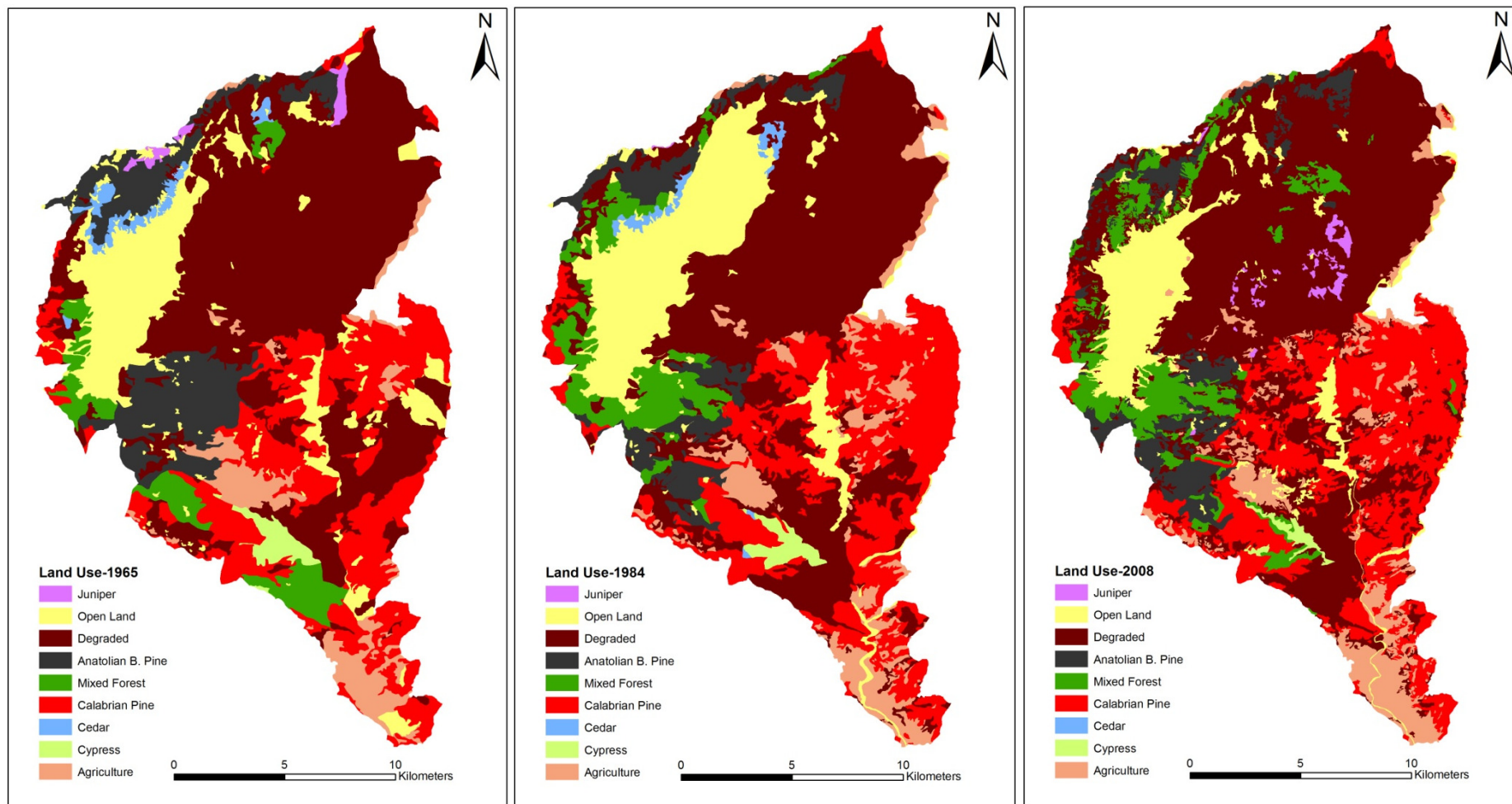
**Table 4.** The transition matrix of land cover/forest cover change in Köprülü Canyon NP from 1965 to 2008.

1965 Forest cover/ land cover type	2008 Forest Cover/Land Cover Type									
	Juniper	A. Pine	C. Pine	Cedar	Cypress	Mixed	Degraded	Open	Agricul.	Total
Juniper	2.2	5.9	0.0	0.0	0.0	25.2	193.8	5.9	1.3	234.4
Anatolian Pine	4.6	1547.6	229.2	0.0	0.0	1171.2	632.2	100.4	35.7	3720.9
Calabrian Pine	0.0	98.3	5073.2	0.0	28.9	164.0	1062.1	128.9	531.0	7086.5
Cedar	0.0	47.7	5.0	0.0	0.0	139.6	247.6	19.1	0.0	459.0
Cypress	0.0	0.0	71.5	0.0	159.1	122.1	71.1	0.0	2.1	425.8
Mixed Forests	0.0	425.5	14.6	0.0	0.0	355.9	220.1	18.8	0.0	1035.0
Degraded	279.8	272.6	1579.1	0.0	7.3	546.6	12315.8	310.4	419.2	15730.8
Open areas	3.3	77.2	386.3	0.0	0.0	74.8	1095.9	2745.9	426.4	4809.9
Agriculture	0.0	5.0	142.5	0.0	0.2	6.4	330.1	154.1	1312.3	1950.7
Total	289.9	2479.6	7501.4	0.0	195.5	2605.7	16168.8	3483.6	2728.2	35452.8

