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Full Length Research Paper

Changes in carbon storage and oxygen production in forest timber biomass of Balci Forest Management Unit in Turkey between 1984 and 2006

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Decrease in forest areas world wide and the damaging of its structures is hazardous to human health, hinders and dries up the spread of oxygen in the air and also destroys carbon storage. In recent years, global warming and changes in climates depending on the increase in the green house gases have been affecting the whole world. The solution seeking, initiated in the international arena with various treaties and processes, has shown itself around the world and in our country as the concept of planning and operation of the forest sources. During the recent ten years in Turkey, in forest management plans, the capacity of carbon storage and the amount of oxygen production by the forest were initiated to be calculated in the planning unit scale. The first forest management plans were prepared and put into force in 1972 in Turkey, where the planned forestry began in 1963. During the period of more than 30 years, neither the structural changes in forests nor their values regarding other functions have been examined enough. In this article, using Balcı Forest Management Units in Borçka Township of Artvin, forests are studied regarding their growing stocks, timber increments, their capacities of carbon storage and oxygen production. The basic management unit scale in the study is standard and the evident standard parameters are tree species, mixture and age class. Balcı Management Unit underwent attacks from bark beetles in the past. After the mechanical struggle, there have been structural changes in forest ecosystem and the potentials of forests have varied both in quality and quantity. Changes in forest ecosystems during that time, not only through natural ways but also through human activities, have been shaping the oncoming forestry practices.

Key words: Carbon storage, oxygen production, forest management, geographic information systems, land cover change.

INTRODUCTION

Today, various ecological and environmental anxieties about forest ecosystems and utilizing them in the best way have begun to appear. Forest ecosystems have faced the problems such as damages in their health and structures, reduction in their areas, non stability or protection in long term as a result of out of use intentions, wrong and unplanned utilization, and natural interferences appearing together with these (global warming, acid rains and fires can be given as examples). During the last 20 years, an ocular increase has been seen in the density of greenhouse gases depending on industrialization. An increase in temperatures has been coming into existence depending on the increase in the greenhouse gases in the atmosphere such as CO_2, methane, chlorofluorocarbon, nitrogen oxide and ozone. Air temperatures in the earth have increased in the rates between 0.3 and 0.6°C from 1800s until now (Nowak and Crane, 2002). According to the best estimations, it is thought that the earth temperature will increase to 1°C between the years 1990 and 2050; moreover it is estimated that temperatures will increase about 2°C during the coming 100 years (Bateman and Lovett, 2000). The oxygen amount in the air is reducing because of the

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increase of negative CO_2 in the atmosphere, which is as a result of decrease or damages of the forest areas and increase in the consumption of the fossil fuels. The rapid increase in the population, on the other hand, is a clear indication that the need for oxygen source will grow day by day (Nowak et al., 2002).

Forests help in oxygen production, which is necessary for human existence, with greenhouse gas as well as the carbon storage that gives rise to the decrease of global warming. Forest ecosystems absorb CO_2 in the air and turn it into biomass; at the end they produce O_2. As the area and quality amounts of the forests ecosystems increase, CO_2 amount in the air decreases, thereby increasing the O_2 amount, necessary for animation. On the other hand, forest ecosystems not only increase the O_2 amount, but they provide very important environmental services giving way to the improvement of the air quality.

As is stated above, forest ecosystems are crucially important for the storage of CO_2 and increase of O_2 in the atmosphere. Therefore, searching the effects of the changes that take place in the areas and qualities of the forest ecosystems on those important forest functions has turned up as a fundamental study area in recent years. In the global scale, the land use change is one of the most important factors influencing the structures and foundations of the forest ecosystems as well as their areas. As taking place in most parts of the world, in developing countries as Turkey, forests are decreasing in terms of lands availability and in their qualities because one, they are wrongly used; and two, their lands are turned into another purpose. A great many scientific studies have been prepared about the land use change and its effects on the carbon storage capacity of the forests (Adger and Brown, 1994; Burrows et al. 2003; Houghton et al., 2000; Kerr et al., 2002; Kerr et al., 2003; Kerr et al., 2004; Upadhyay et al., 2005; Sivrikaya et al., 2007). However, studies about the effects of the variations, especially those land use change focus, on the O_2 production potential are rather limited (Nowak et al., 2007).

Forest biomass is the basic variable in the estimation of the amounts of oxygen produced and carbon sequestered by the forest ecosystems. Forest biomass is a crucial measurement parameter for the numerical evaluation of the assets and services provided by the forests as well as of the structures and foundations of the forest ecosystems (Sivrikaya et al., 2007; Backéus et al., 2005; Brown et al., 1996; Keleş and Başkent, 2006; Keleş et al., 2007). However, in the calculation of forest biomass, the forest inventory data are extremely essential data base. GIS (Geographic Information Systems) are very important means for carrying out the spatial analyses and for the spatial presentation of the biomass, with a function of carbon storage and the presentation of oxygen production in a specific area.

In this article, the changes, depending on time for the amounts of carbon storage and oxygen production in a typical forest planning unit taking place in the North Anatolia region of Turkey, are stated numerically. In the numerical estimation of both forest functions, aboveground and belowground forest timber biomass amounts are calculated for making use of the forest inventory data. In the calculation of biomass amounts, on the other hand, biomass transformation factors developed for the forests in Turkey are used. Planning unit, the classified potentials of the amounts of carbon storage and oxygen production are formed with the help of GIS. After that, the changes taking place that depend on time for the formation of forest structures and foundations as well as land use change and the reasons for those changes are searched. Moreover, the amounts of oxygen production and carbon storage are discussed by associating these factors. Finally, some suggestions are made about the importance and roles of the forest ecosystems on gas regulation functions.

MATERIALS AND METHODS

The study area: Balci Forest Planning Unit

The study area is the Balcı Forest Planning Unit (BFPU) located in the Northeast, the town of Borçka characterized by a dominantly steep and rough terrain with an average slope of 58% and altitude from 340 to 3414 m above sea level. It extends along UTM ED 50 datum 37. It has Zone 732000-751000 E and 4572000 – 4583000 N on the Northeastern black sea region of Turkey (Figure 1). The total area is 10,806.13 ha; it has forest vegetation and the dominant tree species of the vegetation are *Picea orientalis (L.) Link, Fagus orientalis Lipsky, Abies nordmanniana (Stev.) Spach subsp. nordmanniana, Castanea sativa, Tilia rubra subsp. caucasiaca, Alnus glutinosa subsp. barbata, Pinus sylvestris L., Carpinus betulus L.* Although no comprehensive study about plant sociology in the study area has been done, seven various tree species such as *Quercus pontica, Quercus petraea and Ostrya carpinifolia Scop* as well as 14 different shrubs and brushes and 18 plant types, which are grouped sporadically, that is not standing on their own have been detected and recorded. 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. In the planning unit, Balcı village and its neighborhoods take their place. While its population was 705 in 1990, this number decreased to 532 in 2000 and 450 in 2007 (Die, 1990, 2000 and 2007). Public means of living are generally provided from forest works (production, transportation, road construction and forestation). Besides, hazelnut, tea and corn agricultures as well as livestock production necessary enough to meet the basic needs are carried out. Beekeeping is very common and well-known around the district; the hives peculiar to the region are settled in tall trees or in the rock hollows. Because of the high pitched topography and harsh winter conditions in Balcı District, migration from villages to the city has been going on around Artvin, where industrial investments are limited and living conditions are hard (Anonymous, 1984, 2006) (Figure 1).

