TRABZON YÖRESİ YAPAY KAYIN ORMANLARININ KARBON HAVUZLARINA İLİŞKİN PLANLAMA STRATEJİLERİ

MANAGEMENT SCENARIOS FOR CARBON POOLS OF *Fagus orientalis* PLANTED FORESTS IN THE TRABZON REGION

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ÖZET

Avrupa Birliği'nin 2018/841 sayılı yönetmeliğine göre tüm Avrupa Birliği üye devletleri Arazi Kullanımı, Arazi Kullanım Değişikliği ve Ormancılık (AKAKDO)'ya göre karbon bildirimi yapmak zorundadır. Bu kapsamda ormanlarda depolanan karbonun belirlenmesine ilişkin bir temelin oluşturulması önkoşuldur. Mevcut araştırma bu ihtiyacı ele almakta ve Trabzon yöresindeki yapay kayın (*Fagus orientalis*) meşcerelerinde depolanan belirlenmesini amaçlamaktadır. Karbon havuzları ağaç gövdesi, dalları ve yaprakları ile çalılar, otsu diri örtü ve ölü örtüden oluşmaktadır. Trabzon yöresinde bulunan yapay kayın meşcereleri 40 yaşını aşmamakta ve başlangıçtaki gelişimlerine ilişkin değerli bilgiler vermektedir. Alandaki karbon stoklarını iyileştirmek için en uygun orman amenajmanı uygulamalarını belirlemek için farklı planlama stratejileri uygulandı. Bu çalışma, AB'nin bildirim kurallarına uygun olarak orman amenajmanı uygulamalarındaki karbon dengesini dahil etme gerekliliğini göstermektedir. Ayrıca, iklim değişikliği açısından ormanları sürdürülebilir bir şekilde yönetebilmek için dikkate alınması gereken ek hususları da özetlemektedir.

Anahtar kelimeler: Kayın, yapay orman, karbon depolama, orman amenajmanı, strateji

ABSTRACT

Following EU regulation 2018/841 carbon reporting from the LULUCF is required by all EU member states. Within this scope the establishment of a carbon baseline in forests is a prerequisite. The current research addresses this need and focuses on quantifying carbon storage in planted beech (*Fagus orientalis*) stands in the Trabzon region. The carbon pools inventoried include tree stem, branches and foliage, as well as shrubs, herbaceous vegetation and litter. The age of beech stands in the Trabzon region do not exceed 40 years and provide valuable insight in the early stages of their development. Different management scenarios were applied to identify the optimal forest management practices to enhance carbon stocks. The present work sets the grounds for incorporating carbon balance into forest management practices in line with the reporting rules of the EU. It also outlines additional aspects that need to be taken into account in order to sustainably manage forests in view of climate change.

Keywords: *Fagus orientalis*, planted forest, forest management, scenarios

1. INTRODUCTION

Forest functions traditionally included wood production, protection and forest recreation. However, a fourth category was added concerning environmental impacts, after realizing the magnitude of environmental issues worldwide in relation to climate change (Galatsidas, 2012).The twofold role of forests as both sources and sinks of Greenhouse Gases (GHG) makes their influence on the climate extremely significant (SFC, 2010). Therefore

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climate change adaptation and mitigation has been set as a current priority in forest management (Vlachaki et al., 2017a).

Maintaining the carbon stock and enhancing carbon sequestration of forests contribute to the implementation of the UNFCCC and the Kyoto Protocol. This is also one of the commitments of the Signatory States of the Ministerial Conference on the Protection of Forests in Europe and the European Community (Forest Europe, 2015). Moreover, Decision 529/2013/EU, on accounting rules regarding GHG emissions and removals stipulates that all land use should be considered in a holistic manner and Land Use, Land Use Change and Forestry (LULUCF) should be addressed within the Union's climate policy. EU Regulation 841/2018 amended EU Regulation No 525/2013 and the above-mentioned Decision and addresses the inclusion of GHG emissions and removals from LULUCF sector in the EU 2030 climate and energy framework (EU Commission, 2013). According to this regulation Member States should submit national forestry accounting plans to the Commission, including forest reference levels.

