Full Length Research Paper

Spatial distribution and temporal change of old-growth forest: A case study in the Balci forest management unit, Turkey

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Old-growth forests are considered as one of the important conservation targets in sustainable management of forest ecosystems. Stand parameters such as age, diameter at breast height, area, species mixture, canopy closure and snag volume per hectare are employed in estimating the value of the old-growth forests. This article is focused on the main stand parameters in determining potential old-growth forest stands by considering survival rate against 40-year of timber management philosophy in Turkey. The changes in the old growth forest stands between 1984 and 2006 were studied in the Balci Forest Planning Unit in Artvin, Turkey. The study showed that the decrease on the old-growth forest area was mainly attributed to the bark beetles. The Caucasian spruce dominated old growth forest stands were the most effected areas by this insect devastation. These stands left their places to the young oriental beech dominated stands. From the social point of view, "the extinct is not only a tree species or the forest ecosystem produced by it but also the cultural values and history in the region."

Key words: Old-growth forest, forest management, geographic Information systems, forest ecosystems.

INTRODUCTION

Forest ecosystems have important functions from economical, ecological and social perspectives and provide many goods and services such as timber production, biodiversity, water and soil protection, carbon sequestration, recreation and non-wood forest products. In recent years, intensive management has altered the structure of forest ecosystems (FAO, 2007). Human-induced disturbances such as grazing, timber harvest, land conversion to cropland, pollution of air, water and soil, fragmentation and loss of old-growth forests are primary threats to forest-dwelling animals and many species. Most old growth forests in the world have been replaced by younger forests or converted to non-forested areas. Consequently, biodiversity has declined and many have become locally extinct (Siitonen et al., 2002).

Old-growth forests are acknowledged as an essential parameter of sustainable forest management. However, the definition of old-growth forest is also needed to adequately evaluate and manage these forest ecosystems (Diamond, 1998). Old-growth forests are biologically rich ecosystems. They include big old trees, young trees, different kinds of birds, mammals, fungi, insects, reptiles and other living or non-living things. They may also contain the largest trees, the oldest trees, the most at-risk forest species and the largest accumulation of carbon per hectare of any forest type (Lee et al., 2000; Spies, 2004).

Monitoring old-growth forests provides a feedback mechanism to forest managers to aid decision making and to assess the probable impacts of human-induced and natural disturbances over time (Lundquist et al., 2001). To identify and quantify the area of old-growth in any forest area, timber inventory data and forest management plans are the common resources that are used. These data generally include the parameters related to forest stand characteristics.

A change from the timber production centered forest

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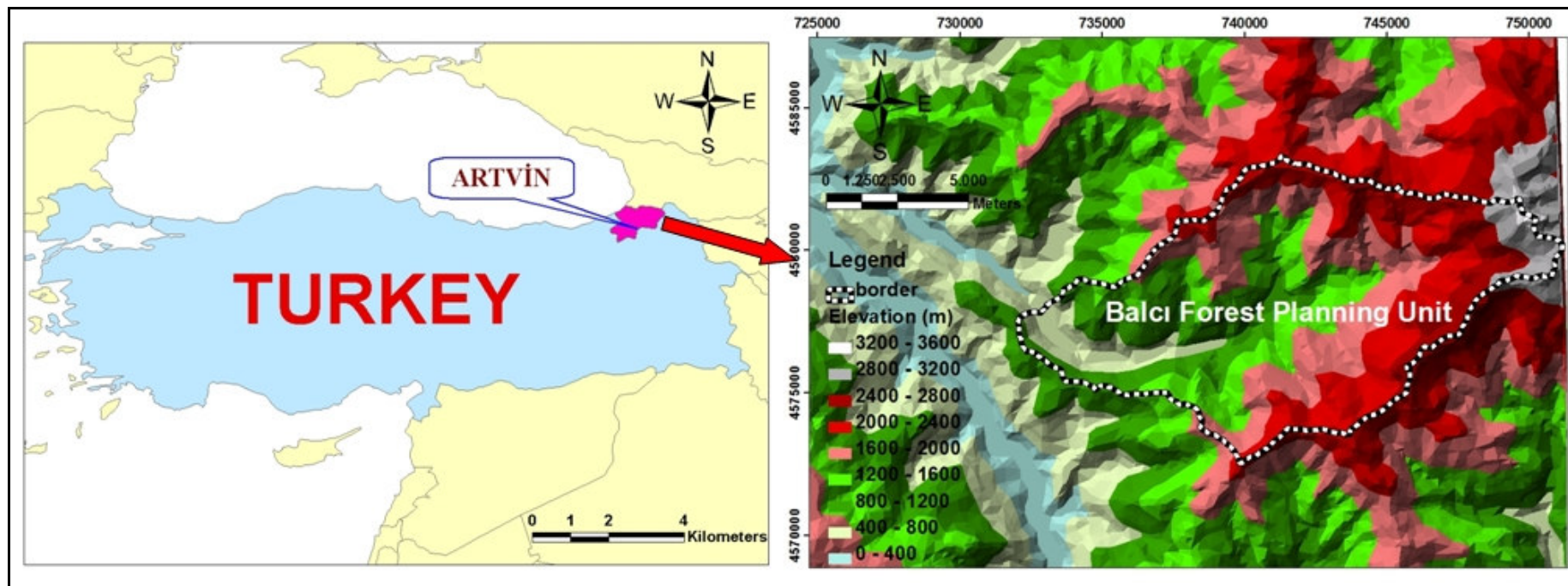
Figure 1. Location of the Balci forest planning unit in artvin, Turkey.

management plans to the ecosystem based multiple use management plans started in 1995. A stand is considered the smallest silvicultural handling unit in the forest management plans. All measurements performed in the inventorial studies are obtained generally from the sample plot and stand characteristics reflected on the forest management plans.