Estimation of biomass, carbon and oxygen

In this paper, carbon storages of hardwood and softwood species were estimated separately. Biomass for each forest types was calculated using biomass conversion factors from the literature (Keleş

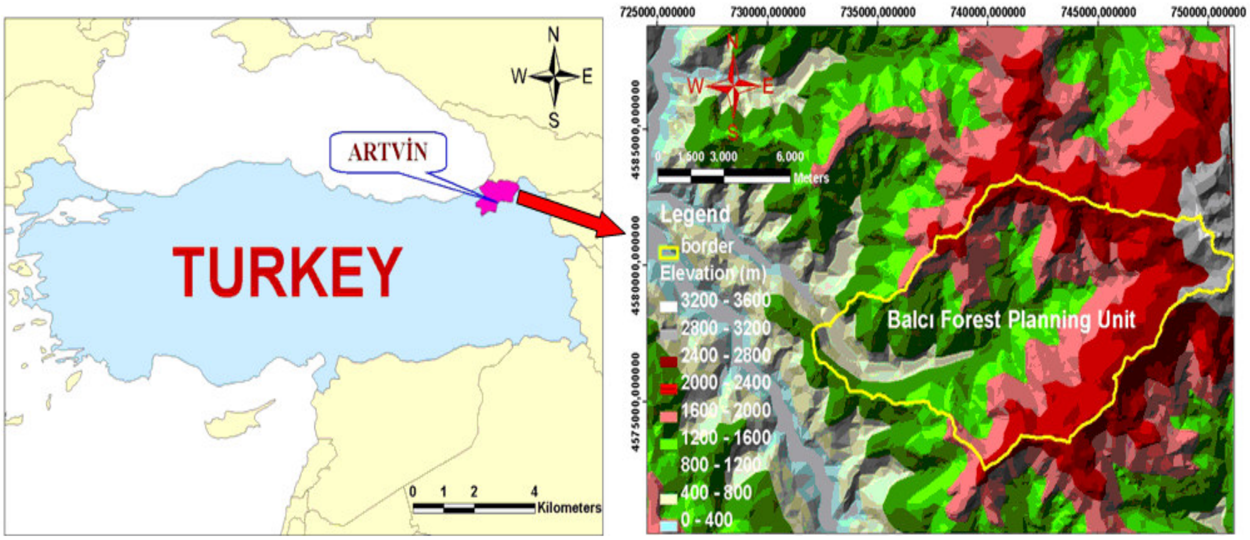

Figure 1. Location of the study area: Balcı planning unit.

and Başkent, 2006; Asan et al., 2002; Yolasığmaz, 2004). To estimate aboveground biomass, timber volume of softwoods and hardwoods were multiplied by species-specific conversion factors. These conversion factors were 1.25 for hardwoods and 1.2 for softwoods (Asan et al., 2002). Equations that compute fresh-weight biomass were multiplied by species specific conversion factors to yield dry-weight biomass. The conversion factors were 0.64 for hardwoods and 0.473 for softwoods (Asan et al., 2002). The root biomass was estimated according to the aboveground biomass. For this reason, the aboveground biomass was multiplied by predetermined root to shoot ratios. These ratios are 0.15 for hardwoods and 0.20 for softwoods (Asan et al., 2002). Total dry weight biomass of a tree was converted to total stored carbon by multiplying by 0.50. In the estimation of oxygen on the other hand, volume calculations were made use of. In carbon estimation, first of all biomass increase was calculated with the help of coefficients used for hardwood and softwood. Total dry weight biomass increment of a tree was converted to total oxygen production by multiplying by 1.2. All conversion factors used in this study are also coefficients proposed for Turkey by near east region convention application guidelines.

The capacity of carbon storage was estimated by making use of the following equations and coefficients:

ABm = (SWGST*0.473*1.20) + (HWGST*0.640*1.25)
BBm = (SWGST *0.473*1.20*0.20) + (HWGST *0.640*1.25*0.15)
Carbon Storage = (ABM + BBm)*0.50

where *ABm* is the aboveground biomass; *BBm,* the belowground biomass; *SWGST,* the softwood growing stock and *HWGST,* the hardwood growing stock.

The amount of oxygen production was estimated by making use of the following equations and coefficients:

IncABm: (IncSWBm*0.473*1.20) + (IncHWBm*0.640*1.25)
IncBBm: (IncSWBm *0.473*1.20*0.20) + (IncHWBm *0.640*1.25 *0.15)
Oxygen Production: (IncABm + IncBBm)*1.2

where *IncABm* is the increment in the aboveground biomass; *Inc BBm,* the increment in the belowground biomass; *IncSWBm,* the increment in the softwood growing stock and *IncHWBm,* the increment in the hardwood growing stock.

Mapping carbon storage and oxygen production

The GIS presentation of above and belowground carbon storage in Balcı was accomplished using the following GIS data: forest cover type maps for Balcı. Source scale of these maps was 1:250 000, based on the National Map Accuracy Standard for 1:250 000 maps. Forest cover type maps of case study areas (Balcı) were firstly digitized and processed using Arc/Info version 8.3 GIS with a maximum root mean square (RMS) error under 10 m and spatial database established. Spatial database consists of stand type, dominant tree species, mixture, crown closure, forest development stages, age class, basal area and stand type area. The stand type volume and increment was added to the database. Above- and belowground carbon storages and oxygen production were calculated using the GIS database including these stand type volumes and increments. Above- and belowground carbon storage maps (m^3/ha) and oxygen production maps (m^3/ha/year) in 1984 and 2006 were produced for Balcı by reclassifying a map of the forest cover type maps.

