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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

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

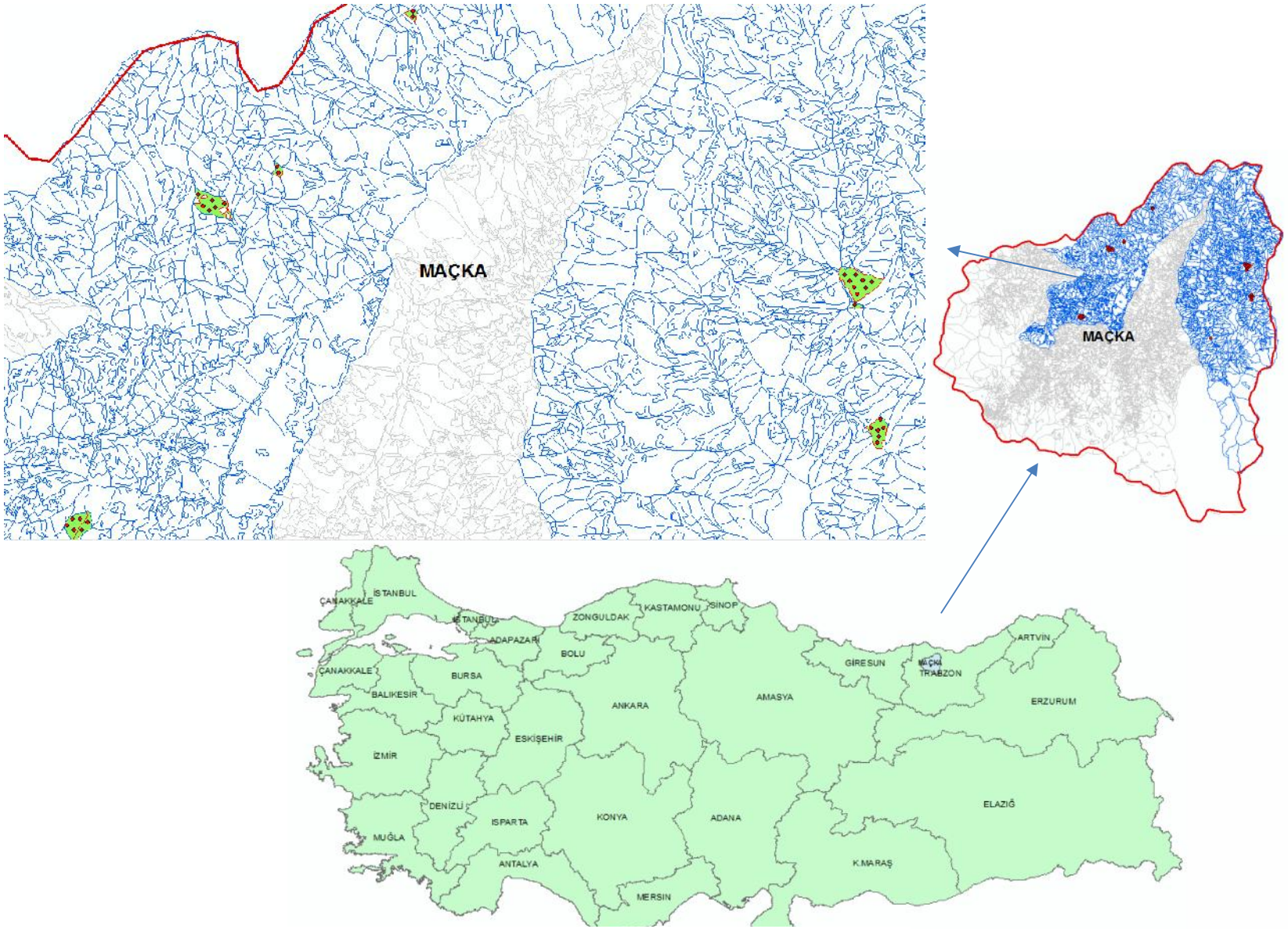

Image 1. Overview of the project area

