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Full Length Research Paper

Effects of Turkish forest management philosophy and applications on forest ecosystem structure and functions

Hacı Ahmet Yolasi maz[1] and Sedat Kele[2]*

[1]Artvin Çoruh University, Faculty of Forestry, Artvin, Turkey.
[2]Çankırı Karatekin University, Faculty of Forestry, Çankırı, Turkey.

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Nowadays, Turkish forest management philosophy has changed from timber management to ecosystem-based multiple-use forest planning (EBMUFM) with the principles of "sustainable forest management" criteria and indicators drafted in a few national and international agreements. This study analyzed the temporal changes in forest ecosystem structure and a few forest values such as tree species, distribution of age class, development stage, canopy closure, species mixture, timber volume and increment, carbon storage and oxygen production in Saçinka Forest Planning Unit in the northeast corner of Turkey. To assess the patterns during a 21-year period (1985-2006), the necessary data were obtained from forest stand maps and evaluated with Geographical Information Systems (GIS). Results showed that the decrease of agricultural and settlement areas caused the increase of productive forests and the decrease of degraded forests. Bark beetles, which have common effect in Artvin, had less effect on the vitality of Saçinka Forest Planning Unit forests compared to the neighboring forest ecosystems. This forest ecosystem vitality and integrity level was a result of the mechanic and biological interventions against the beetle damages and appropriate silvicultural prescriptions.

Key words: Ecosystem based multiple use forest management planning, geographic information systems, land cover change, carbon storage, oxygen production.

INTRODUCTION

In the period of last 20 years, anxieties about the decrease in biological diversity, climate changes, drought, nature and especially forest ecosystems as well as information flow, increase in the effectiveness of civil movements of nature protection have centered the ecosystem management philosophy in the world agenda. Each country adapts the philosophy of forest resources management to forestry in its own entity even under varied names, by support from international conventions, and processes (Brooks and Grant, 1992; Brussard et al., 1998; MacCleery, 1999; Ba kent and Yolası maz, 1999; Brody, 2001; Davis et al., 2001; Dekker et al., 2007) . During the stated period, the world countries took the first pace in Rio (1992) with the convention of Biological Diversity (BD) in search of a common solution. Moreover, they accelerated the solution via processes in the continental scale. Turkey signed BD Convention in 1996 and it supports the solution search with its forests spreading around two continents by including the processes of Pan Europe and Near East because of its geographical position. Forests in the country were planned and operated according to the classical planning approach which focused on timber production from 1963 to 1995, a period of transition to planned

*Corresponding author. E-mail: skeles79@gmail.com. Tel: +90 554 5282986.

forestry. Up to now, the search on planning the forests resources beyond the classical approach has appeared in all times in the name of model plans. In Turkey, the first samples of decisions and applications agreed in the international conventions and processes are Multiple Use Forest Managements belonging to the planning units of the Regional Directory of Istanbul in 1995. After this date, various planning systems have been suggested in different names; however the basic philosophy has the functional planning or in other words Multiple Use Forest Management (Köse et al., 2002; Anonymous, 2004). In Turkey, the sample forest management plans applied or still being carried out, are trials of forestry that are Based on timber production, that do not question the infrastructure of traditional forestry and that have deficiencies in application and supervision stages.

During the period of last 5 years, Multiple Use Forest Management approach has taken the name of EBMUFM by modifying and developing together with the biological diversity supports. Besides, it has been approved by the most of foresters, managers and scientists in Turkey. In the near future, Forest Management Plans will be arranged with this approach (Ba kent et al., 2005; Yolası maz, 2004). The formation process of the EBMUFM to be established on an infrastructure with a focus on timber production shall cause a great many problems at the application stage.

As is stated above, forest ecosystems are crucially important for the storage of CO_2 and increase of O_2 in the atmosphere. Forest ecosystem carbon sequestration is of particular interest to researchers and policy makers be-cause, at global scales, forests account for 80–90% of terrestrial plant carbon and 30–40% of soil carbon (Harvey, 2000; Landsberg and Gower, 1997). 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, forest areas are getting decreased in their lands and qualities because of the reasons such as wrong uses and turning into another land use way. A great many of scientific studies have been prepared about the land use change (Kennedy and Spies, 2000; Taillefumier and Piégay, 2003; Baskent and Kadıo ulları, 2007; Wakael et al., 2005; Xie et al., 2007; Fan et al., 2007) and its effects on the carbon storage capacity of the forests (Adger and Brown, 1994; Neill et al., 1998; Burrows et al., 2003; Houghton, 2000; Kerr et al., 2003; Upadhyay et al., 2005; Sivrikaya et al., 2007; Evrendilek et al., 2007). However, studies about the effects of the variations especially those land use change focused, on the oxygenproduction 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 numerically evaluation of the assets and services provided by the forests as well as of the structures and foundations of the forest ecosystems (Backéus et al., 2005; Brown et al., 1996; Sivrikaya et al., 2007; Kele and Ba kent, 2007; Kele et al., 2007). However, in the calculation of forest biomass the forest inventory data are extremely essential data base. GIS is very important means for carrying out the spatial analyses and for the spatial presentation of the biomass a function of which is carbon storage and for the presentation of oxygen production in a specific area.

In this article, geographical databases have been established by storing the data of forest management plans relating the past and present (1985 and 2006), belonging to Regional Directory of Artvin Forest, Artvin Forest Enterprise, Saçinka Forest Planning Unit (SFPU). Development and modification of SFPU during a period of 21 years have been evaluated comparatively with regard to the stand parameters such as mixture of tree types, canopy closure, age, growing stock and increment, and development stage. The changes depending on time in the amounts of carbon storage and oxygen production are stated numerically. The forest management plan in 1985 was prepared in the axis of timber production whereas the one in 2006 was prepared in the shade of multiple use forest management approach. However, it is clearly seen that even in the new plan, the approach with a focus on timber production is dominant.

MATERIALS AND METHODS

Saçinka Forest Planning Unit

The study area is the SFPU located in the east the town of Artvin characterized by a dominantly steep and rough terrain with an average slope of 57.23% and an altitude from 185 to 2469 m above sea level. It extends along UTM ED 50 datum and zone 37, 732000–746000E and 4584000–4755000N on the northeastern Black Sea region of Turkey (Figure 1). The total area is 13 313.846 ha. The vegetation type is forest vegetation and the dominant tree species of the vegetation are *Picea orientalis (L.) Link, Fagus orientalis Lipsky, Quercus petraea (Maattuschka) Liebl. sub sp. Iberica (Steven ex Bieb.) Krassiln., Pinus sylvestris L., Abies nordmanniana (Stev.) Spach subsp. nordmanniana, Carpinus betulus L., Alnus glutinosa subsp. Barbata*. Although no comprehensive study about plant sociology in the study area has been done, 12 various tree species such as *Quercus pontica, Q. petraea and Ostrya carpinifolia Scop* as well as 19 different shrubs and brushes and 35 plant types taking into the group sporadically that is not standing on their own have been detected and recorded. Mean annual temperature of the study area is 12.7°C, and mean annual precipitation is 644.9 mm. Main soil types are sandy clay loam, clay loam and sandy

