Department of Environment and Natural Resources
Ecosystems Research and Development Bureau

December 29, 2021

ERDB TECHNICAL BULLETIN
NO. 2021-01

SUBJECT: WHOLE-ECOSYSTEM CARBON STOCK AND SEQUESTRATION ASSESSMENT

I. RATIONALE

Forest systems play a vital role in storing and sequestering carbon from the atmosphere. The alarming concentration of CO_2 in the atmosphere in recent years is primarily the result of emissions from fossil fuel combustion, cement production, and tropical deforestation (IPCC 2014). Thus, it is critical to manage forests for carbon storage and sequestration since it requires information on the amount of carbon stored, as well as its contribution in reducing or offsetting the country's carbon emissions according to the targets stated in the Paris Agreement—the legally binding international treaty on climate change.

II. DEFINITION OF TERMS

Aboveground biomass (AGB) – the aboveground standing dry mass of live or dead matter from tree or shrub (woody) life forms, expressed as a mass per unit area, typically Mg ha^{-1}

Below ground biomass (BGB) – is one of seven key agriculture, forestry, and land-use carbon pools. It includes all living biomass of live roots. Fine roots, which are less than 2 mm in diameter, are often excluded because these often cannot be distinguished empirically from soil organic matter or litter.

Biomass – the total amount of live organic matter and inert organic matter (IOM) aboveground and belowground expressed in tonnes of dry matter per unit area (individual plant, hectare, region or country).

Carbon Pool – a reservoir; a system which has the capacity to accumulate or release carbon (e.g., forest biomass, wood products, soils, and atmosphere).

Carbon Sequestration – the process of removing carbon from the atmosphere and depositing it in a reservoir

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Carbon Stock - The absolute quantity of carbon held within a pool at a specified time.

Litter – includes all non-living biomass with a size greater than the limit for soil organic matter (suggested 2 mm) and less than the minimum diameter chosen for dead wood (e.g., 10 cm), lying dead, in various states of decomposition above or within the mineral or organic soil.

Soil Carbon Pool – the relevant carbon in the soil. It includes various forms of soil organic carbon (humus) and inorganic soil carbon and charcoal. It excludes soil biomass (e.g., roots, bulbs, etc.) as well as the soil fauna (animals).

Wood Density – the ratio of the oven-dry mass of a wood sample divided by the mass of water displaced by its green volume (wood specific gravity, or WSG).

III. SCOPE AND COVERAGE

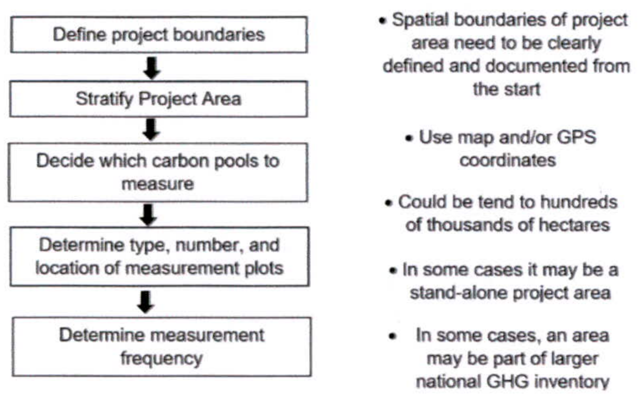
This ERDB Technical Bulletin provides and demonstrates the step-by-step procedure on accounting or quantifying the carbon stored and being sequestered in a forest.

IV. PROCEDURE ON WHOLE-ECOSYSTEM CARBON STOCK AND SEQUESTRATION ASSESSMENT

A. Planning for Field Data Collection

Step 1

Set and decide on the boundary of the area to be assessed.