RESULTS AND DISCUSSION

The spatial distribution of the carbon amounts stored by the planning unit depending on above and belowground biomass amounts in the years of 1984 and 2006 is seen in Figure 2. Besides, the area distribution of the carbon storage amounts in unit area is given in Figure 4. On the other hand, spatial and area distributions of oxygen production amounts in unit area are seen respectively in Figures 3 and 5. When the carbon storage potential of the forest planning unit is evaluated, it is clearly seen that the places with carbon amounts less than 150 ton are much more than the others (Figure 4). This shows that growing stock and biomass of the forest ecosystems are not very high. It can be also seen that low raising places

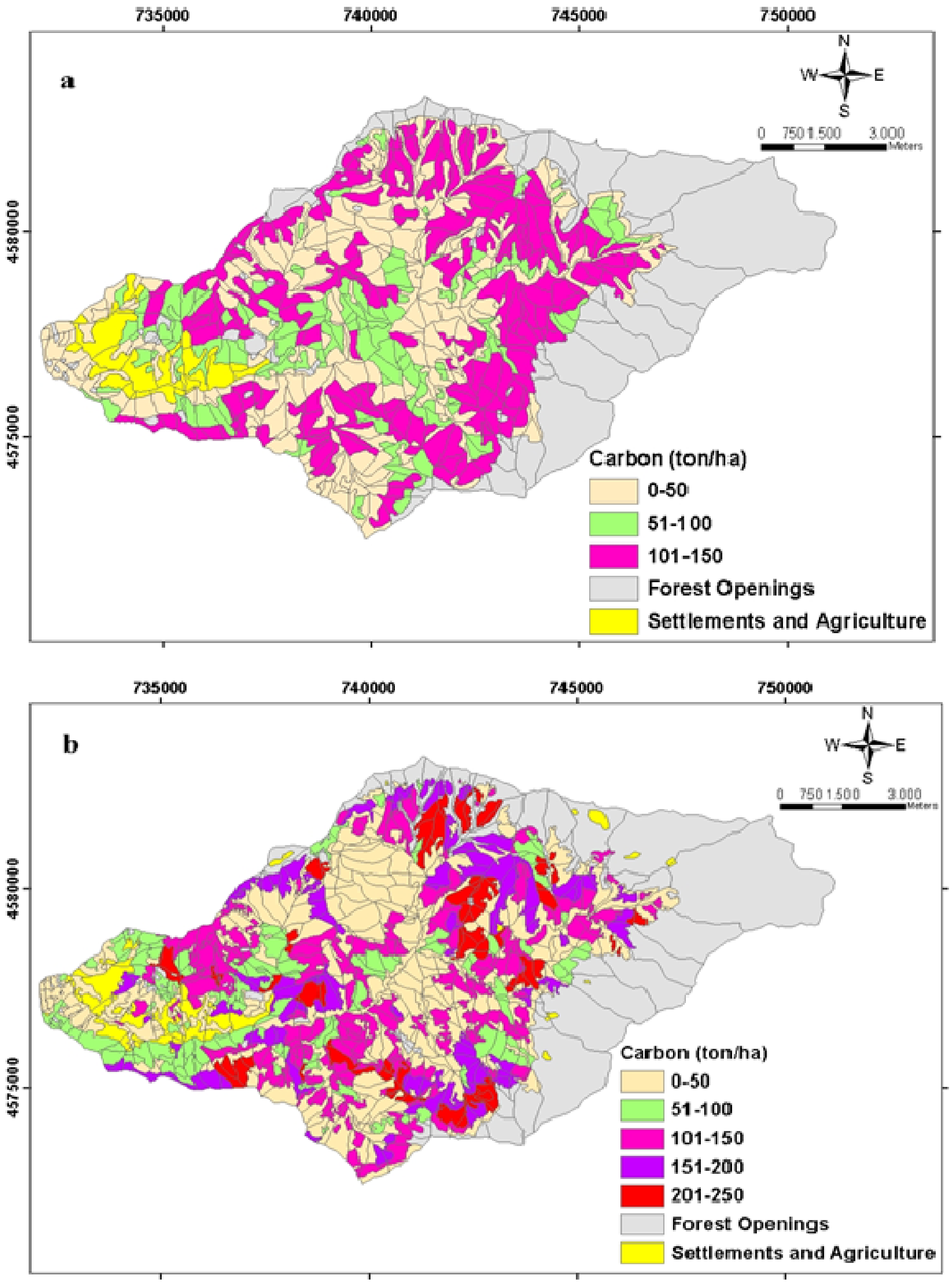

Figure 2. The spatial distribution of the planning unit related to the carbon storage amounts a) in 1984 and b) in 2006 in unit area.

constitute most of the oxygen potential produced by the forest ecosystem annually in a unit area (Figure 5).

Totally 522 784.828 carbon storage in 1984 went up to 614 648.921 ton in 2006. During the period of 22 years, carbon amount stored by Balcı forest ecosystem increased to 91 864.892. Carbon amount stored in productive forest areas was calculated on average as 90.230 ton for each hectare in 1984, while it was calculated as