This study investigates the spatial distribution and temporal changes of the old-growth forest stands in the Balci Forest Planning Unit (BFPU) in Artvin, Turkey. The area is known a natural spruce and beech forest dominated ecosystem that is specific to the Eastern Black Sea Region. The data employed in the study were obtained

from forest management plans of the Artvin Forest Regional Directorate for years of 1984 and 2006. Changes in the potential old-growth forest stands in a 22-year period were described comparatively with the help of Geographic Information Systems (GIS).

MATERIALS AND METHODS

The Balci forest planning unit

The study area is located in the Northeast of the town of Borçka, Artvin, Turkey. It is characterized by a dominantly steep, rough terrain with an average slope of 58% and an altitude from 340 to 3,414 m above sea level. It extends

along 41° 46.329' - 42° 0.128' E and 41° 21.97'- 41° 16.089'N on the Northeastern Black Sea Region of Turkey (Figure 1). The total area is 10,806.13 ha. The vegetation consists of forest dominated tree species such as Caucasian Spruce (*Picea orientalis (L.) Link),* Oriental Beech *(Fagus orientalis Lipsky),* Nordmann Fir (*Abies nordmanniana (Stev.) Spach subsp. Nordmanniana),* Sweet Chestnut (*Castanea sativa*), Caucasian lime *(Tilia rubra subsp. Caucasiaca),* Common Alder *(Alnus glutinosa subsp. Barbata),* Scots Pine (*Pinus sylvestris L.*)*,* and Common Hornbeam (*Carpinus betulus L.)* (Figure 2). Mean annual temperature of the study area is 13.5°C and mean annual precipitation is 1009.3 mm. Main soil types are sandy clay loam, clay loam and sandy loam. The only development area is located around Balci Village and its hamlets. While its population was 705 in 1990, this number decreased to 532 in 2000 and 450 in 2007 Census data (TURKSTAT, 1990, 2000, 2007). The main income

Table 1. Temporal changes in forest and non-forest areas of Balci forest planning unit.

General situation		1984	2006	Percent change
Forest area (hectare)	Productive forest	5571.96	5343.50	-4.10
	Degraded forest	1717.59	1983.55	15.48
	Total	7289.55	7327.06	0.51
Non-forest area (hectare)	Forest openings	3121.39	3144.23	0.73
	Settlements and agriculture	400.92	334.85	-16.48
	Total	3522.31	3479.08	-1.23

sources of the Balci villagers are from forest operations (production, transportation, road construction and forestation), livestocking, hazelnut, tea and corn production (Öztürk et al., 2010). Beekeeping is another source of income for the villagers. An endemic Kafkas honey bee (*Apis mellifera Caucasica*) hives are also located all over the study area. Moreover, the hives particular to the region are settled in tall trees or in the rock hollows. Because of the topography and the harsh winter conditions, the migration is continuing from villages to the cities (Figure 1) (Anonymous, 1984, 2006).

Defining old-growth forest

The tree parameters such as tree species type, diameter at breast height (DBH), age, bark thickness, quality, health and silvicultural status for the trees thicker than 8 cm DBH were measured during the preparation process of the forest management plans in Turkey. The stand parameters such as age class, canopy closure, species mixture, volume, increment, basal area, development stage, snag volume per hectare, stand configuration and living cover density are derived from the tree parameters for each stand.

Old-growth forest is defined on stand parameters such as age, DBH and snag volume per hectare (Lee et al., 2000; Uhlig et al., 2001; Old-Growth Definition Task Group, 1986, 1993). In this project, we picked age > 110 years old, diameter > 36 cm at DBH, area > 10 ha and snag volume > 10 m^3 per ha.

Age class regeneration period intervals are considered as 10 years for rapid-growing trees (red pine, alder, poplar etc) and as 20 years for slow-growing species (spruce, cedar, beech etc). Canopy closure (in percent) which is the degree in top roof's covering the earth is evaluated in four categories: 1. Open canopy if the canopy closure is less than 10% (degraded stand), 2. Semi-open if it is between 10 and 40%, 3. Semi-closed if it is between 40 and 70% and 4. Closed if the canopy closure is between 70 and 100%.

Development stages are categorized into four levels: 1. Young stand if the mean stand DBH is less than 8 cm DBH, 2. Pole stand if it is between 8 and 19.9 cm DBH, 3. Pre-mature stand if it is between 20 and 35.9 cm DBH and 4. Old stand if it is higher than 36 cm DBH.

Snags, which are an important parameter in determining old-growth forests, are also the warranty for ecologic processes and biological diversity in the forest ecosystems (Wulf, 2003; Başkent et al., 2005a, b). Because snag number and planted tree volume were not measured precisely enough in 1984, this criterion was not taken into account in determining changes in old-growth forest capacity. The data from the 2006 forest management plan presents sufficient data on this matter. Therefore, only the existing old-growth forests were examined from this point of view.