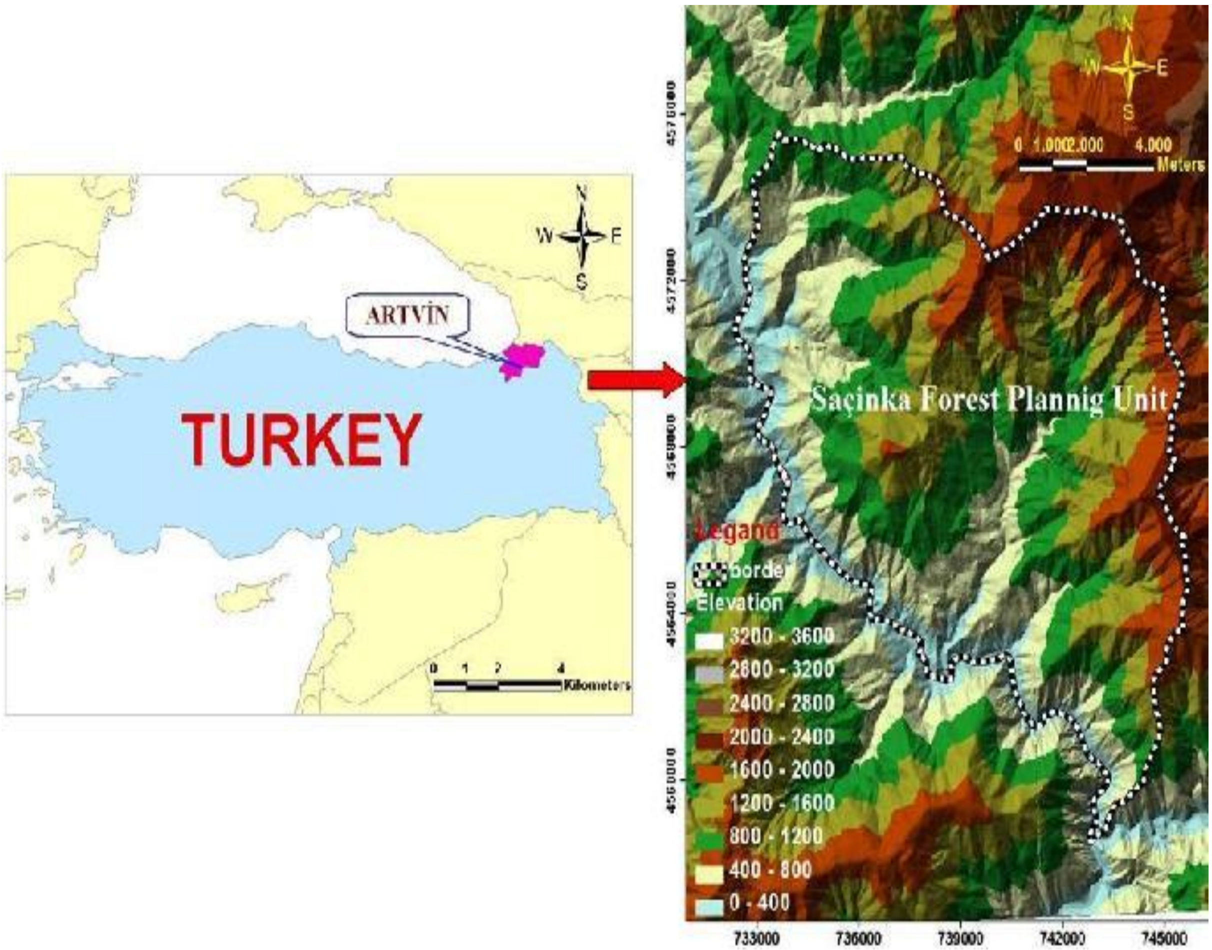

Figure 1. Location of the study area: Saçinka Forest Planning Unit.

loam. In the planning unit, nine villages and its neighborhoods take place. While its population was 3579 in 1990, this number decreesed 2906 in 2000 and 2537 in 2007 (D E, 1990, 2000, 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, moreover 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 Saçinka district the migration from villages to the city have been going on around Artvin where industrial investments are limited and living conditions are hard (Anonymous, 1985, 2006).

Database design and mapping

In the establishment of database related to the study area, geographical databases have been established by storing the data of forest management plans relating the past and present (1985 and 2006), belonging to SFPU. In addition to that, related coverage and a data dictionary were prepared. The GIS presentation in SFPU was accomplished using the following GIS data; forest cover type maps for Saçinka. 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 in 1985 were firstly digitized and processed using Arc/Info version 9.2 GIS with a maximum root mean square (RMS) error under 10 m and spatial database established. The basic database (only stand type map) in 2006 was provided from the Regional Directory of Artvin Forest-Planning and Project Coordinator and the geographical database were developed by being examined once more. Spatial databases consist of stand type, dominant tree species, mixture, canopy closure, forest development stages, age class, basal area and stand type area. The stand type volume and increment was added to the database. Development and modification of SFPU during a period of 21 years have been evaluated comparatively with regard to the stand parameters such as mixture of tree types; canopy closure, development stage, stand age and growing stock. 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 1985 and 2006 were produced for Saçinka by reclassifying a map of the forest cover type maps.

Estimation of timber biomass and the amount of carbon sequestration and oxygen production

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 (Kele and Ba kent, 2006; Asan et al., 2002; Yolası maz, 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. 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. 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. 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, IncBBm the increment in the belowground biomass, IncSWBm the increment in the softwood growing stock and IncHWBm the increment in the hardwood growing stock.

RESULTS AND DISCUSSION

When the study area is evaluated for forest areas, an increase in productive forest areas (6 685.967 hectares in 1985, 7 045.659 hectares in 2006) is seen (- 359.692 hec-tares) while a decrease in degraded forest areas (-495 hectares) is observed. Parallel to the decrease in popula-tion, approximately 252 hectare reduction has been seen in the residential and agricultural areas. Based on the development in techniques of forestry inventory, 47 vari-ous stands were described in 1985 while this number was 100 in 2006. The smallest sub-compartment number, subjected to planning and silvicultural units, was 957 in 1985 while it was 1 477 in 2006.

Figure 2 shows the spatial distribution of dominant tree species in 1985 and 2006. In Figure 3, the area distribution of tree species in 1985 and 2006 is seen. Among the dominant tree species (a tree species with the highest volume rate among the mixed stands and the one with more than 10 % regarding the volume), *Picea orientalis* is the one with the most area. While *P. orientalis* was 3 046.401 (22.61%) hectares in 1985, it covered an area of 2 309.012 (17.34%) hectares according to the data of 2006. The second tree species with the most area on the other hand is *Fagus orientalis*. While it was 1 655.831 (12.29%) hectares in 1985, it showed the distribution of 2 309. 012 (17.34%) hectares in 2006. When the areas of both tree species in 1985 and 2006 are compared, total area of *P. orientalis* decreases as total area of *F. orientalis* increases. Another striking issue at this point is that during 22 years *Carpinus betulus* and *Alnus glutinosa* tree types have come into being (Figure 4).

As a relict taxon in Artvin far out of its natural range, *P. pinea* has been used for plantations in new plan. Figure 4 shows the spatial distribution of stand types in study area between 1985 and 2006 while Figure 5 showing the area distribution of forest types for same period. While softwood- hardwood mixed forests make up 16.53% of productive forest areas in 1985, this share rose up to 30% in 2006. Although the area of pure hardwood stands increased by 5%, pure softwood stands maintained the previous areas. The area of mixed softwood stands decreased by 10% and the area of mixed hardwood stands increased by 4%. The decrease in mixed softwood stands' area and partial increase in mixed hardwood stands' area between 1985 and 2006 is because of the bark beetles (*Dendroctonus micans*, *Ips typographus* and *Ips sexdentatus*). Starting from 1966 and getting severe between 1990 and 2000, bark beetle pestering had serious damages in Artvin forests particularly on *P. orientalis*.

The age class spatial distribution of planning unit between 1985 and 2006 is seen in Figure 6. It can be stated that old growth forest potential of Saçinka forests, which indicates seed rooted and natural, is low. According to data on 1985 forest management plan 94.36% of productive forests was below 100 year age; this percentage is 97.30% in 2006 (Figure 7). The cutting rotations for forests managed for timber are the same - 100 year, for both periods. Forests aging over the cutting rotation (above 100 year) in former plan period were regenerated. According to data on 2006 forest management plan, these regenerated forests ranging 20-40 year ages are 1 456 ha. Conservation forests, which left untouched at former 1985 forest management plan, is subject to rehabilitation regarding the 200 year rotation in 2006.