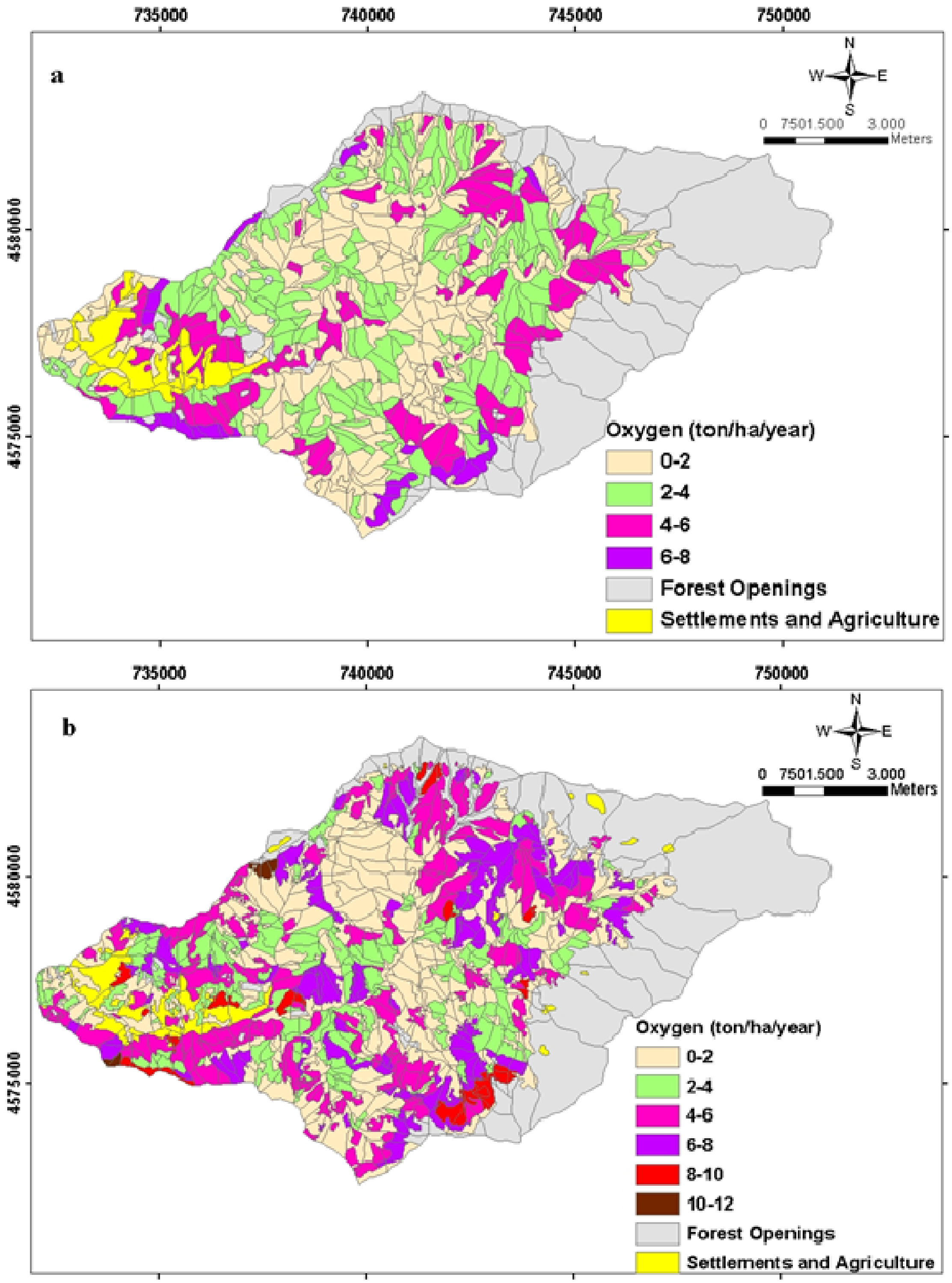

Figure 3. The spatial distribution of the planning unit related to the amounts of oxygen production a) in 1984 and b) in 2006 in unit area.

113.312 in 2006. Oxygen amount produced by forest ecosystem and released into the air has increased from 19 411.060 to 23 537.920 per year depending on the annual timber increment. On average, oxygen production in hectare was calculated as 3.279 ton in 1984 while it was 4.309 in 2006.

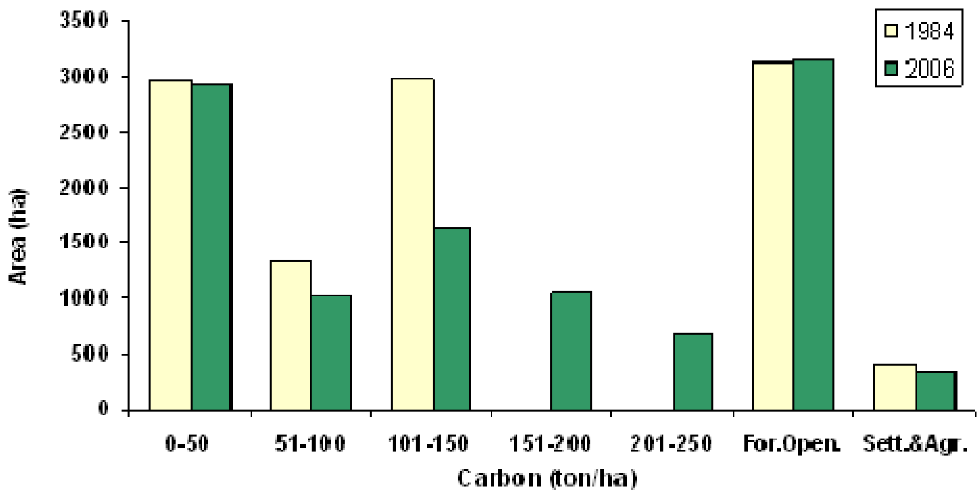

Figure 4. The area distribution of the planning unit related to the carbon storage amounts a) in 1984 and b) in 2006 in unit area.

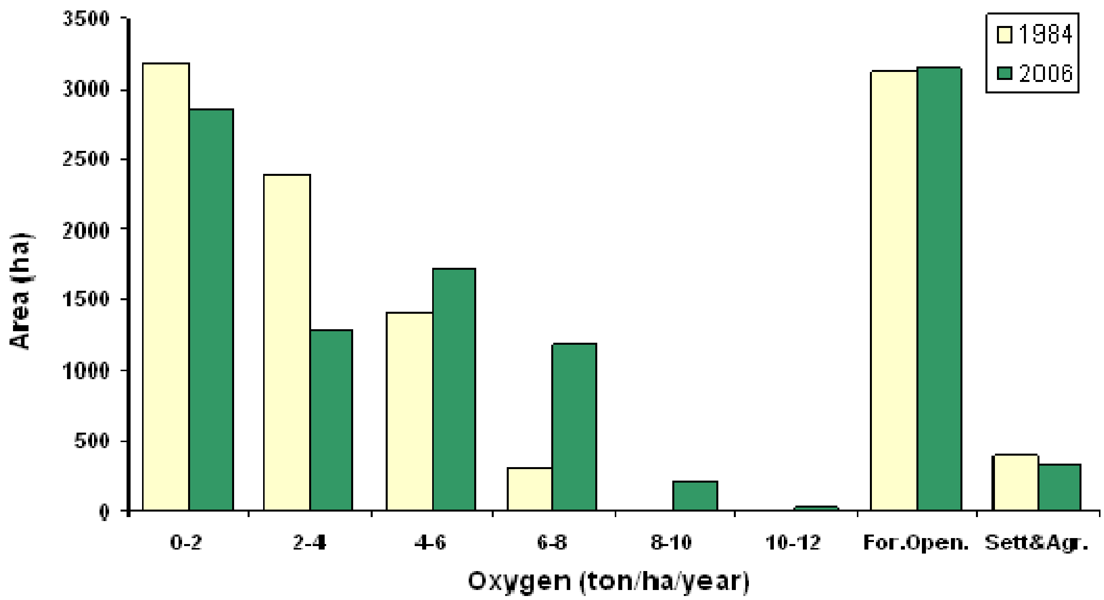

Figure 5. The area distribution of the planning unit related to the amounts of annual oxygen production a) in 1984 and b) in 2006 in unit area.

The areas of dominant tree species in planning unit in the years of 1984 and 2006 are seen in Figure 6. Among the dominant tree species (a tree type with the highest volume rate among the mixed stands), *P.orientalis* is the one with the most area.

While *P. orientalis* was 3 803.96 (68.27%) hectares in 1984; it covered an area of 2 206.31 (41.29%) hectares according to the data of 2006. The second type with the most area on the other hand is *F. orientalis*: while it was 11 449. 47 (20.63%) hectares in 1984, it showed the distribution of 2 131 (39.89%) hectares in 2006. Other types follow these two types (Figure 6). In 1984, most of the carbon storage and oxygen production functions in Balcı forest ecosystem were carried out by the stands in which *P. orientalis* was dominant (carbon, 66.15%; oxygen, 63.89%). In 2006, those functions were presented by the stands in which *F. orientalis* was dominant (carbon, 53.68%; oxygen, 51.71%) (Figures 7 and 8).