Mapping old-growth forest

The GIS representation of old-growth forest in the Balci Forest

Planning Unit was accomplished using the forest cover type maps in the years of 1984 and 2006. Forest cover type maps of case study area were firstly digitized and then processed using ArcGIS 9.0 (Arc/Info license level) to establish spatial database with a 10 m root mean squared error (RMSE) from 1:25 000 scale source maps. The spatial database consists of stand type, dominant tree species, species mixture, canopy closure, forest development stages, age class and stand type area. Number of trees, stand type, diameter and snags volume per hectare were also added to the database. Old-growth maps in 1984 and 2006 were then extracted from the forest cover type maps for the Balci Forest Planning Unit.

RESULTS AND DISCUSSION

Table 1 shows that there is a 5.72 ha difference in total study area between 1984 and 2006. The difference is attributed to the non-plannimetric map source of 1984 forest cover type map. There is a 4.10% decrease on the productive forested areas, but a 0.51% increase in the overall forested areas. A dramatic decrease of approximately 16.48% in the development and agricultural areas in the Balci Forest Planning Unit are attributed to the immigration from villages to cities (a 36.17% decrease in population for Balci Village and 21.02% decrease for the entire Artvin province between 1990 and 2007). The numbers above indicates that the loss of population occurs from around the area rather than within the area. This has impacted negative (illegal forest logging, forest openings for agricultural, residential use and beetle infestation) and positive (self-protected area by villagers for beekeeping, erosion control, drinking water and recreation purposes) pressure elements that the villagers are created on the forested areas (Table 1).

Figure 2 shows the spatial distribution of tree species in the years of 1984 and 2006. Among the dominant tree species, eastern spruce is the one that has the most area. The change in area for the eastern spruce is a decrease of 42%, while the area of eastern beech is increased by 46.08%. Due to the bark beetle infestation, most of the eastern spruce stands left their places to eastern beech, common hornbeam, and eastern chestnut stands.

