A Guideline to Methods of Carbon Measurement in Coarse Woody Debris in the Long-Term Plots Of Black Rock Forest

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Introduction

The canopy of the current Black Rock Forest dates back to over a hundred years. For nearly seventy-five years, the trees on certain long-term plots have been measured for their biomass and carbon content. Research has shown that after 100 years, the trees on these plots continue to sequester carbon in large amounts (Schuster et al., in review). The data collected on the long-term plots is used to estimate the total live aboveground biomass (AGB) of the forest. It is important to monitor AGB and the carbon stored over time, to be able to understand how the forest responds to the ever-increasing amount of carbon dioxide in the atmosphere. With this information, it will be possible to assess its role as a long-term carbon sink. However, the AGB and carbon it contains is only a fraction of the forest's total biomass and carbon. There is a significant amount of carbon in the forest's soil and woody debris as well. The three largest contributors to a forest's carbon pool are trees, soil, and woody debris. On average, the forest's living trees harbor an estimated 33% of the total carbon contained in the forest ecosystem, the soil 51%, and the woody debris 11% (Turner et al '93). The amount of carbon in coarse woody debris (CWD) has not been widely studied. Thus it is difficult to fully understand the evolution of the forest (?) outside of this data. It is the purpose of this project to estimate the amount of carbon in the CWD of the long-term plots as well as to develop a set of methods that can be used in the future and further developed. We designed our project to study only CWD. We decided not to study fine woody debris in light of the fact that its carbon content is universally recorded to contain only 1% of the forest's carbon; it is the CWD that is said to make up most of the 11%. Furthermore, in the interest of time, we found it more efficient to focus our project as specifically as possible.

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Methods

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We used the methods described by Mark Harmon in "Guidelines for Measurements of Woody Detritus in Forest Ecosystems" as guidelines for the project as we found his to be the most developed; for the most part they will resemble his methods. The fact that the plots cannot be disturbed posed a dilemma and necessitated many adaptations to Harmon's rules.

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Part 1: Volume

According to Harmon, it is necessary to obtain the mass of each specimen. Because we could not remove any of the specimens from the plots, it was impossible to directly weigh them. We therefore decided to use the formula **dv = m** where **d** = density, **v** = volume, and **m** = mass. The first part of the project involved obtaining the volume of every piece of coarse woody debris on the long-term plots.

We suggest making a spreadsheet to bring to the field with you containing the following categories: species #, species, log/snag/stump?, length/height, large, small and midpoint diameters, DBH, x and y coordinates, as well as a notes category for any additional information of importance (Fig 1). How about decay class?

Fig. 1

spec #	log/snag?	species	lth/ht	lg end D	mdpt D	sm end D	DBH	DC	x-coor (m)	y-coor (m)	Volume	notes

Methods for measuring the volume of CWD on undisturbed plots:

1) Establish plot dimensions by stringing measuring tape along the four sides. Designate which sides are to be your x-axes and your y-axes.

2) Determine if a specimen fits the course woody detritus definition (i.e. is 1.5 meters or longer and has a base diameter of at least 10 cm).

3) Determine whether the specimen is a log, snag, or stump, its decay class, and (if possible) the species. *If the specimen has a tag number, record this number.* Number the specimen and obtain the x and y coordinates of each. If it's a log, remember to get the coordinates for both the large and small end.

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4) Obtain and record the measurements according to Harmon's formula: diameters from the large end, small end, and midpoint, and the length or height. Can you put the different formulae in here? (Cylinder, ellipse, cone, etc.) Or, if there is another formula that will more accurately calculate the volume for the specimen, obtain

the appropriate measurements for that formula. If it is a snag of any decay class, and it has a tag number, record the tag number.

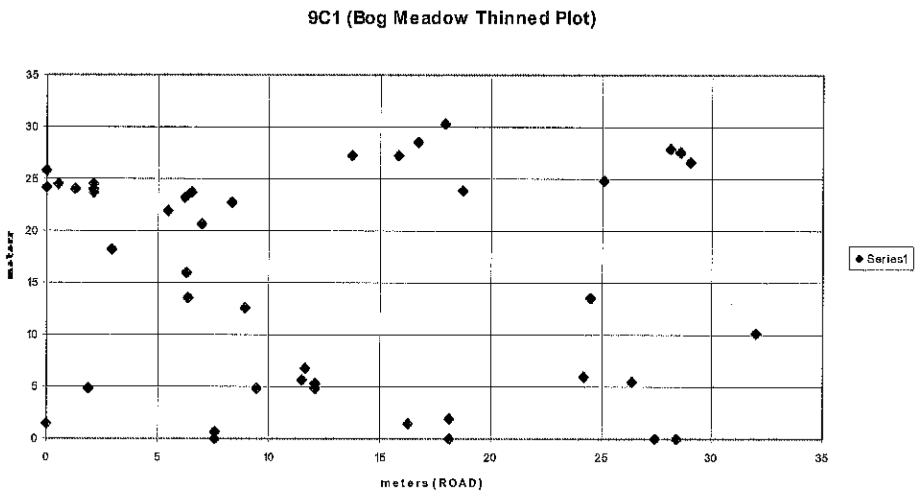
5) Calculate and record the volume of each specimen.