### Transitions among land cover/ forest types

The transition among major forest cover types between 1965 and 2008 were determined based on forest management plans. Between 1965 and 2008; 228.2 ha

juniper stands changed into degraded forests while 1183.2 ha Anatolian Black pine changed to mixed stands. Calabrian pine areas changed into degraded stands with around 902.1 ha, while 378.4 ha of the same species change into agriculture and settlement areas. Degraded



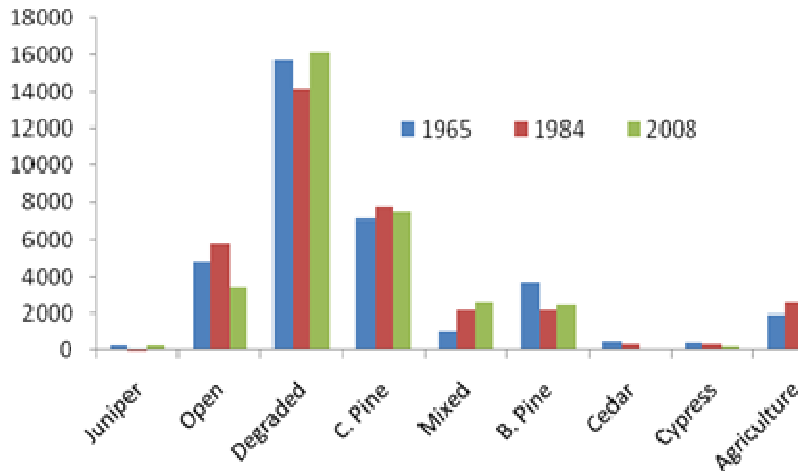
**Figure 2.** The spatial distribution and transition maps of cover types of Köprülü Canyon NP over three periods (1965, 1984 and 2008).

stands change into Calabrian pine forests about 1477 ha, while agriculture and settlement areas change into degraded stands about 336 ha (Table 2).

Nearly 290 ha degraded stands changed

into juniper forest between 1984 and 2008. Also 878.8 ha Calabrian pine stands changed to degraded stands while 821.9 ha degraded stands changed to Calabrian stands in the same period. Another important point is that

nearly 459.0 ha cedar stands changed to especially degraded and mixed stands of 116.0 and 87.2 ha respectively. Significant part of the open lands changed to degraded stands of 2457.6 ha between 1984 and 2008 (Table 3).



**Figure 3.** The distribution of land cover and forest cover types over three periods (1965, 1984 and 2008).

Over 43 years, pure cedar stands changed to other forest cover types and half of the 425.8 ha unique pure cypress lands changed to Calabrian pine of 71.5 ha, mixed forest of 122.1 ha and degraded forests of 71.1 ha. Almost 1095.9 ha open areas turned into degraded stands while 310.4 ha degraded stands changed to open areas. While 419.2 ha degraded stands and 426.4 ha other open areas changed to agriculture and settlement areas, 310.4 ha degraded stands and 154.1 agriculture and settlement lands turned into other open lands like ranges, water, sand, open forest lands (Table 4). As a result, 33.7% of total area changed to another cover types (Figure 4).

### Spatial analysis of the change in spatial forest structure

The spatial analysis of the landscape pattern indicated that the total number of patches increased from 238 to 276 between 1965 and 1984 years as all patch types were taken into account. MPS decreased from 1615.0 ha to 1104.3 ha. The MPS of Anatolian Black pine forests changed significantly from 413.4 ha to 137.7 ha over the same period. Similarly, the MPS of degraded forests changed from 507.4 ha to 253.4 ha (Table 5).

