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Project: Development of a common protocol to assess the impact of forest management practices on climate change

Common Management protocol (guidelines) to increase carbon sequestration in forests

Deliverable 3.1

IMPACT
FOREST MANAGEMENT
&
CLIMATE CHANGE

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Contents

1. Scope

The forest sector is a net primary source of Renewable Energy Sources (RES) and also the greater carbon pool after the oceans. Therefore, increasing forest cover through afforestation and reforestation is expected to play a strategic and twofold role in the new low carbon economy by contributing to the targets of 2050 as a RES provider on one hand and as a major carbon pool on the other. Moreover, decision 529/2013/EU, on accounting rules regarding Greenhouse Gas (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 2018/841 amended EU Regulation No 525/2013 and decision No 592/2013/EU, on the inclusion of greenhouse gas emissions and removals from LULUCF in the EU 2030 climate and energy framework. According to this regulation Member States should submit national forestry accounting plans to the Commission, including forest reference levels.

Forest management represents about 70% of the LULUCF sector and EU has recognized that increased sustainable use of harvested wood products can not only enhance removals of GHG from the atmosphere but also substantially limit emissions. Therefore, sustainable forest management has the potential to play an important role in the reduction of EU emissions in the atmosphere. The LULUCF sector in the EU is a net sink that can offset a significant share of the total Union's GHG emissions.

In view of this fact, the project has developed the current guidelines to support climate change resilience by adapting forest management practices in planted forests correspondingly, having as case study the management units of Vakfıkebir, Tonya and Düzköy of Trabzon, Turkey. Over the period 1991–2015, planted forests, representing 7% of the total forest area in Europe, accounted for a global average carbon sink that was comparable to the sink of natural forest (-1.08 vs. -1.44 Gt CO2 yr-1), driven by continuous increases in total area (Federici et al, 2015). Concerning Turkey, approximately 29% of the forests in the country are planted for multiple purposes: afforestation, erosion control, artificial regeneration, rehabilitation and energy forests (FAO, 2015). The planted forests increased by more than 50% in Turkey 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).

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, where their effectiveness on CO_2 (carbon) sequestration could be assessed and validated using well justified methods and protocols.

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 and are therefore important in promoting economic and social development, while reducing the carbon and ecological footprint of that sector (EU Commission 2018).

The current common guidelines (Protocol) aim at the assessment of carbon sequestration in artificially established forests through afforestation/reforestation projects. This common Protocol also assesses and validates forest management practices and measures in these types of areas, aiming to improve the carbon removal/sequestration balance by reducing the emissions of forest logging and management treatments.

2. Forest management practices and measures to improve the carbon removal/sequestration

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 (Le Quéré et al. 2014). The total carbon stock in Turkey's forests was calculated as 2251.26 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).

Forest carbon storage is controlled by a number of factors. Initially, the climatic conditions in general and climate change. As Karjalainen et al. (2003) 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 Turkey's 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 Turkey's forests, have to be rehabilitated. The carbon stocks may also be increased by taking various silvicultural measures (Tolunay, 2011).

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 (2011), during 1990-2005, an average cutting amount of 7.26 million m^3 /year was done for industrial roundwood production, while an average amount of 6.86 million m^3 /year was done for fuelwood production. Additionally, a volume of 18.69 million m^3 /year is removed from the volume increment, which reached 36.28 million m^3 /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 (Tolunay, 2011).

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.

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

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 (Chiriaco et al. 2013). In this perspective, forest management policies should aim at:

(1) restoring forest stands degraded by past intensive logging (Corona et al. 1997);

(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 (Fares et al. 2015);

(3) converting coppice forest into high forest stands, where technically and economically viable, thus bringing positive effects on above- and belowground biomass accumulation (Ciancio et al. 2006).

Forest management practices for conserving and sequestering carbon can be grouped into four major categories (Dixon *et al.*, 1994):

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 (2012), 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 (Bourque *et al.*, 2007).

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 (Matthews, 1996; Meng *et al.*, 2003). For example, forests with fast growing, short-rotation aged stands have a high rate of carbon uptake (Metting *et al.,* 2001; Ney *et al.*, 2002).

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 (Van Camp et al. 2004; Jalkanen et al. 2005).

Changes in soil properties due to different forest management and silvicultural methods also affect soil C pools and the carbon budget of the atmosphere (McPherson et al. 1993; Bayramzadeh, 2014).

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 (Hoen and Solberg, 1994; Bhatti *et al.*, 2003).

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.

✓ Adapted Stand Management

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).

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).

✓ Extending the Rotation Period

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.

- ✓ Increasing species mixture

Tree species composition, which can be altered by silvicultural methods, affects soil carbon storage by direct and indirect effects on the quality and quantity of litter fall, throughfall and stemflow, soil properties, rooting patterns, soil respiration and consequently the nutrient availability in forest stands (Berger et al. 2002; Bayramzadeh, 2014).

Favoring species mixture is a management practice that needs to be considered towards increasing carbon stocks in a forest. The effects of mixed stands on growth and forest production may vary from no effect to productivity increase up to 50 % when species make different use of available resources, either in space or in time. Mixed stands are more resilient to disturbances and are therefore a favorable practice for adaptation (SFC, 2010).

The choice of tree species is relevant for the terrestrial carbon pool for the following reasons:

- ✓ different growth patterns over time
- ✓ specific achievable stand density;
- ✓ different rooting depths and rooting patterns;
- ✓ different effect on soil carbon pool;
- ✓ specific wood densities;
- ✓ different life spans;
- ✓ different vulnerability to disturbance

Forest stands with mixed species are often seen as a remedy for the establishment of stable forests. The benefits of single tree species can be utilized and the production risk of the entire forest can be minimized. Mixed species are superior to single species stands when the individual species exploit different resources at the same site but can also lead to a competition that reduces the overall productivity of a stand (Pretzsch, 2005; Resh et al, 2002).

According to Jandl *et al*. (2007), in a comparison between beech and spruce, spruce is more productive than beech in terms of stem volume production. When the higher density of beech wood is taken into account, the difference is almost compensated. This particular species comparison is especially important, because spruce is a dominant tree species in central Europe but is believed to have negative effects on the site quality because of the slow decomposition rate of spruce litter and the species' shallow rooting depth. For carbon sequestration, both the volume productivity and the weight of the produced wood needs to be taken into account. For example, broad-leaved trees usually have a higher wood density than coniferous trees (Binkley and Menyailo, 2005).

According to the rules of the Kyoto Protocol and of the UN Framework Convention on Climate Change, forestry can generate a sink for GHG that can contribute to meeting the commitments to emissions reductions (Jandl et al., 2007). Managing mountain forests is also very important for society generally and especially for communities in densely populated mountain regions (Frehner et al., 2007).

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).

3. Analysis results of management scenarios

The current forest management practice in the project area includes frequent thinnings in the oriental beech forests, every 5 – 7 years until the rotation age of 40. The impact of this practice on carbon storage was compared to exploitation scenarios developed and assessed in Deliverable D3.2 *(Report on the scenarios analysis to assess the impact of different forest management practices on climate change).* Currently, the beech forests in the Trabzon area provide short-lived wood products and low carbon pools. The mean DBH rarely exceeds 20 cm, as shown by the sampling results of Work Package 2.

In order to assess the carbon storage potential of the beech forests of the project area, four scenarios were developed and investigated:

Scenario 1. Current management practice

Table 1. Thinning plan of Scenario 1

Stand Age	Thinning intensity per Site class		
	Good	Medium	Poor
15 yrs	20%	15%	10%
22 yrs	30%	25%	20%
27 yrs	40%	30%	25%
30 yrs	40%	30%	25%
35 yrs	45%	35%	27%
40 yrs	45%	35%	30%

Scenario 2. Less frequent thinnings

Table 2. Thinning plan of Scenario 2

Stand Age	Thinning intensity per Site class		
	Good	Medium	Poor
15 yrs	20%	15%	10%
30 yrs	40%	30%	25%
40 yrs	45%	35%	30%

Scenario 3. Less intensive thinnings

Table 3. Thinning plan of Scenario 3

Stand Age	Thinning intensity per Site class		
	Good	Medium	Poor
15 yrs	15%	10%	5%
22 yrs	25%	20%	10%
27 yrs	30%	25%	10%
30 yrs	30%	25%	10%
35 yrs	35%	27%	10%
40 yrs	35%	30%	10%

Scenario 4: Increase of the rotation age, less intense and frequent thinnings

Table 4. Thinning plan of Scenario 4

Stand Age	Thinning intensity per Site class		
	Good	Medium	Poor
15 yrs	15%	10%	5%
30 yrs	30%	25%	10%
60 yrs	35%	30%	10%

Carbon storage under different management practices was calculated through these scenarios, testing their efficiency as proposed adaptations to the current management practice.

