SETSCI Conference Indexing System, Volume 3 (2018), 268-272

ISAS 2018-Winter
2nd International Symposium on Innovative Approaches in Scientific Studies
November 30 – December 2, 2018, Samsun, Turkey

Best Practices and Policies Regarding Forestry in Response to Climate Change

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Presentation/Paper Type: Oral / Full paper

Abstract – Forest functions traditionally included wood production, protection and forest recreation. The twofold role of forests as both sources and sinks of greenhouse gases makes their influence on the climate extremely significant. This fact has led to climate change adaptation and mitigation being set as a current priority in forestry. European Union as well as whole world focuses on the mitigation of climate change impact through increasing the size of the carbon pool in forests, which is a worldwide recommended mitigation measure. Maintaining the carbon stock and enhancing carbon sequestration of forests in Europe contributes to the implementation of the United Nations Framework Convention on Climate Change and the Kyoto Protocol. Mitigation is achieved either through the creation of new forest areas or through sustainable forestry. Both approaches provide carbon sequestration and storage in forest biomass and soils. Therefore, carbon stock needs to be incorporated in sustainable forestry by supporting research and analysis on these topics. Sustainable forestry contributes to climate change mitigation by preserving and expanding carbon stocks in the natural and planted forests. In view of this fact, the paper aims to investigate alternative forestry practices in planted in order to identify the most efficient in terms of carbon sequestration and storage in forests.

Keywords – Carbon stock, sequestration, planted, forestry practices and policy

I. INTRODUCTION

Carbon storage and fluxes in forests have been focused because of the role of CO2 in global climate change. Planted forests have a large potential to sequester carbon primarily through reforestation, agroforestry and conservation of existing forests and the high productivity of planted forests may make them particularly responsive to growth enhancement from increasing atmospheric CO2 concentrations.

Over the period 1991–2015, planted forest, representing 7% of the total forest area, accounted for a global average carbon sink that was comparable to the sink of natural forest, driven by continuous increases in total area [1]. In Turkey, planted forests 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) [2].

Towards the same direction, the Intended Nationally Determined Contribution (INDC) of the Republic of Turkey for the period 2021-2030, which aims to achieve the ultimate objective of the UN Framework Convention on Climate Change, proposes, amongst others, specific actions for increasing forest sink areas and a National Afforestation Campaign. The contribution of those actions is mainly achieved by new forest plantations.

Sustainable forest management contributes to climate change mitigation by preserving and expanding carbon stocks in the forests (including above- and below-ground biomass and soil) [3]. In view of this fact, the paper aims to investigate alternative management practices in order to identify the most efficient in terms of carbon sequestration and storage in planted forests. Planted forests represent approximately 30% of the forests in Turkey, covering 3 386 000 hectares according to FAO [4].

Recently European Union strengthened its climate change strategy by increasing the 20-20-20 targets to 40-27-27 till the year 2030. The corresponding roadmap for a low carbon economy towards 2050 regards the development of Renewable Energy Sources (RES) and the storage of CO2 as key elements for reducing GHG emission by 80% compared to 1990 levels. The forest sector is a net primary source of Renewable Energy Sources and also the greater carbon pool after the oceans. Therefore, appropriate adaptation of forest management is expected to play a strategic and twofold role in the new low carbon economy: on one hand by contributing to the targets of 2050 as Renewable Energy Sources provider and on the other hand as a major carbon pool. Forest conservation (or prevention of deforestation) has been officially recognized in COP16 (2010) as one of the most important options to the post-Kyoto climate policies for combating climate change though stabilizing Greenhouse Gas (GHG) emissions [5].

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. Therefore, Member States have to prepare and maintain accounts that accurately reflect all emissions and removals resulting from forest management. Carbon stock changes need to be estimated in an unbiased, transparent, and consistent manner to allow for uncertainties to be determined and reduced over time, as prescribed in the IPCC Good Practice Guidance for LULUCF activities [6], [7]. According to Federici et al. [1], enhanced country data to cover carbon stock gains and carbon stock losses separately, and disaggregated by forest type (primary forest, other naturally regenerated forest, and planted forest) would significantly improve the 2020 Forest Resources Assessment (FRA) made available by the Food and Agriculture Organization of the United Nations.