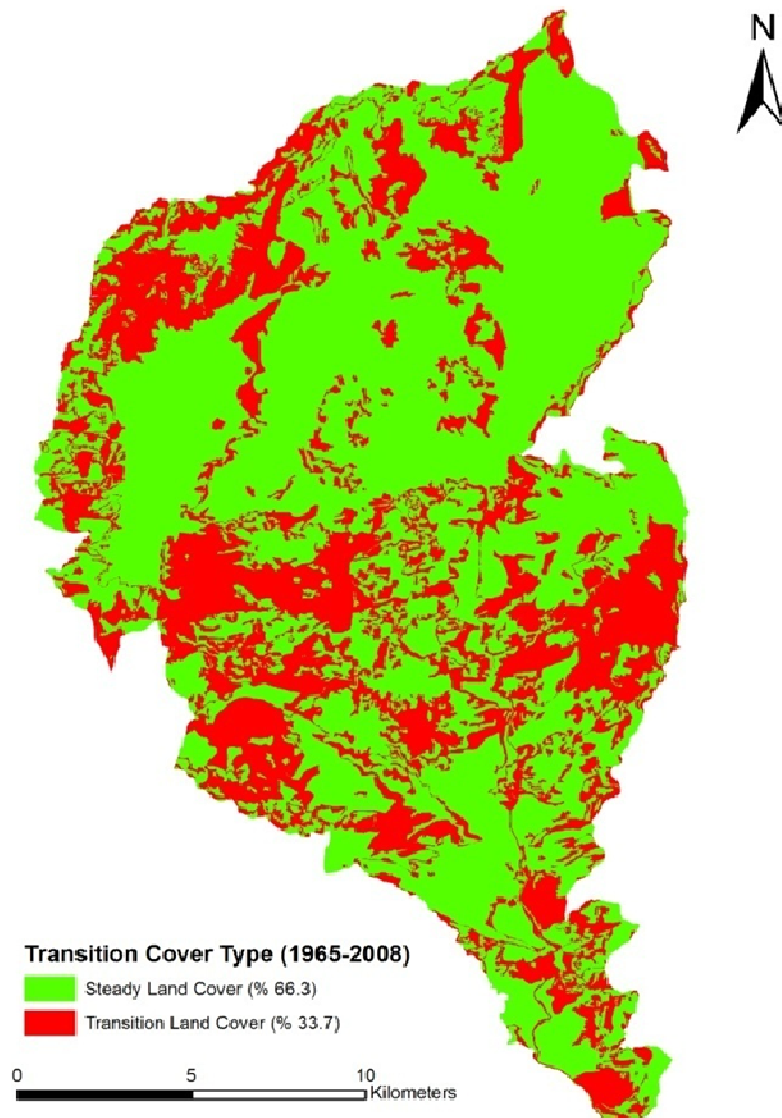
Likewise, patch density increased from 0.67 to 0.78 between 1965 and 1984 years. Area Weighted Shape Index (AWSI) increased from 27.0 to 28.3 (Table 5). Between 1984 and 2008; the total number of patches increased from 276 to 672 incredibly. Similarly, MPS decreased from 1104.3 ha to 425.3 ha. The MPS of Anatolian Black pine forests continued to increase significantly from 137.7 ha to 31.8 ha in the same period (Table 6).

In conclusion, the total number of patches increased from 238 to 672 between 1965 and 2008, almost tripled.

MPS of the land cover/land use classes dropped markedly from 1615.0 ha to 425.3 ha. The degraded and other Anatolian Black pine stands had significant MPS values changing from 507.4 ha to 84.2 ha and from 413.4 ha to 31.8 ha respectively. Patch density increased from 0.67 to 1.90. Similarly AWSI value increased from 27.0 to 36.3 (Table 7). These changes showed that landscape fragmentation increased and the forest has become more susceptible to harsh disturbances.

### DISCUSSION

Turkey has outstanding forest resources with high level of biodiversity. The country has a well established nature reservation program accommodating NPs since 1958 reaching to the number of 40 and covering nearly 900 000 ha to maintain and conserve the wealth of flora and fauna, archaeological and historical monuments and other extraordinary features. Of the NPs, KöprülÜ Canyon accommodates a large number of endemic plants and rare animal species, archaeological and historical ruins, and rich habitats in the province of Antalya in the Mediterranean region. For example, *Cupressus sempervirens* natural forests no longer exist elsewhere in the world forests except the KöprülÜ Canyon NP. In addition to its archaeological and geological treasures, this park also home to water based sportive activities especially rafting and canoeing. Land use and land cover change is generally known to be directly or indirectly affected by human-induced activities and population (Wear et al., 1996), socio-economic factors (Zhao et al., 2003) forestry expansion (Nagashima et al., 2002), urbanization (Doygun and Alphan, 2006) and patterns of agricultural activities (Hietela-Koivu, 1999; Mander et al., 1999). For these reasons, land cover and forest cover type changes have been a major topic in sustainable



**Figure 4.** The spatial transition of cover types of Köprülü Canyon NP from 1965 to 2008.

management of natural resources especially in NPs. Thus, this study was designed to detect and document changes in major land use and forests cover types and analyze patterns of change in landscape of the study area focusing on forest fragmentation from 1965 to 2008.

The digitized stand maps from periodically renewed forest management plans from 1965, 1984 to 2008 with GIS and FRAGSTATS were used to analyze land cover/forest cover types and the spatial configuration of forest resources. The quantitative evidences of land use/land cover dynamics 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 of Köprülü Canyon NP.