Forests, which are the main component of the so-called ''land sinks'', play a vital role in the global carbon cycle through the absorption of 2.9 ± 0.8 Pg of carbon (C) per year (in the period 2004–2013), thus mitigating climate change related to the increase of anthropogenic carbon dioxide (CO_2) in the atmosphere (Le Quéré et al., 2015). Over the period 1991–2015, planted forests – representing 7% of the total forest area, accounted for a global average carbon sink that was comparable to the sink of natural forests (-1.08 vs. -1.44 Gt CO2 yr-1), driven by continuous increases in total area (Federici et al., 2015). In Turkey, planted forests have increased by more than 50% after 2010 due to the implementation of the Afforestation and Erosion Control Mobilization Action Plan (2008–2012) and due to the Combating Erosion Action Plan (2013–2017) (FAO, 2014).

The total carbon stock in Turkey's forests was calculated as 2,251.26 Tg C in 2004. The carbon stock in the living biomass was calculated as 479.87 Tg C. The 92.20% of carbon stock in the living biomass was attributed to productive forests, while the remaining 7.80% to degraded forests (Tolunay, 2011). Using the gain-loss method, Turkey's forests have approximately absorbed 13.68 Tg C year-1 from the atmosphere in 2004. The majority of that amount, 12.63 Tg C year-1, belonged to the productive forests, while the remaining 1.05 Tg C year-1 portion belonged to the degraded forests (Tolunay, 2011).

Even though the current management method is based on sustainability principles, it remains oriented towards wood production. This is a significant improvement in relation to the previous management practices, which is documented by the 48% increase in forest carbon stock in Northern Turkey between 1973 and 2006 (Misir, 2013). The estimation of carbon stock only includes live above-ground tree biomass. Carbon sequestration in standing dead trees, lying dead wood, shrubs and litter has not been included in the overall carbon stock of the forests (Vlachaki et al., 2017b).

In order for measures targeted at increasing carbon sequestration to be effective, the long-term stability and adaptability of carbon pools is essential. Sustainable management practices maintain the productivity, regeneration capacity and vitality of the LULUCF sector. This is important in promoting economic and social development, while reducing the carbon and ecological footprint of that sector (EU Commission 2018). The European accounting rules specify that the mere existence of large terrestrial carbon pools in forest ecosystems represents no advantage for countries. Only changes in the terrestrial carbon pool are relevant for the mitigation of climate change. Countries are required to maintain their forest cover and the increase in the carbon pool by specific forms of forest management (Jandl et al., 2007).

The objective of the present paper is to outline a method for the assessment of the CO_2 removal/sequestration balance and to compare scenarios based on the good forest management practices taken for climate change mitigation.

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2. METHODS

Field sampling was carried out during April – June 2018 in the planted beech (*Fagus orientalis*) forests of the Trabzon region in Turkey. Field measurements were applied to establish the carbon stock baseline, which refers to the amount of carbon currently stored in the project area (Misir et al., 2018). The research focused on the aboveground live tree volume, which included tree stem, tree branches and foliage, as well as herbaceous vegetation, shrubs and litter.

The planted beech forests were stratified into 10-year age classes (4 age classes overall) and 3 types of site quality (good, medium, poor). In order to efficiently estimate the carbon stock, random stratified sampling was applied to minimize the variation within each stratum and provide a more precise estimation. As equal sample plots as possible was allocated to all four age class, in sites of good and medium quality.

The selection of the size and shape of the plots was based on capturing the variation of the stand at each sampling. The plot size varied between 100 to 600 m^2 depending on the age class and site quality (smaller area for trees of smaller dimensions). Each plot included at least 30 trees (Misir et al., 2018). This exceeds the rule of thumb with 10–20 trees in a plot as usually applied in order to obtain a representative sample (ForestWorks ISC, 2014).

A design of nested quadrats of different sizes was implemented in order to measure vegetation of different sizes and strata, as well as to collect litter for estimation of carbon stock. The 1m x 1m quadrat was used for small shrubs biomass (< 2cm *DBH*), herbaceous species and litter.