The development stage spatial distribution of planning unit between 1985 and 2006 is seen in Figure 8. The area of stands that comprises large trees (>36 cm DBH)

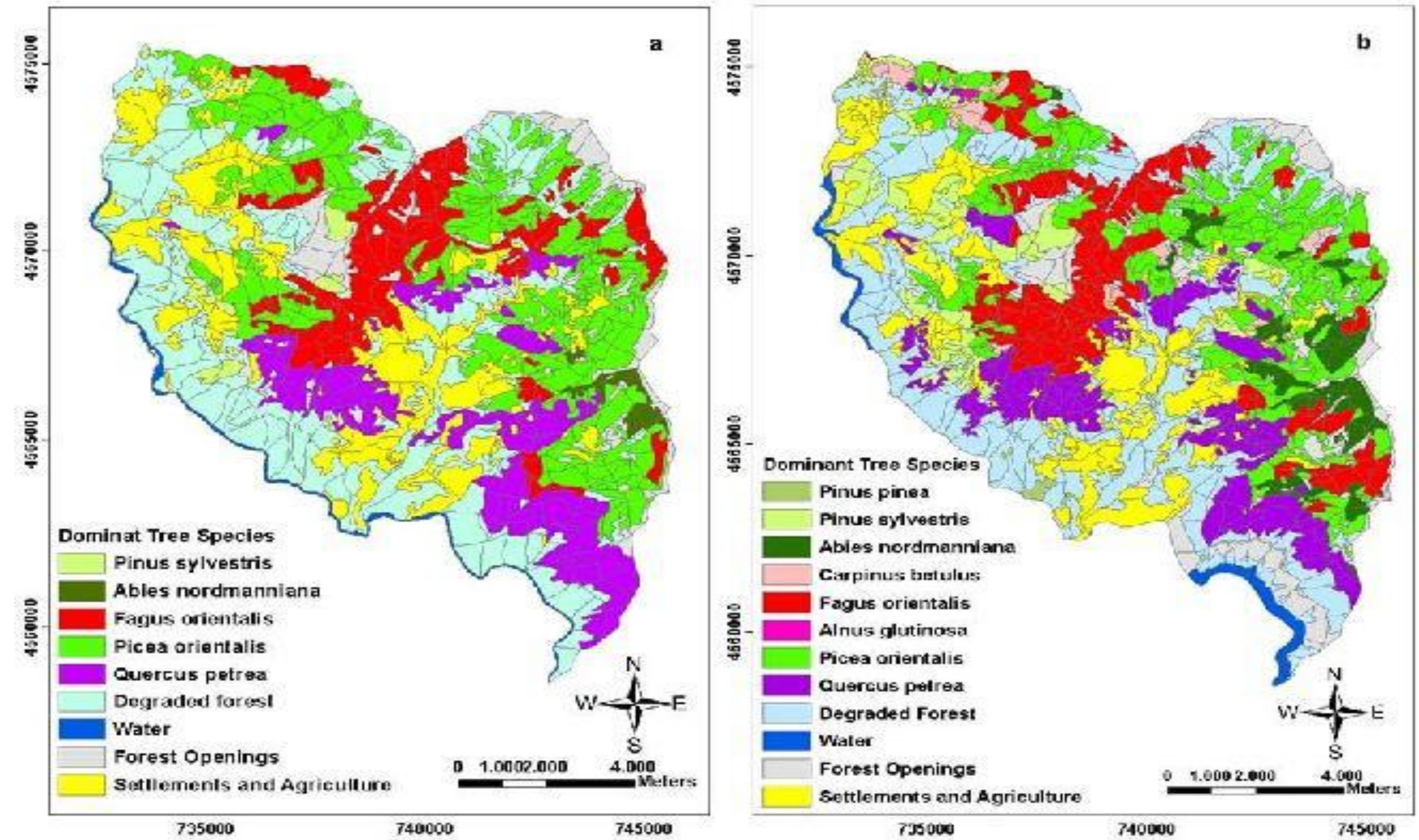

Figure 2. The spatial distribution of the planning unit related to the dominant tree species a) in 1985 and b) in 2006.

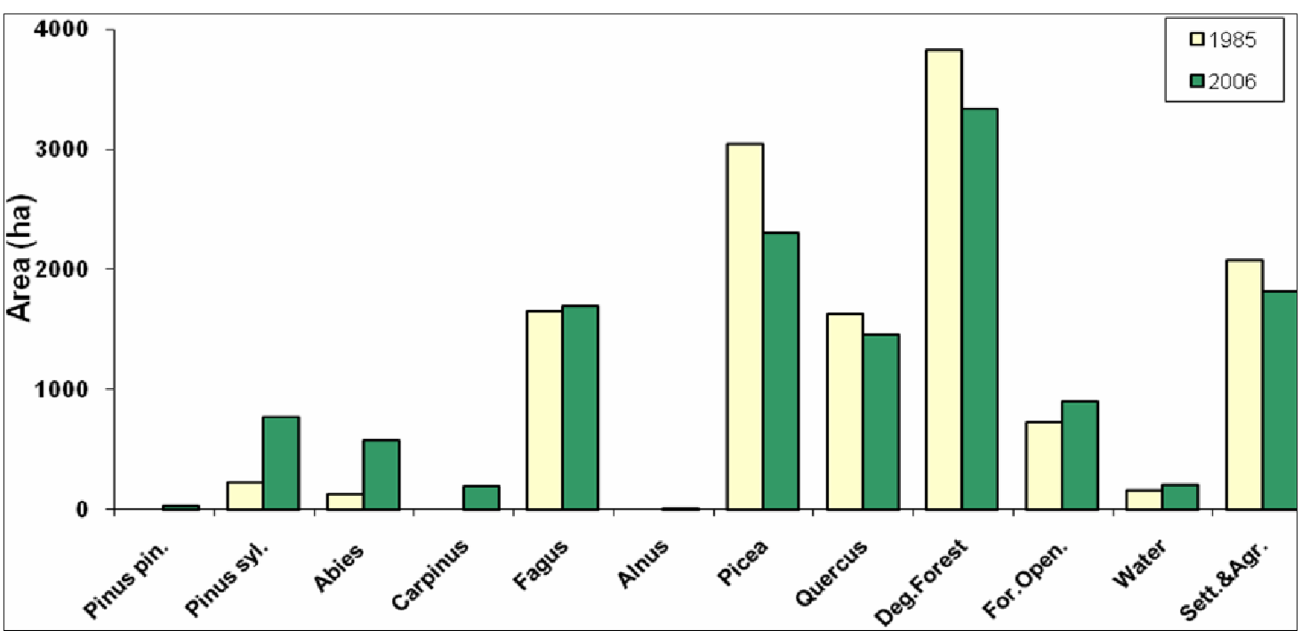

Figure 3. Area distribution of the dominant tree species in 1985 and 2006 in the planning unit.