14.51% of forest area is below 80 years, 10.59% of it is at the ages of between 80 and 100 years and 74.90% of it is older than 100 years according to 1984 forest management plan data. With respect to the year of 2006,
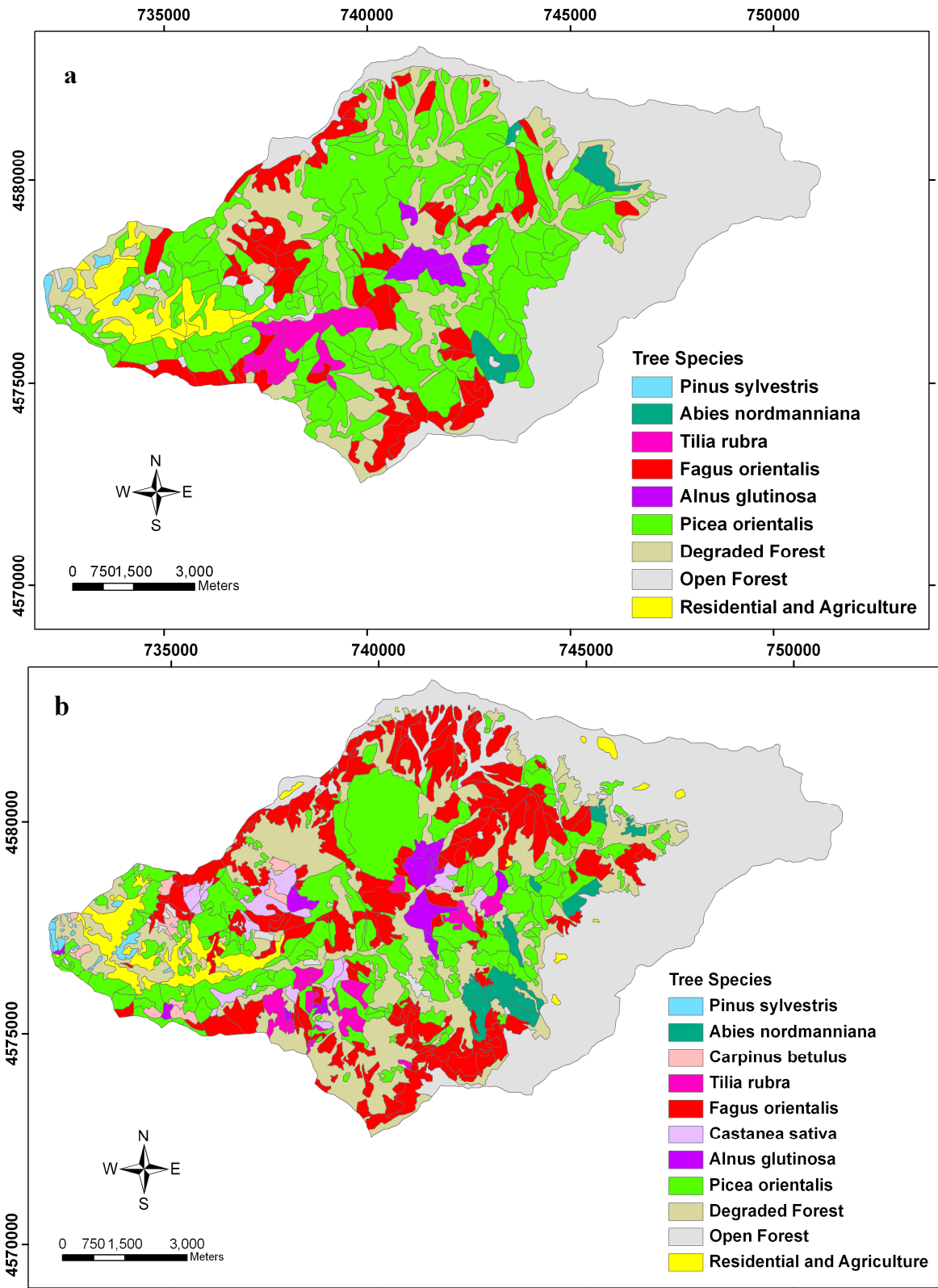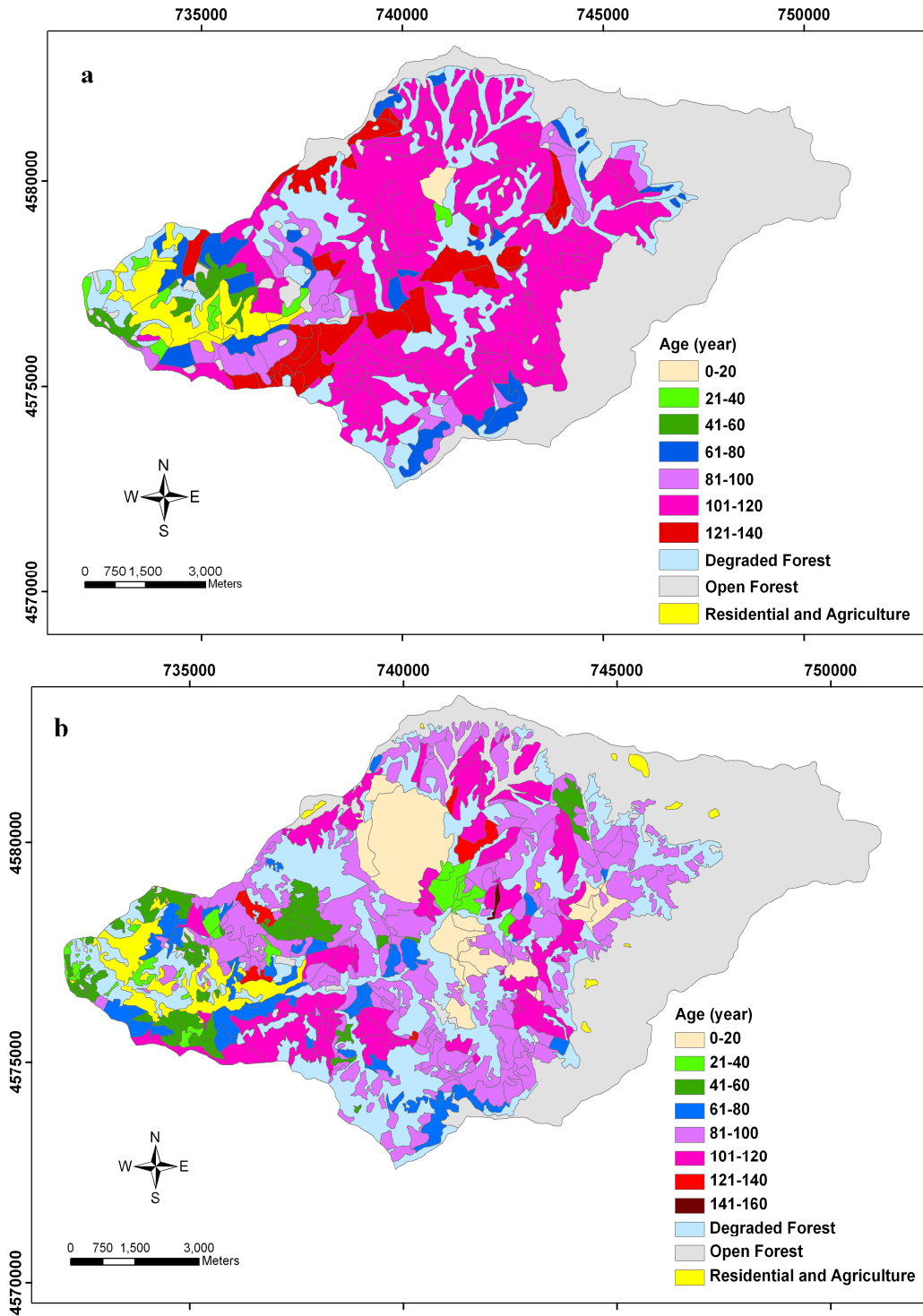
**Figure 2.** Change of tree species in the BFPU; a) 1984, b) 2006.

Figure 3. The spatial distribution of the age classes in the BFPU in the years of a) 1984 and b) 2006.

34.19% of the productive forest area is younger than 80 years, 41.74% of it is at the ages of between 80 and 100 years and 24.07% of it is older than 100 years. As seen, the stands older than 100 years decreased by approximately 50% while the stands younger than 80 years increased by approximately 20% and those at the ages of between 80 and 100 years by 13.5% (Figures 3 and 4).