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<td>Step 2

Stratify the study area

Determine the following:
Type of forest
Slope class
Elevation class
Aspect/exposure
The above classes can be generated using Digital Elevation Model (DEM) of the area in a GIS environment.</td>
<td>Stratified Sampling Technique
Transect lines are established to cover the Following strata:
Forest species
Year of establishment
Slope of Position (bottom, midslope, ridge)
Etc.</td>
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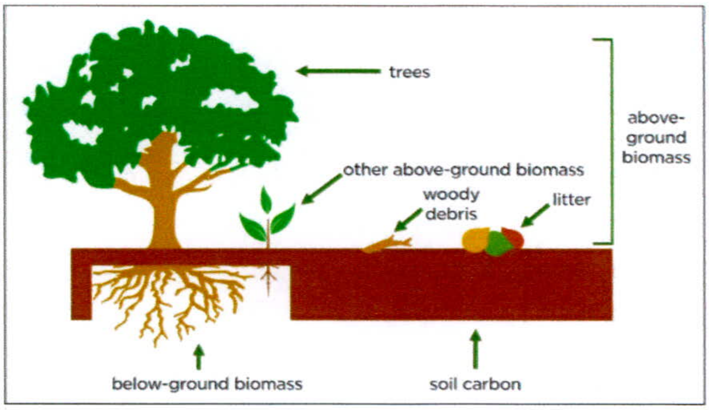
<td>Step 3

Quantify the major Carbon pools in a forested system:
Aboveground biomass
Belowground biomass
Litter
Soil
Woody debris*
*For the purpose of this technical bulletin, woody debris will not be included in the assessment</td>
<td>
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<td>Step 4

Determine the number of plots to be established in the study forest.

This can be computed using the formula on the right panel.</td>
<td>We can use knowledge of variation in C stocks to estimate the needed number.
This knowledge comes from previous data or preliminary sample of 6-10 plots
Simplest formula:
Minimum number of sample plots (n) = $\left(\frac{t*s}{E}\right)^2$

n= the number of sample plots.
t = the sample statistic from the t-distribution for the 95% confidence interval; t usually is set at 2 as sample size is unknown at this stage.
s= standard deviation expected or known from previous/initial data.
E= allowable error or the desired half-width of the confidence interval. Calculated by multiplying the mean stock by the desired precision, i.e., mean * 0.1 (for 10 % precision).</td>
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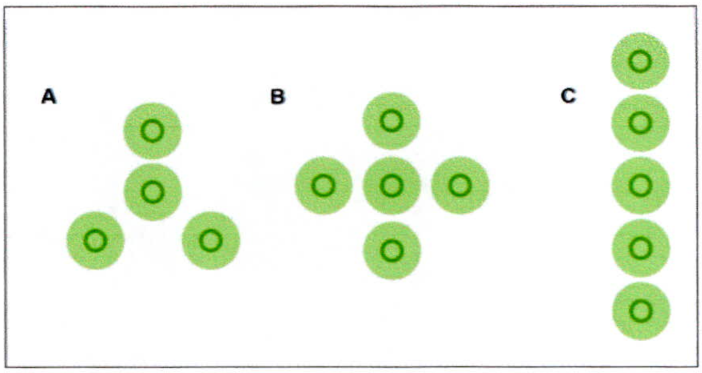
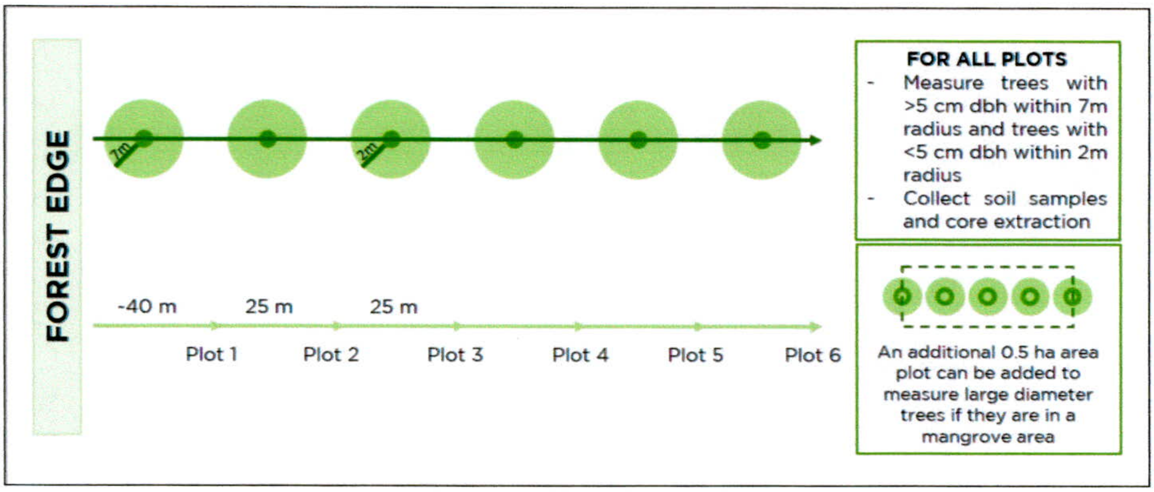
Determine whether the sample plots are sufficient and representative to describe the population's C stock. The example on the right panel shows how to compute the number of plots using initial field data. This can be done after the initial calculation of C stock based on preliminary collection of field data.	• Preliminary data show – C density ~ 300 Mg ha^{-1} – Standard deviation ~ 100 Mg ha^{-1} – Our objective is to be within 10% $n = \left(\frac{2 * 100}{0.1 * 300}\right)^2$ n= 44 plots
Step 5 **Distribute the plots.** Plots can be distributed in clusters or in a linear fashion along a transect line.	