The basic reason of the changes and decrease in softwood areas between 1984 and 2006 is damage caused by insects. When the former forestry applications were examined, it was found out that extraordinary proceeds allowing cuts were taken in the direction of softwoods (especially *Picea orientalis*) and that the forest structure

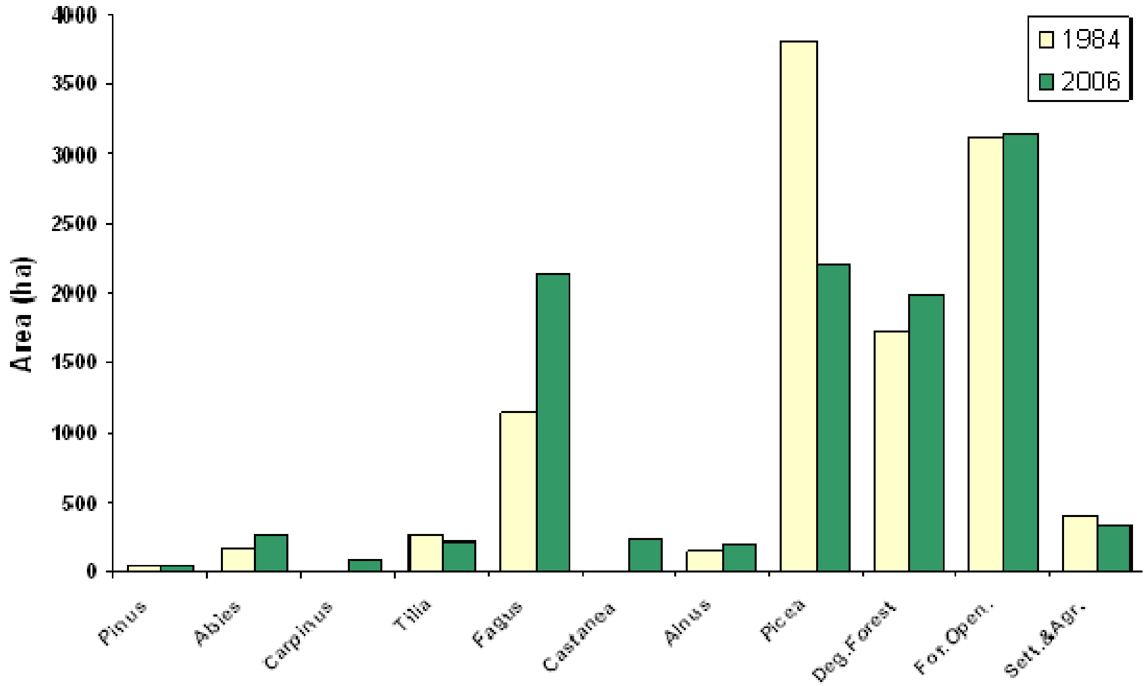

Figure 6. Area distribution of the dominant tree species in 1984 and 2006 in the planning unit.

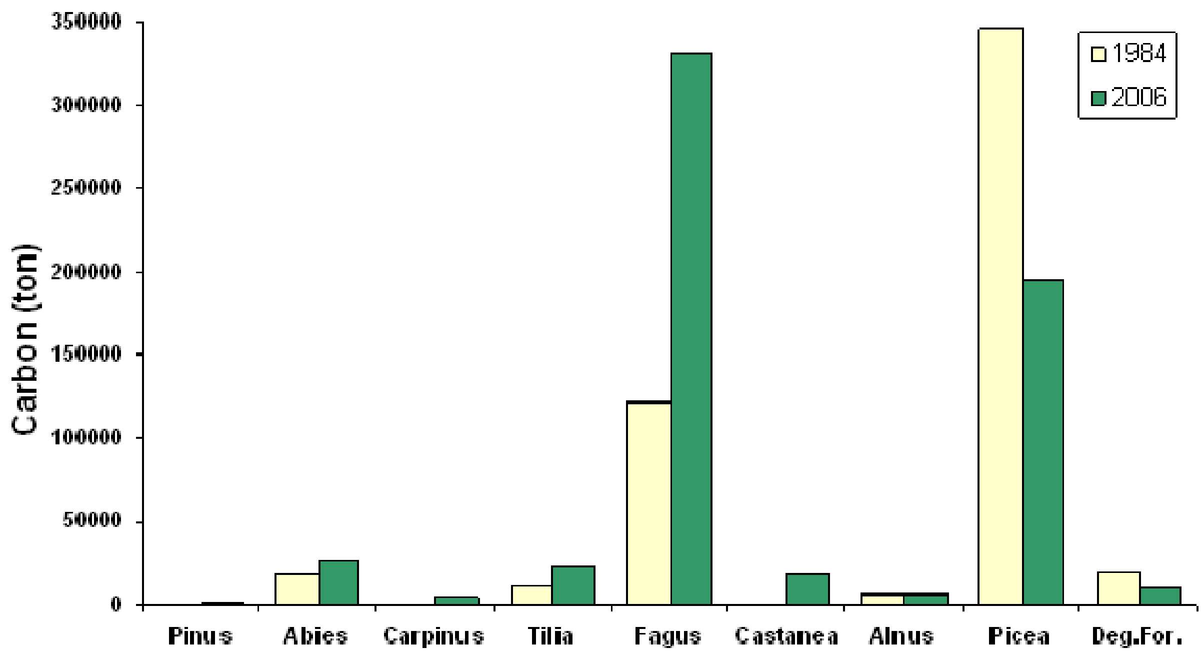

Figure 7. Distribution of carbon storage amount in 1984 and 2006 according to tree species.

changed depending on the damage caused by bark beetles (Dendroctonus micans, Ips typographus and Ips sexdentatus). Removal of *P. orientalis* from the area due to the damages caused by insects, together with the renewal endeavors transformed not only the forest structurally, but the source potential of the services and values as well.