The percentage of stands in the Köprülü Canyon decreased by 5.6% from 1965 to 1984 and increased 8.04%

from 1984 to 2008 based on stand type map. Cumulative forest accretion accounted for 1.9% (548.7 ha) of the whole area of NP. This rate translates to an annual amount of 12.7 ha forest improvement. Similar results can be seen from some important studies in Turkey. Kadioğulları and Baskent (2008) found that the percentage of forest cover in Gümüşhane forests decreased from 23.67% in 1971 to 23.14% in 1987 and increased from 24.5% in 1987 to 26.1% in 2000. Similarly, Torul forests increased from 42.95% in 1984 to 51.20% in 2005 (Kadioğulları et al., 2008). Besides, the same researchers showed that the percentage of forest cover in İnegöl forests increased from 33.7% in 1972 to 37.0% in 1993, from 34.1% in 1987 to 40.9% in 2001 (Baskent and Kadioğulları, 2007). A recent study introduces a net decrease of 2.30% in total forested areas between 1984



**Table 5.** Change of Landscape Pattern in Köprülü Canyon NP from 1965 to 1984.

Forest cover/ land cover type	Number of patches (#)		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	
Juniper	4	1	58.6	5.1	0.7	0.0	0.35	0.01	0.01	0.00	78.1	-	2.0	3.0
A. Pine	9	16	413.4	137.7	10.5	6.2	6.50	1.71	0.03	0.05	187.7	124.2	4.1	2.7
C. Pine	35	44	202.5	176.3	20.0	21.9	4.64	12.28	0.10	0.12	188.8	110.0	3.3	5.1
Cedar	7	8	65.6	39.4	1.3	0.9	0.50	0.30	0.02	0.02	88.6	139.1	3.2	2.5
Cypress	3	2	141.9	184.7	1.2	1.0	1.15	1.03	0.01	0.01	163.0	214.4	2.3	2.3
Mixed For.	9	18	115.0	123.5	2.9	6.3	1.06	3.16	0.03	0.05	113.2	503.6	2.1	2.9
Degraded	31	56	507.4	253.4	44.4	40.0	30.57	26.45	0.09	0.16	391.6	494.5	3.9	3.7
Open areas	111	37	43.3	156.5	13.6	16.3	8.36	13.26	0.31	0.10	454.3	258.3	3.5	3.3
Agriculture	29	94	67.3	27.7	5.5	7.3	2.01	1.03	0.08	0.27	242.3	-	2.8	2.7
Total	238	276	1615.0	1104.3	100.0	100.0	55.15	59.54	0.67	0.78	2107.5	2219.8	27.0	28.3

**Table 6.** Change of landscape pattern in Köprülü Canyon NP from 1984 to 2008.

Forest cover/ land cover type	Number of patches (#)		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	
Juniper	1	24	5.1	12.1	0.0	0.8	0.01	0.26	0.0	0.07	-	161.3	3.0	2.0
A. Pine	16	78	137.7	31.8	6.2	7.0	1.71	2.76	0.05	0.22	124.2	380.4	2.7	4.5
C. Pine	44	77	176.3	97.4	21.9	21.2	12.28	12.12	0.12	0.22	375.7	509.7	5.1	7.1
Cedar	8	-	39.4	-	0.9	-	0.30	-	0.02	-	110.0	-	2.5	-
Cypress	2	2	184.7	97.7	1.0	0.6	1.03	0.47	0.01	0.01	139.1	100.0	2.3	3.6
Mixed For.	18	62	123.5	42.0	6.3	7.3	3.16	2.86	0.05	0.17	214.4	319.0	2.9	4.1
Degraded	56	192	253.4	84.2	40.0	45.6	26.45	31.12	0.16	0.54	503.6	955.9	3.7	7.4
Open areas	37	82	156.5	42.5	16.3	9.8	13.26	6.70	0.10	0.23	494.5	622.0	3.3	4.5
Agriculture	94	155	27.7	17.6	7.3	7.7	1.32	1.72	0.27	0.44	258.3	354.7	2.7	3.1
Total	276	672	1104.3	425.3	100.0	100.0	59.54	58.00	0.78	1.90	2219.8	3403.0	28.3	36.3

**Table 7.** Change of landscape pattern in Köprülü Canyon NP from 1965 to 2008.

Forest cover/ land cover type	Number of patches (#)		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	
Juniper	4	24	58.6	12.1	0.7	0.8	0.35	0.26	0.01	0.07	78.1	161.3	2.0	2.0
A. Pine	9	78	413.4	31.8	10.5	7.0	6.50	2.76	0.03	0.22	187.7	380.4	4.1	4.5
C. Pine	35	77	202.5	97.4	20.0	21.2	4.64	12.12	0.10	0.22	188.8	509.7	3.3	7.1
Cedar	7	-	65.6	-	1.3	-	0.50	-	0.02	-	88.6	-	3.2	-
Cypress	3	2	141.9	97.7	1.2	0.6	1.15	0.47	0.01	0.01	163.0	100.0	2.3	3.6
Mixed For.	9	62	115.0	42.0	2.9	7.3	1.06	2.86	0.03	0.17	113.2	319.0	2.1	4.1
Degraded	31	192	507.4	84.2	44.4	45.6	30.57	31.12	0.09	0.54	391.6	955.9	3.9	7.4
Open areas	111	82	43.3	42.5	13.6	9.8	8.36	6.70	0.31	0.23	454.3	622.0	3.5	4.5
Agriculture	29	155	67.3	17.6	5.5	7.7	2.01	1.72	0.08	0.44	242.3	354.7	2.8	3.1
Total	238	672	1615.0	425.3	100.0	100.0	55.15	58.00	0.67	1.90	2107.5	3403.0	27.0	36.3

and 2007 in Rize province of Turkey (Günlü et al., 2009).

