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Analysing land cover changes for understanding of forest dynamics using temporal forest management plans

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Abstract This study analyses forest dynamics and land use/land cover change over a 43-year period using spatial-stand-type maps of temporal forest management plans of Karaisalı Forest Enterprise in the Eastern Mediterranean Region of Turkey. Stand parameters (tree species, crown closures and developmental stages) of the dynamics and changes caused by natural or artificial intervention were introduced and mapped in a Geographic Information System (GIS) and subjected to fragmentation analysis using FRAGSTATS. The Karaisalı Forest Enterprise was first planned in 1969 and then the study area was planned under the Mediterranean Forest Use project in 1991 and five-term forest management plans were made. In this study, we analysed only four periods (excluding 1982 revision plans): 1969, 1991, 2002 and 2012. Between 1969 and 2012, overall changes included a net increase of 3,026 ha in forested areas. Cumulative forest improvement accounted for 2.12 % and the annual rate of total forest improvement averaged 0.08 %. In addition, productive forest areas increased from 36,174 to 70,205 ha between 1969 and 2012. This translates into an average annual productive forest improvement rate of 1.54 %. At the same time, fully covered forest areas with crown closure of “3” (>70 %) increased about 21,321 ha, and young forest areas in developmental stage of “a” (diameter at breast height (dbh)<8 cm) increased from 716 to 13,305 ha over the 43-year study period. Overall changes show that productive and fully covered forest areas have increased egregiously with a focus on regenerated and young developmental stages. A spatial analysis of metrics over the 43-year study period indicated a more fragmented landscape resulting in a susceptible forest to harsh disturbances.

Keywords Forest dynamics · Forest improvement · Forest management plan · FRAGSTATS · GIS · Land cover change

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Introduction

Nowadays, understanding forest dynamics and spatiotemporal changes of forest ecosystem is an important factor along with determining land use/land cover changes in management of forest products and services. Amount, as well as spatial configuration, of forest stands or patches over landscape has important impacts on sustainability of both forest products and services. Control of the spatial configuration of stands provides ability to better design and manage forest values based on understanding of the spatiotemporal analysis of forest dynamics. As known, focus of sustainable use of forest ecosystems can ensure their transfer to future generations.

The temporal and spatial changes of land use have been examined in many studies (Kennedy and Spies 2004; Wakeel et al. 2005; Cayuela et al. 2006; Çakır et al. 2007; Sancar et al. 2009; Özen Turan et al. 2010; Upadhyay et al. 2005; Liu et al. 2006; Park and Stenstrom 2008; Xu et al. 2007; Pavón et al. 2003; Karnieli et al. 2008). In particular, the changes in forest ecosystems and the factors affecting them have been analysed (Kadıoğulları 2013; Kadıoğulları et al. 2008; Başkent and Kadıoğulları 2007). Regarding changes in forest resources all over the world, there was a loss of 16 million hectares between 2000 and 2010 in addition to 13 million hectares of forest area lost between the years 1990 and 2000 (FAO 2010). It is important for natural resource informatics and management to determine similar temporal and spatial changes in forest resources (Başkent and Jordan 1995a,b; Kadıoğulları and Başkent 2008; Başkent and Kadıoğulları 2007; Echeverría et al. 2006a, b; Echeverria et al. 2008.). Forest management plans for a 10-year period were completed for the first time in Turkey between 1963 and 1972 and provided basis of forest land cover changes. From the beginning of that planning period to the present, forest management plans have been updated every 10 or 20 years. When comparing inventory data for the first term (1963–1972) and for the 2012 management plan, a net increase of 1,478,838 ha in forest area can be seen. During this period, the amount of productive forest area increased by 2,702,211 ha (GDF 2013).

Importance of forest ecosystems is increasing rapidly worldwide as is their role in offering products/services to society. In addition, there is better understanding of the need to protect ecological balance. Accordingly, because of rapid population growth and destructive pollutant effects of rapid developments in industry, social pressure requires us to be much more sensitive to the forests (Rudel et al. 2005; Perz 2007; Lambin et al. 2001; Perz and Skole 2003). Additionally, structure of forest ecosystems is rapidly changing due to lack of appropriate utilisation; the balance of the forest ecosystem is disrupted by offering products and services via incorrect or incomplete silvicultural interventions (Gautam et al. 2003; Sivrikaya et al. 2007; Kadıoğulları et al. 2008) Understanding the change and effect factors requires comprehension of forest dynamics. Analysing all of the factors disturbing the forest ecosystems through an understanding of forest dynamics will play a key role in the planning of forest resources in a sustainable manner. Data related to changes, dynamics and spatial structures of forest ecosystems over a period of time, as well as that of present-day conditions, are especially needed in the context of contemporary planning approaches like Ecosystem Based Multi Objective Planning (ETÇAP).

This study analyses the forest dynamics and the spatial and temporal patterns of cover types in the Karaisalı Forest Enterprise for four planning periods (excluding revised plans for 1982) between 1969 and 2012 based on forest-stand-type maps using a Geographic Information System (GIS) and FRAGSTATS, a spatial statistics programme. In this context, the objective of this study is to contribute to the understanding of the forest dynamics, fragmentation and development in the Mediterranean forests of south-eastern Turkey.

Material and methods

The case study area

The 2012 study area of Karaisalı State Forest Enterprise included Çatalan, Kızıldağ, Çukurova, Karaisalı, Akarca and Hacılı forest planning units located in Adana Province in the Eastern Mediterranean Region of Turkey, UTM European 50 datum 36 zone 668,970–716,792 E, 4,103,218–4,151,137 N. The area consists of mountain forests, flat agricultural land and scattered settlements and highlands. The altitude varies between 20 and 2,420 m (Fig. 1).

The region is naturally covered by *Pinus brutia*, *Pinus nigra*, *Pinus pinea*, *Abies cilicica*, *Cedrus libani*, *Juniperus* spp., *Quercus* spp. and *Laurus nobilis* L., the most widely distributed species in the Mediterranean region. In this study, stand parameter data of each forest stand type were obtained from the Karaisalı forest management plans carried out in 1969, 1991, 2002 and 2012 (GDF 1969; GDF 1991; GDF 2002; GDF 2012). This study area is a fire-sensitive ecosystem because the dominant species, Calabrian pine (*P. brutia*), covers about 66 % of the total forest area located in the Mediterranean climate region. From 1969 to the present, many forest fires have occurred in the study area, affecting about 6,100 ha.

The Karaisalı State Forest Enterprise includes the district of Karaisalı. Demographic changes in the district varied considerably between 1965 and 2011, according to the Republic of Turkey State Institute of Statistics (Table 1). This table shows that very significant changes in the total population of Karaisalı District have occurred over the 46-year period. From 1965 to 2011, the urban population increased by 673 %, while the

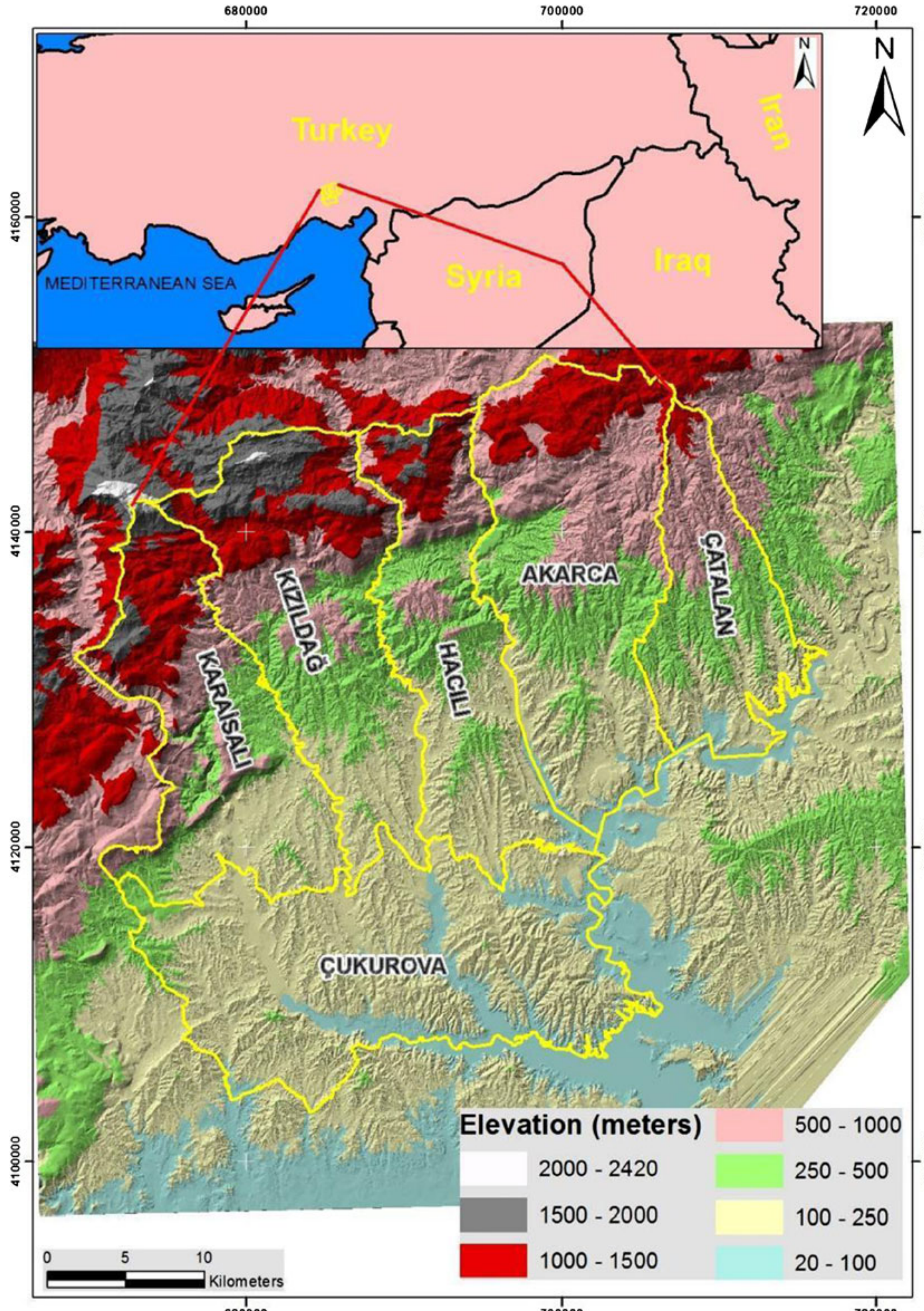

Fig. 1 The geographic location of the study area

Table 1 Human population changes in Karaisalı District between 1970 and 2010

Years	1965	1970	1980	1990	2000	2007	2011
Urban				7,235	6,883	6,580	7,494
Rural				30,349	2,8239	2,2160	15,207
Karaisalı total				37,584	35,122	28,740	22,701
Urban	Since 1987, the district of Aladağ separated from the district of Karaisalı			4,990	6,674	3,938	4,129
Rural				18,217	16,905	13,568	12,945
Aladağ total				23,207	23,509	17,506	17,074
Urban	1,814	1,643	2,711	12,225	13,557	10,518	11,623
Rural	45,629	46,999	51,983	48,566	45,144	35,728	28,152
Karaisalı and Aladağ total	47,443	48,642	54,694	60,791	58,631	46,246	39,775

rural population only increased from 1965 to 1990. After 1987, Karaisalı District was divided into Karaisalı and Aladağ districts. After this, while the urban population remained almost unchanged, the rural population decreased from 30,349 to 15,207 (50 %). After 1990, many people left the rural areas to become residents in urban centres in order to seek better job opportunities. This decrease in the rural population has changed the human pressure on forest areas, most probably resulting in a positive development of the forest ecosystems.