Most of the study area is made up of mixed stands including the coniferous. It has been found out that as its dominant tree species, there is an increase in hardwood (HW) stands (pure and mixed) (in 1984, 28.2%; in 2006, 46.25%), whereas there is a decrease in softwood (SW)

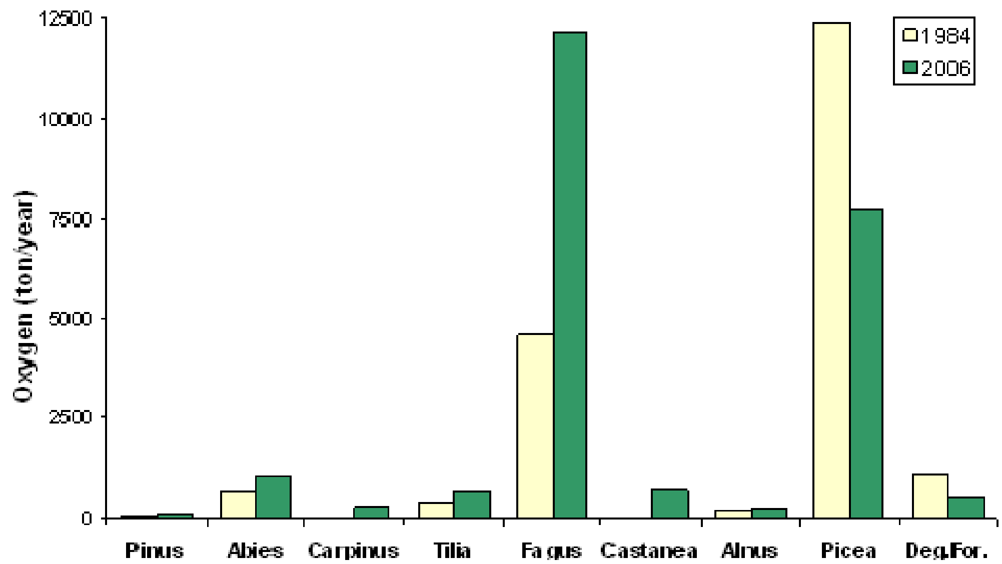

Figure 8. Distribution of annual oxygen production amount in the planning unit in 1984 and 2006 according to tree species.

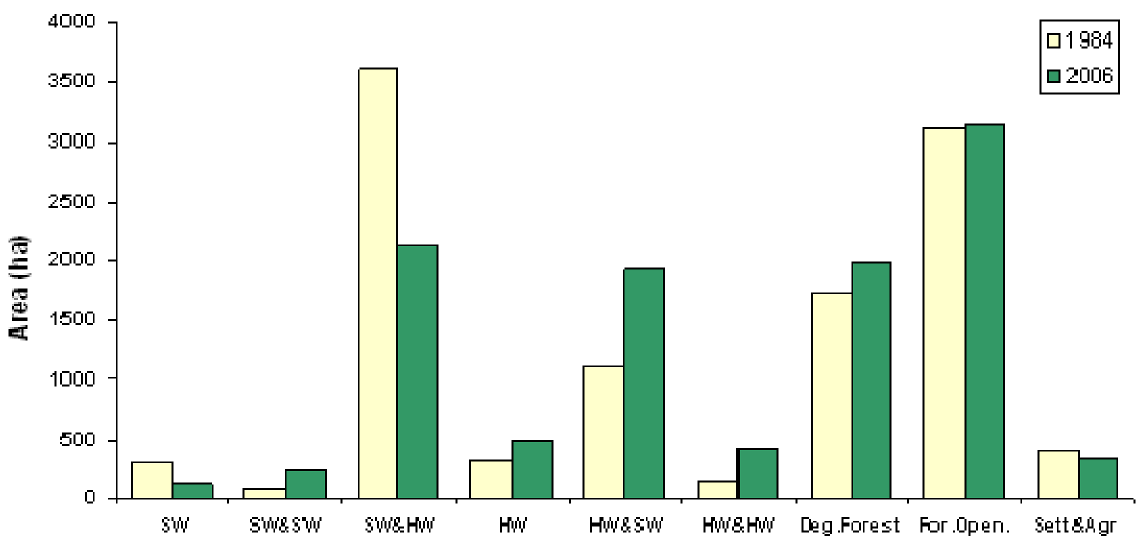

Figure 9. Area distribution of the forest types in the planning unit in 1984 and 2006.

stands (pure and mixed) (in 1984, 71.80%; in 2006, 53.75%) (Figure 9). As seen in Figures 10 and 11, throughout the studying period of 22 years, it can be seen that most of the amounts of carbon storage and oxygen production are provided from mixed stands.

The age class distribution of planning unit between 1984 and 2006 is seen in Figure 12. According to Figure 12, as to the forest management data, 33.63% of the productive forest areas are under the age of 80; 42.3% are between 80 and 100; and 24.07% are above the age of 100. Therefore, it can be stated that old growth forest potential of Balcı forests, which indicate seed rooted and natural spreading, is high. Most of the carbon storage and oxygen production were provided from the stands aged between 100 and 120 in 1984 (In 1984, carbon (63.837%); in 2006 carbon (30.341%) and oxygen (24.837%)). However, it began providing from the stands aged between 80 and 100 in 2006 (in 1984, carbon (10.529%); oxygen, (10.938%); in 2006, carbon (63.837) and oxygen (56.814%)) (Figures 13 and 14).

In Turkey, especially in the Black Sea region, the fact that cadastre and ownership problems are not being solved is the basic reason for the changes in the areas without forest. There exists 7.8 million forest villagers living within and around the forests by making use of the forest sources in 20 974 forest villages (In 1985, this was

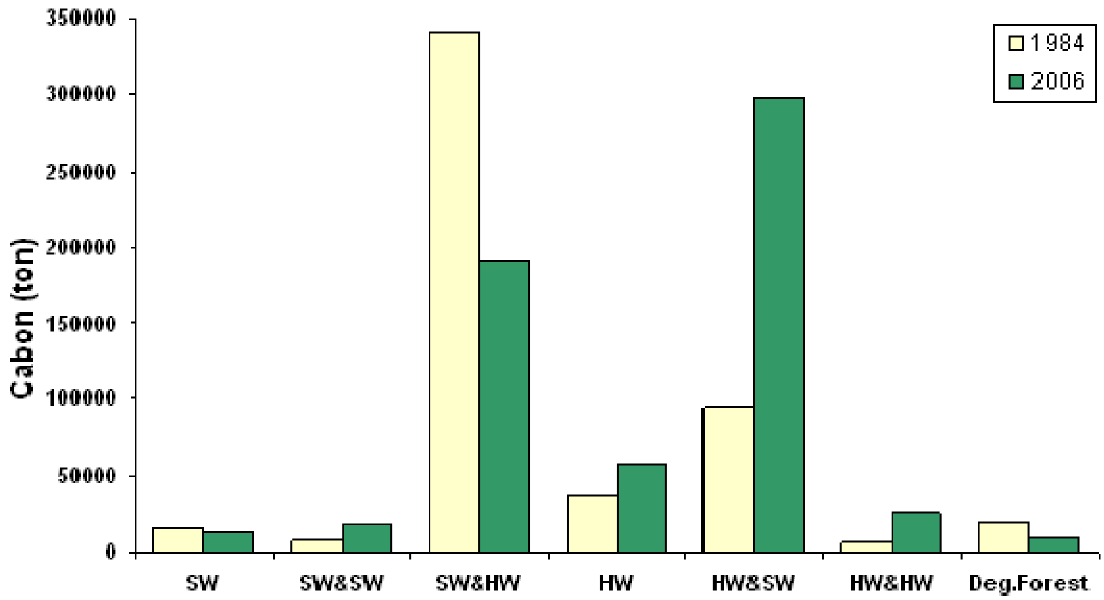

Figure 10. Distribution of carbon storage amount in the planning unit in 1984 and 2006 according to forest types.