The recorded field data included:

i. general stand information (slope, aspect, elevation, location, etc.)
ii. stand characteristics (main wood species, canopy closure, stand structure, etc.)
iii. tree information (species, total height, breast height, diameter, state – either live or dead)
iv. understorey information (lying dead wood & shrubs)

During the field measurements, biomass samples were also collected from different parts of the trees as well as herbaceous vegetation, shrubs and litter.

3. RESULTS AND DISCUSSION

The results obtained field sampling was given Table 1.

Table 1. Summaries of Stand Characteristics of Planted Beech Stands

Stand characteristic	Min	Max	Mean	Standard deviation
Mean diameter (cm)	0.80	22.7	10.9	5.21
Basal area (m^2/ha)	0.1	53	28.5	14.4
N (number of trees)	800	9600	2967	2086.2

The sampling results provide how carbon storage is allocated among various forest stand carbon pools (Table 2). Tree stem biomass and litter account for more than 70% of the carbon storage. However, the accumulation of large amounts of litter in forest stands inhibits soil enrichment with nutrients and reduces soil carbon storage.

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Table 2. Some Carbon Pools of Planted Beech Stands of Trabzon Region

Carbon pool	Min	Max	Mean	Standard deviation
Herbaceous (kg/ha)	0	6525	1550.1	1726.30
Shrubs (kg/ha)	0	2610	205.8	528.53
Litter(kg/ha)	2000	302800	10575.5	6743.31
Lying dead wood (kg/ha)	0	6990	2060.2	1816.24

The analysis of the field data revealed that canopy closure affects the balance between tree stem and litter carbon pools within the plots. Higher canopy closure was found to be inversely proportional to the carbon storage in tree stems. However, the most important carbon pool was the tree stem, as expected, followed by the lying deadwood, shrubs and tree foliage.

The results of the field measurements had provided the carbon storage baseline in the Trabzon area (Misir et al., 2018). The next step was to investigate the impact of different forest management scenarios on carbon storage, according to the best practices regarding forest management in response to climate change (Vlachaki et al., 2017a). According to EU regulation 2018/841, it is essential to ensure the long-term stability and adaptability of carbon pools in order for forest management measures aiming at increasing carbon sequestration to be effective. The development of the scenarios examined through this Action has been based on this principle. Moreover, the scenarios are in line with forest management policies and measures taken for Climate change mitigation in the EU regarding planted forests.

In order to increase the amount and time of carbon storage specific management practices need to be applied. A brief summary of these practices is presented below to investigate ways that they can potentially be incorporated in the forest management currently applied in the project area. The objective of the management is not only to increase carbon storage but also to improve stand stability and adaptation potential to climate change.

A wide range of forest management practices to improve carbon sequestration are available in the literature, however the following practices are further outlined because stand density, rotation age and species mixture are considered the most important for both Turkey and Greece.

The density of forest stands during their life cycle needs to be actively modified by forest managers in order to improve stand conditions, reduce competition-induced tree mortality and to avoid natural disturbances such as storm damage and insects' infestation. Stand thinning has a long history in practical forest management. However, in the context of carbon sequestration, thinning removes amounts of carbon sequestered in biomass and dead organic matter for the sake of sustainability, improved stand stability and longevity.

The amount of carbon stored in a forest stand depends on its age and productivity. Uneven-aged management creates overall more complex stand structure and maintains a steady flow of yields and aboveground carbon stocks through time (Sharma et al., 2016). Selection cuttings maintain late-successional forest characteristics and species assemblages better than even-aged stands (Kuuluvainen et al., 2012). Both even- and uneven-aged management options have the potential to improve production and carbon storage and are a substantial improvement over no action (Sharma et al., 2016).

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Thinned stands contain fewer trees with larger diameters and therefore higher value and potential to provide long-lived wood products. Thinning not only removes biomass but also stimulates microbial soil processes by exposing the forest floor to solar radiation and precipitation. Therefore, stands that have undergone thinning never hold the maximum amount of carbon (Vesterdal et al, 1995; Skovsgaard et al., 2006), but are less vulnerable to disturbances and thus create more stable carbon pools than unmanaged forests (Jandl et al., 2007).