Database development

First, a spatial database developed as part of this study consisted of forest-stand-type maps. Second, temporal changes and transition of cover types/stand parameters were analysed using GIS (Table 2). Finally, the fragmentations of cover types were evaluated with FRAGSTAT™. The forest-cover-type maps of 1969 and 1991, at 1/25,000 scale cover type, were produced with 1/23,000 scale black-and-white aerial photos. The forest-stand-type maps for 1969 and 1991 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 neighbour rules. Rectified forest-stand-type maps with a 1/2,000 to 1/3,000 screen view scale were digitised by a number of qualified foresters with substantial GIS experience. Stand-type maps for 2002 derived from 1/25,000 scale forest-stand-type maps were produced with 1/16,000 collared infrared aerial photos. Lastly, the forest-stand-type maps for 2012 were produced with digital collared infrared aerial photos. These forest-stand-type maps were derived from visual interpretation of aerial photos (species mix and the development stages) and rectified with field survey data. These procedural differences and change of aerial photograph resolutions may also affect the areal changes and limited to the accuracy over the 43-year period. Also, the stand labelling procedure has slightly changed over the period. The spatial database included stand attributes such as species, crown closure, developmental stages and other stand parameters.

It is important to note that the forest maps generated by different photo interpreters may involve some accuracy problems. However, the field survey provides great help in reducing possible errors from happening. Furthermore, there is also another source of possible error with respect to the scales of aerial photos used in the study. This error is, of course, indispensible as it is impossible to change the scale of the previous maps or aerial photos.

Table 2 Classification of crown closures and developmental stages

Crown closure types	Criteria (% cover)	Developmental 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 %	B (young-mature) (only 1969 plans)	8–35.9 cm
2 (medium coverage)	41–70 %	c (mature)	20–35.9 cm
3 (full coverage)	>71 %	d (over-mature)	>36 cm
		e (over-mature) (only 2012 plans)	>52 cm

Table 3 The transition matrix of land cover change in the study area from 1969 to 2012

1969 land cover types	2012 land cover types												
	Juniper	Open areas	Almond and carob tree, laurel bush	Degraded forest	Stone pine	Fir	Settlement	Calabrian pine	Black pine	Oak	Cedar	Water	Landscape
	Area (ha)	Area (ha)	Area (ha)	Area (ha)	Area (ha)	Area (ha)	Area (ha)	Area (ha)	Area (ha)	Area (ha)	Area (ha)	Area (ha)	Area (ha)
Juniper	367.3	15.8	0.0	24.5	0.0	47.1	0.0	147.5	67.5	0.0	18.4	0.0	688.2
Open areas	291.1	4,0937.3	220.3	3,202.7	43.2	40.9	836.5	7,738.7	73.4	85.0	1,088.8	3,398.6	57,956.5
Degraded forest	3,230.6	7,297.5	753.4	10,769.2	144.7	176.9	129.6	21,261.3	740.3	1,117.7	654.8	575.9	46,851.9
Fir	307.1	32.4	0.0	73.7	0.0	555.2	0.0	87.5	92.2	2.2	89.7	0.0	1,240.1
Settlement	1.6	255.8	0.1	31.6	0.0	0.0	221.6	14.1	0.0	2.7	0.0	24.5	552.0
Calabrian pine	392.0	1,502.6	25.7	1,544.8	26.6	221.9	18.3	28,177.1	171.1	41.1	27.4	113.8	32,262.5
Black pine	93.5	62.1	0.0	93.8	0.0	27.3	4.8	151.2	575.5	2.8	196.0	0.0	1,207.1
Oak	0.0	37.7	5.3	13.9	0.0	0.0	1.4	18.7	0.0	0.0	0.0	52.4	129.4
Cedar	80.8	13.1	0.0	68.1	0.0	195.9	0.0	17.4	3.5	0.0	268.6	0.0	647.4
Water	0.0	161.2	0.0	25.6	0.0	0.0	0.0	24.4	0.0	0.0	0.0	840.4	1,051.7
Landscape	4,763.9	50,315.5	1,004.7	15,848.0	214.6	1,265.3	1,212.2	57,638.0	1,723.6	1,251.5	2,343.6	5,005.8	142,586.7

Understanding the dynamics of productive forest improvement is critical for the production of multiple-use forest planning. Annual forest improvement 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 productive/total forest improvement per year, and A_1 and A_2 are the amounts of total forest covers or productive forest areas at times t_1 and t_2, respectively.

Transition and spatial analyses of stand parameters/land cover types

In addition to analysing the changes in the amount of land cover types and stand parameters, the temporal transitions among the cover types/stand parameters were also documented and evaluated in order to see the temporal dynamics among various parameters indicative of both composition and configuration of forest resources. The transitions of stand parameters were evaluated using periodic results of stand-type maps. The stand-type polygon themes for 1969, 1991, 2002 and 2012 were overlaid, converted from each of the classes to those of the other classes and computed.

The spatial dynamics of the forest landscape were analysed using a few metrics as proxy to quantify and spatially analyse the change in spatial structure as demonstrated by Başkent and Kadıoğulları (2007), Kadıoğulları et al. (2008), McGarigal and Marks (1995), Günlü et al. (2009), Paudel and Yuan (2012), Armenteras et al. (2003), Echeverría et al. (2006a, b) and Kadıoğulları (2013). Specifically, the FRAGSTATS programme was used (McGarigal and Marks 1995) to quantify the landscape structure of Karaisalı State Forest for each of the land cover type classes. We analysed some metrics for the cover-type class for the landscape. These metrics were: percent of landscape (PL; percent of landscape), 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

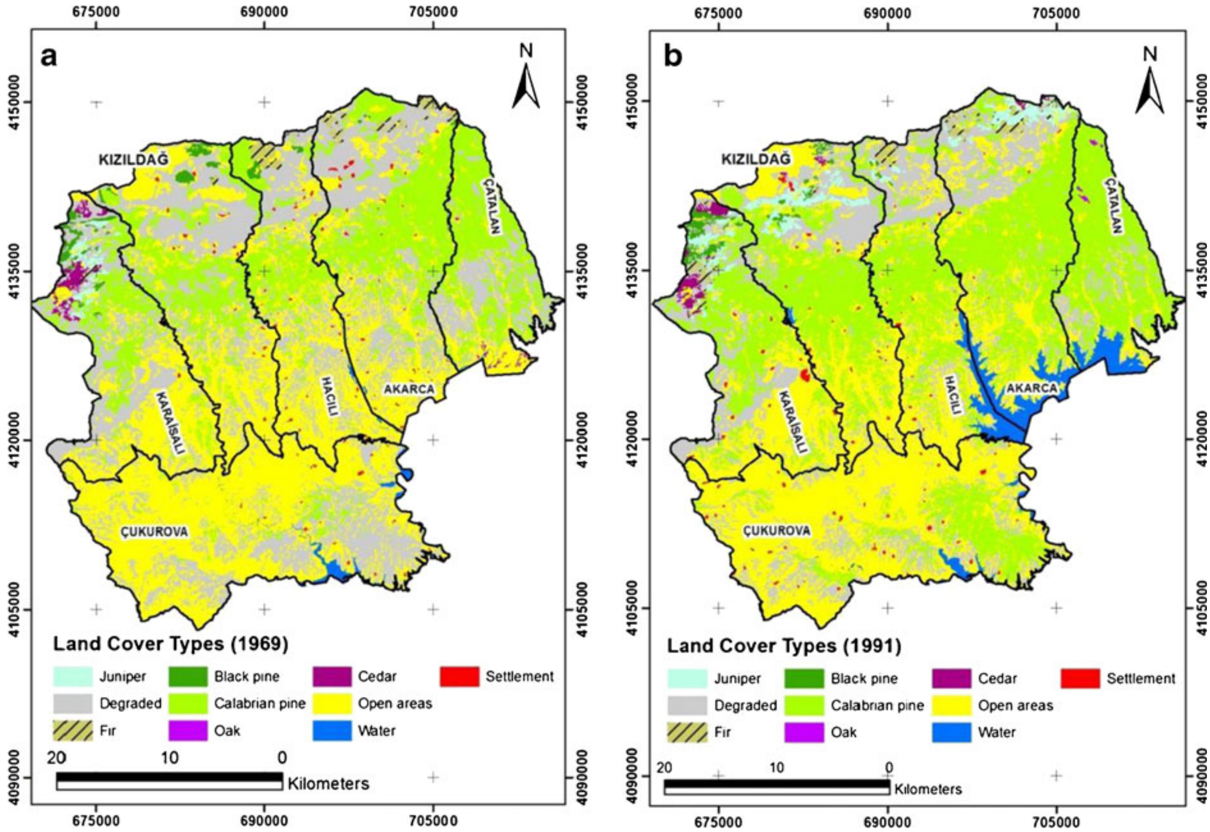

Fig. 2 Land cover changes of Karaisalı Forest Enterprise in the years **a** 1969 and **b** 1991

100), 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).

Results

Changes in land cover types

According to the digitised stand-type maps from forest management plans between 1969 and 1991, there was a net increase of 19,539 ha in total productive forest areas. Total forest areas (productive and degraded forest) increased by 764 ha and water areas increased by 4,028 ha (Table 3 and Fig. 2). In the period between 1991 and 2002, there was a net increase of 4,474 ha in total productive forest areas. In the last period, between 2002 and 2012, there was a net increase of 10,016 ha in total productive forest areas (Fig. 3).