The incorporation of adaptation and mitigation aspects of climate change in sustainable forest management is necessary in order to fully utilize its potential. However, a broad range of policy measures is still required to support this task (e.g. incentives for afforestation and reforestation, taxation, public procurement rules to promote the use of wood, national and regional legislation to enhance the use of timber in the construction sector, proper technical and biological forest education) [3].

The development of forest management strategies for addressing climate change has become an increasingly important issue around the globe. Currently, management approaches are being proposed that intend to mitigate climate change by enhancing forest carbon stores [8]. While sustainable management, planting and rehabilitation of forests are efficient ways to conserve or even increase forest carbon stocks, it should be noted that deforestation, degradation and poor forest management do reduce carbon stocks [9].

In this scope, mitigation activities include conserving forests with large stocks of biomass from deforestation and degradation, avoiding significant carbon emissions to the atmosphere and sustainably managing forests in order to restore their carbon sequestration potential [10].

Incorporating carbon sequestration and storage in forest management raises a lot of questions regarding age, rotation period, stand structure and mixture, as well as management practices. 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 [3].

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 [8], [11]. 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 [12]. However, 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 [3]. Moreover, the resilience of forests to climate change impacts is often decreased with increasing stand age and basal area [13].

The critical question to consider is when should the carbon stock of the living biomass, the forest floor carbon and the soil carbon be replaced. Carbon pools and fluxes are strongly determined by the applied rotation lengths, the thinning intensity, and the resulting age–class distribution of the forests. While short rotation length increases the carbon sequestration rate, it accounts for lower average carbon stock in the biomass and other conflicts e.g. regarding nature conservation [3].

Regeneration methods and thinning treatments that retain a large proportion of mature trees are more efficient in maintaining carbon stores compared to more intensive removals, even in cases when off-site storage is considered [8]. Furthermore, the soil temperature may go up in open spaces created after intensive thinnings which may lead to increased decomposition of soil organic matter. However, moderate thinning in young stands does not seem to give a net flux of CO2 to the atmosphere [3]. Therefore, multi-aged stands are proposed as an effective means to strengthen forest resilience against disturbances [13] – [15].

Uneven-aged management creates overall more complex stand structure (Stand Structural Diversity) and maintains a steady flow of yields and aboveground carbon stocks [16]. Selection cuttings maintain late-successional forest characteristics and species assemblages better than even-aged stands at least at the stand scale and in the short term [14]. Both even- and uneven-aged management options have the potential to improve production and carbon storage and are a substantial improvement over no action [16].

There are still many uncertainties regarding the impacts of climate change on forests, despite the significant body of existing research. As a result, climate change may impact forests in ways that are partly opposing and therefore can require adaptation activities that are difficult to design and to plan [17]. Carbon sequestration should only be one of the goals that drive forest management decisions in relation to climate change. Optimal achievement of multiple benefits across the landscape may require maintaining an assortment of management strategies to enhance ecosystem resilience while improving production and carbon storage [16], [17].

The aim of the paper is to assess and validate forest management practices and measures to improve the carbon removal/sequestration balance. In this paper, a number of forest management practices are outlined that are commonly used towards increasing carbon storage in the forest sector.

II. MATERIALS AND METHOD

Data were collected from sample trees and from sample plots to determine amount of carbon stored in forests. Sample plots were collected from areas of rectangular plots in plantations and circular plots in natural forests generally varied from 200 m2 and 1200 m2. Sample trees were selected every diameter classes with an effort to equal allocation. For each diameter classes, effort was made to include every height classes.

Living trees biomass and carbon storage includes amount of carbon stored in biomasses all live vegetative biomass above the soil including stem, stump, branches, bark, seeds and foliage. The biomass contained in the trees is the primary source of carbon stocks.