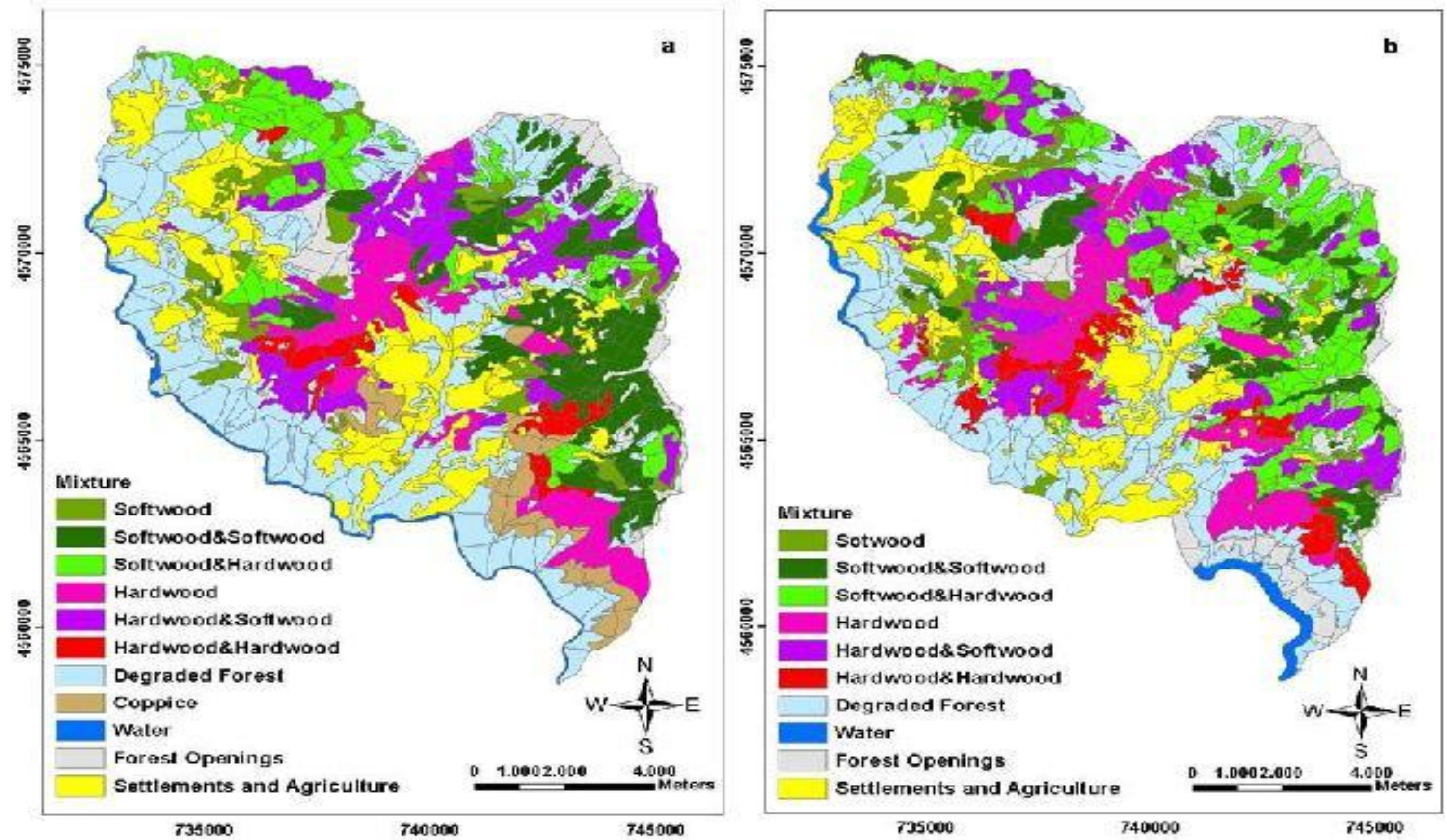

Figure 4. The spatial distribution of the planning unit related to the forest types a) in 1985 and b) in 2006.

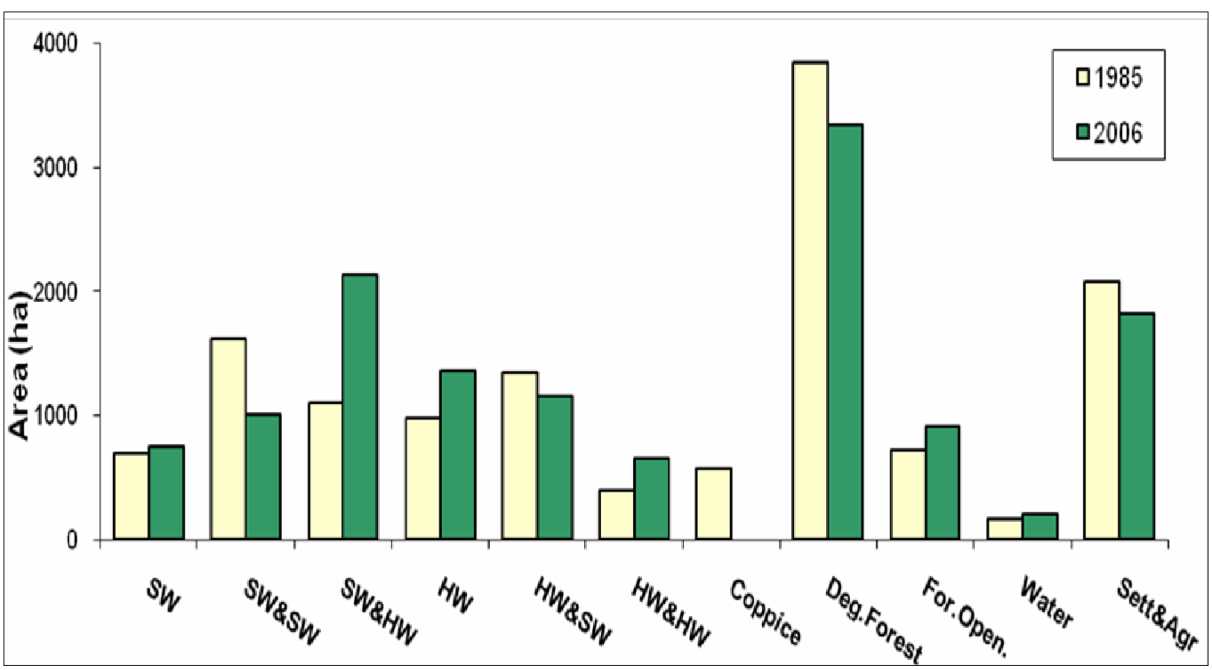

Figure 5. Area distribution of the forest types in 1985 and in 2006 in the planning unit.