Regarding overall changes between 1969 and 2012, there was a net increase of 34,030 ha in the productive forest areas, and total forest areas (productive and degraded forest) increased by 3,026 ha. Cumulative forest improvement accounted for 2.12 % as a whole (3,026 ha) and 3.64 % of the forested area of the study site from 1969 to 2012. This translates into an average annual total forest (degraded and productive) improvement rate of 0.08 %. Based upon only the productive forest areas, productive forest improvement accounted for 23.86 % as a whole (34,030 ha) and 40.98 % of the forested area of the Karaisalı State Forest from 1969 to 2012. This is an average annual productive forest improvement rate of 1.54 %.

Changes in crown closures and developmental stages

The stand-type maps were further analysed to examine any changes in forest structure and forest dynamics. In terms of crown closure change, in the first period, between 1969 and 1991, in the total combined forest areas, the percentage of stands with a crown closure of 3 (>70 %) increased by about 8.01 %, the percentage of those with a crown closure of 1 (11–40 %) increased by

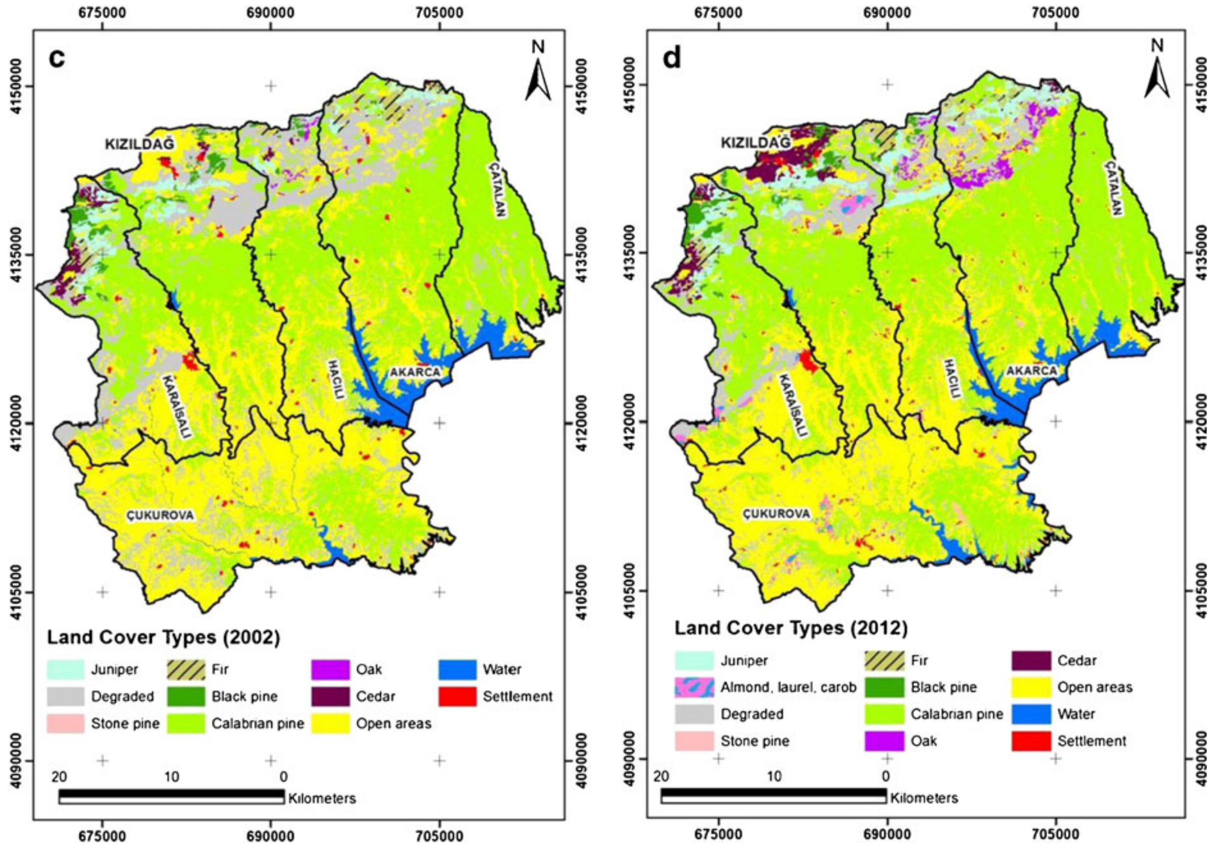

Fig. 3 Land cover changes of Karaisalı Forest Enterprise in the years **c** 2002 and **d** 2012

about 8.72 %, the percentage of those with a crown closure of 2 (41–70 %) increased by about 2.92 % and the percentage of degraded forest (<10 %) decreased by about 21.81 % in the combined forest areas. In the second period, between 1991 and 2002, another change of crown closures can be seen in the total combined forest areas, where percentage of stands with the crown closure of 3 increased by about 10.03 % and percentage of degraded forest (<10 %) decreased by about 4.16 %. Another change of crown closures occurred in the third period, between 2002 and 2012, in the total combined forest areas, where percentage of stands with a crown closure of 3 increased by about 6.73 % and percentage of degraded forest (<10 %) decreased by about 10.04 %. The general changes of crown closures in the overall period between 1969 and 2012 for the total combined forest areas were as follows: crown closure 1 and 2 areas increased by about 7,078 ha (8.22 % of the

Table 4 The transition matrix of crown closure classes in the study area from 1969 to 1991

1969 crown closure classes	1991 crown closure classes						
	Regeneration areas Area (ha)	1 Area (ha)	2 Area (ha)	3 Area (ha)	Degraded Area (ha)	Open areas Area (ha)	Total Area (ha)
1	123.3	2,895.7	2,886.6	2,345.3	2,042.6	1,010.1	11,303.7
2	375.9	3,800.1	4,515.6	4,569.0	1,101.4	778.0	15,139.9
3	96.9	2,660.2	1,908.4	4,476.2	232.8	356.6	9,731.0
Degraded	1,790.4	7,612.9	6,175.2	3,500.6	19,345.7	8,427.0	46,851.9
Open areas	243.2	1,838.6	2,172.1	1,727.9	5,354.3	48,224.1	59,560.2
Total	2,629.6	18,807.6	17,657.9	16,619.0	28,076.8	58,795.9	142,586.7

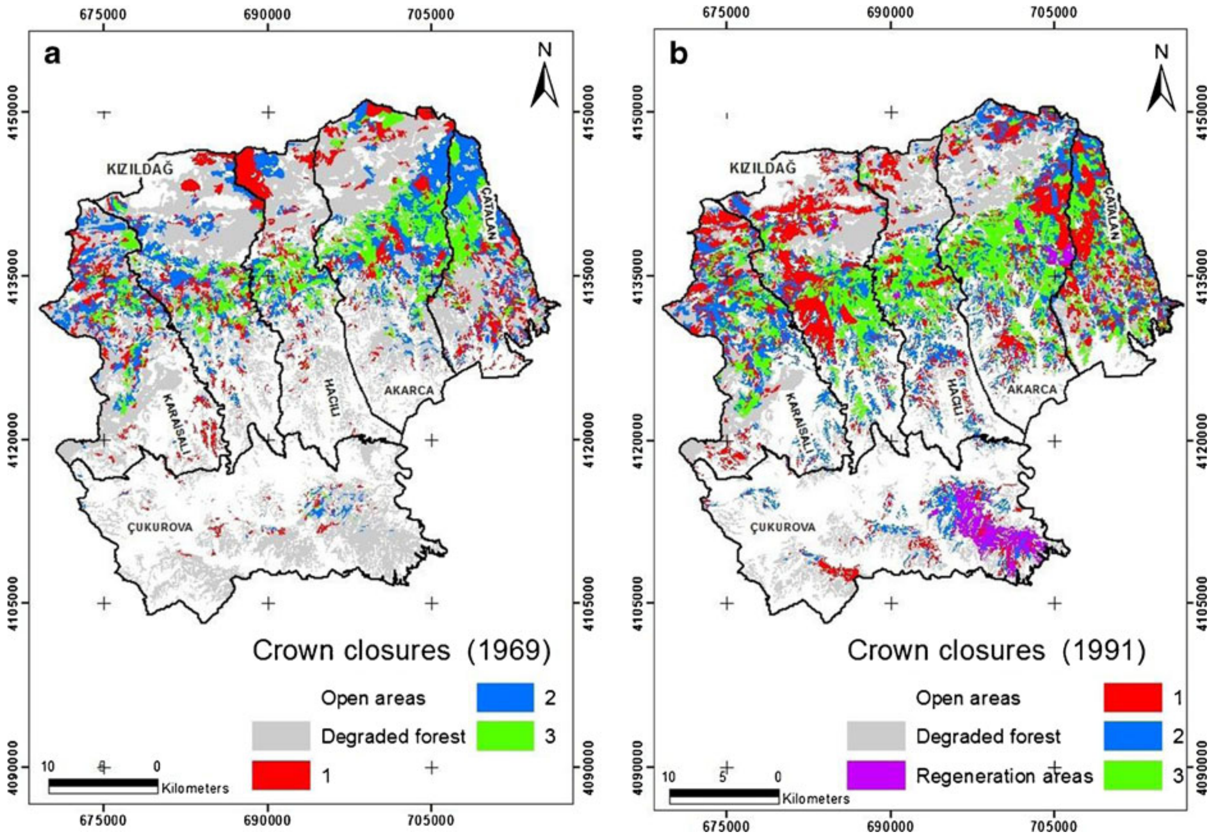

Fig. 4 Crown closure changes of Karaisalı Forest Enterprise in the years **a** 1969 and **b** 1991

total forest areas) and 2,211 ha (2.56 % of the total forest areas), respectively; crown closure 3 areas greatly increased by 21,321 ha (about 24.77 % of the total forest areas); the degraded forest decrease was about 36.02 % of the total forest areas; and the quality of the forest structure increased.

The developmental stages of forest ecosystems are used as another stand parameter to analyse the change in the quality of the forest structure. According to stand-type maps, the forests in 1969 were mostly classified into B (young-mature), Bd (young-overmature), dB (mature and overmature) and d (overmature) developmental stages with areas of 11,843, 7,762, 14,098 and 1,748.7 ha, respectively (Table 8). In 1991, the forest area was generally concentrated into regenerated (a=9,458 ha) and mature (c=33,207 ha) stages of development (Table 9). In 2002, the forest was generally categorised in regenerated (a=14,487 ha), young (b=13,353 ha) and mature (c=28,189 ha) stages of development (Table 10). In the last period, 2012, the forest was generally divided into regenerated (a=19,697 ha), young (b=11,212 ha) and mature (c=34,429 ha) stages of development (Tables 10 and 11). This overall change shows that regenerated areas are adequate for sustainable forestry because of the increase in a and b developmental stages between 1969 and 2012. The rest of the area was left to grow into mature and over-mature developmental stages. The general implication is that the forest is developing into young and young-mature stages (Table 11).