For each tree the diameter at breast height is measured at 1.3 m above the soil surface, except where trunk irregularities at that height occur (plank woods, tapping or other wounds) and necessitate measurement at a greater height [18].

The above-ground biomass measurement includes all trees and shrubs within each plot that are greater than 2 cm diameter at breast height (dbh), and also their branches and foliage. The living tree biomass and carbon storage capacity have been determined using the biomass and carbon storage allometric models developed by researchers for tree and tree components. In other words, whole tree biomass including stem, branches, foliage, bark and carbon storage capacity have been estimated from dbh using allometric biomass equations.

Since the diameter at breast height and total height of each tree in the sample plot are measured, they are used to fill in the corresponding places for diameter and height in the biomass and carbon storage models. Stem, branch, bark, leaves, and tree biomass and the amount of carbon stored in the tree biomass have been estimated. By correlating with the size of the sample area, stem, branch, bark, leaf, tree biomass and the amount of carbon stored in these biomass have been found in the hectare.

General information (aspect, slope, elevation) and stand characteristics have also been recorded during the samplings (structure, cover, etc.). The cover within the sample area of the shrubs or herbaceous species has also been determined. After that, it has been cut from the soil ground with motorized saws and scissors, and the leaves, shrubs and herbaceous layer has been weighed individually in the each field. Each component has then been subjected to sub-sampling and transported to laboratories for biomass measurements and carbon analysis. In addition, all of the fine woody debris and coarse woody materials have been collected and weighed from the sample plots; sub-samples have been taken and brought to the laboratory for further analysis.

The below-ground biomass have been estimated using the root to shoot ratio, which is based on the relationship between biomass in shoot and roots for a tree of a given species as well as for a given forest or plantation type or direct measurements obtained by taking root samples in sample plots.

Dead woody materials with a diameter of 1-10 cm have been categorized as fine and those larger than 10 cm have been categorized as coarse woody material and their biomass have been determined. Each sample has been pulverized by grinding in a grinding mill and three sub-samples have been taken from this powder mixture. Their carbon content has been determined with elemental analysis device. Thus, the amount of carbon stored in each sample has been found and converted into tons per hectare.

Litter is material that is too small to be considered lying dead wood, dead leaves, twigs (diameter < 2 cm), fruits/flowers, and barks is classed as litter. This includes branches, stumps, leaves and duff.

In order to determine the amount of litter on the forest floor, the litter organic matter of 25 x 25 cm size in at least 4 points which are not destroyed in sample areas and determined by random sampling has been collected up to mineral soil and transported to laboratories. Thus, for each sample plot, the amount of litter (litter biomass) in the unit area and the amount of carbon stored in the litter has been determined. Litter samples have been kept in a drying oven at 65 ± 3 ° C for 48 hours and when they reach constant weight, their dry weights have been measured (sensitivity 0.01 g). Utilizing the biomass of this sample, several transformations have been found on the hectare of litter biomass. In addition, samples are grinded in a grinding mill and analyzed by Elemental Analyzer to determine the amount of carbon stored.

Mineral soil samples were taken with a cylindrical soil sampler at two random points within each plot. There was no organic layer present a top the mineral soil. Soil samples were taken one at each 10 cm of depth to a 1 m depth in each point. Bulk density for each soil depth was determined by weighing the whole sample and drying subsamples at 65 ± 3 ° C. After determination of bulk density, soils were sieved with a 2 mm sieve, and homogenized for further chemical analysis.

III. Results

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 (CO2) in the atmosphere [19]. The total carbon stock in Turkey’s forests was calculated as 2648.5 Tg C in 2015. The carbon stock in the living biomass was calculated as 786.6 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. 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 [20].

Forest carbon storage is controlled by a number of factors. Initially, the climatic conditions in general and climate change. As Karjalainen et al. [21] have reported carbon densities in northern and southern European forests are lower than those of central European forests, due to northern Europe’s cold climate and drought in southern Europe. Furthermore, natural disturbance (e.g., fire, pests, hurricanes), human management (i.e., what to do with harvest), and policies on a national or global scale affect carbon accumulation and storage.