These results are quite comparable to similar other research results. As known, annual disturbance rates for many other temperate forests have been generally higher. 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) presented a 5.2% increase in forest landscape between 1976 and 2000 year in Nepal. In Eastern US, Hall et al. (1991) reported annual conifer forest disturbances of 1.8% in northern Minnesota, while Luque, (1994) found annual pine-oak forest declines in the Pine Barrens region of New Jersey to be 2.2%. 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. For western Oregon annual forest disturbance rates due to clear cutting between 1972 and 1995 ranged from 0.5%-1.2% overall with nearly a 20% total forest impact (Cohen et al., 1995). The Tillamook Bay watershed of mid coastal Oregon showed an annual forest disturbance rate of 1.0% (Strittholt and Frost, 1995). Rao and Pant (2001) noted that natural forest area decreased while agriculture areas, which include settlements, pasture, and shrubs area, increased in Himalaya, India.

When looking at studies for protected areas, forest decrease is conspicuous. Zheng et al. (1997) reported 1.12% annual rate of forest disturbance outside of the Changbai Biosphere Reserve in China. In the Sikhotealinskiy 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. Hayes et al. (2002) analyzed forest clearing and regrowth over a 23-year time period for 21 forest concession and management units within the Maya Biosphere Reserve (MBR), Guatemala. The study area

as a whole experienced a clearing rate of 0.16% per year from 1974 through 1997. Another study for small Ballıbucaç planning unit, one of the seven planning units of Köprülü Canyon NP, displayed the increase of degraded forests about 0.5% (63.6 ha) and urban areas 850% (37.4 ha) while open lands decreased about 3.2% (97.5 ha) and productive forests 0.4% (18.8 ha) from 1965 to 2004 (Karahalil et al., 2007).

Besides the forest composition and land cover/forest cover type changes, the spatial structure of forest configuration was also investigated. Total number of patches increased from 238 in 1965 to 672 in 2008. Increase in number of patches and smaller patches, and decrease in MPS demonstrated that the forest landscape has gone into a more fragmented structure that negatively affects biodiversity and the resilience of the ecosystem. These results are quite comparable to similar other research results. Karahalil et al. (2007) found that total number of patches increased from 59 to 287 between 1965 and 2004 in Ballıbucaç planning unit of Köprülü Canyon NP. Another study showed that MPS decreased from 163.6 ha to 47.9 ha between 1984 and 2007 (Günlü et al., 2009). Similarly Keleş et al., (2008a) displayed an increase in the number of patches from 108 to 202 between 1972 and 2002 years in Artvin province of Turkey.

In general, there is a decrease in forested areas and accretion in patchiness from 1965 to 1984, yet the forested lands increased from 1984 to 2008. The main reason of this result is the declaration of Köprülü Canyon as a NP in 1973. Before the status of NP, the area was subject to excessive timber management, illegal cutting and over grazing activities. So, the diminution in forested stands continued in the first period of the Park. After the declaration, a master plan was designed and timber production activities stopped until 1984. In this year, a 10 year forest management plan was prepared according to master plan and moderate timber production was allowed without damaging ecological integrity. However, this plan

was unable to reach to the target as it was not put in practice as desired. Forestry activities in terms of regeneration or thinning have not been undertaken since that time. Furthermore, after the announcement of NP, tourism activities developed rapidly resulting in heavy tourism activities leading rather reduction in pressure on forests. Agriculture and stockbreeding were gradually diminished and the area of forested stands began to improve in that period.

Meanwhile, a biodiversity conservation project, supported by the World Bank-Global Environmental Fund, was initiated in 2000 for an efficient, intersectoral and participatory planning and sustainable management of nature conservation in Köprülü Canyon NP. New master plan was completed for Köprülü Canyon NP with core, buffer and the transition zones supported by corridors around them. The core zone is a securely protected site for conserving biological diversity, monitoring minimally disturbed ecosystems like cypress forest and endemic species. Based on the master plan, a 20 year forest management plan was prepared in 2008 with the participatory and ecosystem based approach focusing on meeting the needs of the people living in or around the protected areas as well as the requirements of nature conservation and natural resource management.