Transitions among land cover types

Based on forest management plans, the transitions among major forest cover types over the years 1969, 1991, 2002 and 2012 were determined (Table 3 and Figs. 2 and 3). This analysis showed that for the overall period between 1969 and 2012, about 21,261 ha of degraded forest areas changed into productive Calabrian forest, while 1,544 ha of productive Calabrian forest areas changed into degraded forest areas, with productive pine areas showing a net increase of 25,376 ha. In the same period, about 7,738 ha

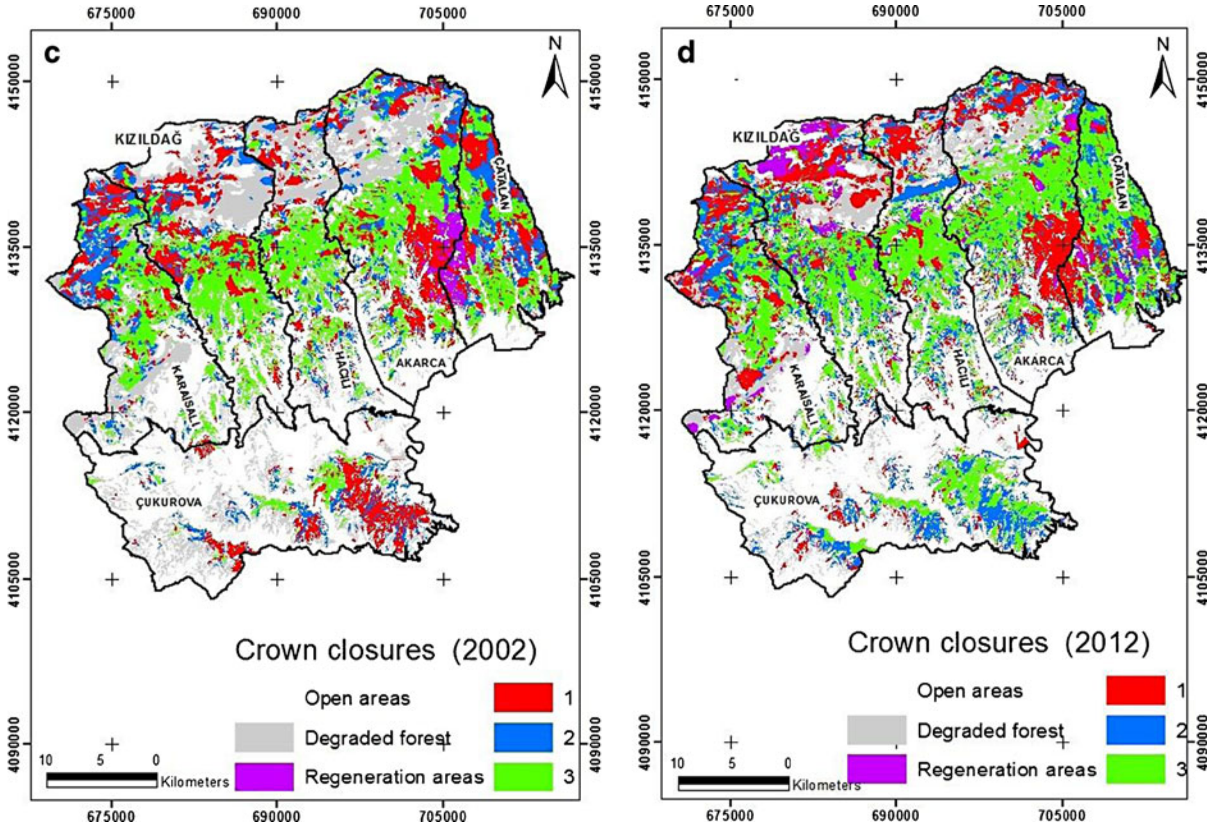

Fig. 5 Crown closure changes of Karaisalı Forest Enterprise in the years **c** 2002 and **d** 2012

of open areas changed into productive Calabrian pine and 3,230 ha of degraded forest changed into productive juniper forest areas. Unchanged areas between 1969 and 2012 included: 40,937 ha of unchanged open areas, 28,177 ha of productive Calabrian pine and 840 ha of water (lakes), as shown in Table 3. In the study area, between 1969 and 2012, about 3,398 ha of open areas changed into water areas due to construction of dams. Other changes of land cover types for the four periods are shown in Figs. 2 and 3.

Transitions among crown closures and developmental stages

Further temporal dynamics or transition among crown closures were subsequently analysed based on the stand-

Table 5 The transition matrix of crown closure classes in the study area from 1991 to 2002

1991 crown closure classes	2002 crown closure classes						
	Regeneration areas Area (ha)	1 Area (ha)	2 Area (ha)	3 Area (ha)	Degraded Area (ha)	Open areas Area (ha)	Total Area (ha)
Regeneration areas	283.0	1,669.0	134.7	95.2	110.1	337.7	2,629.6
1	383.2	6,369.9	3,982.4	4,564.4	2,162.7	1,344.9	18,807.6
2	192.0	3,742.1	4,603.0	6,641.1	997.9	1,481.6	17,657.9
3	149.3	2,261.3	2,340.2	10,502.1	436.9	929.2	16,619.0
Degraded	382.8	3,502.7	2,283.4	1,530.7	15,948.8	4,428.3	28,076.8
Open areas	57.4	1,490.0	1,109.2	1,919.4	4,833.8	49,386.0	58,795.9
Total	1,447.8	19,035.0	14,453.0	25,252.9	24,490.3	57,907.7	142,586.7

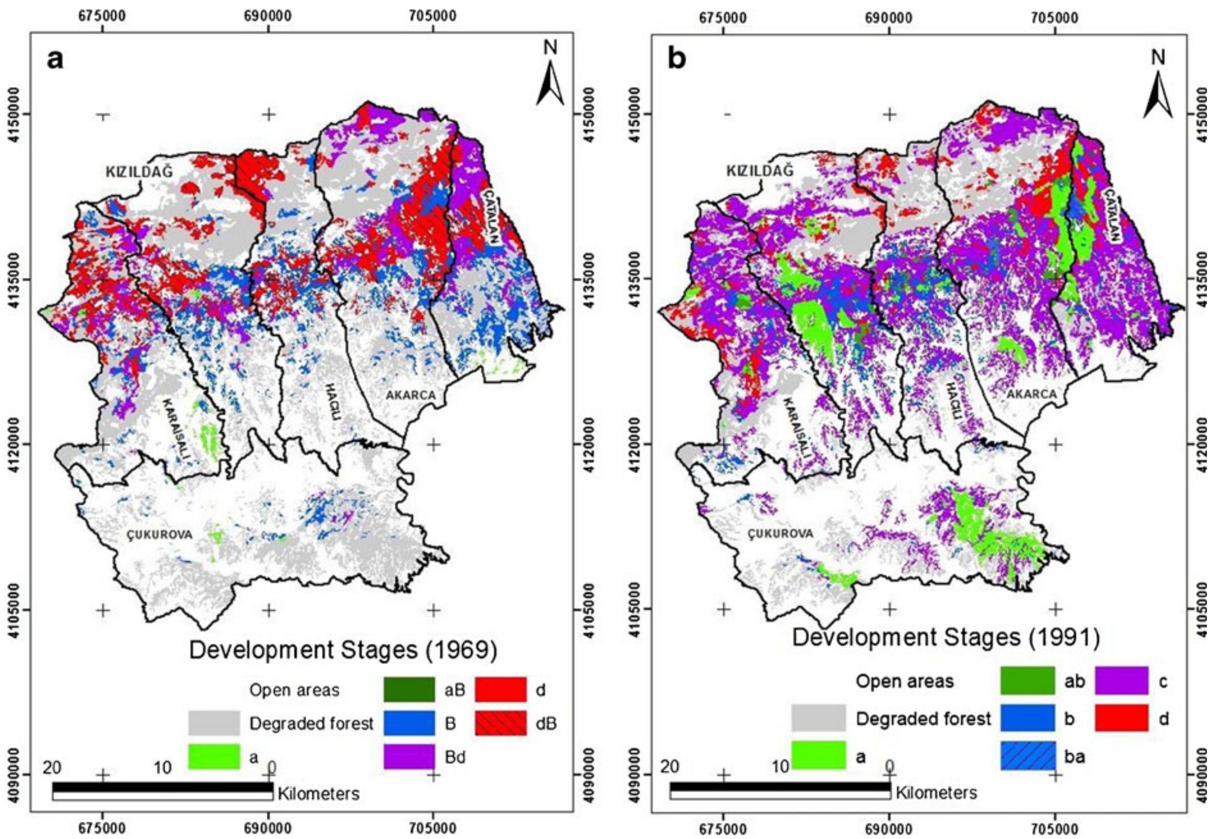

Fig. 6 Development stage changes of Karaisalı Forest Enterprise in the years **a** 1969 and **b** 1991

type maps for the four periods. For the first period covering 1969 to 1991, approximately 1,908 ha of areas with full closure (3) were thinned into medium coverage (2), 2,660 ha of full closure areas were heavily thinned into low coverage (1), 4,569 ha of medium-covered (2) areas were developed into fully covered (3) areas and 2,345 ha of low-covered (1) areas were developed into fully covered (3) areas (Table 4). In addition, degraded forest areas were changed into productive areas; these changes show that nearly 3,500 ha of degraded forest areas were developed into fully covered areas, 6,175 ha into medium-covered (2) areas and 7,612 ha into substantially low-covered (1) areas (Figs. 4 and 10). At the end of this period, forest transitions show a substantial increase in the productive forest area of Karaisalı Forest Enterprise, as fully covered areas increased by about 6,888 ha, medium-covered forest areas increased by about 2,520 ha and low-covered areas increased by about 7,500 ha (Fig. 10).

For the second period covering 1991 to 2002, nearly 3,502 ha of degraded forest were developed into low-covered forest, 2,283 ha of degraded forest areas were developed into medium-covered forest, and 1,530 ha of degraded forest were developed into fully-covered areas. In addition to these changes, 2,162 ha of low-covered forest areas were heavily thinned into degraded forest and 2,340 ha of fully covered areas were heavily thinned into medium-covered forest areas (Fig. 5). At the end of this period, fully covered forest areas increased by about 8,633 ha and degraded forest areas decreased by about 3,600 ha (Table 5).