Figures 5 and 6 shows the development stage of the study area in the BFPU from 1984 - 2006. Approximately there is a decrease of 25% in the trees that have 36 cm
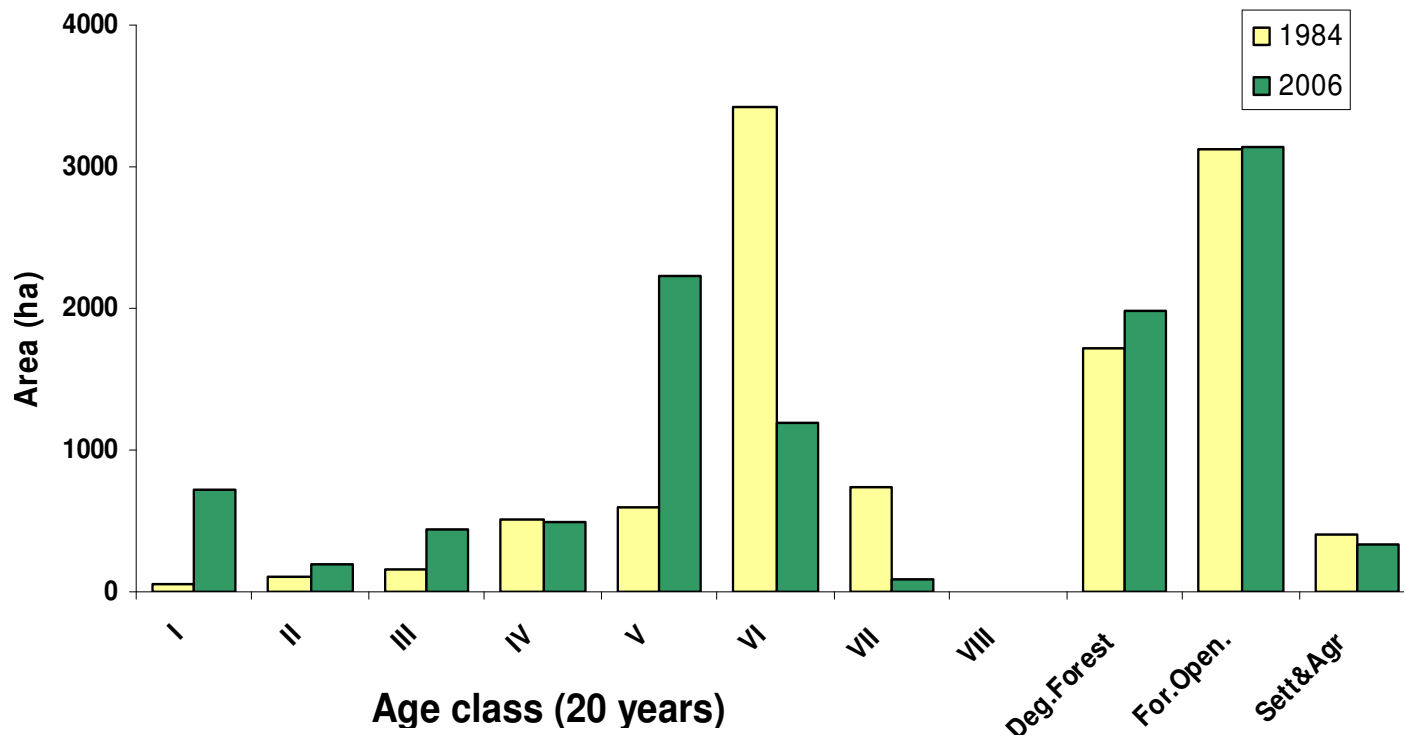
Figure 4. Area distribution of the age classes in the BFPU in 1984 and 2006.

DBH and above. This is definitely a big sign of diminishing old-growth forest in the BFPU.

Spatial distribution of the old-growth forest in the BFPU in the years of 1984 and 2006 is shown in Figure 7. As a result, the total old-growth forest in 1984 was 3275.74 and 728.10 ha in 2006. The change in the old-growth forest areas is a decrease of 77.77%. A from-to change results can be seen in Table 2. The most important reasons responsible for the loss of the old-growth forest are the bark beetle infestation, extraordinary logging activities, and consequently lacking timber management approaches for the threes that are over 110 years old (Figure 7, Table 2).

Most of the old-growth forest stands on the BFPU have average slope of 26.47° in 1984 and 27.87° in 2006 with South or Southeast aspect. The mean elevation of the old-growth forests in 1984 is 1605 m at Mean Sea Level (MSL) and is 1524 m at MSL in 2006 (Table 3). The old-growth forests range elevation from 730 to 2258 m at MSL. The snag volume per hectare data was derived from the Artvin Forest Regional Directorate's 2006 forest management plans. There was no snag volume data for the 1984 forest management plan. The snag volume for the closed canopy old-growth forest stands was 17.70 m^3/ha and was 3.41 m^3/ha for the semi-closed old-growth forest stands (Table 3).

The proximity analysis from old-growth forests to mean nearest roads and residential areas (Table 4) supports land use conversion from the agricultural/residential

areas to the forested areas. But it also shows a negative effect on the decrease of old-growth forest. Uncertainties on the ownership and unfinished cadastre areas left the non-forested areas to forested areas.

The patch analysis results (Table 5) showed that the number of the old-growth forest patches is decreased (44.19%). Mean patch size (MPS) is decreased from 74.32 to 28.92 ha (- 67% change). The edge density (ED) on the old-growth forest is decreased (68.11%) between 1984 and 2006. These results indicate that the old-growth forests in the BFPU have been fragmented since 1984.