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

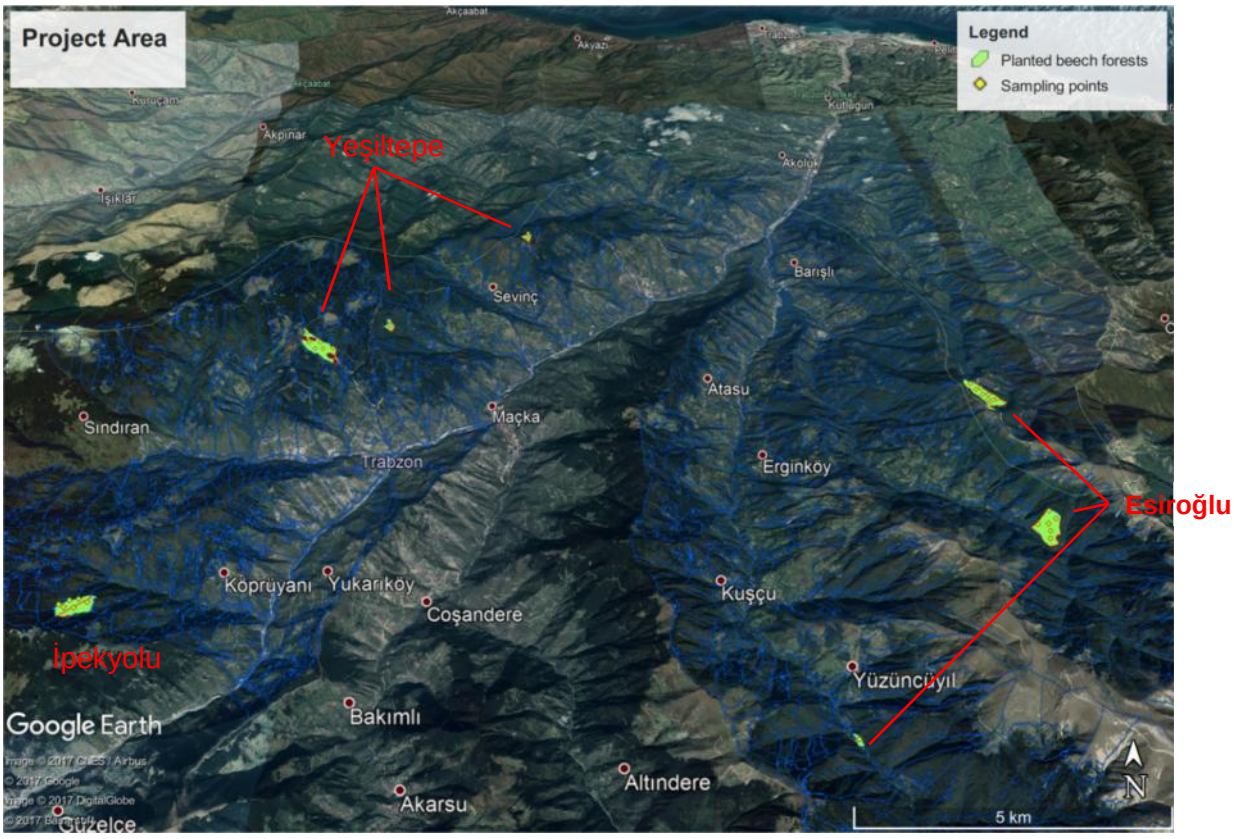

Image 2. Allocation of sampling plots within the project area

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.