Over the third period covering 2002 to 2012, 4,556 ha of degraded forest were developed into low-covered forest, 2,510 ha of degraded forest areas were developed into medium-covered forest and 1,746 ha of degraded forest were developed into fully covered areas (Figs. 6 and 7). In addition to these changes, 986 ha of low-covered forest areas were heavily thinned into degraded forest and 2,202 ha of fully covered areas were heavily thinned into low-covered forest areas (Table 6).

During the overall planning period covering 1969 to 2012, around 8,995 ha of degraded forest were developed

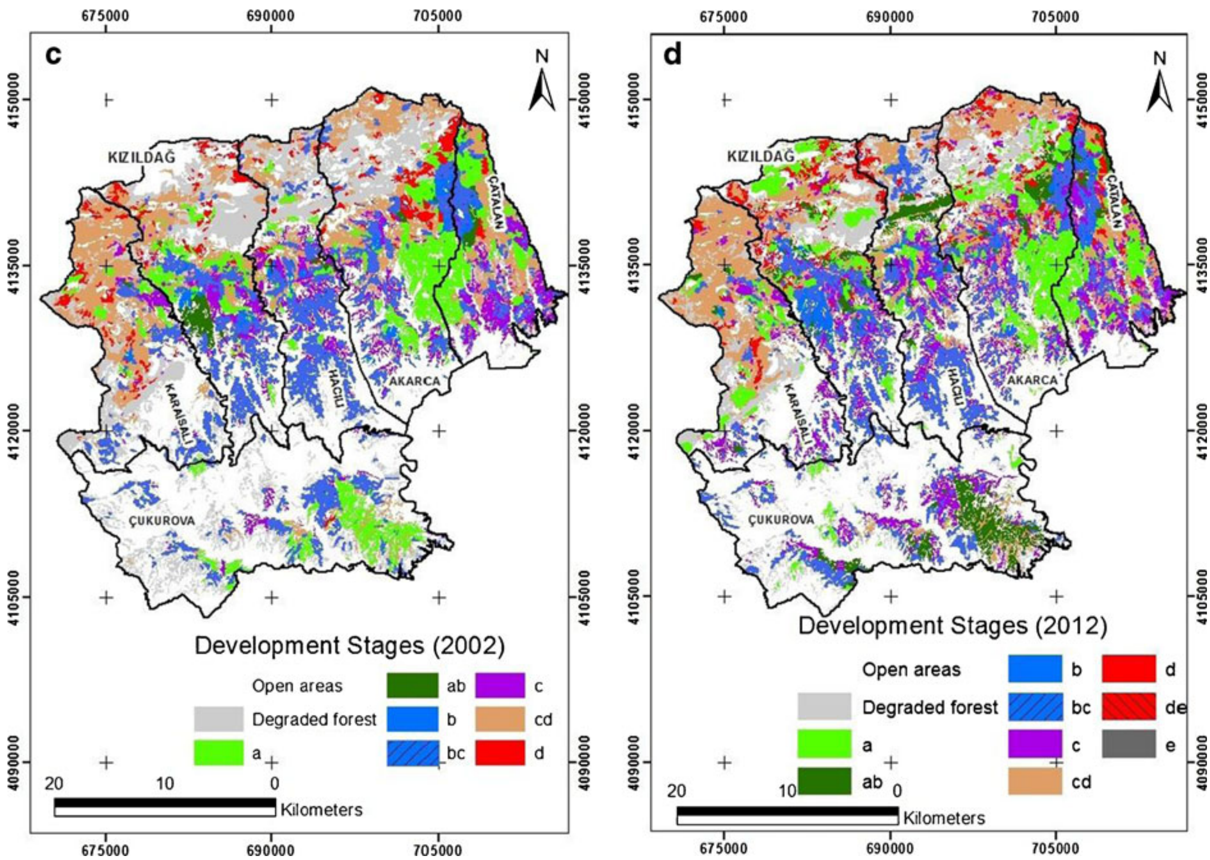

Fig. 7 Development stages changes of Karaisalı Forest Enterprise in the years **c** 2001 and **d** 2012

into low-covered (1) areas, 8,316 ha of degraded forest areas were developed into medium-covered (2) areas and 9,803 ha of degraded forest were developed into fully covered (3) areas. In addition, 3,677 ha of low-covered areas and 7,533 ha of medium-covered areas were developed into fully covered forest areas (Fig. 6). However, 1,097 ha of low-coverage areas were heavily thinned into degraded forest and 1,487 ha of fully covered forest areas were fired and heavily thinned into low-covered forest areas (Fig. 7). These overall changes show that productive forest areas had increased; fully covered forest areas increased by about 21,321 ha, low-coverage forest areas increased by about 7,069 ha and degraded forest areas decreased by about 31,000 ha (Fig. 5 and Table 7).

Further temporal dynamics or transitions among developmental stages were analysed using stand-type maps for four periods. During the first period between 1969 and 1991, around 1,158 ha of areas of the young developmental stage (Bd) grew naturally into the overmature stage (*d*) and 6,653 ha of areas of stage Bd grew into the mature stage (*c*), while 1,810 ha of stage dB were converted into stage *a*, possibly through regeneration activities (Fig. 8). Around 2,961 ha of degraded forests were regenerated into stage *a* (Fig. 5); 1,810 ha of stage dB forest areas were regenerated (stage *a*) and 1,328 ha of stage *B* were regenerated (stage *a*) due to the effects of forest fires (Fig. 9). Over the same period, 2,192 ha of degraded forest developed into stage *b*, 12,522 ha of degraded forests developed into stage *c*, and 1,163 ha of degraded forests to stage *d* (Table 8). At the end of this planning period, stage *a* (regeneration) areas increased from 716 to 8,100 ha due to the effects of forest fire and through the work of successful regeneration activities.

During the second period between 1991 and 2002, about 1,124 ha of regeneration stage areas (*a*) grew naturally into the young stage (*b*), while 4,659 ha in stage *c* were converted into stage *a*, possibly through regeneration activities (Figs. 8 and 10). Around 1,685 ha of degraded forest and 1,590 ha of stage *d* forest areas were regenerated (stage *a*). Over the same period,

Table 6 The transition matrix of crown closure classes in the study area from 2002 to 2012

2002 crown closure classes	2012 crown closure classes						
	Regeneration areas Area (ha)	1 Area (ha)	2 Area (ha)	3 Area (ha)	Degraded Area (ha)	Open areas Area (ha)	Total Area (ha)
Regeneration areas	110.9	1,196.7	6.1	64.1	36.2	33.9	1,447.8
1	369.0	6,602.4	3,530.3	6,578.0	986.3	969.0	19,035.0
2	652.7	2,329.7	5,904.2	4,149.9	680.4	736.1	14,453.0
3	541.5	2,202.7	4,022.2	16,920.7	442.4	1,123.5	25,252.9
Degraded	660.6	4,556.2	2,510.4	1,746.9	11,301.4	3,714.7	24,490.3
Open areas	1,084.9	1,494.4	1,378.1	1,592.7	2,401.2	49,956.4	57,907.7
Total	3,419.5	18,382.0	17,351.3	31,052.4	15,848.0	56,533.5	142,586.7

1,663 ha of degraded forest developed into stage bc, 2,888 ha into cd and 682 ha into stage d (Table 9).

During the third period, covering 2002 to 2012, about 4,449 ha of areas in the regeneration stage (*a*) grew naturally into the young stage (ab) and 524 of areas of stage *a* grew into the young stage (*b*), while 1,968 ha in stage cd were converted into stage *a*, possibly through regeneration activities (Fig. 10). Around 2,328 ha of degraded forest and 759 ha of stage *d* forest areas were regenerated (stage *a*). Over the same period, 1,182 ha of degraded forest developed into stage *c*, 2,461 ha developed into cd and 2,017 ha changed to bc (Table 10). Also, during this period, 1,884 ha of open areas were changed into *a* developmental stage through afforestation activities.

For the purpose of general assessment, the developmental stages were grouped according to the dominant stage class such as *a* (*a*, ab), *b* (*b*, *B*, bc, Bd), *c* (*c*, cd), *d* (*d*, dB, de, *e*) for the overall planning period between 1969 and 2012. Around 5,348 ha of degraded forests were regenerated to stage *a*, 3,387 ha was regenerated to stage ab, 5,818 ha was developed into stage *c* and 8,022 ha was developed into stage cd. In addition, 2,541 ha of open areas were changed into a developmental stage, and of these, 502 ha was a result of afforestation activities. Also in this period, around 187 ha of a developmental stages developed into stage *c* over the 43-year period, based on the growth curve of Calabrian pine (Table 11). By the end of this period, the *a* stages (*a*, ab) increased from 716 to 19,697 ha, the *d* stages (*d*, dB, de, *e*) decreased from 15,857 to 4,866 ha, and young-mature forests (stages *B* and Bd in 1969 and stages *b*, bc, *c* and cd in 2012) increased from 19,608 to 45,640 (Table 11). These changes show that regenerated areas, young and young-mature forest areas increased quite remarkably and over-mature forest areas decreased significantly. Regarding the developmental stages, the forest dynamics of the Karaisalı Forest ecosystem had been focused on young and young-mature forest by the end of the overall study period between 1969 and 2012.