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 extending rotation periods and adapted stand management which includes thinnings and selection cuttings to improve stand structure (Figure 1).

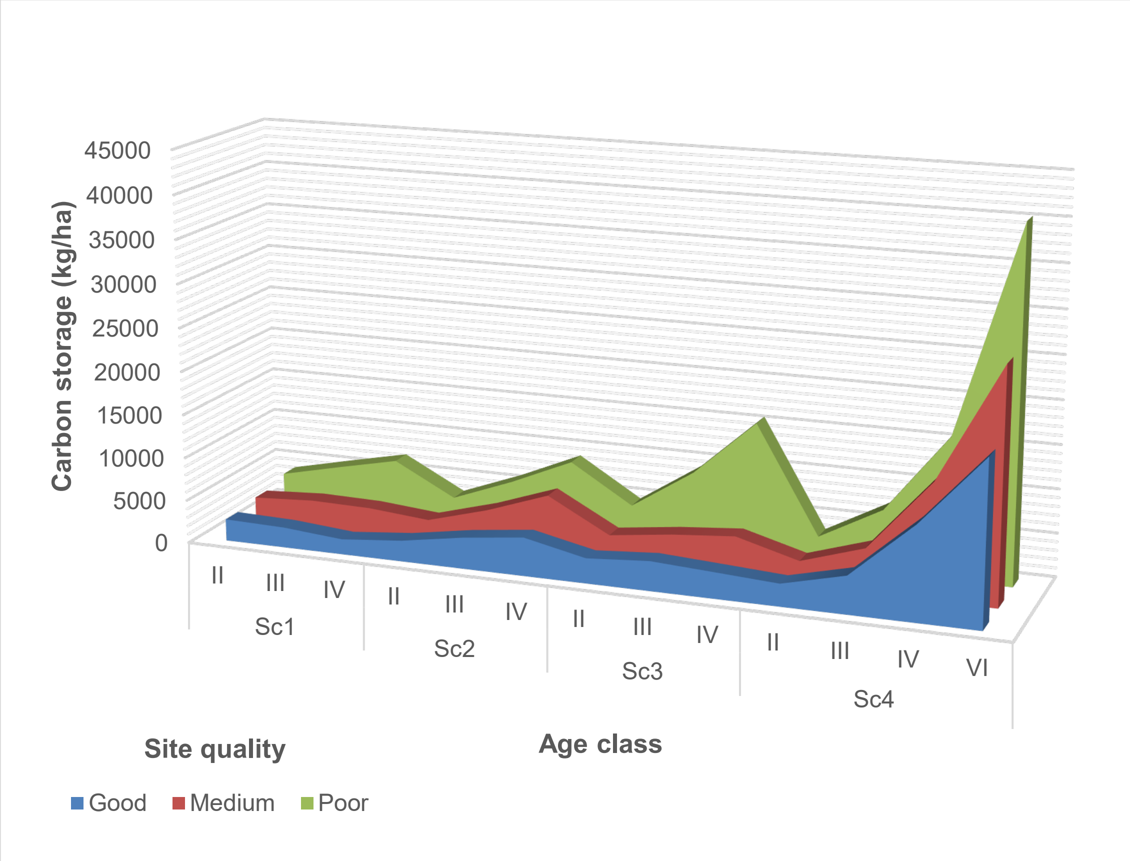

Figure 1. Carbon storage in tree stem biomass per age class, site quality category and management scenario

Stands of poor site quality have shown potential to act as the most important carbon sinks of the forests of the project area. Field measurements (D2.1) and scenarios analysis (D3.2) both point at the same conclusion. Carbon storage is consistently increasing in poor sites under all management practices examined. The small growth rates in these sites induce low efficiency in wood production but high carbon storage values, indicating that these stands may be utilized as carbon pools. This process may also gradually improve the site conditions and productivity of the stands.

Regardless of site quality, the scenarios' analysis (figure 1) has shown that less frequent thinnings (Scenario 2) lead to less carbon storage in young stands (age class II[1]), by 10% to 30% compared to the current practice. However, as the stand grows the benefits of extending the time interval between thinnings are evident in age classes III & IV, when carbon storage increases by 35 – 55%. On the other hand, less intense

[1] Ten-year age classes (II:10-20, III: 20-30, IV: 30-40; VI: 50-60)

thinnings (Scenario 3), compared to the currently applied practice (Scenario 1), generally increase carbon storage by approximately 10% in age class II to over 35% in age class IV. The combination of extending the rotation period and decreasing the intensity of the thinnings (Scenario 4) is by far the optional practice to increase carbon storage in the project area.

4. Carbon Stock Quantification and Monitoring Guidelines

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 be accumulated as carbon into vegetation and soils in terrestrial ecosystems (UNFCCC, 2015). The overall CO_2 sequestered or released through forest management can be calculated taking into account that 1 tonne of stored carbon corresponds to the removal of 3.67 tonnes carbon dioxide (t CO_2) from the atmosphere.

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 logical framework required for this process is outlined in Figure 2.

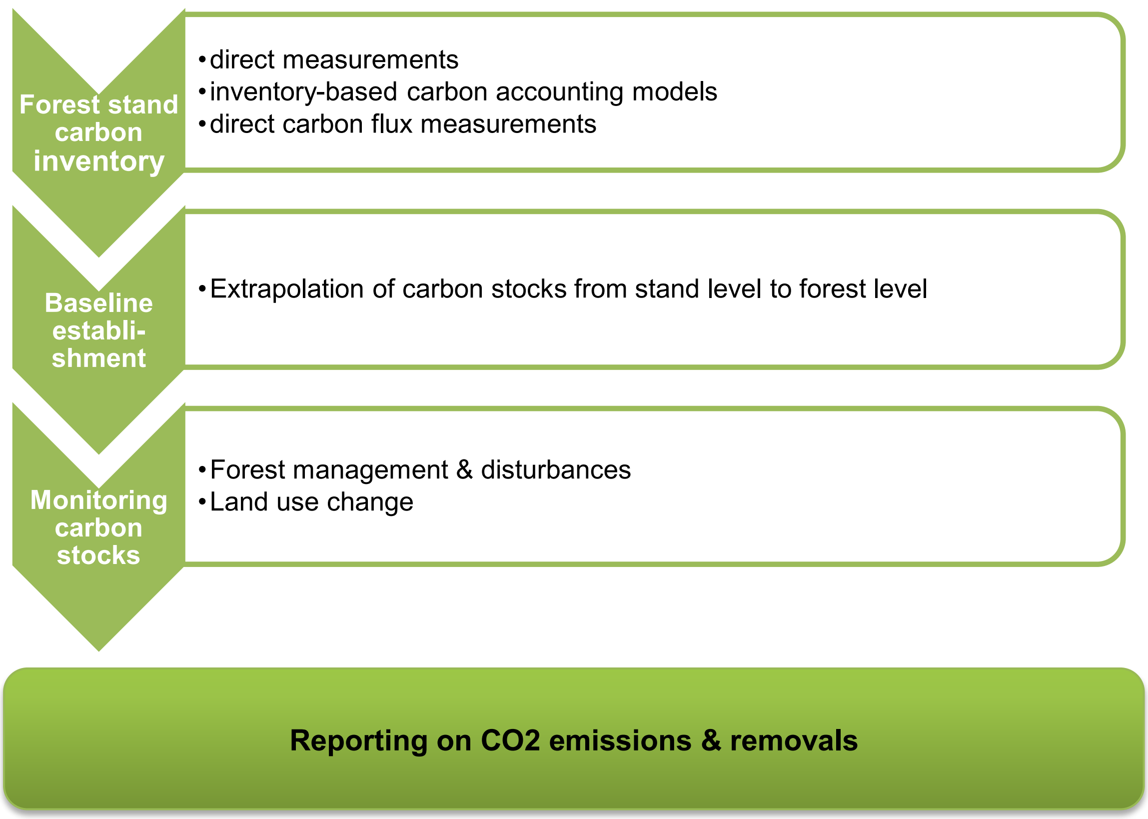

Figure 2. Logical framework for carbon stock assessment, monitoring and reporting

Each of the steps presented in Figure 2 is described below, based on literature review and the results of the current Action for the Trabzon area.

a. Forest stand inventory

The purpose of the stand inventory is to obtain knowledge about carbon Sources Sinks or Reservoirs (SSRs) in planted forests in order to set a baseline and monitor any changes. The scope of the sampling plan for the inventory includes the following activities:

- Identification of SSRs to be measured/assessed
- Planning for SSRs measurement/assessment (carbon stock sampling, GHG sources measurement, etc.)
- Measurement/assessment of SSRs
- Data analysis and interpretation
- Development/use of growth models to predict biomass and carbon stocks

The main 'carbon pools' identified during the Action included:

- Aboveground biomass, which can be divided into tree and non-tree pools (e.g. herbaceous understorey, shrubs etc.)
- Dead wood (including debris such as fallen branches and logging residues)
- Litter (i.e. fallen leaves)

According to UK Forest Research (2018) carbon levels in forestry are accounted for either through:

- periodic, direct measurements of carbon in forestry stock
- inventory-based carbon accounting models
- direct carbon flux measurements

During the current Action the second pathway has been followed, by implementing a field sampling to derive the baseline situation of the forest stands. The field sampling carried out recorded the stand characteristics (structure, composition, etc.) and also overstorey and understorey characteristics (species, cover, DBH, height, etc.). More information regarding the field sampling plan is available in Annex I (D1.2 Sampling plan and field inventory sheet).

b. Carbon stock baseline establishment

According to EU Regulation 2018/841, removals from managed forest land should be accounted against a forward-looking forest reference level. The projected future removals by carbon pools should be based on an extrapolation of forest management practices and their intensity compared to the baseline.