To determine the accumulation of carbon in forests, there is a need to adapt the carbon management approach to forest management. The principal aim of carbon management is to increase the amount of carbon accumulated in the forest ecosystems. Reduction of deforestation, forest fires, illegal cuttings, and afforesting are the main measures for increasing the carbon accumulation. In particular, the degraded forests, making up half of forests, have to be rehabilitated. The carbon stocks may also be increased by taking various silvicultural measures.

In other words, forests become substantial carbon sinks depending on how they are managed. In Turkey, carbon accumulated in the forests due to volume increment, however, is removed from the forests through the fuelwood and industrial roundwood production – as the management plans suggest. According to Tolunay [20], during 1990-2005, an average cutting amount of 7.26 million m3 /year was done for industrial roundwood production, while an average amount of 6.86 million m3 /year was done for fuelwood production. Additionally, a volume of 18.69 million m3 /year is removed from the volume increment, which reached 36.28 million m3 /year by logging in Turkey’s forest in 2004.

On the other hand, conversion of coppices to high forest, rehabilitation of degraded forests, and an increase of plantations lead to an increase in carbon sequestration.

IV. DISCUSSION

In the long run, the carbon accumulated in the growing stock will be released through respiration, death, and the decay of litter and humus, and oxidation of wood products. The delay between the accumulation and release represents the sequestration, which is a temporary stock by definition. In this respect, forests and wood products can provide only temporary carbon stocks compensating for the human induced carbon releases. These stocks can be, however, long lasting ones and they can be affected by management.

Key issue to promote forest carbon storage is the recovery of the ecological efficiency of forests, which in many cases have been overexploited for thousands of years [22]. In this perspective, forest management policies should aim at:

(1) restoring forest stands degraded by past intensive logging [23].

(2) promoting a gradual increase of forest growing stock and, possibly, the adoption of longer rotation cycles in old/healthy forests that are at low risk from pests or environmental disturbances [24];

(3) converting coppice forest into high forest stands, where technically and economically viable, thus bringing positive effects on above- and belowground biomass accumulation [25].

Forest management practices for conserving and sequestering carbon can be grouped into four major categories [26]:

1. the maintenance of existing carbon pools (slow deforestation and forest degradation)

2. the expansion of existing carbon sinks and pools through forest management

3. the creation of new carbon sinks and pools by expanding tree and forest cover

4. the substitution of fossil fuels and fossil fuel-based product with renewable wood-based fuels and products.

In line with the above, as already proposed by the Climate Action Reserve [27] carbon stock may be enhanced by the following sustainable forestry management activities:

- increasing the overall age of the forest by extending the rotation period;
- increasing the forest productivity by thinning diseased and suppressed trees,
- managing competing brush and short-lived forest species, and
- maintaining stocks at a high level [28].

Furthermore, forest management involves decision-making that may have a significant impact on the level and time of carbon sequestered either in forests or in the wood products generated from these forests [29, 30]. For example, forests with fast growing, short-rotation aged stands have a high rate of carbon uptake [31], [32].

Generally, the changes in biomass stock or annual volume increment are used in determining the change in biomass carbon stocks in forests. However, determining the forest biomass appears to be an important problem because the forest inventories are not generally designed to determine the carbon budget, but are focused mostly on determining the stem volume [33], [34].

Changes in soil properties due to different forest management and silvicultural methods also affect soil C pools and the carbon budget of the atmosphere [35], [36].

However, the time over which the carbon is stored is relatively short, especially if burned or converted into paper. Short-lived products like paper, wood chips, sawdust, and hog fuel enter the waste stream quickly and decompose fairly rapidly [37], [38].

V. CONCLUSION

The main conclusions of the study should be summarized in a short Conclusions section.

IPCC provides the following default half-life values for the most common forest products:

(a) 2 years for paper;
(b) 25 years for wood panels;
(c) 35 years for sawn wood.

The carbon stored in short-lived products returns to the atmosphere and re-enters the carbon cycle in just a few years, whereas investing in other products may secure its storage for more than 30 years.

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 all country.

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