SUMMARY AND CONCLUSION

In this study, we, first time, analyzed spatial distribution and temporal change of the old-growth forest by stand level in Turkey. We showed that total area of the old-growth forest decreased and the old-growth forest structure is fragmented. These are attributed to the last twenty years of the bark beetle damage (Göktürk and Eldemir, 2005; Yüksel, 1998), excessive forest operations, and illegal forest use. However, any serious study about the degree of damages and how they affected the forest ecosystem has not been performed yet. Beside the importance of this study, ecosystem and vertical structures of the old-growth in the region must be investigated and integrated in the nation's forest inventory and management system.
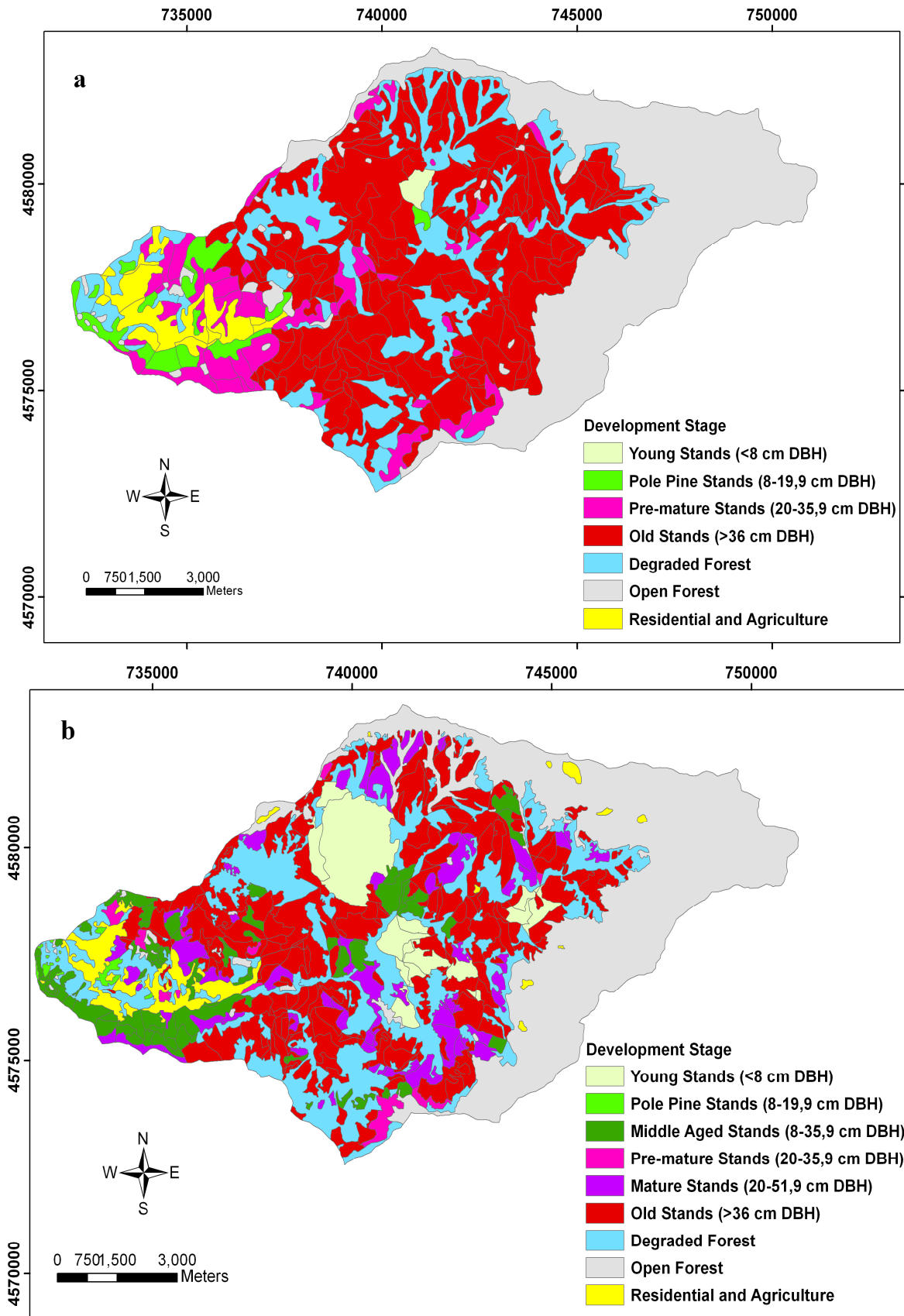
Figure 5. The spatial distribution of the development stages in the BFPU in the years of: a) 1984; and b) 2006.
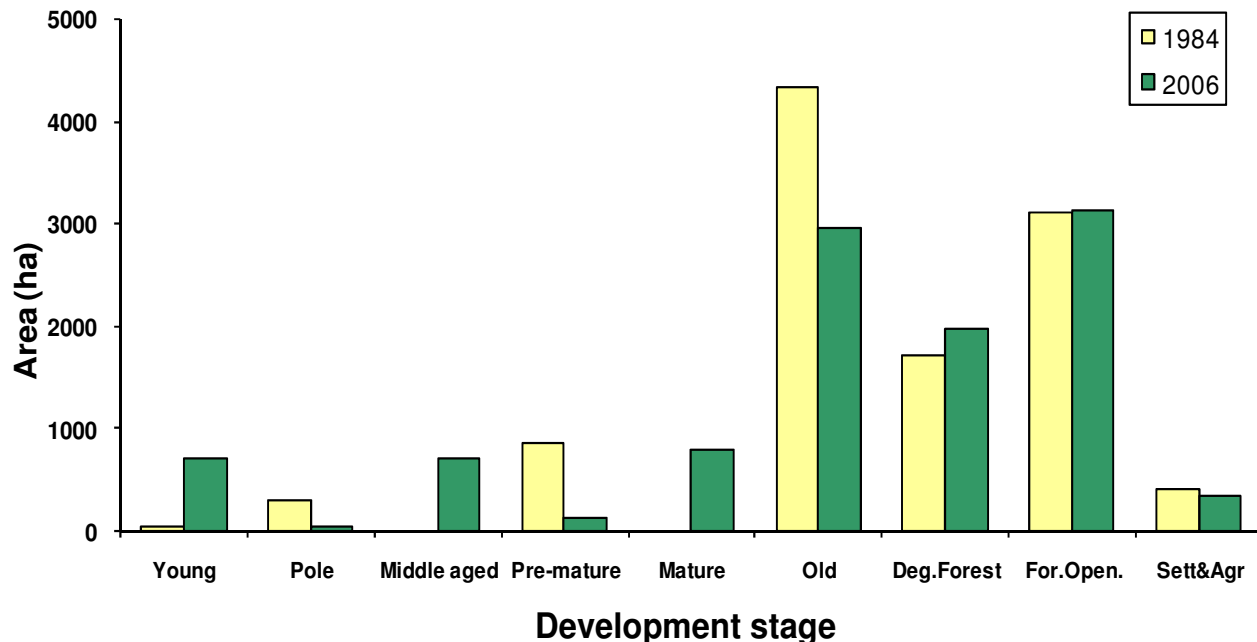
Figure 6. Area distribution of the development stages in the BFPU in 1984 and 2006.