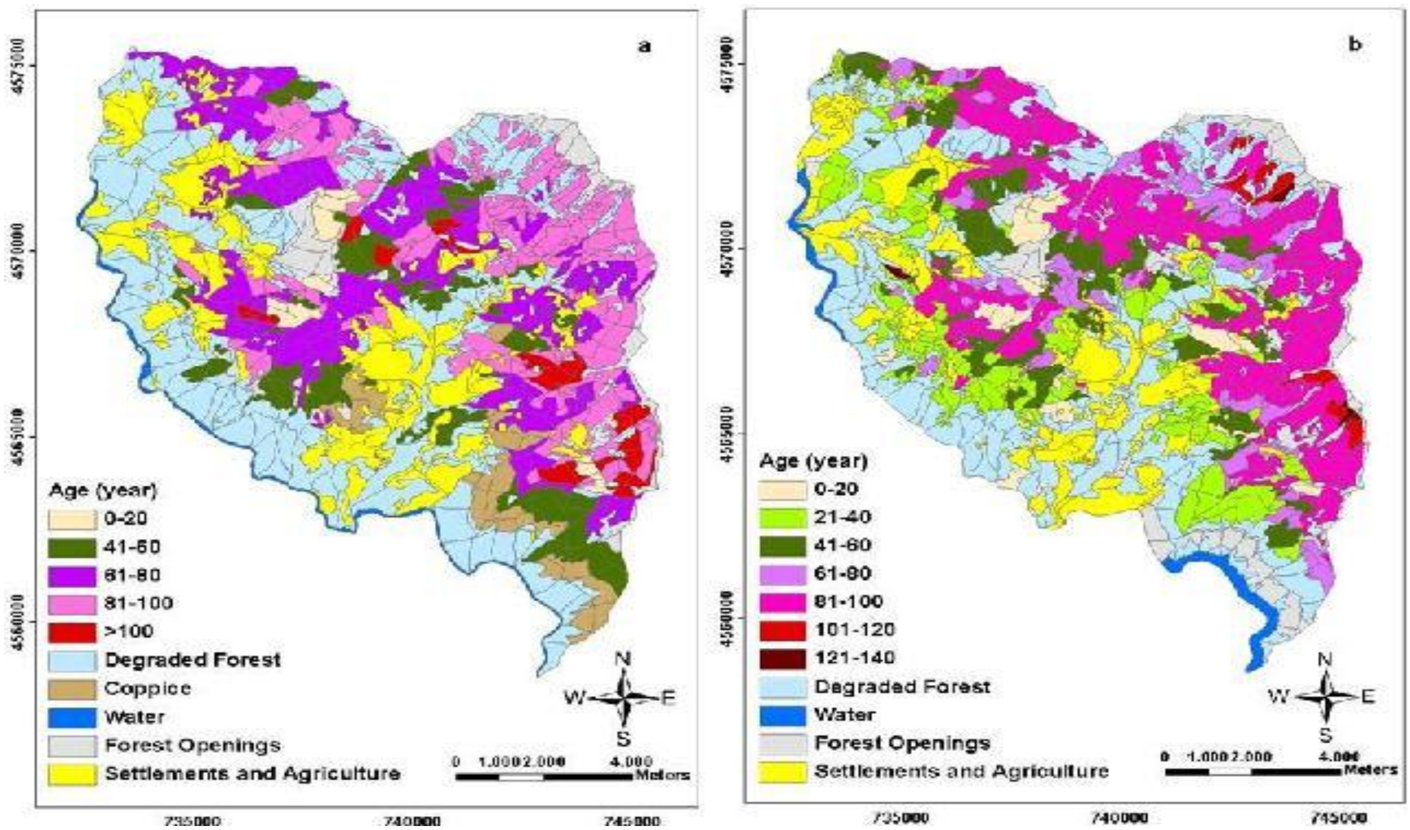

Figure 6. The spatial distribution of the planning unit related to the age class distribution a) in 1985 and b) in 2006.

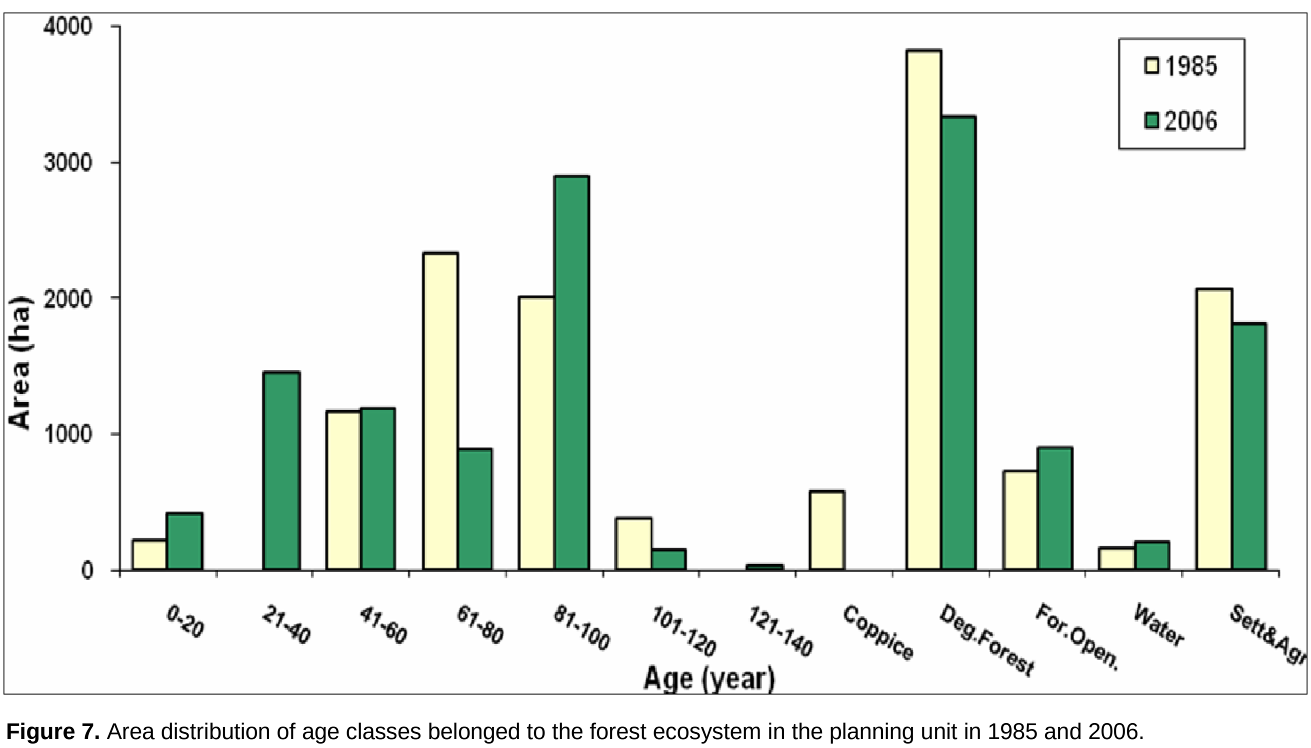

Figure 7. Area distribution of age classes belonged to the forest ecosystem in the planning unit in 1985 and 2006.

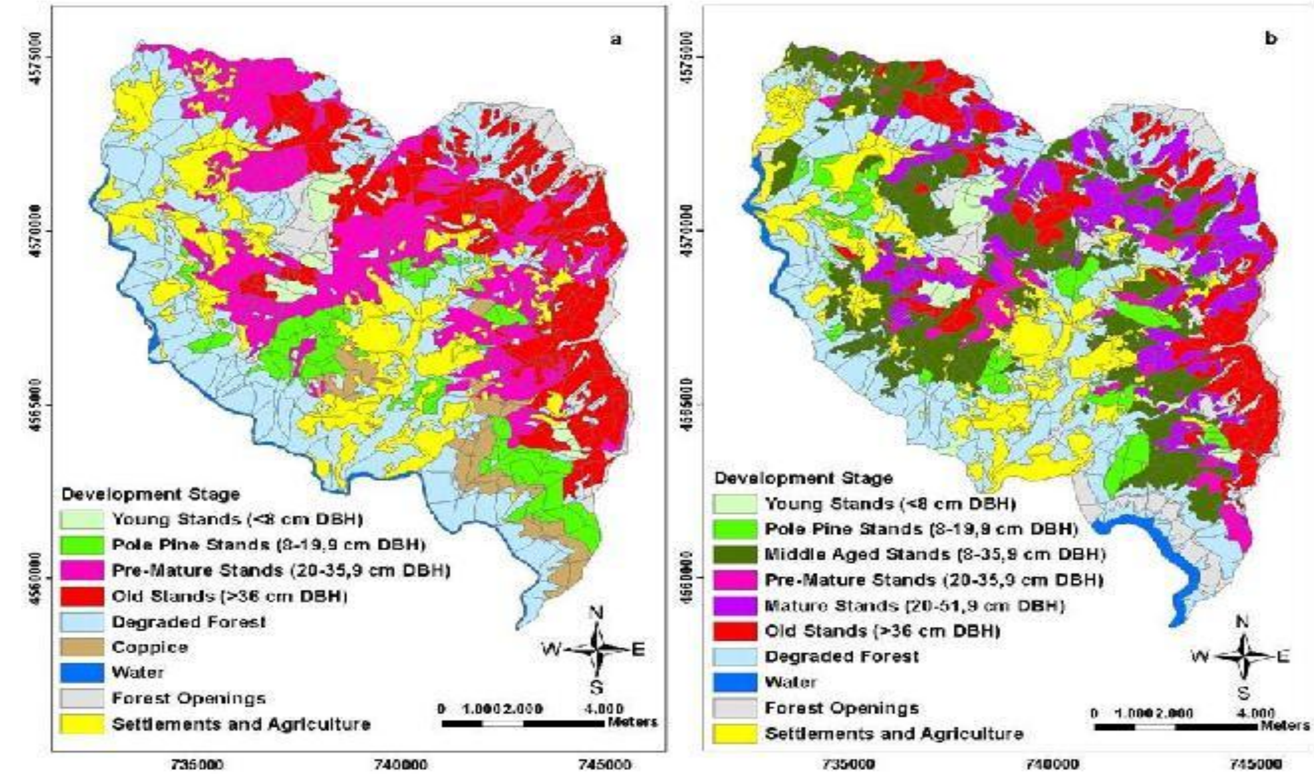

Figure 8. The spatial distribution of the planning unit related to the development stage a) in 1985 and b) in 2006.

has lessened between 1985 and 2006. Two periods have different classification in terms of development stages (2006 forest management plan includes mature and middle aged categories). Thus, it is also possible to state that the area of stands that comprises large trees increased when mature and old aged stands are dealt with together. The area of young and pole pine stands (<20 cm DBH) more or less was stable.