B. Field Data Collection

Step 1

Lay out the field plots in a straight line along a 125 m transect (red line).



Kauffman and Donato (2012)

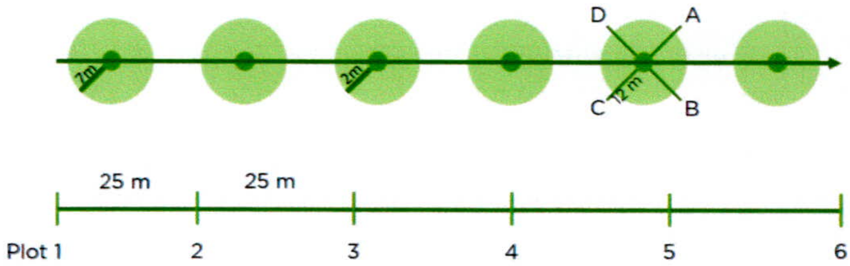
The total number of plots in a transect could range from 3 to 6 plots.

Transects can be laid on north, south, east and west portions of the study site, as well as on the ridge, mid slope, and foot slope of the forest. The greater number of transects established, the better.

Step 2 Establish the transect lines and plots along the transect.	➢ Transect lines are established perpendicular to the plantation edge ➢ Each transect is 150m in length with 6 plots spaced every 25m (P1, P2, P3, P4, P5, and P6) ➢ To avoid edge effects, start of the transect (zero mark of the tape) is placed 15m from the edge. ➢ Center of Plot 1 is at 25m mark of the tape, Plot 2 at 50m mark, Plot 3 75m mark......... and Plot 6 at 125 mark.
Step 3 Collect general information of each plot.	➢ Name/ Number of sampled Plot ➢ General location of Plot (Sitio, Brgy., Town, Province) ➢ Date ➢ Name of Recorded and Crew Members Present ➢ GPS Coordinated and Precision ➢ Directions to the plot location ➢ Site category (Forest, Scrub, etc.) ➢ Ecological condition (intact, degraded, deforested) ➢ Photos at 4 cardinal directions taken from the plot center

Step 4

Aboveground Protocol



FOR ALL PLOTS

- Measure trees with >5 cm dbh within 7m radius and trees with <5 cm dbh within 2m radius
- Collect soil samples and core extraction
- Collection of large wood debris and litter

Step 5

<u>Aboveground Biomass</u>

- Tree layer (7 m radius plot)
- Understory layer (2 m radius plot)

➢ 7m –radius from Plot Center

- All individual with 5cm and above in DBH are measured and recorded with the following
  - Species ID
  - DBH and Height

➢ 2m- radius from Plot Center

- All individuals less than 5cm in DBH are measured and recorded with the following:
  - Species ID
  - DBH and Height
- Individual < 3 1.3 m in height (seedlings) are just counted and sample individuals are harvested in just one of the plots

<u>Field plots sample form (2 m radius)</u>

Use the same form format for 7 m radius plots in DBH trees with >5 cm as seen on the right panel.