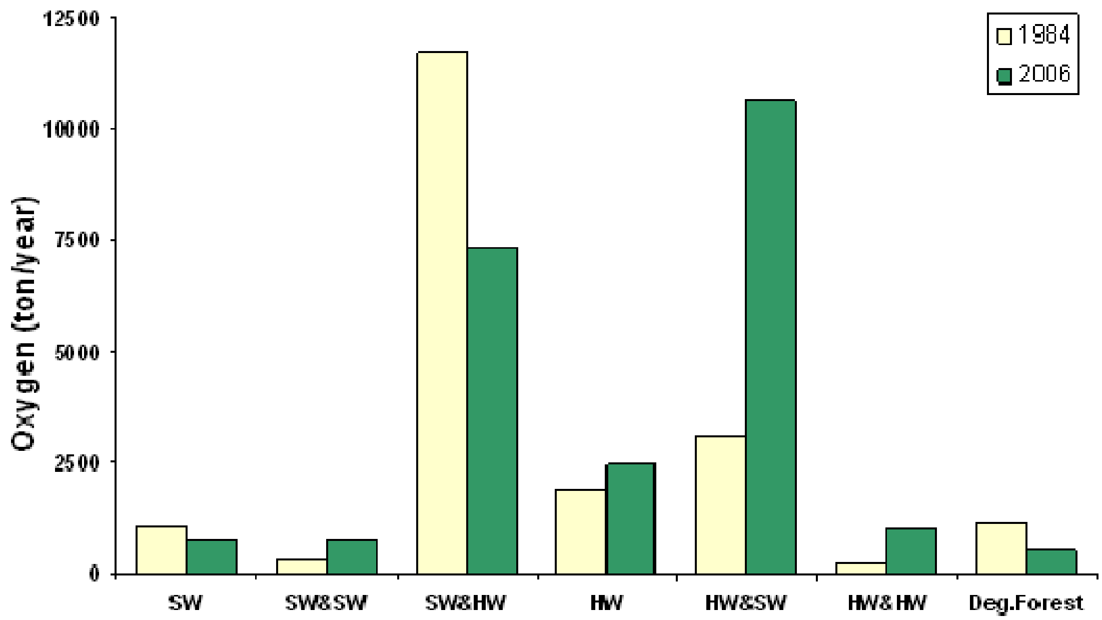

Figure 11. Distribution of annual oxygen production amount in the planning unit in 1984 and 2006 according to forest types.

10.2 million). Economic conditions of the people living in these areas are rather low, that is they make their living generally from forestry, partially from agriculture and livestock. Forest villagers constitute a domination factor on the forest areas in both positive and negative ways. Their positive effects are their socio-cultural life styles in or around the forests of their residential areas, the lack of compromise and forming a resistance against the technical disturbances towards the forest because of their utilizing the ecological and economic values and services (such as festival, bee stands, flood, rolling of rocks). Negative effects are expansion with the aim of agriculture, illegal chopping and burning. Because of the physical deficiencies, the district is losing its population constantly; therefore, recently negative social effects have decreased.

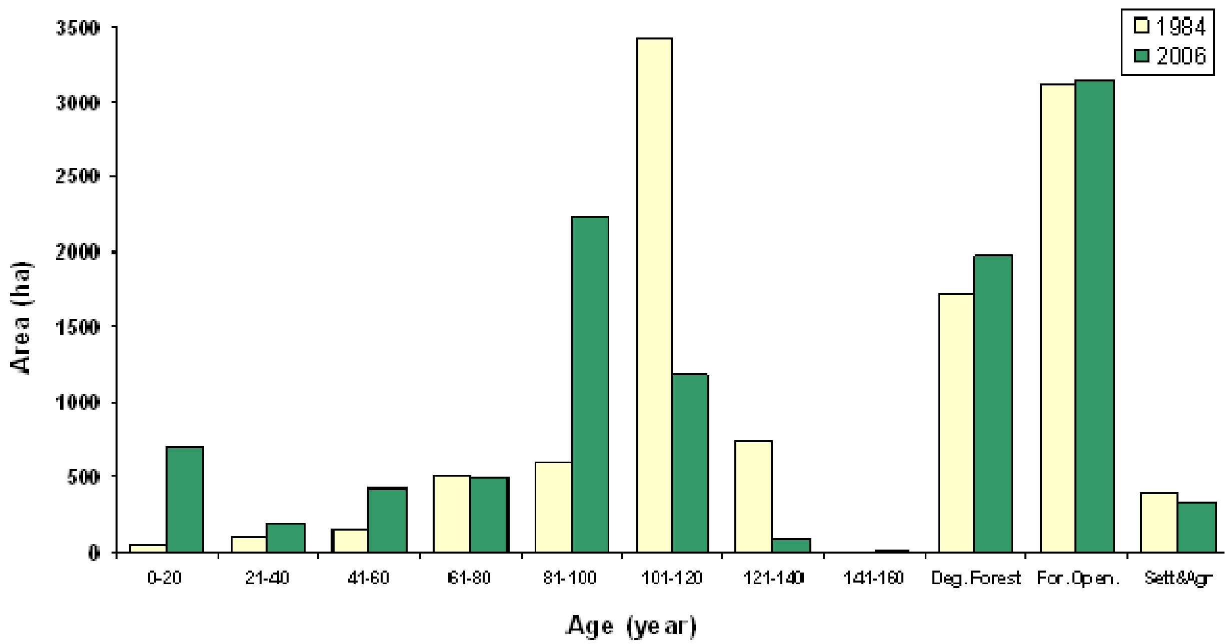

Figure 12. Area distribution of age classes belonged to the forest ecosystem in the planning unit in 1984 and 2006.