The crown closure spatial distribution of planning unit between 1985 and 2006 is seen in Figure 9. Through this period, the area of stands with crown closure of 71–100% increased, while the area of stands with 10–40% crown closure decreased. The stands with 40–70% crown closure were stable in terms of their area. Regeneration and afforestation works weighted the same as former period. Today, about 65% of forests have full and half closure (53.5% in 1985).

Figures 10 and 11 depict the growing stock and increment respectively between 1985 and 2006 in Saçinka planning unit. Total growing stock of Sacinka planning unit was 1 548 096.706 m^3 and increased to 187,832.87 m^3 reaching up 1 735 929.576 m^3 in 2006. Average grow-ing stock on productive forests was 231.544 m^3/ha in 1985; it is in 2006 272.523 m^3/ha. Annual increment is 37 903.988 m^3 in 2006 with an increase of 8 523.666 m^3 from 29 380.322 m^3 in 1985. Productive forests have an annual increment rate of 5.38 m^3/ha in 2006 and 4.40 m^3/ha in 1985. Most important cause of the increase in both growing stock and increment is increase of productive forests and decrease of degraded forests. Another factor is the decrease of agricultural and settlement areas. The migration from forest villages to the town and cities resulted in abandonment of agricultural lands which had not cadastral survey. Normally in Karadeniz Region those lands get forested with ease in short time while not used. Third and last factor is the young and middle aged structure of the Saçinka forests. Since 65% of the productive forests are in 60-100 age range and 17.44% of them are in 40-60 age range, forest ecosystem has great growing energy. Annual allowable cut is 6 765 m^3/year for Saçinka planning unit according to 2006 management plan. Annual cut was 5 458 m^3/year for last five years and 69% of this was exceptional cuts (Anonymous, 2006).

The spatial distribution of the carbon amounts stored and oxygen amounts by the planning unit depending on above and belowground biomass amounts in the years of 1984 and 2006 are seen in Figures 12 and 13. When the carbon storage potential of the forest planning unit is evaluated, it is clearly seen that the places whose carbon amounts are less than 150 ton are much more than the others (Figure 12). This situation shows that growing stock and thus biomass of the forest ecosystems in the

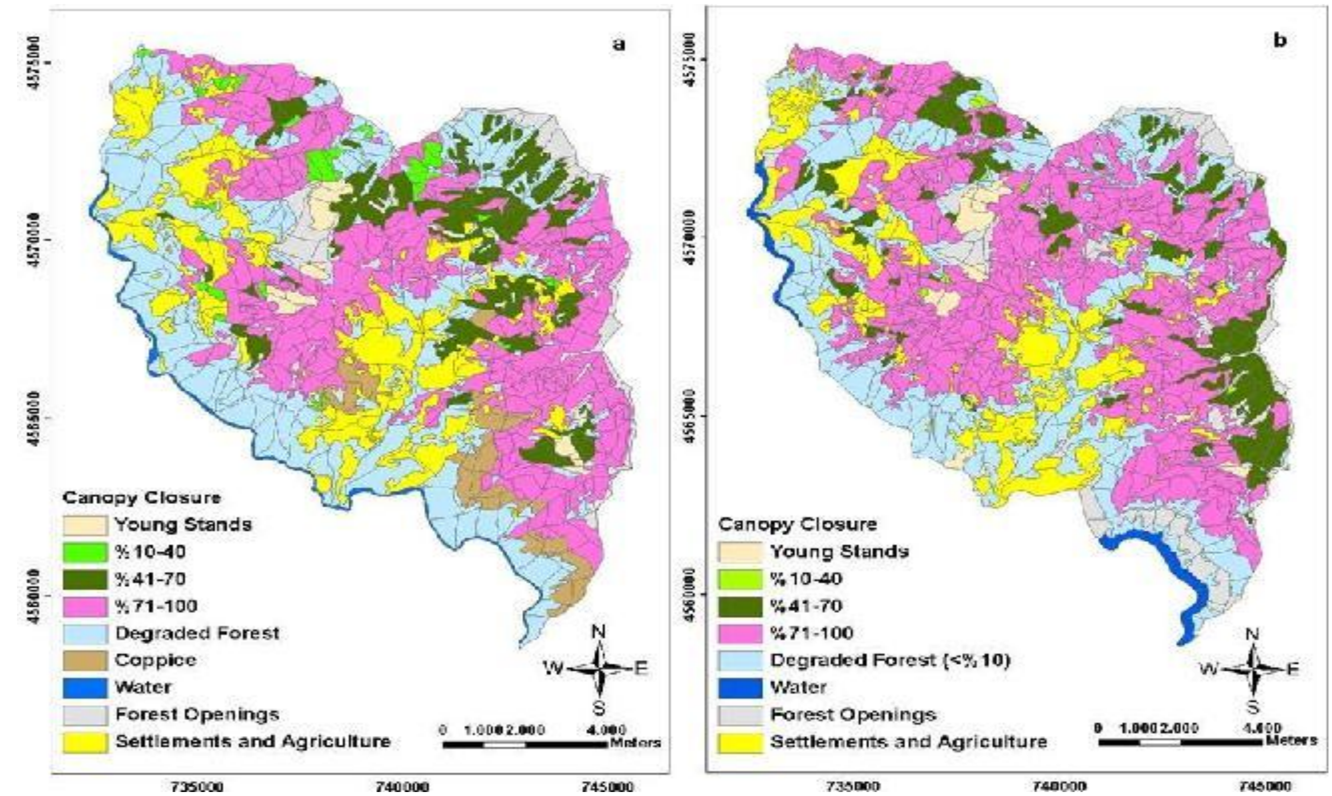

Figure 9. The spatial distribution of the planning unit related to the forest canopy closure a) in 1985 and b) in 2006.

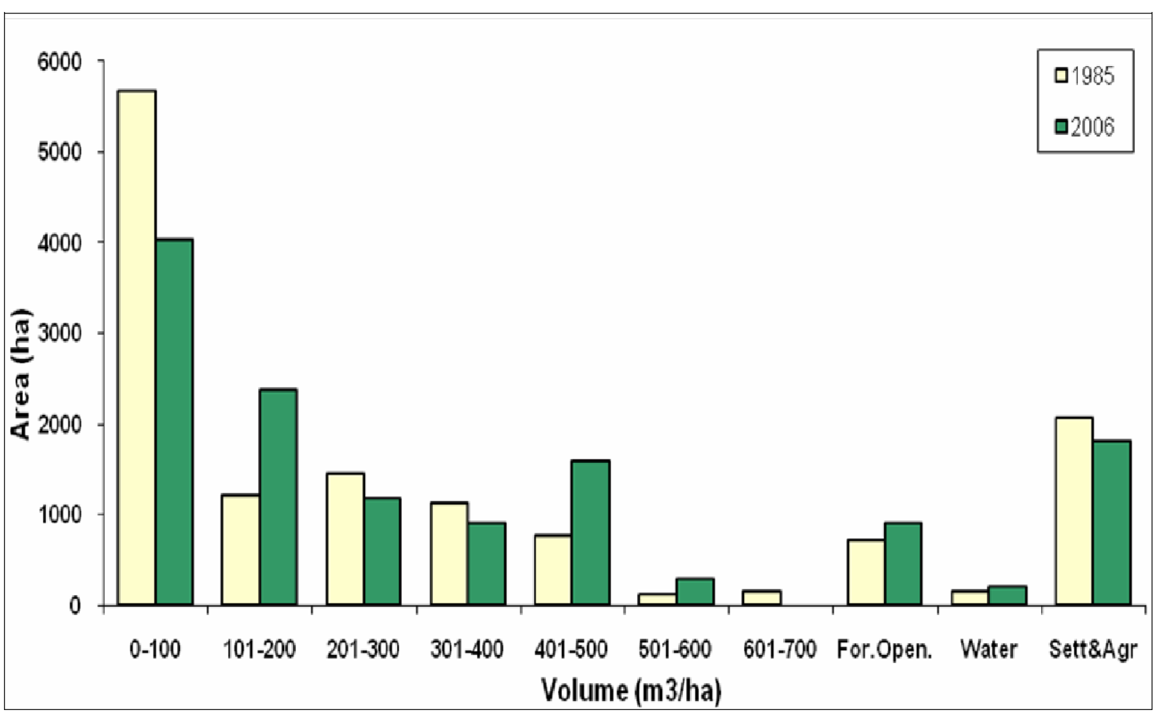

Figure 10. Distribution of areas by volume per hectare of SFPU in the years of 1985 and 2006.