Saplings: < 5 cm DBH (2m nested plot)

Project: ____________

Forest Type:____________

Name of Area Sampled: ______________

Date: ______________ Direction of Central Transect: ______________

Transect Length: _________

Crew Members: ______________________________

Plot	Species	DBH (cm)	Height (m)	Status

Data Entry Name: ___________ Date:_________

Check by: ________________ Date: _________

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➢ If trees >50cm DBH are present within 20m from each side of transect line, they are measured and recorded in 40x125m rectangular plot surrounding the circular plots (established 20m at each side of the transect from Plot 1 up to Plot 6) also with the following:

- Species ID
- DBH

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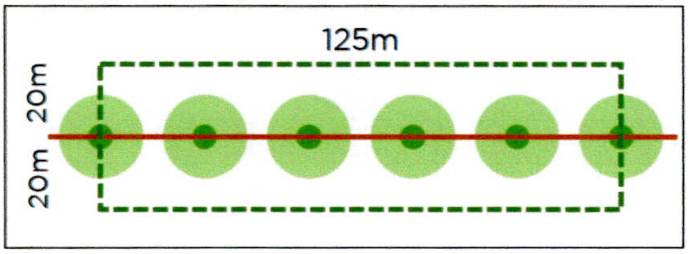

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Review the proper measurements for the DBH of a tree.

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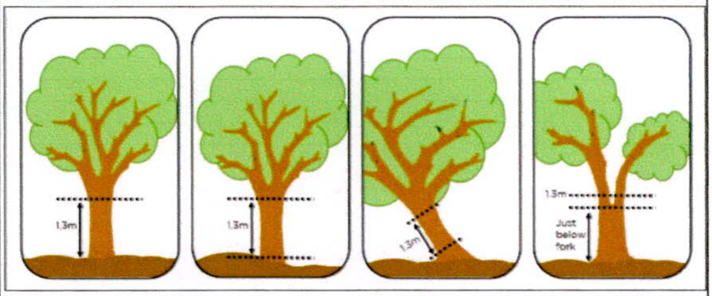

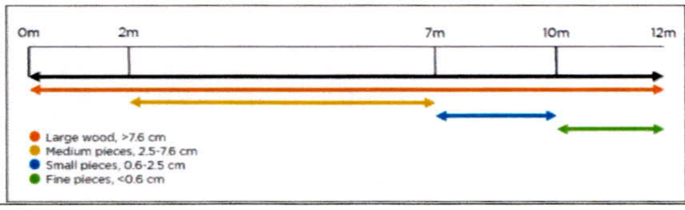

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Step 6

Litter

- Litter above the ground are collected in two 0.5 x 0.5 m subplots randomly within the plot
- The collected litter are placed in labeled plastic bags for processing
- The litter collection is done in every plot

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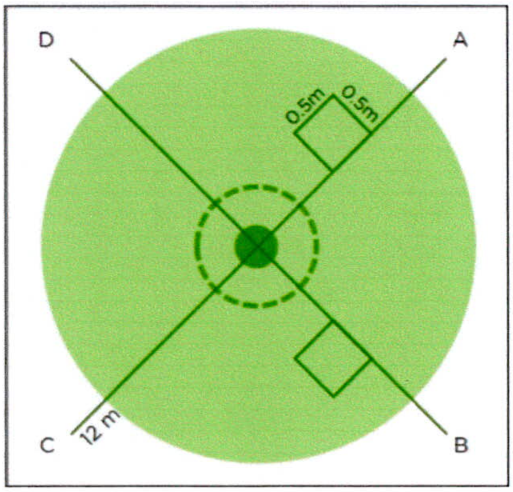