The forest reference level should be set with regard to dynamic age-related forest characteristics, using the best available data. In order to establish the carbon stock baseline allometric equations are required to convert the data from the forest stand inventory to carbon inventory. During the Action, samples were collected from all the carbon pools in the forests to estimate the amount of carbon in each one, through laboratory analysis performed by KTU.

The field data and analysis results were then used to develop the following allometric equations for the calculation of biomass and carbon storage in tree stems, branches and foliage for oriental beech in the project area:

$$Stem\ Biomass\ (Kg, inside\ bark){=}0.927{-}0.611{\times}d{+}0.289{\times}d^2, R^2 = 0.977, S_{y.x} = 6.2\ kg$$

$$Branch\ Biomas\ (Kg) = 0.05036 \times 1.43373^d, R^2 = 0.82, S_{y.x} = 1.02\ kg$$

$$Leaf\ Biomass\ (kg) = 0.01627 \times 1.31125^d, R^2 = 0.925,\ S_{y.x} = 0.5\ kg$$

$$Stem\ Carbon\ (kg) = 0.06373 - 0.13234 \times d + 0.22919 \times d^2, R^2 = 0.976, S_{y.x} = 2.7 kg$$

$$Branch\ carbon\ (kg) = 0.02378 \times 0.14339^d, R^2 = 0.82, S_{y.x} = 1.0\ kg$$

$$Leaf\ carbon\ (kg) = 0.00742 \times 1.3123^d, R^2 = 0.927, S_{y.x} = 1.5\ kg$$

NOTE: All models are statistically significant with $P < 0.001$.

Moreover, carbon storage was estimated also for the shrub and herbaceous understoreys, dead wood and litter. More information regarding the sampling results is available in Annex II (D2.1 Field sampling).

c. Forest management & Disturbance monitoring

Forest management and natural disturbances, such as forest fires and severe insect outbreaks influence the carbon stocks in forest ecosystems (NRCAN, 2016). Forests sequester carbon by capturing carbon dioxide from the atmosphere and transforming it into biomass through photosynthesis. Sequestered carbon is then accumulated in the form of biomass, deadwood, litter and in forest soils (UNECE, 2006).

Forest ecosystems release carbon through natural processes (respiration and oxidation) as well as a deliberate or unintended result of human activities (i.e. harvesting, fires, deforestation). A decrease in a pool relative to the reference level should be accounted for as emissions. Specific national circumstances and practices, such as lower harvest intensity than usual or ageing forests during the reference period, should also be taken into account (European Commission, 2018).

Monitoring forest management is necessary to acquire data on carbon removals through carbon storage and also on carbon emissions through management practices (thinnings). In cases of natural disturbances carbon emissions should also be quantified based on the area affected and the amount of carbon stored. The contribution of forests to carbon cycles has to be evaluated taking also into account the use of harvested wood, e.g. wood products storing carbon for a certain period of time, or energy generation releasing carbon in the atmosphere (UNECE, 2006).

Therefore, monitoring is required to 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.

d. Tracking land-use change

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). A review of the forest cover of the project area must be conducted on an annual basis to determine changes in forest cover.

To facilitate data collection and methodology improvement, land use should be inventoried and reported using geographical tracking of each land area, corresponding to national data collection systems. The best use should be made of existing land use change tracking programmes and surveys. Data management, including sharing of data for reporting, reuse and dissemination, should conform to the requirements provided for in Directive 2007/2/EC (European Commission, 2018).

e. Reporting on CO2 emissions & removals

Reporting on emissions and removals should be done for each calendar year (IPCC, 2006). Therefore, the monitoring results of forest management and disturbance monitoring, as well as land-use change data described above should refer to this time period.

In cases where the net balance of carbon emissions by forests is negative, i.e. carbon sequestration prevails, forests contribute to mitigating carbon emissions by acting as both a carbon reservoir and a tool to sequester additional carbon. In cases when the net balance of carbon emissions is positive, forests contribute to enhancing greenhouse effect and climate change (UNECE, 2006).

5. Abbreviations and Acronyms

DBH	Diameter at breast height (1.3m)
FAO	Food and Agriculture Organization of the United Nations
GHG	Greenhouse gases
INDC	Nationally Determined Contribution of the Republic of Turkey
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land Use, Land Use Change of Forestry
NRCAN	National Resources Canada
RES	Renewable Energy Sources
SSR	Sources Sinks or Reservoirs
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change

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Project: Development of a common protocol to assess the impact of forest management practices on climate change

Sampling Plan

Deliverable 1.2

IMPACT
FOREST MANAGEMENT
&
CLIMATE CHANGE

KARADENİZ TEKNİK ÜNİVERSİTESİ 1955

ΔΗΜΟΚΡΙΤΕΙΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΘΡΑΚΗΣ

15 December 2017

Contents

1. Scope

The aim of the Action is to establish reference levels and monitor inter-annual fluctuation of net carbon storage (or loss), focusing on CO_2 (no other GHG) in forests. The Action involves the development of common guidelines (Protocol) for the assessment of carbon storage in planted forests through afforestation/reforestation projects. This common protocol will also assess and validate forest management practices and applied measures in these types of areas, aiming to improve the CO_2 removal/sequestration balance through management treatments.

The Action incorporates the identification and measurement/assessment of carbon Sources Sinks or Reservoirs (SSR), as defined bellow by IPCC (2001):

Source: *Any process, activity, or mechanism that releases a GHG*[1]*, an aerosol, or a precursor of a greenhouse gas or aerosol into the atmosphere*

Sink: *Any process, activity or mechanism that removes a GHG, an aerosol, or a precursor of a greenhouse gas or aerosol from the atmosphere*

Reservoir: *A component of the climate system, other than the atmosphere, which has the capacity to store, accumulate, or release a substance of concern (e.g., carbon, a GHG, or a precursor).*

The main 'carbon pools' or reservoirs which can be included in a forest carbon sampling program are five, according to the Intergovernmental Panel on Climate Change (IPCC, 2006):

1. Aboveground biomass, which can be divided into tree and non-tree pools (e.g. shrubs etc)
2. Belowground biomass (live tree roots)
3. Dead wood (including debris such as fallen branches and logging residues)
4. Litter (i.e. fallen leaves)
5. Soil organic matter

The scope of the sampling plan includes the following activities:

- Identification of SSRs to be measured/assessed
- Planning for SSRs measurement/assessment (carbon stock sampling, GHG sources measurement, etc.)
- Measurement/assessment of SSRs
- Data analysis and interpretation
- Development/use of growth models to predict biomass and carbon stocks

The purpose of the inventory is to obtain knowledge about carbon stocks stored in planted forests in order to set a baseline and monitor their changes. The Action will provide insight into the impact of different management practices on the carbon stock of planted forests.

[1] In this case CO_2

2. Identification of SSRs

Carbon Sources, Sinks and Reservoirs are related or affected by the forest management practices applied. Therefore, it is necessary to identify them beforehand and set a baseline in order to assess future changes due to the implementation of different management scenarios.

Only the 'key categories' should be included within the project in order to make the most efficient use of available resources. 'Key categories' refer to the carbon SSRs that have the greatest contribution to the carbon stock and GHG emissions. The SSRs that are related to the Action have been identified and are described in Table 1. Depending on their contribution as either a source or a reservoir they have been included or excluded from the sampling and analysis process.