Spatial analysis of land cover types

The spatial analysis of the landscape patterns indicated several metrics calculated for the cover-type class for the four periods. The total number of patches (NP) increased

Table 7 The transition matrix of crown closure classes in the study area from 1969 to 2012

1969 crown closure classes	2012 crown closure classes						
	Regeneration areas Area (ha)	1 Area (ha)	2 Area (ha)	3 Area (ha)	Degraded Area (ha)	Open areas Area (ha)	Total Area (ha)
1	325.9	2,651.0	2,639.0	3,677.6	1,097.7	912.5	11,303.7
2	529.1	2,870.9	2,950.1	7,533.8	573.8	682.3	15,139.9
3	323.1	1,497.1	1,056.4	6,447.3	147.4	259.8	9,731.0
Degraded	965.1	8,995.6	8,316.1	9,803.0	10,769.2	8,003.0	46,851.9
Open areas	1,276.4	2,367.3	2,389.8	3,590.7	3,259.9	46,676.0	59,560.2
Total	3,419.5	18,382.0	17,351.3	31,052.4	15,848.0	56,533.5	142,586.7

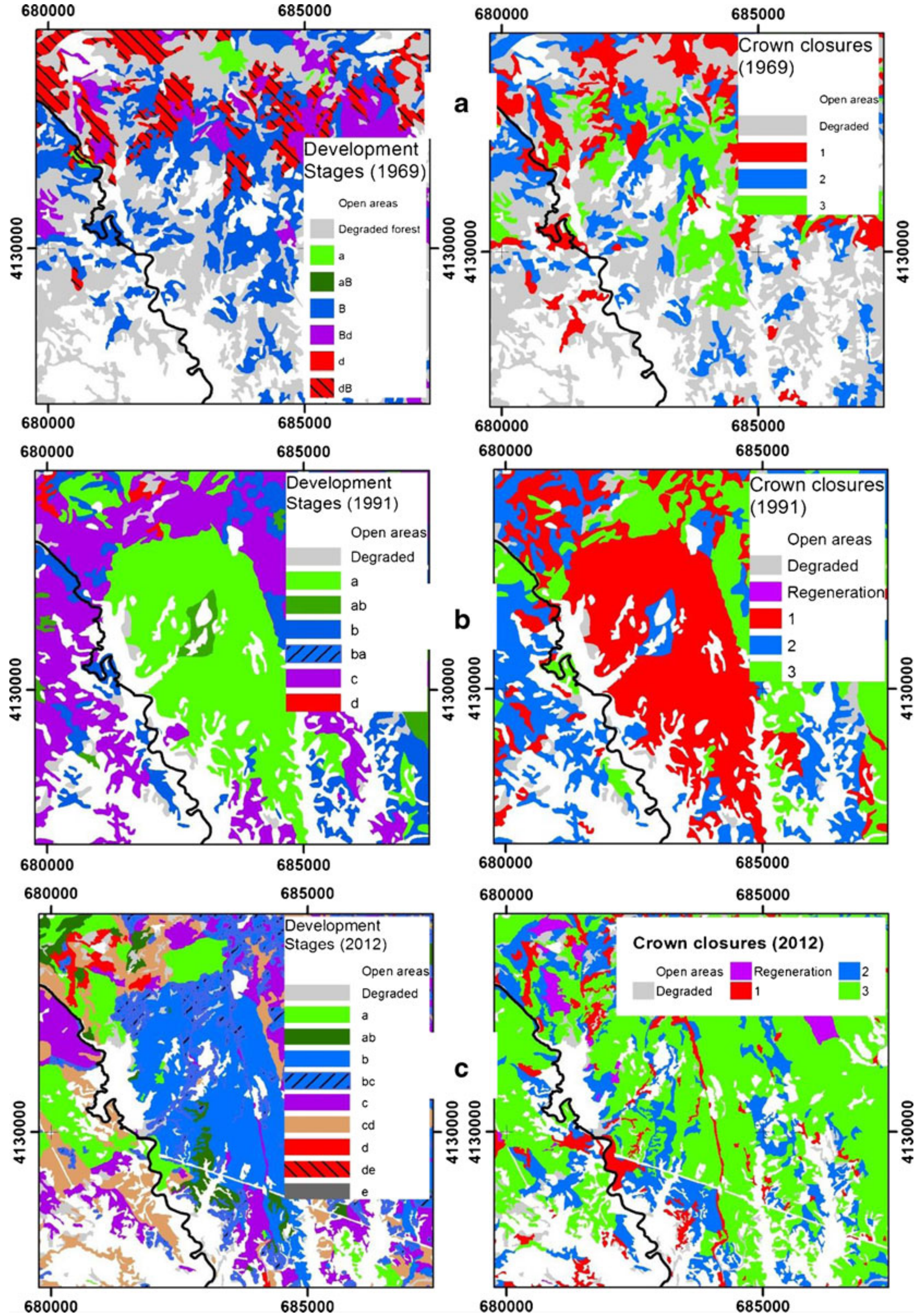

Fig. 8 Changes of stand parameters on fired area (about 600 ha in the year 1979) in the years 1969 (**a**), 1991 (**b**) and 2012 (**c**)

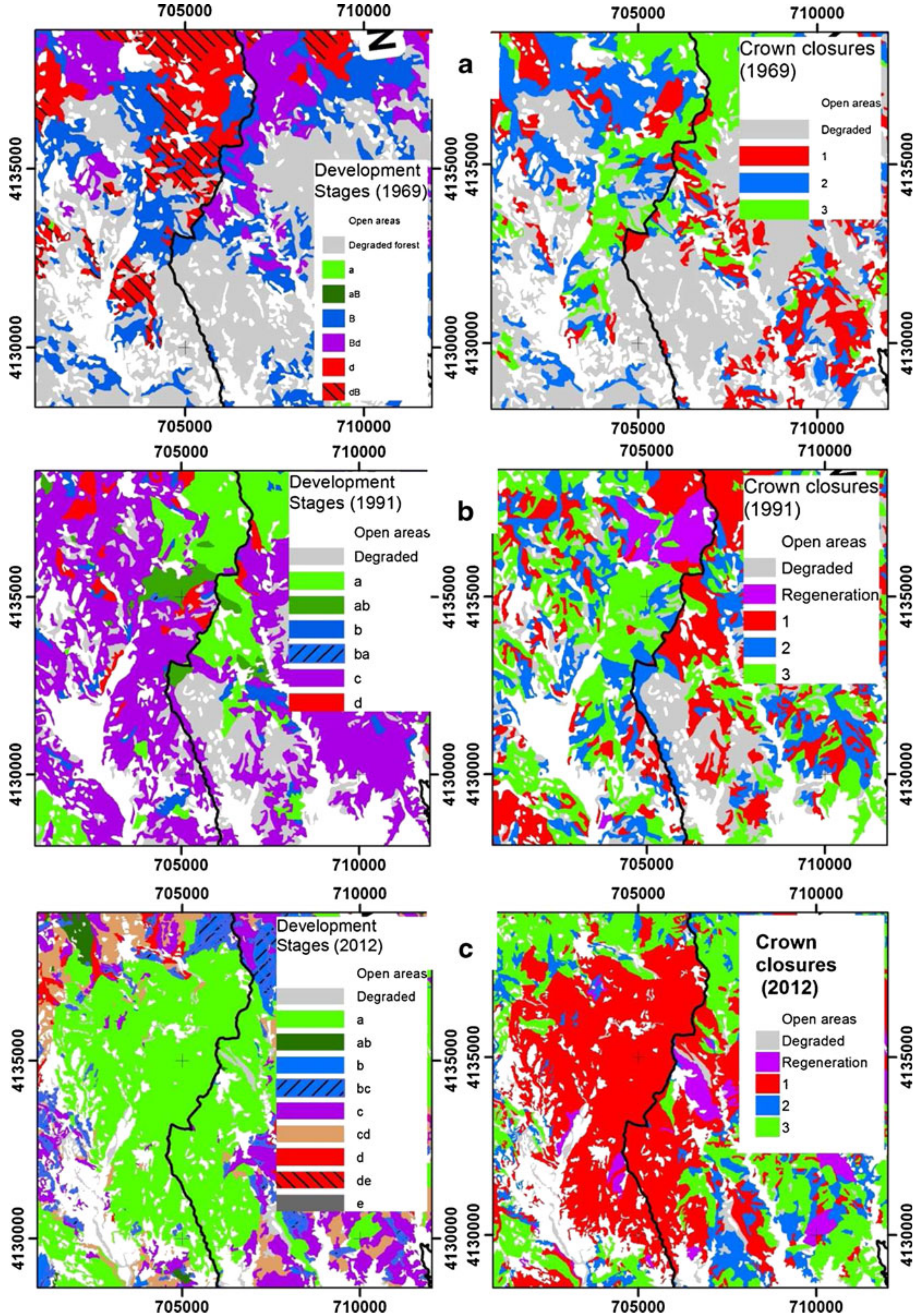

Fig. 9 Changes of stand parameters on fired area (about 3,100 ha in the year 2000) in the years 1969 (**a**), 1991 (**b**) and 2012 (**c**)

Table 8 The transition matrix of developmental stages in the study area from 1969 to 1991

1969 developmental stages	1991 developmental stages								
	Open areas Area (ha)	a Area (ha)	ab Area (ha)	b Area (ha)	ba Area (ha)	c Area (ha)	d Area (ha)	Degraded Area (ha)	Total Area (ha)
Open areas	48,224.1	785.6	164.2	1,141.5	1.7	3,545.7	343.1	5,354.3	59,560.2
a	221.4	12.3	0	31.4	0	206.3	15.5	205.1	692
aB	0	0	0	4.3	0	18.1	0	2.4	24.8
B	989.1	1,328.9	213.9	1,135.2	15.7	6,653.9	742.4	792.1	11,871.3
Bd	256.4	883.5	193.6	623.5	24.1	4,084.2	1,158.8	514.5	7,738.5
d	91.6	318.1	116.7	139.0	5.1	538.0	353.3	187	1,748.7
dB	586.3	1,810.8	440.6	948.8	129.3	5,639.1	2,868.9	1,675.6	14,099.4
Degraded	8,427.0	2,961.5	228.4	2,192.0	10.9	12,522.6	1,163.8	19,345.7	46,851.9
Total	58,795.9	8,100.6	1,357.4	6,215.6	186.8	33,207.9	6,645.8	28,076.8	142,586.7

from 3,614 to 7,087 between 1969 and 2012, all patch types being taken into account. The mean patch size (MPS) decreased from 39.5 to 20.1 ha. The MPS of the water areas changed significantly from 7.4 to 131.7 ha between 1969 and 2012, having been affected by the building of a dam. However, the MPS of the degraded forest areas changed from 46.4 to 6.8 ha. The reasons for these changes in degraded forest areas probably relate to the decrease from 46,871 to 15,848 ha in the class areas affected by changed productive forest areas and the increase of NP from 1,010 to 2,330 patches (Table 12). The number of patches increased from 474 to 848 in 43 years; however, the MPS of productive Calabrian pine areas remained stable at 68 ha. The reasons for these changes in Calabrian pine areas were mainly due to the net increase of 25,376 ha in the class areas. Similarly, the area weighted mean shape index (AWMSI) value increased from 15.2 to 17.4, mainly due to the substantial increase in the AWMSI value of the Calabrian pine. However, patch density value increased from 2.53 to 4.97 and patch size coefficient of variation (PSCV (%)) value increased from 1,781.97 to 2,438.75 over 43 years. Last parameters showed the level of fragmentation, as the largest patch index (LPI) value decreased from 25.11 to 20.10 over43 years. All these changes, which include a remarkable increase in productive forest areas, as well as an increase in landscape fragmentation, show that the forest has become more susceptible to harsh disturbances.