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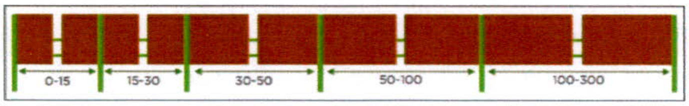
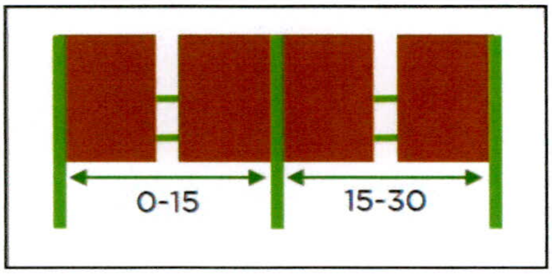
Step 7 Soil • Using an auger, soil coring is done in each plot in an undisturbed portion near the plot center. • Soil cores are divided into 0-15 cm, 15-30 cm in the case of terrestrial forests.	
• For mangroves and peat forests, divide the soil cores into 0-15 cm, 15-30 cm, 30-50 cm, 50-100 cm, and >100 cm. • Collect the subsamples (3 cm in length) in the middle of each soil layer and place them in labelled paper cups for %Carbon determination. • Take another subsample (3 cm in length) from each layer for bulk density determination.	

C. Laboratory Works and Data analysis

A. Laboratory Works	
Step 1 Litter	Litter samples from 0.5 m x 0.5 m plots are ovendried until constant weight is achieved to get the **ovendry weight (ODW)**.
Step 2 Soils	• Soil samples for bulk density determination are dried in an oven at 100 – 110 ^{0}C until constant weight is achieved (about 40 hours). • Soil samples for %C analysis are airdried until ready to be pulverized for Organic Matter analysis. However, if an Elemental Analyzer is available, the subsamples are oven dried at 60 ^{0}C until constant weight and then sent for %C analysis.

B. Data Analysis

Step 1

Aboveground Biomass and Belowground Biomass

- Above-ground biomass of each tree is computed using existing allometric equation.
- The same is true for BGB when equation is available; otherwise published root-shoot ratio can be used.
- Biomass is multiplies to the Carbon fraction | (47% = AGB; 39% = BGB) to get the carbon stock.
- Carbon stock of all trees are summed-up per plot (radius=7m) and scaled-up to a hectare; the same is done for the understorey (2m radius plot)

Sample models for aboveground biomass estimation

Life Zone (rainfall, mm/yr)	EQUATION (W= tree biomass, kg/tree; D-dbh, cm; H= heigh, m; ρ= wood density, g cm^{-3}	
Dry (<1500)	$W= 0.139\ D^{2.32}$	(Brown, 1997)
Moist (1500-4000)	$W= 0.118\ D^{2.53}$	(Brown, 1997)
	$W= 0.049\ \rho\ D^2\ H$	(Brown et al., 1995)
	$W= 0.11\ \rho\ D^{2+c}$	With c (default 0.62)
	$H= a\ D^c$	(Ketterings et al., 2001)
WET (>4000)	$W= 0.037\ D^{1.89}\ H$	(Brown, 1997)

(Hairiah et al. 2001)

<u>Sample aboveground biomass calculation using a biomass equation and 47% C fraction</u>

The computation is done for every individual in the plot (kg/plot), scaled-up to a ton per hectare basis, and multiplied to 47% C fraction to arrive at tC/ha unit.

Add the values for each tree to get the plot total.