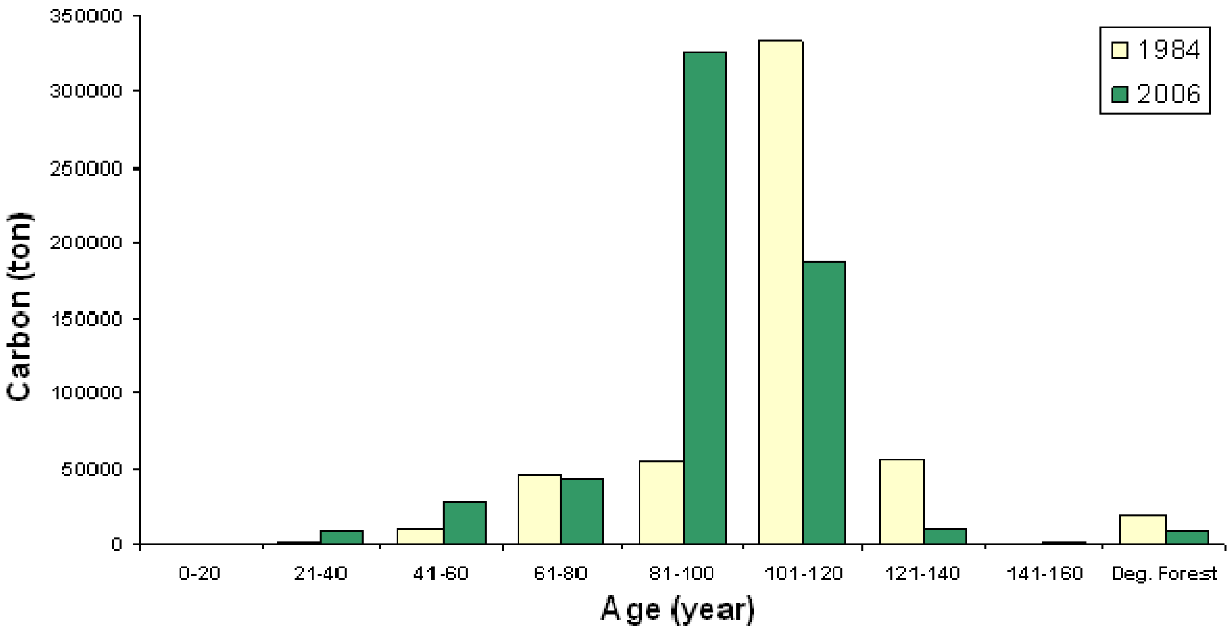

Figure 13. Distribution of carbon storage amounts in the planning unit in 1984 and 2006 according to age classes.

Parallel to the decrease in population, approximately 65 hectare reduction has been seen in the residential and agricultural areas (Figures 6, 9 and 12). Similarly, a decrease has been detected in agricultural areas in the center of the city and town Balcı village belongs to. The immigration from villages to the city and town centers is increasingly going on. Most of the immigrants include young population.

Conclusion

In the world, the only forests colour responsible for storing of carbon and cleaning of the air by production of oxygen is green. While climate changes are turning up due to the global warming and the theories related to this are increasing worries and anxieties, they also bring about forests' functions of carbon storage and oxygen

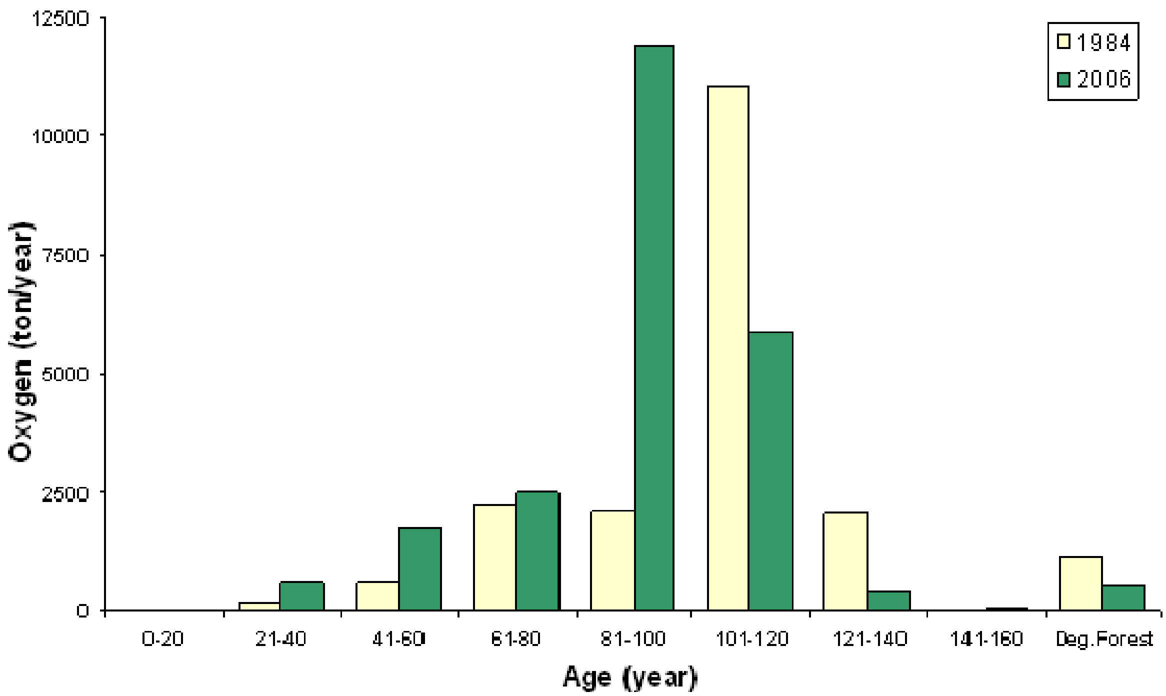

Figure 14. Distribution of annual oxygen production amounts in the planning unit in 1984 and 2006 according to age classes.

production. According to the treaties and procedures in global scale, each country puts forward its own carbon circle so that each one estimates its carbon storage capacity together with the amount of oxygen production. It is likely that the countries with positive values in carbon circle will claim serious compensations in the future. Per year 4.309 ton/ha oxygen is produced in Balcı forests with 614 648.921 ton carbon storage. According to FAO (UN-ECE/FAO, 2000), only the economic value of carbon stored is about 12.29 million dollars when it is thought that the economic value of one ton carbon is 20 dollars. If other functions of the forest ecosystems are added into this calculation, the value will considerably increase.

The natural events such as fire, damages from insects, avalanches, landslides, and snow and wind turndowns having a crucial place in the concept of forest management planning affect considerably the shape, amount and frequency of the cultural interferences in the forest. In Turkey, fires in the south, terrorism and harsh winter conditions in the east and south, drought in the interior regions together with the damages from insects in the north affect forestry activities very much. During the last 20 years, bark beetles have marked the forestry in Artvin district.

However, no serious study has been done on the extent of damages and how it affects the forest ecosystem so far. The consequence is that the spatial data bases of the study area have not been able to form up till now and as a result, it is a very important issue that needs to be discussed.

Parallel to the changes in the philosophy of forestry activities in the country, geographical data bases of forests in the country have been established, together with adopting the multi use management. However, in the existing practice, the evaluation of structural changes in forest cannot be done because there is no geographical data base about the past. In this study, the geographical data bases related to the past and present of the region have been established. That is how the structure of Balcı Planning Unit forest ecosystem has changed and the effects of this change on carbon storage capacity as well as oxygen production have been put forward.

Turkey, especially the Black Sea Forests, is of great importance because of its biological diversity capacity and it having potential of old forests growth, besides carbon storage and oxygen production, has a crucial place among the countries of Pan-Europe in which Turkey also takes part and those in the process of Near East. Using and protecting these values properly give way to benefits not only for Turkey but for other countries as well. Each country, region or district should take its own share by determining the positive and negative issues in its part.

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