The composition and the configuration of forest resources changed considerably in the study area. While the forest area increased over 43 years, the number of patches and patch density increased resulting in a fragmented landscape. There are some reasons for such changes. Tourism activities like rafting and recreational uses of forests in NP caused changes in forest landscape structure such as increased forest degradation and fragmentation. Tourism season begins at the end of May and slows down at the end of August. In June, July and August, nearly an average of 3000 tourists visit NP reaching up to 8000 daily persons because of concurrent fabulous features. Two ancient Oluk and Büğrüm Bridges at the lower part of the Köprüçay Creek attract many visitors due to their cultural significance and tourism potential. Rafting is very popular sport in the water courses of the NP whose income goes out of the park. As such, tourism activities have caused some problems like building official or industrial constructions. The population growth and urbanization near Beşkonak village have affected the dynamics of forest structure. There are 11 villages in the park; one of them is Beş whose population increased from 1243 to 2408 from 1980 to 2007. There are endemic species around the cultural heritage of Selge ancient city located in the NP. Tourism activities intended to see the Selge ancient city have the potential to jeopardize the existence of endemic species. Other threats of the Park are forest fires having always had a pervasive influence on the stability of the ecosystems. The park is sensitive to forest fires as it is located in the Mediterranean region. Despite the obvious global importance of this ecoregion, coniferous forests have been subjected to substantial levels of disturbance throughout

the last century primarily through fire suppression. This NP is also adjacent to the acute Serik-Taşağıl (Antalya) forest fire, which broke out in August 2008 and was fanned by strong winds reaching up to 70 km per hour, destroyed part of the several villages and burned down about 60 houses and nearly 16000 ha of forest areas. Historically, forest fires caused by lightning or anthropogenic actions have shaped forest landscape patterns in this eco-region.

Unlike most other forests, Köprülü Canyon NP retains a large proportion of primary forest with its rich biodiversity.

The forests also have very high commodity value. Synchronizing the balance between conservation and the recreational use is a challenging task and must be pursued on a sustainable basis. Any forest management actions or regulations will change the status of forest ecosystems, including forest biodiversity thus designing appropriate management actions (that is, silvicultural prescriptions) to protect and monitor biodiversity is crucial. Here, new forest management plan based Ecosystem-Based Multiple Use (ETÇAP) approach is a promising move towards the sustainability of the NP's ecosystems. The new planning approach focuses on the maintenance of biodiversity, productivity, regeneration capacity, vitality and their potential to satisfy ecological, economic and socio-cultural values without jeopardizing the long-terms of rural forest users should be improved (Başkent et al., 2008).

Understanding forest dynamics is critical to design the sustainable management of NPs as the temporal change of both composition and configuration of forest cover types are crucial factors of ecosystem conditions and functions. The rate and amount of land/forest cover type changes as a result of either the historical legacy of forest structure or ongoing threats or factors affecting the current pattern to shape are to be quantified to help better design future forest management actions and environmental policies for a given country.

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## REFERENCES

- Aksoy E, Özsoy G (2004). Mapping Land Use in Uludağ University Campus Using Remote Sensing and GIS Techniques. *Journal of Uludağ University Agriculture Faculty* 18: 57-68
- Alphan H (2003). Land use change and urbanization of Adana. *Turkey. Land Degradation Dev.* 14: 575-586.
- Anonymous (2009a). General Directorate of Nature Conservation and National Parks web site, <http://www.milliparklar.gov.tr/mpd/mp/milliparklar.asp>, visited 18<sup>th</sup> of April.