Greenhouse gas emissions are linked to the use of fossil fuels in industry (2/3) and 1/3 is due to land use change and agricultural activities. Therefore, the emissions from forest management (establishment, treatment, harvesting) are not considered significant and are excluded. The carbon pools that will be included in the Action are aboveground and belowground biomass, dead wood and litter, in accordance with the accounting rules for all afforestation and reforestation project activities under the Clean Development Mechanism (UNFCCC, 2015). The first two pools are mandatory (above- and below-ground biomass), whereas deadwood and litter are optional.

Table 1. Carbon Sources, Sinks and Reservoirs in planted forests (adapted from Tree Canada, 2015)

Stage	Identified SSR	Description	Include/ Exclude	Justification for Exclusion
Production of planting material/ Establishment of plantation	1a. Fossil fuel combustion – seedling production, labour and materials transport	Fossil fuel used (for heat or electricity production) in seedling production and for transport of planting stock, labour and equipment to project site for the establishment of planted forests	Exclude	The emissions from fossil fuel that is combusted to heat the greenhouses where the seedlings are produced is not considered significant.
	2. Fertilizer use	Non-CO_2 GHG emissions (CH_3 and N_2O)	Exclude	The emissions from fertilizer used to produce the tree seedlings is not considered to be significant.
	1b. Fossil fuel combustion — labour and materials transport	In vehicles and equipment used for site preparation and plantation establishment	Exclude	The emission from fossil fuel that is combusted to transport labour and materials to the project site is not considered significant.

Stage	Identified SSR	Description	Include/ Exclude	Justification for Exclusion
Onsite forest SSR	**3. Above-ground C reservoir**	Biomass in live trees, including branches and foliage	**Include: live trees and shrubs**	Live tree, above-ground biomass must be considered in the baseline, as well as the project. Live aboveground shrub biomass must also be included where the shrubs have a diameter of at least 2 cm at a stem height of 10 cm. The amount of live herbaceous biomass will also be measured.
	4. Below-ground C reservoir	Live tree root biomass	**Include (estimation)**	No measurements can be carried out during the project implementation period due to the weather conditions
	5. Standing Dead Wood	**Biomass in standing dead wood**	**Include**	Dead wood must be quantified at the project start, and forecast in both the baseline and the project.
	6. Lying Dead Wood	**Biomass in lying dead wood**	**Include**	Dead wood must be quantified at the project start, and forecast in both the baseline and the project.
	7. Litter C reservoir	**Biomass in litter**	**Include**	Project is likely to increase the amount of litter
	8. Soil Organic C reservoir	Organic C, dead root and live fine root content of soil	Exclude	Project impacts are likely to be positive over the project period. Any changes will not be significant.
Management activities/ Harvesting	1c. Fossil fuel combustion	In vehicles and equipment used for plantation maintenance, monitoring and any harvesting activities.	Exclude	Not significant and exclusion results in more conservative estimate
Transport to facility/ Production of wood products	1d. Fossil fuel combustion — transport of harvested biomass	Transport of any harvested biomass to processing facility	Exclude	Emissions from combusting fossil fuel to transport harvested wood /agricultural products to a processing facility are judged to be not significant since the amount of harvesting permitted in a project is limited.

Stage	Identified SSR	Description	Include/ Exclude	Justification for Exclusion
	9. Processing facility	Process emissions at wood product or biomass energy facility. Emissions related to energy used in processing of crops /food products	Exclude	Exclude, for reasons analogous to those for excluding emissions associated with transport of product to mill.
	10: Harvested wood products	Wood from thinning or partial harvests may be converted into wood products. A proportion of the products remains for some time in the products pool and can be considered as offsets.	Exclude	Exclude, since the scale of the projects is very small relative to the regional landbase and supply capacity.

Carbon stock in the belowground biomass will be estimated as a fixed percentage of the carbon stock in the aboveground biomass (root:shoot ratio). Generally, belowground C stock is lower in broadleaved species than in coniferous forests (Dar and Sundarapandian, 2015; Tufekcioglu *et al.*, 2004).

3. Planning for measuring/ assessing Carbon Sink & Reservoir

The project site (Maçka forest) covers 21471.6 ha overall, with approximately 200 ha of scattered planted areas of beech (*Fagus orientalis*), up to 34 years old (Image 1). Past management was based on previous management plans (1973, 1984, 2006 & 2016), with different priorities.

Field measurements will be applied to estimate the aboveground live tree volume, using allometric equations (Misir *et al.*, 2013). Field measurements will also be applied to estimate the aboveground live tree biomass in branches and foliage, as well as the shrub volume. Other measurements will provide data for standing dead wood, lying dead wood and litter. The parameters to be measured/assessed are included in the Inventory sheet (Annex I).

The beech plantations were stratified into 10-year age classes (4 age classes overall) and 3 types of site quality in the forest (good, medium, poor). In order to efficiently estimate the carbon stock, random stratified sampling will be applied. Stratification minimizes the variation within each stratum therefore providing a more precise estimate, with less effort and cost. Effort has been made to equally allocate at least three sample plots to each age classes. For each age class, effort was also made to include the full range of site conditions (from poorest to best). Sampling will therefore be carried out in 3 plots for each age class – site quality combination (stratum) which sums up to 32 plots overall (Table 2).

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 will vary between 400 to 800 m^2 depending on the age class and site quality (smaller area for trees of smaller dimensions). Each plot will include at least 30 trees, which exceeds the 10–20 trees set as a rule of thumb in order to obtain a representative sample (ForestWorks ISC, 2014). The number and area of the plots per stratum is shown in Table 2.

Table 2. Plot area and number per stratum

Site Quality	Age class			
	I	II	III	IV
	0 - 10	10 - 20	20 - 30	30 - 40
Good (A)	3	3	3	3
	400 m^2	800 m^2	800 m^2	800 m^2
Medium (B)	3	3	3	3
	400 m^2	400 m^2	800 m^2	800 m^2
Poor (C)	2	2	2	2
	400 m^2	400 m^2	400 m^2	800 m^2

Number of Plots

Plot Area

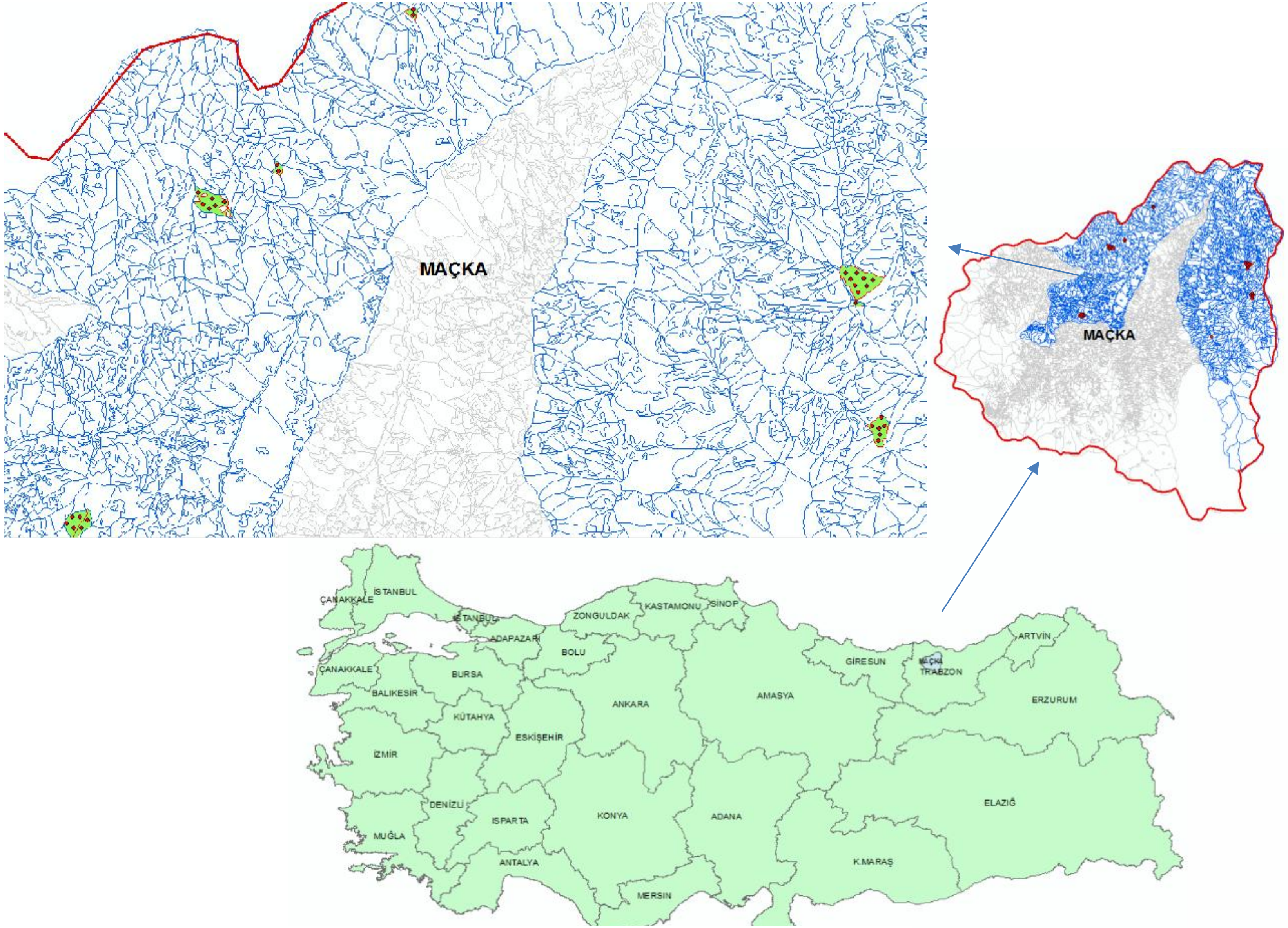

Image 1. Overview of the project area

The sampling plots will be allocated between planning units of the Maçka State Forest (Image 2) as follows:

Esiroğlu planning unit: 16 sampling plots

Yeşiltepe planning unit: 10 sampling plots

İpekyolu planning unit: 6 sampling plots

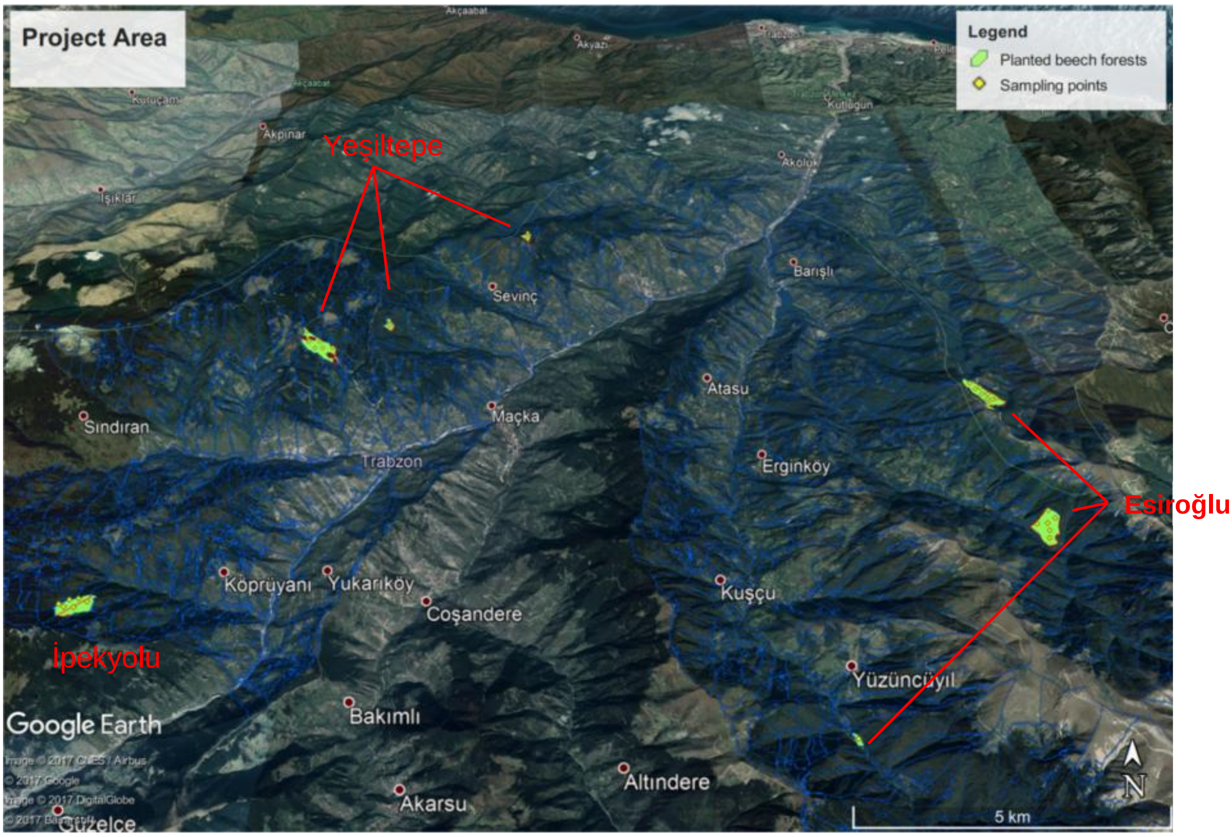

Image 2. Allocation of sampling plots within the project area

A design of nested quadrats of different sizes will be implemented in order to measure vegetation of different sizes and strata, and for collecting litter to estimate carbon stock (Figure 1). The 1m X 1m quadrat will be used for small shrubs biomass (< 2cm DBH), herbaceous species and litter.

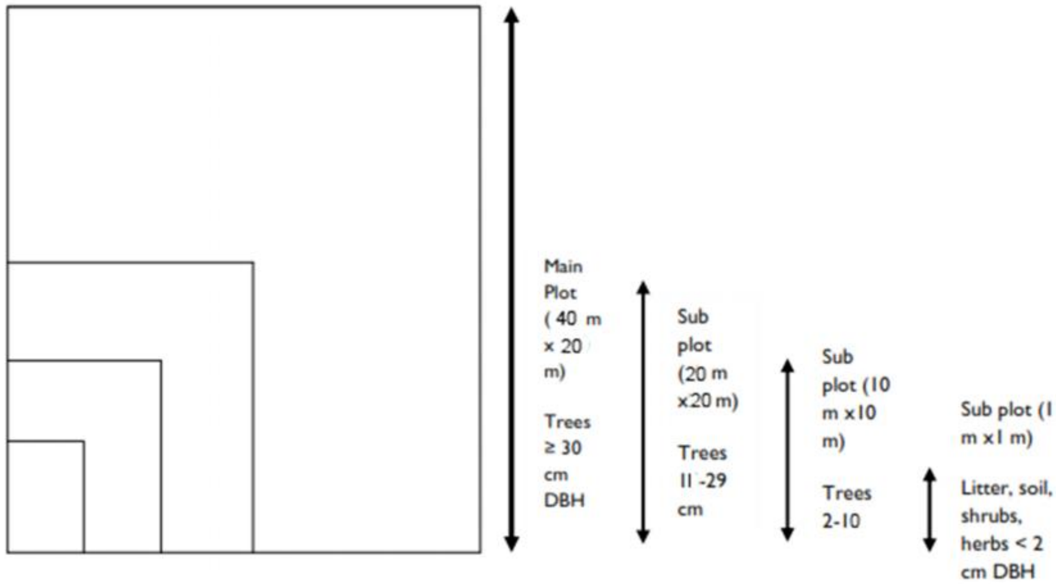

Figure 1. Nested plot design for sampling various carbon pools in homogeneous stratum (adapted from Assefa *et al.*, 2013)

The 10m X 10m quadrat will be used for sampling above ground live trees with 2-10 cm DBH and dead wood. The second quadrat will be used for trees with *DBH* between 11 – 29 cm. Trees with *DBH* ≥ 30 cm should be counted in the entire sample plots. The size of the sampling plots will depend on the stratum (age class and site quality).

4. Measurement/ assessment of Carbon Stock (Sinks & Reservoirs)

4.1 Determination of Living tree Biomass and Carbon Storage

Above-ground live biomass: Includes 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 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 (Hairiah *et al.*, 2001).

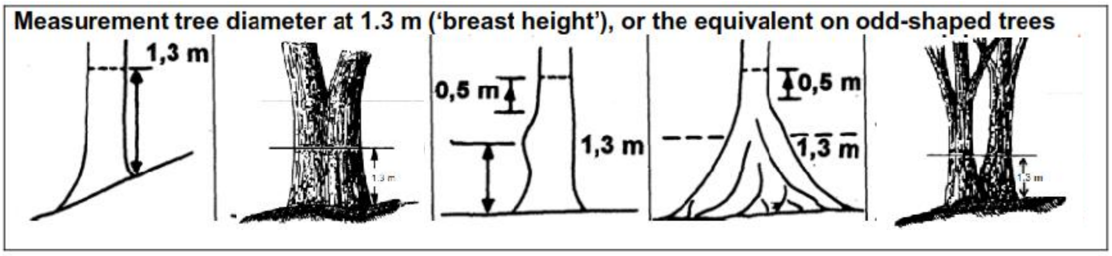

Figure 2. Tree measurement at breast height diameter (Hairiah *et al.*, 2001; Climate Action Reserve, 2017)

The aboveground biomass measurement will include 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 of beech plantations will be determined using the biomass and carbon storage models developed by Misir et al. (2013) for tree and tree components. In other words, whole tree biomass and carbon storage capacity will be estimated from *DBH* for oriental beech using allometric biomass equations proposed by Misir et al. (2013).