Table 2. From 1984 to 2006 change analysis table for the old growth of the BFMU in hectare.

	Old growth F. (closed)	Old growth F. (semi-closed)	Degraded F. (semi-open)	Other F.	Open F.	Residential and Agr.
Old growth (semi-closed)	45.36	17.76	225.25	768.22	15.51	0.57
Old growth (closed)	334.61	70.86	341.79	1419.95	35.65	0.22

Table 3. Mean snag volume, slope, aspect and elevation of the BFMU.

	Snag volume (m³/ha)		Slope (degree)		Aspect		Elev at MSL (m)	
	1984	2006	1984	2006	1984	2006	1984	2006
OldGrowth Forest (closed)	N/A	17.70	27.15	30.81	South	Southwest	1679.85	1551.59
OldGrowth Forest (semi-closed)	N/A	3.41	25.78	24.93	Southeast	Southeast	1531.72	1497.72
Degraded Forest (semi-open)	N/A	N/A	30.22	29.04	South	South	1522.14	1507.06
Other Forest (open)	N/A	5.32	28.24	27.25	South	South	1362.54	1490.84
Open Forest	N/A	N/A	19.30	20.05	South	South	2377.25	2383.57
Residential and Agr.	N/A	N/A	22.99	20.23	South	Southeast	712.42	907.07

Table 4. Proximity analysis from old growth forest stands to roads and residential areas in the BFPU.