The results of the scenarios analysis are in agreement with the international literature reviewed for the current deliverable on forest management practices and measures to improve carbon sequestration. In particular, management scenarios of this project suggest that biomass and stocked carbon amount increase through forestry management practices that involve adapted stand management which includes thinnings and selection cuttings to improve stand structure.

Biomass and carbon sequestration increase with stand age. Therefore postponing harvesting to the age of biological maturity may seem as the only logical step to forming a large carbon sink. Carbon stocks can be maintained and increased through the use of extended rotation periods. This recommendation is supported by widely documented positive relationships between aboveground carbon stores and stand age (D’ Amato *et al.,* 2011; Yavuz *et al.*, 2010).

Very high carbon stocks have been recorded in mature forest ecosystems, where the sum of carbon in the biomass and the soil peaks (Knohl *et al.,* 2003; Harmon *et al.,* 1990). The net carbon balance in forests between 15 and 80 years of age (including the soil), is usually positive and old-growth forests seem to continue to accumulate carbon (Luyssaert *et al.*, 2008).

Old forests have a high carbon density whereas young stands have a large carbon sink capacity. Young forests have high carbon sequestration rates which decline as they age. Mature forests eventually reach equilibrium in which no or little further sequestration takes place, leading to limited mitigation potential and carbon storage capacity in time (SFC, 2010). Moreover, the resilience of forests to climate change impacts is often decreased with increasing stand age and basal area (Seidl *et al.*, 2017).

Short rotation lengths maximize aboveground carbon sequestration, but not carbon storage in the forest or in the wood products. On the other hand, mature forests represent a large, but saturated carbon pool that has little potential for future additional carbon sequestration.

Apart from ecological considerations, the question remains whether forests fulfil their climate change mitigation potential best by storing a large quantity of carbon (either in situ or as long-lived wood products) or by providing short-lived wood products that substitute goods produced from non-renewable resources.

Adapted management of existing forests may have a less obvious or slower effect on the terrestrial carbon pool. After analyzing the effects of harvesting, rotation length, thinning, fertilizer application and tree-species selection it has been concluded that these have an impact on the forest productivity and consequently on carbon sequestration in the ecosystem. Many forest treatments are already an integral part of sustainable forestry practice. In the context of carbon sequestration and its accounting in national greenhouse-gas budgets, ecosystem stability is highly rated. Forests that are robust against disturbances up to a certain degree of severity are better suited for national carbon pools than stands of maximum productivity with a high risk of damages (Jandl et al., 2007).

Different analyses of national or local forest systems reveal that cessation of forest management in productive forests would yield much lower mitigation effects than those provided by the substitution effect of the currently harvested wood (SFC, 2010).

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By reducing the number of thinnings in the forest, GHG emissions decrease and disturbances due to forest works are also less frequent. Moreover, wood products of larger dimensions keep carbon stored for longer periods of time compared to firewood or paper. These benefits come along with the price of reduced financial revenues for prolonged periods of time which range from 15 to 30 years, based on the proposed scenarios. However, it is necessary to monitor and record carbon net balance from stand level, to forest level up to national level annually in order to provide up to date information at all times (Vlachaki et al., 2018).

4. CONCLUSIONS

The rate of build-up of CO_2 in the atmosphere can be reduced by taking advantage of the fact that atmospheric CO_2 can accumulate as carbon in vegetation and soils in terrestrial ecosystems (UNFCCC, 2015). However, due to the dynamic nature of carbon sinks, assessing their current state offers only limited insight into their role. Carbon balance needs to be monitored and assessed consistently in order to provide substantial results.

The European Union Directives concerning climate change set monitoring and reporting requirements for each Member State. The first step to that end is creating a forest stand inventory in order to establish a carbon stock baseline. This was achieved through the present work for the beech forests of the Trabzon area. However, in order to comply with EU regulations, further action is required. Monitoring the forest management activities and their impact on CO_2, as well as any disturbances in the forest or land-use change, are key elements for reporting on both CO_2 emissions and removals. The current research has set the grounds for incorporating these aspects in forest management practices in line with the reporting rules of the EU, and has outlined additional aspects that need to be taken into account in order to sustainably manage forests in view of climate change.

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