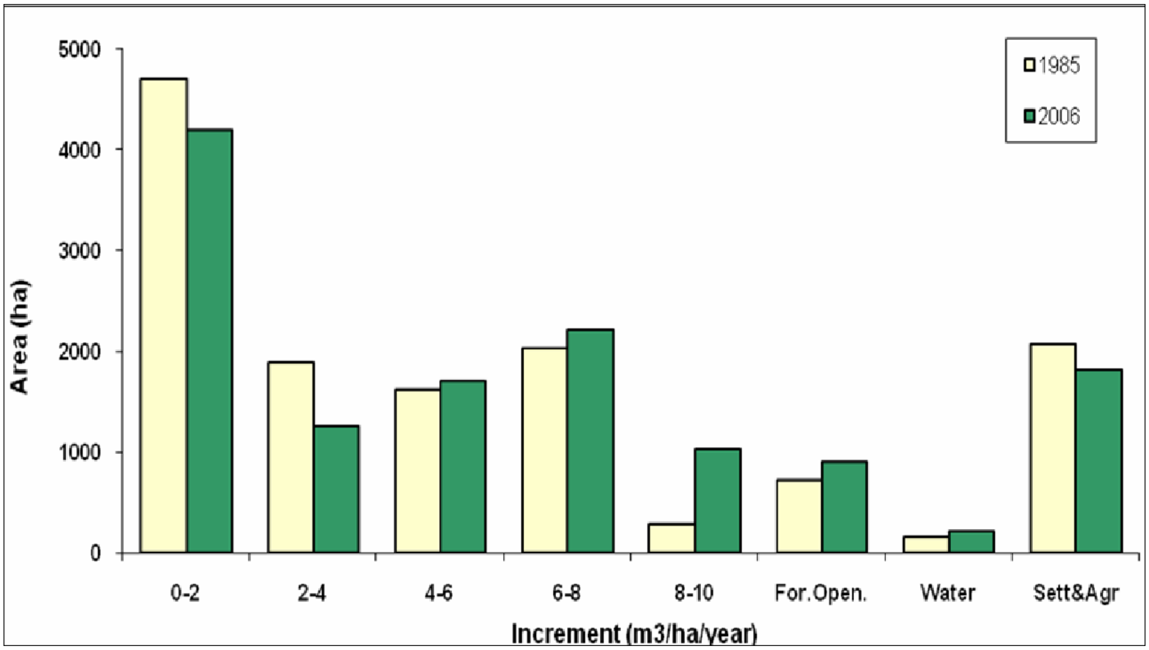

Figure 11. Distribution of areas by increment per hectare of SFPU in the years of 1985 and 2006.

planning unit are not very high. Totally 612 319.759 carbon storage in 1985 went up to 753 404.572 ton in 2006. During the period of 22 years, carbon amount stored by planning unit increased to 141 084.813 ton. Carbon amount stored in productive forest areas was calculated on average as 90.669 ton for each hectare in 1985, while it was calculated as 103.075 ton in 2006. Oxygen amount produced by forest ecosystem and released into the air has increased from 27 024.825 to 34 593.571 per year depending on the annual timber increment. Average annual oxygen production in hectare in productive forests was calculated as 4.03 ton in 1985 while it was 4.811 ton in 2006. It can be seen that low raising areas constitute most of the oxygen potential produced by the forest ecosystem annually in a unit area (Figure 13).

Throughout the study period of 21 years, it can be seen that most of the amounts of carbon storage and oxygen production are provided from *P. orientalis* stands that is dominant tree species. On the other hand, there were decreases in carbon storage amounts (20%) and oxygen production amounts (17%) during the study period. Compared to 1985, carbon storage and oxygen production amounts in the stands in which *Abies nordmanniana* was dominantly increased by 10% in 2006. As is seen in Figures 12 and 13, throughout the study period of 21 years, it can be seen that most of the amounts of carbon storage and oxygen production were provided from mixed stands. Most of the carbon storage was provided from the stands aged between 80 and 100 as 42.76 % in 1985 and 59.24% in 2006. Also, most of the oxygen production was provided from the stands aged between 80 and 100 as 37.06% in 1985 and 53.24% in 2006. The rest amounts of carbon stored and oxygen produced comprised the stands lower than 80 years because there was a little area above the age of 100 years.

Summary and Conclusion

In Turkey, during the preparation of forest management plans, the comparison of the past and future was made partially by examining graphics and tables after the prior calculations in the past because there were no geographical databases. Thanks to the GIS, now it can be fulfilled in faster, straighter ways and visually including the spatial characteristics. Initiating from sub-compartment and compartment with the smallest database design, the evaluation in each scale will be easier in such issues as planning unit, forest enterprises, regional directories and forests in Turkey. Moreover, database design is crucially important for various companies and facilities, private enterprises and non-governmental organizations (NGOs) in order to evaluate the produced data through their own purposes consistent to the software they use. Turkey needs to develop a comprehensive forest database related to the country facts while it is still at the beginning of the way. As there are no or limited numerical values about the ecological and social benefits offered by forests, together with the biological diversity, leading the way, they cannot be transferred to geographical databases. The evaluations in that sense can be fulfilled indirectly