		Min	Max	Mean	SD
Old growth to road (m)	1984	9.46	2211.32	630.22	488.32
	2006	135.04	1966.08	786.03	487.98
Old growth to residential area (m)	1984	797.88	9922.82	5319.94	2190.82
	2006	758.31	3000.25	1681.53	630.34
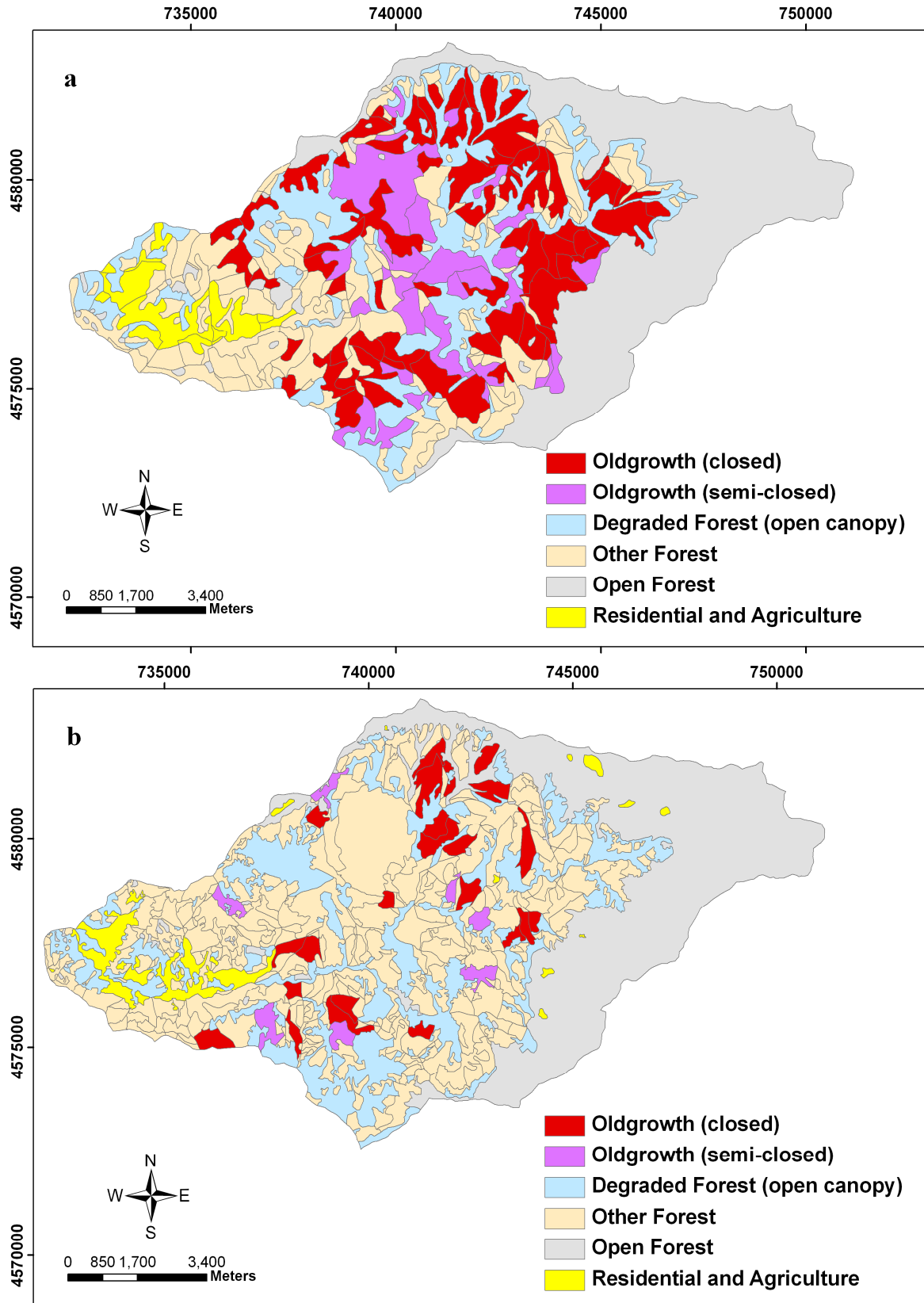
Figure 7. The spatial distribution of the old growth forest in the years of: a) 1984; b) 2006.

Table 5. Patch Analysis of the Balcı Forest Planning Unit for the years of 1984 and 2006.

	Class	AWMSI	MSI	MPAR	MPFD	AWMPFD	TE	ED	MPE	MPS	NumP	MedPS	PSCoV	PSSD	CA
1984	OldGrowth Forest (closed)	2.59	1.89	103.77	1.29	1.30	161810.69	14.97	5992.99	81.60	27.00	38.43	147.36	120.24	2203.07
	OldGrowth Forest (semi-closed)	2.60	1.86	119.03	1.29	1.30	82904.81	7.67	5181.55	67.04	16.00	24.13	162.51	108.95	1072.67
	Degraded Forest (semi-open)	3.63	2.16	165.74	1.32	1.35	212284.59	19.63	5586.44	45.20	38.00	15.47	143.95	65.06	1717.59
	Other Forest (open)	4.34	1.60	183.52	1.29	1.34	185093.50	17.12	3777.42	46.86	49.00	7.42	395.16	185.18	2296.21
	Open Forest	3.33	1.26	240.40	1.28	1.29	91819.30	8.49	2869.35	97.54	32.00	2.75	532.87	519.78	3121.39
	Residential and Agr.	3.95	2.93	109.35	1.33	1.35	30896.44	2.86	15448.22	200.46	2.00	200.46	90.37	181.15	400.92
2006	OldGrowth Forest (closed)	1.70	1.60	112.26	1.28	1.28	54079.53	5.00	3181.15	32.33	17.00	27.17	60.00	19.40	549.62
	OldGrowth Forest (semi-closed)	1.96	1.92	139.01	1.31	1.31	24036.44	2.22	3433.78	25.50	7.00	25.70	31.32	7.99	178.48
	Degraded Forest (semi-open)	3.85	2.21	255.04	1.34	1.37	285289.78	26.40	4528.41	31.48	63.00	9.03	191.92	60.43	1983.55
	Other Forest (open)	7.43	1.70	269.38	1.31	1.38	316865.35	29.32	5029.61	73.26	63.00	4.78	592.00	433.70	4615.41
	Open Forest	4.95	1.69	390.06	1.34	1.34	123991.20	11.47	5166.30	131.01	24.00	1.75	461.82	605.03	3144.23
	Residential and Agr.	2.77	1.67	269.59	1.31	1.34	50125.86	4.64	2386.95	15.95	21.00	3.85	176.85	28.20	334.85

AWMSI = Area weighted mean shape index, MSI = mean shape index, MPAR = mean perimeter-area ratio, MPFD = mean patch fractal dimension, AWMPFD = area weighted mean patch fractal dimension, TE = total edge, ED = edge density, MPE = mean patch edge, MPS = mean patch size, NumP = No. of patches, MedPS = median patch size, PSCoV = patch size coefficient of variance, PSSD = patch size standard deviation and CA = class area.

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