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 will be 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 will be found in the hectare.

General information (aspect, slope, elevation) and stand characteristics will also be recorded during the samplings (structure, cover, etc.). The cover within the sample area of the shrubs or herbaceous species will also be determined. After that, it will be cut from the soil ground with motorized saws and scissors, and the leaves, shrubs and herbaceous layer will be weighed individually in the field. Each component will then be 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 will be collected and weighed from the sample plots; sub-samples will be taken and brought to the laboratory for further analysis.

4.2 Determination of Belowground Biomass and Stored Carbon

The belowground biomass will be 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.

According to (Cairns *et al.*, 1997) the average below-ground (root) biomass to average above-ground (shoot) biomass ratio for tropical, temperate and boreal areas is 0.26.

4.3 Determination of Standing Dead Tree, Lying Dead Wood and Shrubs Biomass and Stored Carbon

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

4.4 Determination of Litter Biomass and Stored Carbon

Litter: Material that is too small to be considered lying dead wood 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 4 points which are not destroyed in sample areas and determined by random sampling will be 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 will be determined. Litter samples will be kept in a drying oven at 65 ± 3 °C for 48 hours and when they reach constant weight, their dry weights will be measured (sensitivity 0.01 g). Utilizing the biomass of this sample, several transformations will be found on the hectare of litter biomass. In addition, samples are grinded in a grinding mill and analyzed by COSTECH's Elemental Analyzer to determine the amount of carbon stored.

5. Equipment and supplies

The following list includes the basic equipment and supplies that will be required for the carbon sampling field crew:

- GPS, for navigation to plot locations and Maps
- Diameter tape for measuring Diameter at Breast Height at 1.3 m
- Laser rangefinder/distance measuring device, for measuring tree height (if required). Otherwise, a clinometer and measuring tape can be used.
- Measuring tape, for laying out plots
- Corner posts/stakes
- Metal sampling frame (for litter measurements)
- Satellite phone, two way radio or mobile phone (if there is reception)
- Data recording device (i.e. waterproof paper-based sheets, or electronic data logger), pens/pencils
- Flagging tape
- Motorized saws and scissors
- Camera
- Safety equipment such as a first aid kit, hard hat, sun protection, high visibility vest, etc.

Work health and safety, environmental and organizational requirements that apply to any forest operation in Turkey will be taken into account when carrying out the carbon stock sampling.

6. Abbreviations and Acronyms

DBH	Diameter at breast height (1.3m)
FAO	Food and Agriculture Organization of the United Nations
FRA	Forest Resources Assessment
GHG	Greenhouse gases
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land Use, Land Use Change of Forestry
MCPFE	Ministerial Conference on the Protection of Forests in Europe
SSR	Sources Sinks or Reservoirs
UNFCCC	United Nations Framework Convention on Climate Change
WBCSD	World Business Council for Sustainable Development
WRI	World Resources Institute

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Annex I: Field Inventory Sheet

A. GENERAL INFORMATION

Forest Management Unit	
Stand	
Location	

Plot No/ Area		400/ 800 m^2
Date		
Inventory Personnel		

Aspect (°)	
Slope (%)	
Elevation (m)	

Plot coordinates (left bottom point of quadrat 1x1m)	
Longitude	
Latitude	

B. STAND CHARACTERISTICS (overall plot area)

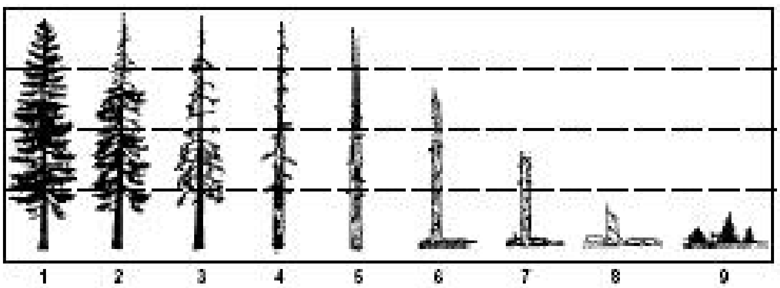
Canopy closure (%)				
Main wood species				
Stand structure	**Even-aged ☐ Uneven-aged groups ☐ Uneven-aged individuals ☐**			
Maturity stage	**Saplings☐ (d<7 cm)**	**Poles ☐ (DBH 7 - 20 cm)**	**Mature trees ☐ (DBH 20 - 35 cm)**	**Mature trees ☐ (DBH>35 cm)**
Number of stems per diameter class (percentage %)	**<25cm:**	**25-50cm:**	**>50cm:**	
Stand storeys	**One-storey ☐ Two-storey ☐ Multi-storey ☐**			
Mean overstorey height (m)				
Mean height of 2nd storey (m)				
Forest edge – Ecotone	**Yes ☐ No ☐**			
Water locations	**Yes ☐ No ☐**			

C. TIMBER CRUISING

No	Type (LT, DST, BT)[2]	Branched (Y or N)?	Species	DBH (cm)	Total height (m)	Time of necrosis (for DST)[3]
1						A ☐ B ☐ C ☐
2						A ☐ B ☐ C ☐
3						A ☐ B ☐ C ☐
4						A ☐ B ☐ C ☐
5						A ☐ B ☐ C ☐
6						A ☐ B ☐ C ☐
7						A ☐ B ☐ C ☐
8						A ☐ B ☐ C ☐
9						A ☐ B ☐ C ☐
10						A ☐ B ☐ C ☐
11						A ☐ B ☐ C ☐
12						A ☐ B ☐ C ☐
13						A ☐ B ☐ C ☐
14						A ☐ B ☐ C ☐
15						A ☐ B ☐ C ☐
16						A ☐ B ☐ C ☐
17						A ☐ B ☐ C ☐
18						A ☐ B ☐ C ☐
19						A ☐ B ☐ C ☐
20						A ☐ B ☐ C ☐
21						A ☐ B ☐ C ☐
22						A ☐ B ☐ C ☐
23						A ☐ B ☐ C ☐
24						A ☐ B ☐ C ☐
25						A ☐ B ☐ C ☐
26						A ☐ B ☐ C ☐
27						A ☐ B ☐ C ☐

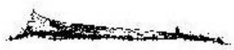
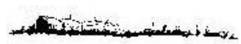
[2] Live tree (LT), Dead standing tree (DST), Big tree with diameter over 30 cm (BT)
[3]

A: recently (1, 2), **B**: a few years ago (3, 4), **C**: a lot of years ago (5 – 9).



No	Type (LT, DST, BT)[2]	Branched (Y or N)?	Species	DBH (cm)	Total height (m)	Time of necrosis (for DST)[3]
28						A ☐ B ☐ C ☐
29						A ☐ B ☐ C ☐
30						A ☐ B ☐ C ☐
31						A ☐ B ☐ C ☐
32						A ☐ B ☐ C ☐
33						A ☐ B ☐ C ☐
34						A ☐ B ☐ C ☐
35						A ☐ B ☐ C ☐

D. UNDERSTOREY: LYING DEAD WOOD & SHRUBS (10 X 10 m Quadrat)

LYING DEAD TREES				
No	**Species**	**Average diameter (cm)**	**Length (m)**	**Stage of Decaying**
1				A ☐ B ☐ C ☐
2				A ☐ B ☐ C ☐
3				A ☐ B ☐ C ☐
4				A ☐ B ☐ C ☐
		A. Early stages 	**B. Middle stages:** 	**C.Final stages:** 

UNDERSTOREY	
Shrub understorey	**Yes** ☐ **No** ☐
Dominant species	
Cover (%)	
Mean height (m)	
Herbaceous understorey	**Yes** ☐ **No** ☐
Cover (%)	
Mean height (cm)	

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Project: Development of a common protocol to assess the impact of forest management practices on climate change

Field Sampling

Deliverable 2.1

May 2018

Contents

1. Scope

The aim of the Action is to report result and data field sampling needed monitor inter-annual fluctuation of net carbon storage, focusing on CO_2 (no other GHG) in forests. The Action involves all data and analysis results used the development of common guidelines (Protocol) for the assessment of carbon storage in planted forests through afforestation/reforestation projects. This common protocol will also assess and validate forest management practices and applied measures in these types of areas, aiming to improve the CO_2 removal/sequestration balance through management treatments.