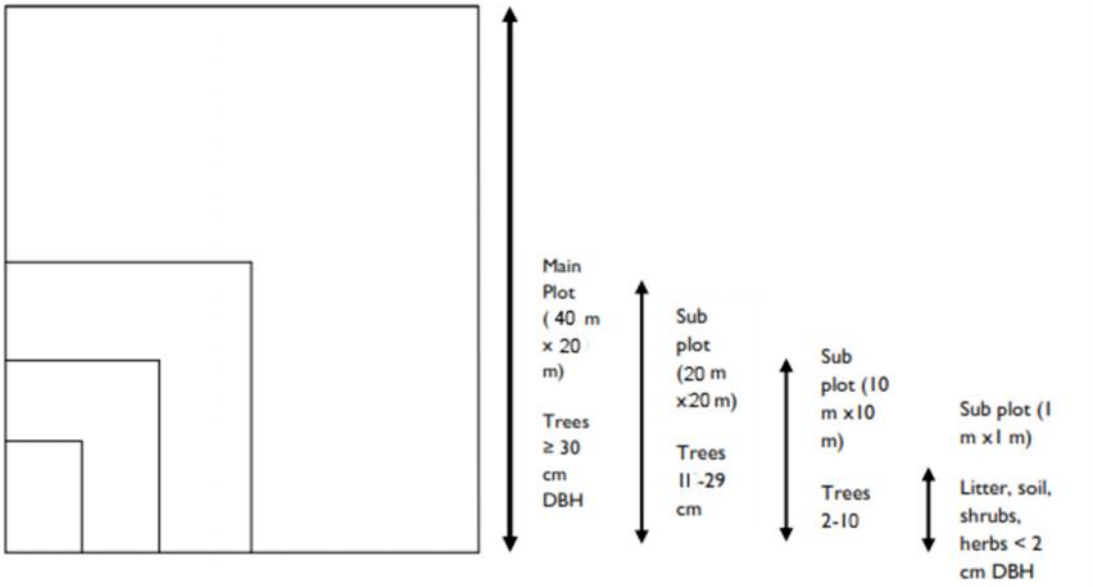

Figure 1. Nested plot design for sampling various carbon pools in homogeneous stratum (adapted from Assefa *et al.*, 2013)

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).

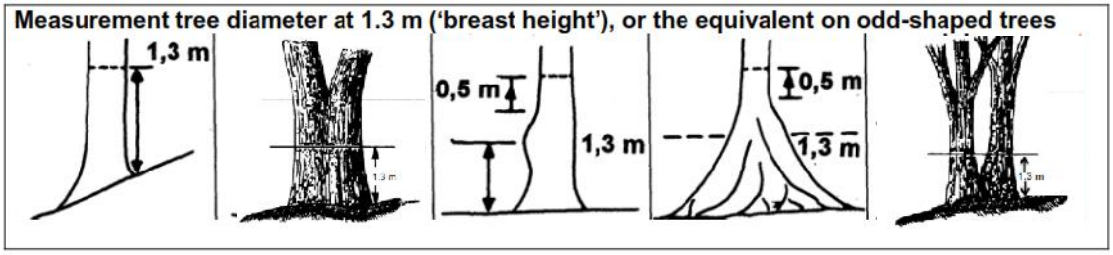

Figure 2. Tree measurement at breast height diameter (Hairiah *et al.*, 2001; Climate Action Reserve, 2017)

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)

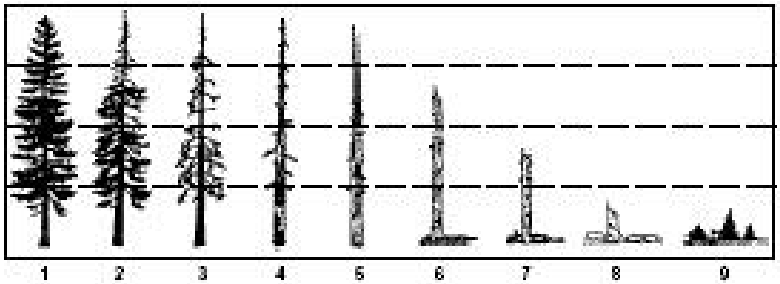
Canopy closure (%)				
Main wood species				
Stand structure	**Even-aged** ☐	**Uneven-aged groups** ☐	**Uneven-aged individuals** ☐	
Maturity stage	**Saplings** ☐ **(d<7 cm)**	**Poles** ☐ **(DBH 7 - 20 cm)**	**Mature trees** ☐ **(DBH 20 - 35 cm)**	**Mature trees** ☐ **(DBH>35 cm)**
Number of stems per 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 ☐

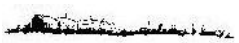
[2] Live tree (LT), Dead standing tree (DST), Big tree with diameter over 30 cm (BT)
[3]

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)	