- Anonymous (2009b). Draft Master Plan of Köprülü Canyon National Park, General Directorate of Nature Conservation and National Parks, Ankara.
- Başkent EZ, Jordan JA (1995a). Characterizing spatial structure of forest landscapes: a hierarchical approach. *Can. J. For. Res.* 25(11): 1830-1849.
- Başkent EZ, Jordan JA (1995b). Designing forest management to control spatial structure of landscapes. *Landscape Urban Planning*, 34: 55-74.
- Başkent EZ, Jordan GA, Nurullah AMM (2000). Designing Forest landscape (ecosystems) management. *Forest Chronicle*, 76: p. 739.
- Başkent EZ, Kadioğulları Aİ (2007). Spatial and temporal Dynamics of land use pattern in Turkey: A case study in İnegöl. *Landscape Urban Planning*, 81(4): 316-327.
- Başkent EZ, Başkaya Ş, Terzioğlu S (2008). Developing and implementing participatory and ecosystem based multiple use forest management planning approach (ETÇAP): Yalnızçam case study. *For. Ecol. Manage.* 256: 798-807.
- Cayuela L, Rey, Benayas, JM, Echeverria C (2006). Clearance and fragmentation of tropical montane forests in the Highlands of Chiapas, Mexico (1975-2000). *For. Ecol. Manage.* 226: 208-218.
- Cohen WB, Spies TA, Fiorella, M (1995). Estimating the age and structure of forest in a multi-ownership landscape in western Oregon, USA. *Int. J. Remote Sensing*, 16(4): 721-746.
- Cushman AS, Wallin OD (2000). Rate and patterns of landscape change in the Central Sikhote-alin Mountains, Russian Far East. *Landscape Ecol.* 5: p. 643.
- Doygun H, Alphan H (2006). Monitoring Urbanization Of Iskenderun, Turkey, and its Negative Implications, *Environ. Monit. Assess.* 114: 145-155.
- Echeverria C, Coomes D, Salas J, Reybenayas JM, Lara A, Newton A (2006). Rapid deforestation and fragmentation of Chilean Temperate Forests. *Biol. Conserv.* 130: p. 481.
- Fan F, Wang Y, Wang Z (2008). Temporal and spatial change detecting (1998-2003) and predicting of land use and land cover in Core corridor of Pearl River Delta (China) by using TM and ETM+ images. *Environ. Monit. Assess.* 137: 127-147.
- Gautam AP, Webb EL, Shivakoti G, Zoebisch M (2003). Land use dynamics and landscape change pattern in a mountain watershed in Nepal. *Agric. Ecosyst. Environ.* 99: p. 83.
- Genç L, Bostancı YB (2007). Determining Land Cover and Land Use Changes in Troya National Park Using Remote Sensing and Geographic Information Systems. *J. Tekirdağ Agric. Fac.* (4)1: 27-41.
- GDF (1965). General Directorate of Forestry of Turkey, Forest Management Plans of Beşkonak, Karabük, Şanlı, Ballıbucaç, Bozburun, Çayıçi, Eliftepisi Planning Units, Ankara.
- GDF (1984). General Directorate of Forestry of Turkey, Forest Management Plans of Köprülü Canyon National Park, Pınargözü, Sütçüler Planning Units, Ankara.
- GDF (2008). General Directorate of Forestry of Turkey, Forest Management Plan of Köprülü Canyon National Park, Ankara.
- Guler M, Yomraloğlu T, Reis S (2007). Using landsat data to determine land use/land cover changes in Samsun, Turkey. *Environ. Monit. Assess.* 27(1-3): 155-167.
- Günlü A, Kadioğulları Aİ, Keleş S, Başkent EZ (2009). Spatiotemporal changes of landscape pattern in response to deforestation in Northeastern Turkey: a case study in Rize. *Environ. Monit. Assess.* 148: 127-137.
- Hall FG, Botkin DB, Strebel DE, Woods KD, Goetz SJ (1991). Large-scale Patterns of Forest Succession as Determined by Remote Sensing. *Ecology*, 72(2): 628-640.
- Hayes DJ, Sader SA, Schwartz NB (2002). Analyzing a forest conversion history database to explore the spatial and temporal characteristics of land cover change in Guatemala's Maya Biosphere Reserve. *Landscape Ecol.* 17: 299-314.
- Hayes DJ, Cohen WB, (2007). Spatial, spectral and temporal patterns of tropical forest cover change as observed with multiple scales of optical satellite data. *Remote Sensing Environ.* 106: 1-16.
- Hietela-Koivu R (1999). Agricultural landscape change: a case study in Ylane, southwest Finland. *Landscape Urban Planning*, 46: p. 103.
- Iida S (1995). Forest fragmentation and its effect on species diversity in sub-urban coppice forests in Japan. *For. Ecol. Manage.* 73: 197.
- Kadioğulları Aİ, Başkent EZ (2008). Spatial and temporal Dynamics of land use pattern in Turkey: A case study in Gümüşhane. *Environ. Monit. Assess.* 138: 289-303.
- Kadioğulları Aİ, Keleş S, Başkent EZ Günlü A (2008). Spatiotemporal Changes of Landscape Pattern in Response to Forestation in Northeastern Turkey: A case study in Torul, *Scottish Geographical J.* 124(4): 259-273.
- Kammerbauer J, Ardon C (1999). Land use dynamic and landscape change pattern in a typical watershed in the hill side region of Central Honduras. *Agric. Ecosyst. Environ.* 75: 93.
- Karabulut M, Küçükönder M, Gürbüz M, Sandal E (2006). Analyzing Temporal Changes of Kahramanmaraş City and Environment Using Remote Sensing and GIS, Fatih University The Fourth Informatics Days, 13-16 September, İstanbul, Turkey.
- Karahalil U, Kadioğulları Aİ, Başkent EZ, Köse S (2007). Investigating Spatial and Temporal Changes in Ballıbucaç Planning Unit in Köprülü Canyon National Park Using GIS, National Geographic Information System Congress, 30 October-2 November, Trabzon, Turkey.
- Keleş S, Sivrikaya F, Çakır G, Başkent, EZ, Köse S (2008a). Spatial and Temporal Changes in Forest Cover in Turkey's Artvin Forest, 1972-2002. *Polish J. Environ. Studies*, 17(4): 491-501.
- Keleş S, Sivrikaya F, Çakır G, Köse S (2008b). Urbanization and Forest Cover Change in Regional Directorate of Trabzon Forestry from 1975 to 2000 Using Landsat Data. *Environ. Monit. Assess.* 140: 1-14.
- Kennedy RSH, Spies TA (2004). Forest Cover Changes in the Oregon Coast Range from 1939 to 1993. *For. Ecol. Manage.* (200): p. 129.
- Kılıç S, Evrendilek F, Berberoğlu S, Demirkesen AC (2006). Environmental Monitoring of Land-Use and Land-Cover Changes in a Mediterranean Region of Turkey. *Environ. Monit. Assess.* 114(1): 157-168.
- Kirdar U (Ed.) (1992). *Ecological Change: Environment, Development and Poverty Linkages*, New York: United Nations Publications.
- Luque S (1994). Temporal and Spatial Changes in an Area of the New-Jersey Pine-Barrens Landscape. *Landscape Ecol.* 9(4): p. 287.
- Luque S (2000). Evaluating temporal changes using multispectral scanner and thematic mapper data on the landscape of a natural reserve: The New Jersey Pine Barrens, A case study. *Int. J. Remote Sens.* (21): 2589-2611.
- Mander U, Mikk M, Kulvik M (1999). Ecological and low intensity agriculture as contributors to landscape and biological diversity. *Landscape Urban Planning*, 46: 169.
- McGarigal K, Marks BJ (1995). FRAGSTATS: Spatial pattern analysis program for quantifying landscape structure. U.S. forest Service General Technical Report PNW 351.
- Musaoglu N, Coskun M, Kocabaş V (2005). Land Use Change Analysis of Beykoz İstanbul by means of satellite images and GIS. *Water Sci. Technol.* 51(11): 245-251.
- Musaoglu N, Gürel M, Ulugtekin N, Tanik A, Şeker DZ (2006). Use of Remotely Sensed Data for Analysis of Land-Use Change in a Highly Urbanized District of Mega City, İstanbul, *J. Environ. Sci. Health, Part A*, 41(9): 2057-2069.
- Nagashima K, Sands R, Whyte AGD, Bilek EM, Nakagoshi N (2002). Regional landscape change as a consequence of plantation forestry expansion: an example in the Nelson region, New Zealand. *For. Ecol. Manage.* 163: 245-261.
- Rao KS, Pant R (2001). Land use dynamics and landscape change pattern in a typical micro watershed in the mid elevation zone of central Himalaya, India. *Agric. Ecosyst. Environ.* 86: p. 113.
- Ruddle K, Manshard W (1981). Renewable natural resources and the environment, Tycooly International, Dublin.
- Sivrikaya F, Çakır G, Kadioğulları Aİ, Keleş S, Başkent EZ, Terzioğlu S (2007). Evaluating land use/land cover changes and fragmentation in the Camili Forest Planning Unit of Northeastern Turkey from 1972 to 2005. *Land Degradation Dev.* 18: 383-396.
- Southworth J, Munroe D, Nagendra H, (2004). Land cover change and landscape fragmentation-comparing the utility of continuous and discrete analyses for a western Honduras region. *Agric. Ecosyst. Environ.* 101: p. 185.
- Spies TA, Ripple, WJ, Bradshaw GA (1994). Dynamics and Patterns of a Managed Coniferous Forest Landscape in Oregon, *Ecol. Appl.* 4(3): 555-568.
- Status LN, Strittholt RJ, DellaSala A (2002). Dominick ve Robinson