The Action incorporates sample plots and sample trees data. The results of sample plots include stand type, stand diameter (two type: mean diameter and quadratic mean diameter), stand height, basal area, number of trees, herbaceous biomass, shrub biomass, litter biomass, lying dead wood biomass, herbaceous carbon amount, shrub carbon amount, litter carbon amount and lying dead wood carbon amount. The Sample trees results include diameter at breast height, tree height, stem biomass, branch biomass, foliage biomass, stem carbon amount, branch carbon amount and foliage carbon amount.

The project site (Vakfıkebir forest) has approximately 200 ha of scattered planted areas of beech (*Fagus orientalis*), up to 34 years old (Image 1). Past management was based on previous management plans (1973, 1984, 2006 & 2016), with different priorities.

Field measurements were applied to estimate the aboveground live tree volume, using allometric equations developed in this project. Field measurements were also applied to estimate the aboveground live tree biomass in branches and foliage, as well as the shrub/herbaceous volume. Other measurements provided data for standing dead wood, lying dead wood and litter. The parameters to be measured/assessed were included in the Inventory sheet.

The beech plantations were stratified into 10-year age classes (4 age classes overall) and 3 types of site quality in the forest (good, medium, poor). In order to efficiently estimate the carbon stock, random stratified sampling will be applied. Stratification minimizes the variation within each stratum therefore providing a more precise estimate, with less effort and cost. Effort has been made to equally allocate at least three sample plots to each age classes. For each age class, effort was also made to include the full range of site conditions (from poorest to best). Sampling will therefore be carried out in 3 plots for each age class – site quality combination (stratum) which sums up to 32 plots overall (Table 1).

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 will vary between 100 to 600 m^2 depending on the age class and site quality (smaller area for trees of smaller dimensions). Each plot will include at least 30 trees, which exceeds the 10–20 trees set as a rule of thumb in order to obtain a representative sample (ForestWorks ISC, 2014). The distribution of site quality and age classes the sample plots is shown in Table 1.

Table 1. Distribution of site quality and age classes of sample plots

Site Quality	Age class (no of sample plots)			
	I	II	III	IV
	0 - 10	10 - 20	20 - 30	30 - 40
Good (A)	9 10 16	11 20 21	5 19 26	2 17 25
Medium (B)	8 12 14	4 7 18	22 27 32	6 28 29
Poor (C)	13 15	23 31	3 30	1 24

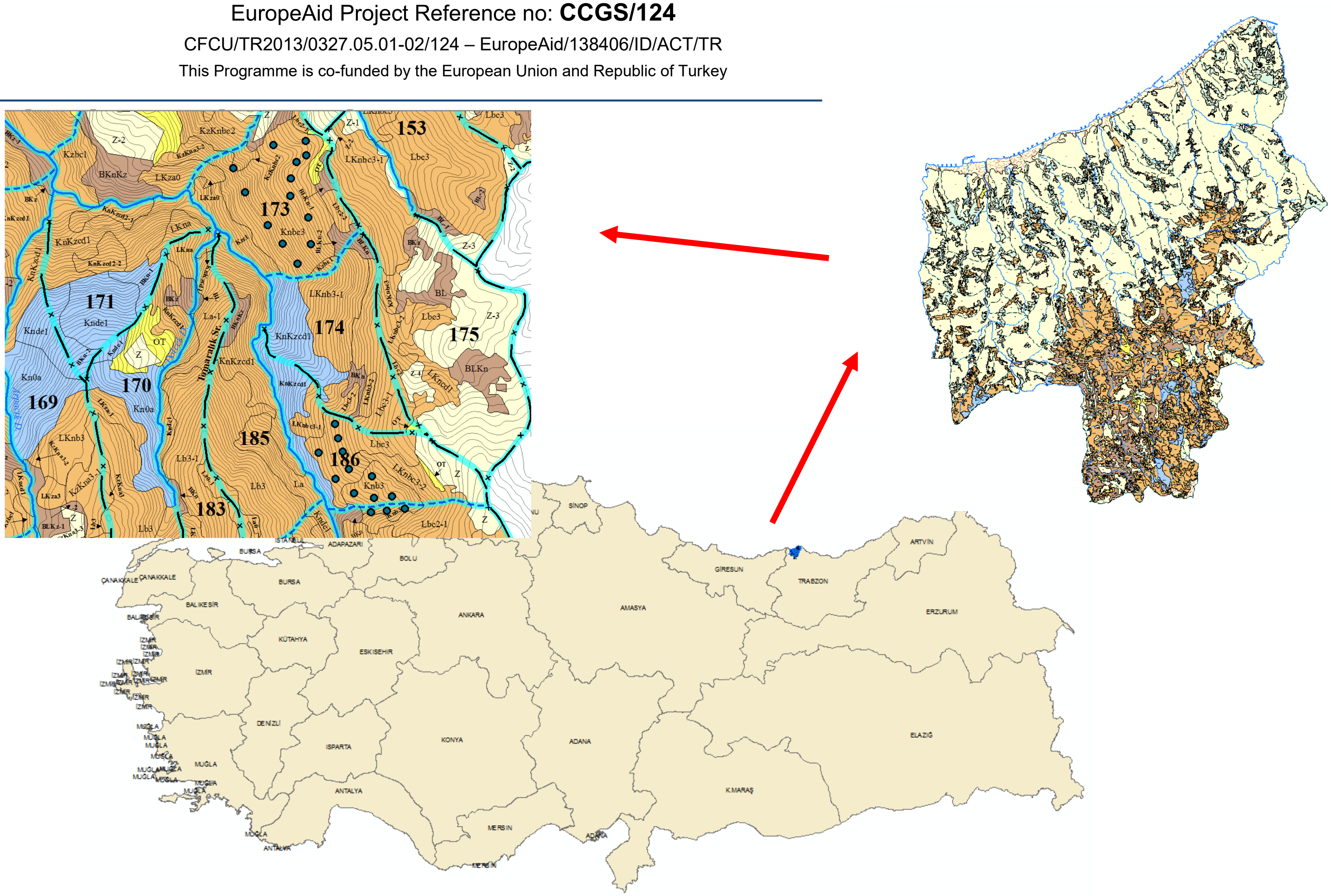

Figure 1. Overview of the project areas

The sampling plots will be allocated between planning units of the Vakfıkebir State Forest (Figure 2 and Figure 3) as follows:

Vakfıkebir planning unit: 19 sampling plots

Tonya planning unit: 13 sampling plots

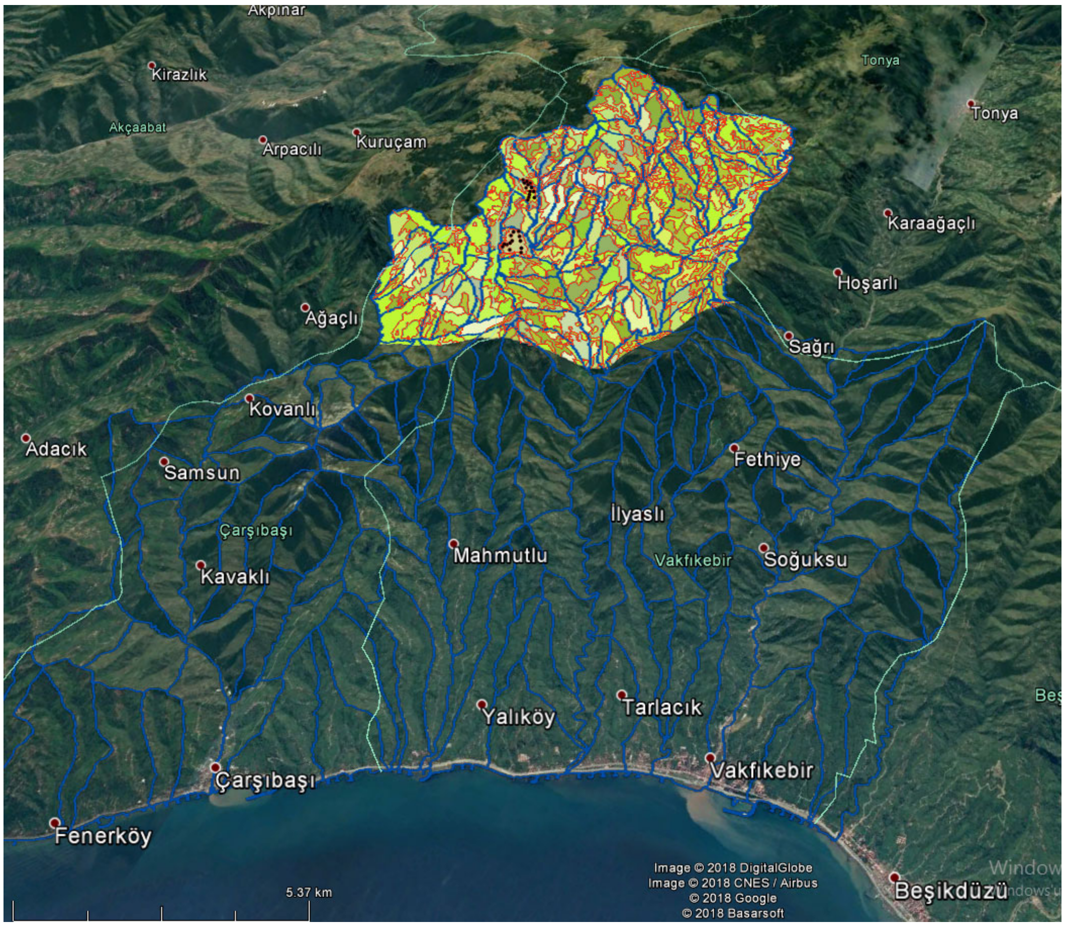

Figure 2. Project area

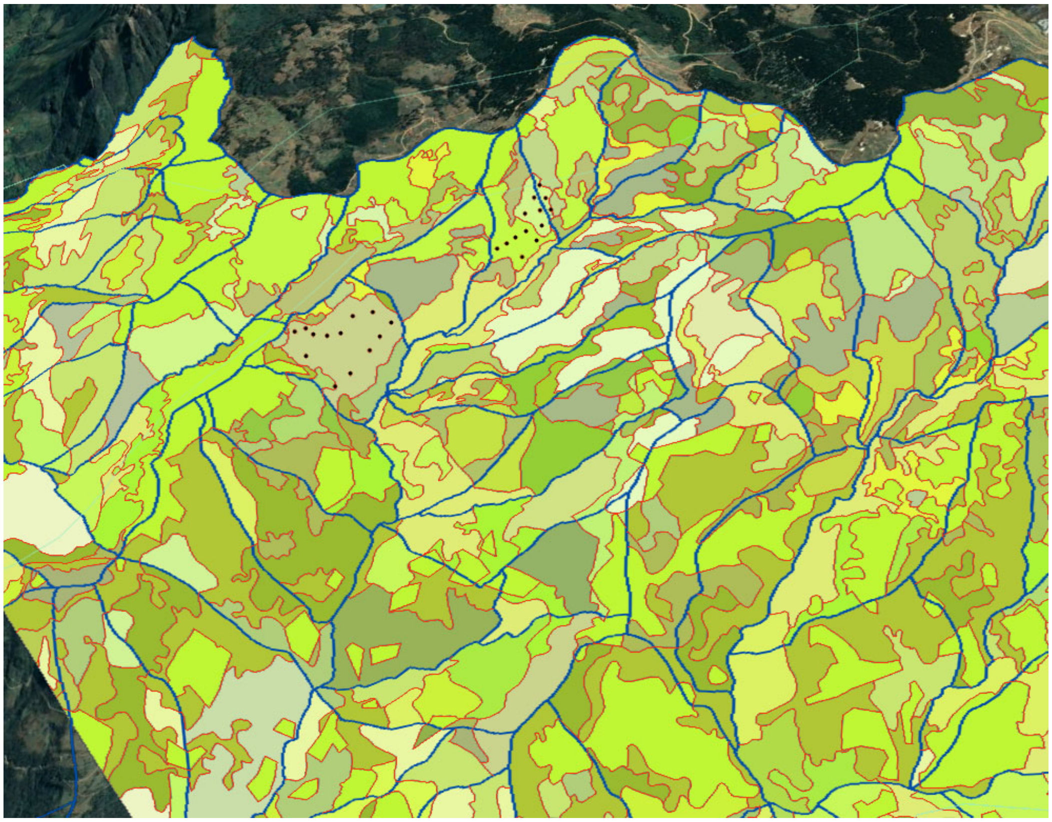

Figure 3. Sampling Plots

A design of nested quadrats of different sizes will be implemented in order to measure vegetation of different sizes and strata, and for collecting litter to estimate carbon stock (Figure 4). The 1m X 1m quadrat will be used for small shrubs biomass (< 2cm DBH), herbaceous species and litter.

The 10m X 10m and 20 m x 20 m quadrats will be used for sampling above-ground live trees with 2-10 cm *dbh* and dead wood. The second quadrat will be used for trees with *dbh* between 11 – 29 cm. Trees with *dbh* ≥ 30 cm should be counted in the entire sample plots. The size of the sampling plots depended on the stratum (age class and site quality).

2. The results of Sample Plots

The results obtained from measurements made of sample plots were presented in Table 1 and Table 2.

Table 1. Some characteristics of the sample plots

Sample Plot No	Mean diameter (cm)	Age class	Site class	Basal area m^2/ha	Number of trees
1	17.0	IV	Poor	19.4	800
2	10.8	IV	Good	44.7	4000
3	13.2	III	Poor	36.1	2000
4	9.3	II	Medium	37.2	4100
5	12.8	III	Good	53.0	3400
6	14.3	IV	Medium	29.9	1550
7	9.7	II	Medium	33.1	3700
8	5.5	I	Medium	25.5	9600
9	5.7	I	Good	29.9	6700
10	6.8	I	Good	36.1	8000
11	7.8	II	Good	20.7	3400
12	0.8	I	Medium	0.1	867
13	1.3	I	Poor	0.4	2500
14	1.1	I	Medium	0.7	5200
15	0.9	I	Poor	0.2	3067
16	6.7	I	Good	17.4	3800
17	13.3	IV	Good	37.1	2200
18	11.5	II	Medium	39.1	2867
19	12.6	III	Good	26.8	1645
20	11.4	II	Good	52.2	4300
21	10.8	II	Good	43.1	4000
22	13.5	III	Medium	49.0	2900
23	11.6	II	Poor	32.9	2534
24	22.7	IV	Poor	40.9	925
25	15.9	IV	Good	33.0	1500
26	14.7	III	Good	26.6	1425
27	15.0	III	Medium	24.0	1200
28	16.9	IV	Medium	27.1	1050
29	15.8	IV	Medium	38.1	1700
30	13.1	III	Poor	20.2	1325
31	12.4	II	Poor	19.6	1475
32	13.7	III	medium	19.2	1225

Table 2. Biomass of the sample plots

Sample Plot	Biomass (kg)			
	Herbaceous	Shrub	Litter	Lying dead wood
1	0	1830	7200	0
2	0	4950	12000	3375
3	38	750	3200	1080
4	0	4980	26400	2370
5	129	3870	14200	3270
6	76	3020	19580	2280
7	23	57.5	10800	200
8	125	750	23000	6030
9	30	0	30200	480
10	58	345	8200	2490
11	75	150	8600	2030
12	975	163	5867	303
13	2610	6525	2000	5925
14	260	0	2600	0
15	1280	80	8600	345
16	700	4200	14000	3480
17	0	1245	10600	6990
18	0	1890	10200	1960
19	23	1125	11600	2175
20	40	2370	17200	1140
21	21	735	13600	1698
22	26	1820	8800	1540
23	52	3090	10400	1710
24	0	500	6000	500
25	10	1000	10000	1701
26	20	1200	8000	3252
27	15	950	9008	4000
28	0	1200	7040	3270
29	0	750	3040	1050
30	0	57	10560	201
31	0	0	2720	0
32	0	0	3200	1080

3. The results of Sample Trees

The results obtained from measurements made of sample trees were presented in Table 3.

Table 3. Biomass and some characteristics of sample trees

Sample tree no	*Dbh* (cm)	Tree Height (m)	Stem biomass (kg)	Branch biomass (kg)	Foliage Biomass (kg)
1	11.70	11.55	37	2.25	0.01
2	8.80	10.80	16	0.24	0.01
3	7.00	11.90	16	0.47	0
4	5.30	7.15	4	0.21	0.05
5	15.50	12.20	43	4.83	0
6	6.20	8.60	4	4.62	0
7	15.50	13.10	58	20.10	0.68
8	12.80	15.20	50	5.49	0.76
9	14.20	13.10	49	14.10	0.54
10	8.00	7.90	10	2.13	0.08
11	7.50	10.25	17	3.19	0.37
12	10.50	11.90	21	4.03	0.34
13	16.40	14.80	79	20.52	1.71
14	6.90	10.65	14	2.60	0.26
15	0.30	1.60	0	0.02	0.02
16	1.40	1.25	0	0.04	0.01
17	1.20	1.45	0	0.03	0.02
18	1.20	1.33	0	0.03	0.03
19	8.20	11.60	19	1.30	0.13
20	4.90	10.70	6	0.70	0.08
21	24.8	18.40	165	124.40	10.9