Discussion and conclusion

This study analysed the forest dynamics and spatiotemporal pattern of land use/land cover change over a 43-year period in the Karaisalı Forest Enterprise in Turkey. The digitised stand maps from the periodically renewed forest management plans of 1969, 1991, 2001 and 2012, along with GIS and FRAGSTATS, were used to analyse land cover/forest dynamics and the spatial configuration of forest resources. The quantitative evidence of forest dynamics presented here show that there were drastic changes in the temporal and spatial patterns of stand parameters, especially on the regeneration class and fully covered developmental stages of forests in the study area.

The results of forest dynamics in the study area show that the total forested areas (degraded and productive forests) increased from 83,026 ha (58.22 %) to 86,062 ha (60.35 %) during the 43-year period. In other words, cumulative forest improvement accounted for 2.12 % as a whole (3,026 ha) from 1969 to 2012. This translates into an average annual forest improvement rate of 0.08 %. Considering only the productive forest areas, this represents an average annual productive forest improvement rate of 1.54 %. Similar results are also shown in the analyses of reforestation and forest improvement of Turkey. Based on the assessment of inventory results between 1963 and 1972, Turkey had 20,199,296 ha of forest area covering about 26.1 % of the country's total land area. Now, based on the assessment of the inventory results in the forest management plans up to the end of 2012, Turkey has 21,678,134 ha of forest area, accounting for about 27.6 % of the country's total land area, and 99.9 % of the forest area is owned by the state (GDF 2012). The results show that the total forested areas increased by 1.44 million hectares during the 40-year period. In other words, cumulative forest improvement was calculated at 1.88 % as a

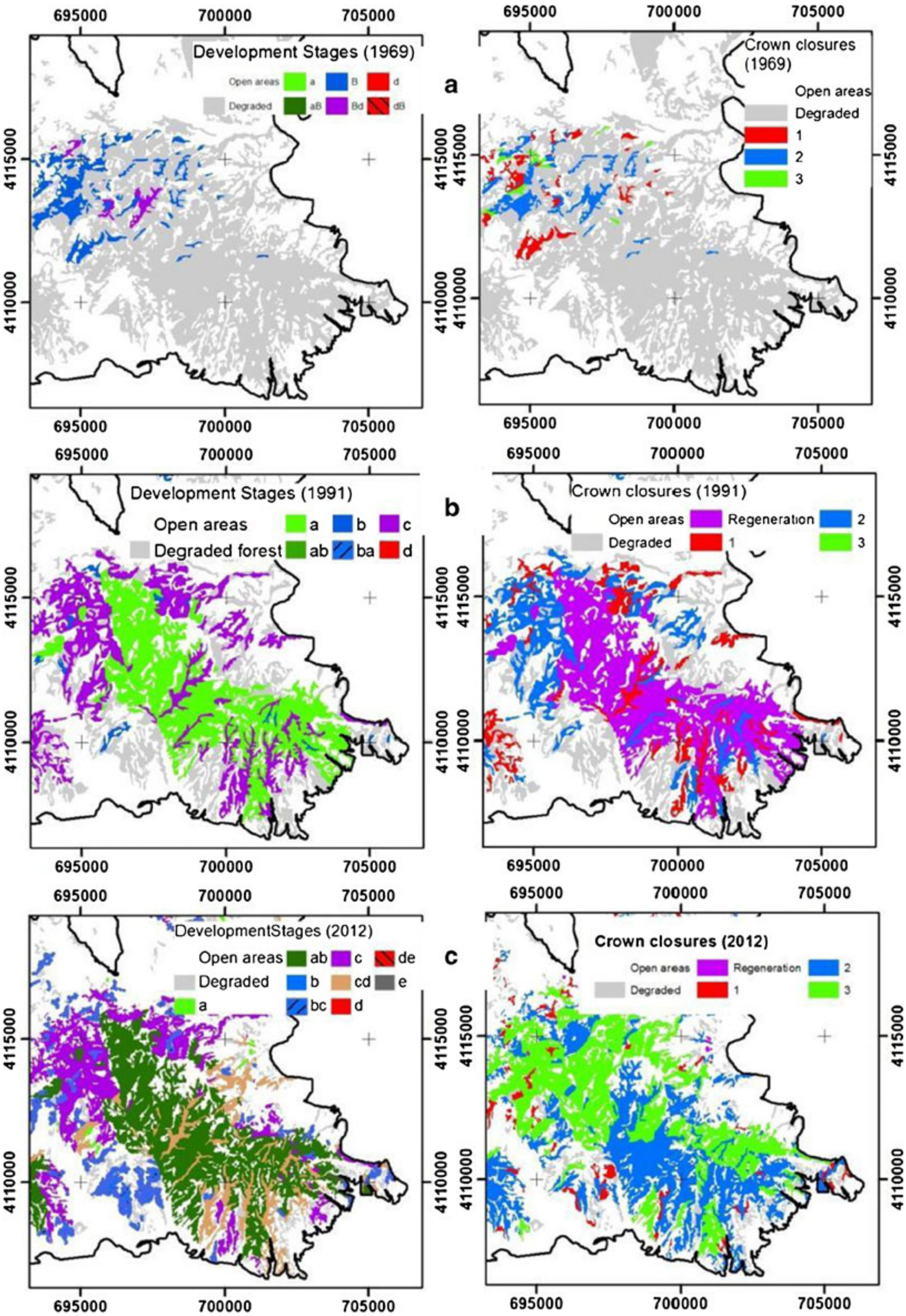

Fig. 10 Changes of stand parameters in the years 1969 (**a**), 1991 (**b**) and 2012 (**c**)

Table 9 The transition matrix of developmental stages in the study area from 1991 to 2002

1991 developmental stages	2002 developmental stages									
	Open areas Area (ha)	a Area (ha)	ab Area (ha)	b Area (ha)	bc Area (ha)	c Area (ha)	cd Area (ha)	d Area (ha)	Degraded Area (ha)	Total Area (ha)
Open areas	49,386.0	983.1	72.1	76.7	1,529.6	826.2	880.8	207.6	4,833.8	58,795.9
a	612.5	3,575.0	1,124.8	1,174.5	775.7	190.2	267.2	45.1	335.6	8,100.6
ab	59.9	259.5	33.8	236.4	500.7	116.5	118.6	9.3	22.7	1,357.4
b	692.7	372.9	50.8	149.7	1,872.8	1,361.1	1,303.4	75.1	337.2	6,215.6
ba	3.7	9.0	0.0	18.9	149.1	1.1	2.0	3.0	0.0	186.8
c	2,512.9	4,659.0	18.3	137.6	4,813.3	4,688.9	12,409.9	1,730.1	2,238.0	33,207.9
d	211.7	1,590.6	40.8	45.0	163.3	82.8	2,331.7	1,405.8	774.1	6,645.8
Degraded	4,428.3	1,685.5	12.0	46.8	1,663.5	721.6	2,888.0	682.2	15,948.8	28,076.8
Total	57,907.7	13,134.5	1,352.6	1,885.6	11,467.9	7,988.4	20,201.5	4,158.1	24,490.3	14,2586.7

Table 10 The transition matrix of developmental stages in the study area from 2002 to 2012

2002 developmental stages	2012 developmental stages											
	Open areas Area (ha)	a Area (ha)	ab Area (ha)	b Area (ha)	bc Area (ha)	c Area (ha)	cd Area (ha)	d Area (ha)	de Area (ha)	e Area (ha)	Degraded Area (ha)	Totals Area (ha)
Open areas	49,956.4	1,884.3	416.2	63.5	920.6	1,098.7	908.2	215.5	42.8	0.3	2,401.2	57,907.7
a	643.3	5,874.5	4,449.8	524.9	554.8	201.7	494.6	89.6	5.0	0.6	295.8	13,134.5
ab	56.3	8.2	138.1	756.2	290.2	63.5	16.9	2.0	0.0	0.0	21.3	1,352.6
b	46.8	16.0	44.7	398.6	981.4	308.0	60.4	2.8	0.0	0.0	26.9	1,885.6
bc	964.2	190.8	73.2	65.4	3,184.1	5,247.7	1,257.2	70.5	6.6	0.0	408.3	11,467.9
c	509.1	476.2	39.0	29.6	797.4	3,571.4	2,218.4	146.3	8.6	0.0	192.3	7,988.4
cd	534.7	1,968.3	129.2	35.1	512.6	2,019.2	11,830.1	1,992.9	274.9	0.0	904.6	20,201.5
d	107.9	759.2	20.5	23.6	35.6	122.4	1,367.0	1,161.7	260.6	3.6	296.1	4,158.1
Degraded	3,714.7	2,328.1	881.3	20.9	2,017.3	1,182.3	2,461.5	435.7	146.8	0.0	11,301.4	24,490.3
Totals	56,533.5	13,505.5	6,192.0	1,918.0	9,294.0	13,814.8	20,614.3	4,116.8	745.3	4.5	15,848.0	142,586.7

Table 11 The transition matrix of developmental stages in the study area from 1969 to 2012

1969 developmental stages	2012 developmental stages Open areas Area (ha)	a Area (ha)	ab Area (ha)	b Area (ha)	bc Area (ha)	c Area (ha)	cd Area (ha)	d Area (ha)	de Area (ha)	e Area (ha)	Degraded Area (ha)	Totals Area (ha)
Open areas	46,676	2,541.6	502.5	203.4	2,030.3	2,290.7	1,719.7	277.6	56.6	1.8	3,259.9	59,560.2
a	226.9	48.7	5.2	1.9	71.5	187.6	57.7				92.4	692
aB					0.4	9.3	14.6	0.5			0	24.8
B	852.6	2,219.9	612.1	601	1,009.5	2,766.6	2,913.7	474.1	69.1	0	352.7	11,871.3
Bd	226.0	1,098.1	557.8	285.3	577.6	988.4	3,074.1	631.0	53.0		247.3	7,738.5
d	50.1	375.3	47.4	42.6	120.7	206.6	385.5	306.6	93.0		121.1	1,748.7
dB	498.9	1,873.4	1,079.6	367.1	1,502.3	1,547	4,426.2	1,498.5	298.4	2.6	1,005.4	14,099.4
Degraded	8,003.0	5,348.4	3,387.4	416.7	3,981.8	5,818.6	8,022.9	928.6	175.3		10,769.2	46,851.9
Totals	56,533.5	13,505.5	6,192.0	1,918.0	9,294.0	13,814.8	20,614.3	4,116.8	745.3	4.5	15,848.0	142,586.7

whole and 7.32 % for the forested area of Turkey. Total productive forest improvement increased by about 2.7 million hectares and degraded forests decreased by about 1.22 million hectares. This comes to an average annual total forest improvement rate of 0.17 %, an average annual productive forest improvement rate of 0.66 % and an average annual rate of −0.28 % for degraded forest areas disturbed. Generally, these observed trends can be explained by plantation of degraded forestlands and open areas, natural regeneration on lands abandoned as a result of migration from the villages inside or near the forests, increased public awareness of and respect for the environment and, lastly, forest sustainability managed by the General Directorate of Forestry (GDF 2009). Considering only the annual rate of total productive forest improvement, this value in the study area (1.54 %) is higher than that of Turkey as a whole (0.66 %).