Plot	Species	DBH (cm)	Ht (m)	AGB model	AGB (kg)	Area (m^2)	AGB kg/ha	AGB tC/ha
1	Narra	10	5	0.0378D^.89*H	14.36	153.94	932.87	0.44
1	Narra	9	5	0.0378D^.89*H	11.77	153.94	746.43	0.36
1	Narra	7	5	0.0378D^.89*H	7.32	153.94	475.40	0.22
1	Narra	8	5	0.0378D^.89*H	9.42	153.94	611.87	0.29
1	Narra	3.5	3	0.0378D^.89*H	1.18	153.94	76.96	0.04
1	Narra	3	3	0.0378D^.89*H	0.89	153.94	57.51	0.03
1	Narra	3.5	3	0.0378D^.89*H	1.18	153.94	76.96	0.04
1	Narra	3	3	0.0378D^.89*H	0.89	153.94	57.51	0.03
							Total P1	1.44

<u>Biomass Summary</u>

- List the total Aboveground Biomass Carbon density per plot.
- The value of belowground biomass can be computed as 37% of the Aboveground biomass (t/ha). The value is further multiplied to 39% C fraction to get the

Biomass

Plot	AGB tC/ha	BGB tC/ha
1	1.44	0.53
2		
3		
Mean		
Std Dev		
Std E		

Belowground biomass Carbon density (tC/ha).

Step 2

Litter

- Multiply the ovendry weight of litter samples (plot size= 0.5 x 0.5m) by the carbon fraction (45%) and scaled-up to a hectare basis.
- Summarize the computed plot data to show the values per plot.

Plot	Litter ODW, g	Area, m2	Litter t/ha	Litter tC/ha
1	15	0.25	0.7	0.32
2				
3				
n				
Mean				
Std Dev				
Std error				

Step 3

Compute for the Soil Organic Carbon:

SOC (MgC/ha = BD(g/cm^3) x depth (cm) x %C

For each plot

Layer (cm)	Dry Wt (g)	Vol. Of Soil (cc)	Bulk density (BD)
0-15	52.57	74.30	0.71

Layer (cm)	BD	Depth (cm)	% C	SOC (MgC/ha)
0-15	52.57	74.30	0.71	106.5

Step 4

Carbon Density

- Summarize the results of each Carbon pool per plot, and compute the Mean C density.
- C density (MgC/ha) = aboveground biomass + belowground biomass + litter+ DWD + soil carbon

Carbon Pool (Mg C/ha)	Plot 1	Plot 2	Plot n
Aboveground Biomass			
Belowground Biomass			
Litter			
Soil Organic Carbon			
Carbon Density			
Mean			
Std Dev			
Std Error			

V. TOOLS, SUPPLIES, MATERIALS, AND MANPOWER

A. Tools

a. GPS - used to locate sampling points within the established transects
b. Meter Tape - used to measure transects to be established
c. Diameter Tape - used to measure the DBH of standing trees and logs
d. Soil Corer - used to measure the bulk density of soil
e. Rubber Mallet - used to press down soil corer
f. Trowel - used to collect soil samples for soil organic content analysis
g. Fuel Gauge - used to measure size of woody debris

h. Digital/Electronic balance - used to measure fresh weight of collected litter

B. Supplies
   a. Containers - plastic bags for the soil samples collected
   b. Paper, Markers and Pens - to label samples collected

C. Manpower

   a. Technical Personnel
      It is recommended to have at least five (5) technical personnel to compose a Team:
      1. Team Leader - serves as the overall supervisor of the Activity; ensures correctness of data collected.
      2. Leads Man - reviews the map submitted and helps in the identification of the transects
      3. Litter and Soil samples Collector - ensures that the right methodology in the collection of samples is used
      4. Documentation personnel - accomplishes the Meta Data Template; documents through photos and/or videos.
      5. Tree Assessment Personnel - identifies species present in the area; determines the proper DBH and Height Measurement.

   b. Laborers (through Spot Hiring)
      Laborers are hired through spot hiring to guide the technical personnel in the set-up of plots and collection of samples.

D. Cost of Sample Analysis
      1. Analysis of soil samples - includes the assessment of the soil bulk density and soil organic matter
      2. Cost for oven drying of plant tissue collected - fresh and oven dry weight are determined for the assessment

VI. REFERENCES

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