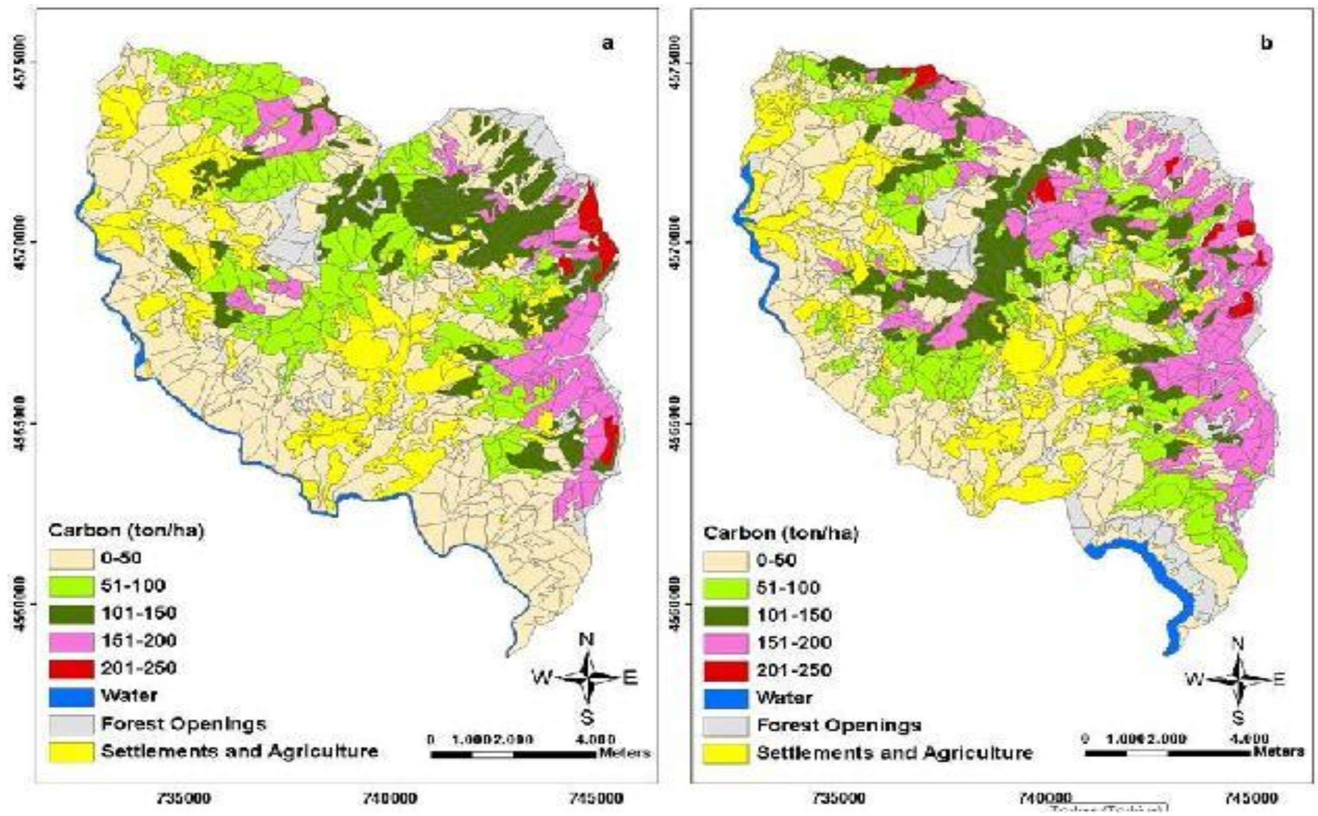

Figure 12. The spatial distribution of the planning unit related to the carbon storage amounts a) in 1985 and b) in 2006 in unit area.

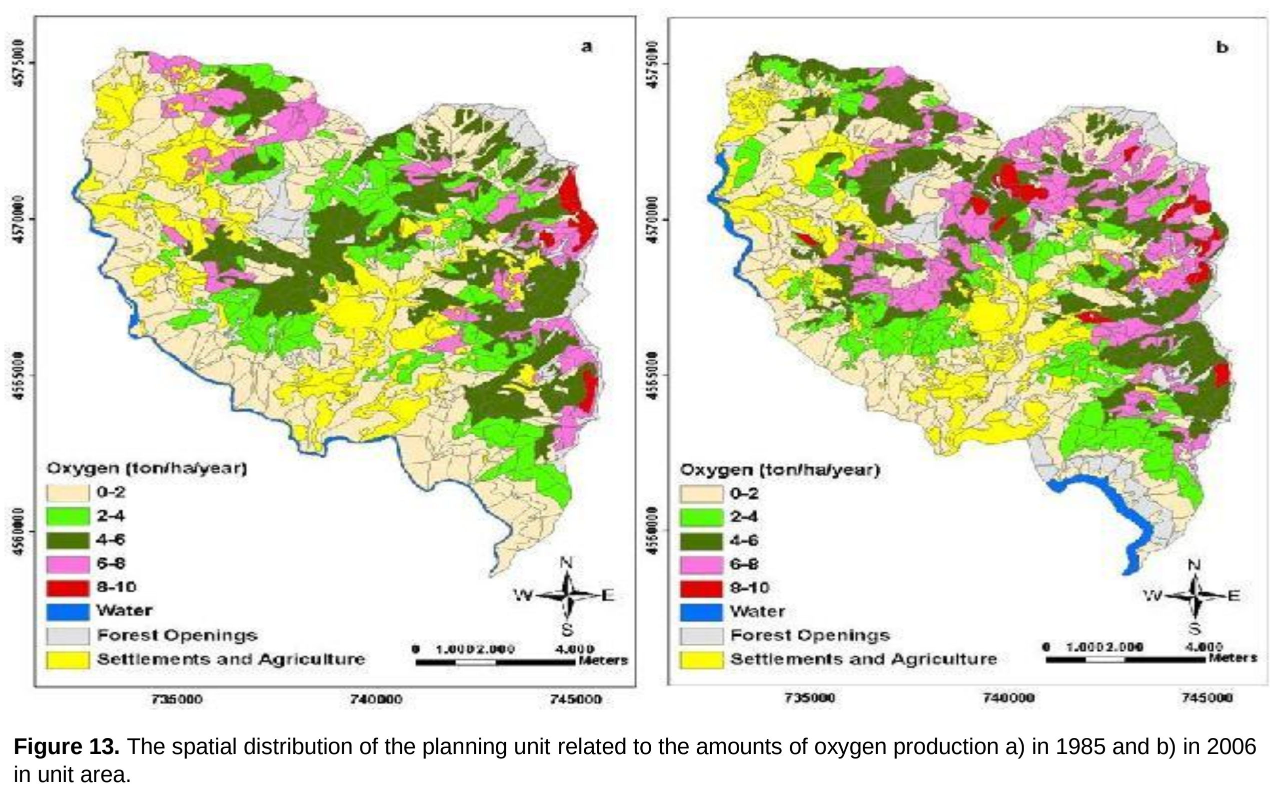

Figure 13. The spatial distribution of the planning unit related to the amounts of oxygen production a) in 1985 and b) in 2006 in unit area.

by initiating from stand parameters. However, all numerical data obtained from flexible databases can be updated by being added afterwards.

The basic reason of the changes in residential and agricultural areas is that the ownership in the forest, residential and agricultural areas has not become definite yet. Especially 7.8 million forest villagers living in or around the forest make their living from the forest. Recently, the traditional life styles of Turkish people, especially of the young population, have shown a transition from rural areas/life to urban areas/life parallel to the changes in technological and informational fields. Therefore, the populations of the villages have reduced; average age has considerably increased in the remaining ones. Parallel to the decrease in young population in the villages, a recession in agriculture and livestock sectors has been seen. Especially, as the areas that are within or around forests and used for agriculture and livestock before, are left on their own; they have become forest areas via the seeds coming from the edges. During the last five years in which cadastre has gained importance, as many such areas have lost their characteristics of being pasture and agricultural sites, they are recorded on forest maps as forest areas during cadastre procedures. It is anticipated that the forest cadastral, one of the general problems of Turkey, will be solved in the next five years.

In the world the only color both storing carbon and cleaning the air by producing oxygen is green that is trees and forests. While climate changes 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 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 4.811 ton oxygen is produced in Saçinka forests with 753,404.572 ton carbon storage. According to FAO (UN-ECE/FAO, 2000), only the economic value of carbon stored is about 15 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. Especially, 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 impact of that the spatial data bases of the study area have not been able to form up to now is very important in this issue. Parallel to the changes in the philosophy of forestry activities in the country, geographical data bases of forests in the country have been started to establish 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, moreover that how the structure of SFPU forest ecosystem has changed and the effects of this change on carbon storage capacity as well as oxygen production have been put forward. This study concluded that technical forestry activities carried out in Saçinka forests were successful in the context of sustainable forest management. Mechanical and biological struggles in response to beetle attacks as well as sustainable silvicultural prescriptions quantitatively showed that forest ecosystem health and integrity was protected. We concluded that these forestry activities applied in all forest ecosystems in the black sea region of Turkey. Methods towards to application should be developed in the context of strategic, tactical and operational planning.

In order to anticipate the future of forests in the country, new plan data which are prepared by multiple use forest management, as well as the plan data of about 40 years need to be recorded in geographical databases. In that way, models of spatial forest ecosystem indicating the dynamics of forest ecosystem which changes according to silvicultural prescriptions and natural events shall be produced. Short-term and long-term research projects about the difficult positions described in this context need to be developed in order to achieve EBMUFM successfully. Universities as in the leading position, researchers, managers, administrators, NGOs, foresters and all the related groups are considerably responsible for this issue.

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