Similar results from other important research initiatives carried out in Turkey are also shown. A study by Kadıoğulları et al. (2008) of the northeast region of Turkey stated that the percentage of forest cover in the Torul Forest Enterprise had increased from 42.95 % in 1984 to 51.20 % in 2005, based on stand-type maps. This translates to an annual rate of forest improvement of 0.92 %. Another study from the northeast region of Turkey found that from 1972 to 2005, cumulative forest improvement accounted for 2.06 % as a whole (1,823 ha) and 14.13 % of the forested area of the Yalnızçam and Uğurlu forest planning units. This is calculated as an average annual rate of 0.40 % for forest improvement (Kadıoğulları 2013). In addition, another study in the western part of Turkey showed that from 1972 to 1993, 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 İnegöl Province. This translates to an average annual rate of 0.44 % for forest improvement (Başkent and Kadıoğulları 2007). Contrasting data have been shown for the northeast part of Turkey, where cumulative forest disturbance from 1984 to 2007 accounted for 2.30 % of the whole area of the Rize Forest Enterprise (2,299 ha) and 4.52 % of the forested area of Rize Province. This translates to an annual forest disturbance rate of 0.20 % (Günlü et al. 2009). In addition to this study, another study from the same region found that from 1971 to 1987, cumulative forest disturbance accounted for 0.52 % of the whole area of Gümüşhane Forest Enterprise (2,271 ha) and 2.22 % of the forested area

Table 12 Change of landscape pattern in the study area (1969, 1991, 2002, and 2012 forest cover type maps)

Years/index	Class area (ha)				Number of patches				Mean patch size (ha)				Percent of landscape (%)				Area-weighted mean shape index			
	1969	1991	2002	2012	1969	1991	2002	2012	1969	1991	2002	2012	1969	1991	2002	2012	1969	1991	2002	2012
Almond, carob and laurel				1,004.7				57				17.6				0.70				
Black pine	1,207.1	1,039.4	1,473.4	1,723.6	24	31	55	72	50.3	33.5	26.8	23.9	0.85	0.73	1.03	1.21	2.542	4.161	2.285	2.648
Cedar	647.4	696.6	889.4	2,343.6	13	16	14	35	49.8	43.5	63.5	67.0	0.45	0.49	0.62	1.64	3.717	2.485	3.595	4.681
Degraded forest	46,851.8	28,076.8	24,490.3	15,848.0	1,010	1,089	1,345	2,330	46.4	25.8	18.2	6.8	32.86	19.69	17.18	11.11	11.090	9.964	9.087	6.487
Fir	1,240.1	1,235.5	1,363.9	1,265.3	18	32	21	34	68.9	38.6	64.9	37.2	0.87	0.87	0.96	0.89	2.170	2.836	2.946	3.013
Juniper	688.2	3,047.5	2,965.2	4,763.9	21	57	42	98	32.8	53.5	70.6	48.6	0.48	2.14	2.08	3.34	3.359	4.083	3.611	4.859
Oak	129.4	67.4	178.9	1,251.5	14	4	17	58	9.2	16.8	10.5	21.6	0.09	0.05	0.13	0.88	2.679	1.642	2.276	5.350
Open areas	57,956.6	53,026.2	51,702.3	50,315.5	1,774	1,755	2,347	3,276	32.7	30.2	22.0	15.4	40.65	37.19	36.26	35.29	21.568	20.905	18.510	20.721
Calabrian pine	32,262.3	49,627.8	53,313.1	57,638.0	474	529	586	848	68.1	93.8	91.0	68.0	22.63	34.81	37.39	40.42	11.875	20.043	17.237	21.588
Settlement	552.0	689.6	1,127.7	1,212.2	124	116	98	208	4.5	5.9	11.5	5.8	0.39	0.48	0.79	0.85	1.331	1.260	1.557	2.163
Stone pine			4.8	214.6			2	33			2.4	6.5			0.00	0.15			1.233	2.715
Water	1,051.7	5,080.1	5,077.8	5,005.8	142	238	12	38	7.4	21.3	423.1	131.7	0.74	3.56	3.56	3.51	5.068	6.642	8.092	9.771
Landscape	142,586.7	142,586.7	142,586.7	142,586.7	3,614	3,867	4,539	7,087	39.5	36.9	31.4	20.1	100.00	100.00	100.00	100.00	15.216	17.110	15.170	17.486
Years/index	Largest patch index (LPI (%))				Patch density (PD; NP/100 ha)				Patch size coefficient variant (PSCV (%))											
	1969	1991	2002	2012	1969	1991	2002	2012	1969	1991	2002	2012								
Almond, carob and laurel				0.12				0.04				189.01								
Black pine	0.23	0.26	0.15	0.28	0.02	0.02	0.04	0.05	149.18	226.43	161.33	223.15								
Cedar	0.23	0.14	0.27	0.77	0.01	0.01	0.01	0.02	175.27	134.77	161.21	295.93								
Degraded forest	9.86	7.30	6.70	1.61	0.71	0.76	0.94	1.63	1,060.53	1,265.25	1,481.35	1,046.81								
Fir	0.30	0.18	0.33	0.24	0.01	0.02	0.01	0.02	146.30	149.88	164.15	167.00								
Juniper	0.17	0.58	0.30	0.67	0.01	0.04	0.03	0.07	175.65	248.71	150.33	276.82								
Oak	0.02	0.02	0.02	0.35	0.01	0.00	0.01	0.04	84.98	50.47	98.73	328.73								
Open areas	25.11	24.71	17.23	17.51	1.24	1.23	1.65	2.30	2,633.92	2,789.32	2,444.54	2,957.67								
Calabrian pine	8.87	24.12	18.96	20.10	0.33	0.37	0.41	0.59	1,018.38	1,602.02	1,357.94	1,597.18								
Settlement	0.01	0.05	0.09	0.13	0.09	0.08	0.07	0.15	71.03	116.57	135.32	264.44								
Stone pine			0.00	0.06			0.00	0.02			69.20	227.39								
Water	0.34	3.02	2.93	2.50	0.10	0.17	0.01	0.03	580.12	1,312.92	2,81.78	453.48								
Landscape	25.11	24.71	18.96	20.10	2.53	2.71	3.18	4.97	1,781.97	2,213.91	1,943.84	2,438.75								

of Gümüşhane Province. This converts to an annual forest disturbance rate of 0.14 % (Kadıoğulları and Başkent 2008).

Furthermore, as a whole, changes of crown closures show that productive forest areas increased overall by about 34,030 ha between 1969 and 2012; fully covered forest areas increased by about 21,321 ha, low-coverage forest areas increased by about 7,069 ha and degraded forest areas decreased by about 31,000 ha. Considering crown closures, productive forest areas and fully covered areas increased substantially. Developmental stages, as another stand parameter, were also analysed between 1969 and 2012. Overall changes showed that *a* (*a*, ab) stages increased from 716 to 19,697 ha, *d* stages (*d*, dB, de, *e*) decreased from 15,857 to 4,866 ha, and young-mature forest areas (*B* and Bd stages in 1969 and *b*, bc, *c* and cd stages in 2012) increased from 19,608 to 45,640 ha (Table 11). These changes show that regenerated, young and young-mature forest areas increased remarkably and over-mature forest areas decreased significantly. The Karaisalı Forest ecosystem, considering developmental stages, was focused on young and young-mature forests between 1969 and 2012. The results indicated that the increased productive forest areas and fully covered areas with the decrease of the degraded and understocked forest have the potential to cause an increased level of carbon storage in the landscape. The similar results also provide favourable condition and opportunity for the conservation of biodiversity as the level of disturbance is better managed towards natural forest landscape.

In general, while the productive forest areas increased remarkably and the total forest areas increased slightly, qualitative analysis of the forest resources based on crown closures and developmental stages showed improvement. Forest improvement in the study area was affected by successful silvicultural forest management interventions, regeneration activities in degraded and productive forest areas, reforestation activities in open areas, fire ecology and a better response to the ecosystem due to all the interventions made.

The spatial structure of the forest ecosystems was also analysed in this study. The number of patches (NP) and their sizes were relatively good spatial metrics of landscape fragmentation (Southworth et al. 2004; Echeverría et al. 2006a, b; Kadıoğulları 2013). 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. The number of patches increased from 474 to 848 and patch density value increased from 2.53 to 4.97 over 43 years; however, the MPS of productive Calabrian pine areas remained stable at 68 ha. The reasons for these changes in Calabrian pine areas were mainly due to the net increase of 25,376 ha. Similarly, the AWMSI value increased from 15.2 to 17.4, mainly due to the substantial increase in the AWMSI value of Calabrian pine. All these changes show that as landscape fragmentation increased, the forest became more susceptible to harsh disturbances.

The possible reasons for the increased fragmentation of the study area could be related to forest fires, construction of dams, creation of firebreaks by the GDF, regeneration and rehabilitation activities in degraded forest areas and, lastly, reforestation activities in open areas. At the same time, it is possible to indicate that the decrease of social pressure on the forest ecosystem and the increased quality of forest parameters were a result of the decrease in the rural population in the study area during the study period.

Remote sensing seems to be a valuable and cost-effective tool for defining and understanding forest structure with the help of land use/land cover change analysis (Ozdemir and Karnieli 2011; Kadıoğulları and Başkent 2008; Sağlam et al. 2008; Anderson et al. 2008; Cho et al. 2009). However, it is limited due to its resolution of old images as happens in Landsat™ and other images (before 2000 year). Ironically, though, it is also limited due to the high-resolution images with high cost for wide area applications that require a high rate of revisit (Wolter et al. 2009).

In conclusion, understanding land cover changes and temporal and spatial variations in addition to comprehending forest dynamics for the planning of sustainable forest resources has become increasingly important during the preparation of Ecosystem Based Multi Objective (ETÇAP) forest management plans. This study examined the forest dynamics using a number of spatial and non-spatial measurements or factors in Karaisalı Forest Enterprise from the beginning of the Turkish planning period (1963–1972) up to the present using forest management plan data.

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