- Rob. Rate and pattern of forest disturbance in the Klamath-Siskiyou Ecoregion, USA between 1972 and 1992. *Landscape Ecol.* 17: 455-470.
- Strittholt JR, Frost PA (1995). Landscape change in the Tillamook Bay watershed. A report to the Tillamook Bay National Estuary Project, Garibaldi, Oregon. Earth Design Consultants, Corvallis, Oregon, USA.
- Tunay M, Ateşoğlu A (2004). Determining Unnatural Changes in Bartın Using Remote Sensing and GIS, Fatih University The Third Informatics Days, 6-9 October, İstanbul, Turkey.
- Turner MG, Pearson SM, Bolstad P, Wear DN (2003). Effects of land-cover change on spatial pattern of forest communities in the Southern Appalachian Mountains (USA). *Landscape Ecol.* 13: 449-464.
- Verburg PH, Veldkamp A, Bouma J (1999). Land-use change under conditions of high population pressure: The case of Java. *Glob. Environ. Change*, 9: 303-312.
- Wakeel A, Rao KS, Maikhuri RK, Saxena KG (2005). Forest management and land-use/cover changes in a typical micro watershed in the mid-elevation zone of Central Himalaya, India. *For. Ecol. Manage.* 213: 229-242.
- Wear DN, Turner MG, Flamm RO (1996). Ecosystem management with multiple owners: Landscape dynamics in a southern Appalachian watershed. *Ecol. Appl.* 6: 1173.
- Yıldırım H, Özel ME, Divan NJ, Akça A (2002). Satellite Monitoring of Land Cover/Land Use Change Over 15 Years and its Impact on the Environment in Gebze/Kocaeli -Turkey. *Turk. J. Agric. For.* 26: 161-170.
- Zhang LQ, Wu JP, Zhen Y, Shu HA (2004). A GIS-based gradient analysis of urban landscape pattern of Shanghai metropolitan area, China. *Landscape Urban Planning*, 69(1): 1-16.
- Zheng D, Wallin DO, Hoa Z (1997). Rates and patterns of landscape change between 1972 and 1988 in the Changbai Mountain area of China and North Korea. *Landscape Ecol.* 12: 241-254.
- Zhao B, Nakagoshi N, Chen JK, Kong LY (2003). The impact of urban planning on land use and land cover in Pudong of Shanghai, China. *J. Environ. Sci.* 15: 205.