Repeat steps 2 through 5 for all other specimens within the plot.

Step 1

It may be necessary to return to the plots multiple times to fill in holes or double-check the data. In this case, having a map of each plot will be a great help. This is why it is necessary to extend a measuring tape from each of the four posts in order to create a grid. Once this is done, give each specimen x and y coordinates and a number. When the points are plotted on Excel and the lines between the dots are connected, it will be easy to return to the plots and locate each specimen (Fig 2). Due to the imperfect shape of the plots as well as the error in estimating a specimen's coordinates, the maps will not be precise or fully accurate. They are to facilitate your work; a map is very useful for finding specific specimens later should the need arise. These maps will be solely for your own benefit and need not be included in the final report.

Figure 2



Step 2

Harmon's definition of a piece of CWD is one that has a diameter of 10 cm at the large end (how about the small end?) and a length of 1.5 meters.

Step 3

Harmon classifies CWD under the categories of a snag, log, or stump. Snags are standing dead trees and any dead wood with an angle greater than 45 degrees from the ground. Logs are any dead wood at an angle less than 45 degrees from the ground.
The long-term plots are used for another study that is measuring the changing aboveground biomass (AGB) over time. Thus all the trees on each plot are tagged with a number, and recorded in Black Rock Forest's database. We were able to identify some snags on the plots if they weren't too decayed, and obtain their final live AGB before they died. If possible, *try to locate a tag number and record it.* Or, record the tag numbers of live trees around the specimen; using the data at BRF we were often able to identify the specimen's number using the numbers of other trees as well as such information as its species and diameter at breast height (DBH).

Stumps are dead wood created by a saw; there are very few stumps on the plots, as they are "undisturbed plots."

We found it necessary to come up with a classification system for stages of decay, because undoubtedly the further the decay, the less biomass and carbon in the specimen. Our decay classes run from 1 to 5, and the definitions are as follows: (how do these compare to other decay classifaction systems?)

1) mostly standing (snags), retains many fine twigs and branches and all the bark, died within last 2 years, resembles very closely live wood therefore use live tree equation for biomass

2) mostly standing (snags), retaining the main branches and most of the bark, dead for 2 – approximately 5 years

3) mostly on the ground (logs), retaining the cylindrical shape, all or most branches gone, bark mostly gone, wood mostly sound

4) on the ground (logs), may have an irregular shape, branches gone, bark gone, mostly soft, fragmenting wood

5) too decayed to measure: all soft, fragmenting wood, highly irregular shape, indistinguishable from the soil in some parts

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Step 4

Mostly, the CWD specimens can be measured as cylinders; it was the formula we predominately used. We also categorized some specimens as cones, ellipses and rectangles. In some cases we were undecided and used multiple methods of measurement in order to determine the most accurate method.

When there is a log or felled tree with multiple branches, we measured all of the coarse branches separately, and added their volumes to the volume of the basal area in order to calculate a total volume for the specimen.

If it is a snag of any decay class and has a tag number, you need only to record its tag number and diameter at breast height (DBH). With its tag number, you can obtain its biomass from the records and adjust it according to its decay class to account for the loss of branches, leaves, etc. If there is no tag number, and it is impossible to measure it any other way, record the DBH. With the DBH, species and decay class information, it will be possible to determine which tag number it is, and thus obtain and adjust its biomass. (see Part 3)

In the event of a leaning dead tree, we used the Pythagorean Theorem to calculate its length by deciphering the angle at which it was leaning, the distance from it to the tree against which it was leaning, and if necessary the height of the tree against which it was leaning.

Step 5

Harmon's formula for volume of a cylindrical specimen:
V = length(base area + 4(midpoint area) + top area)/6

Harmon's formula for a cone-shaped specimen:
V = length(base area + (base area * top area)^0.5 + top area)/3

Harmon's formula to determine a round diameter (in the event of an elliptically-shaped log):
Dround = square root(Dmax * Dmin)

Part 2: Density

Methods for obtaining densities of CWD:

1) Obtain samples of each species and each decay class, relative the data on your plots; the samples should be small enough to weigh on a scale.

2) Obtain and record the total wet weight and total volume of each sample

3) With a saw, take a portion of each sample. Obtain and record the wet weight and volume of each smaller portion and determine its percentage of the whole, according to both volume and weight.

4) Using the weight percentages obtained in Step 3, calculate and record the percent error for the volumes.

5) Dry the smaller portion in an oven. Continue to weigh the sample until its mass ceases to decrease. Record the dry weight.

6) Using the sample dry weight, calculate and record the total dry weight of each original sample.

7) Calculate and record the density of each specimen using the total dry mass and volume. Calculate and record average densities according to species and decay class.

Step 1

The second part of the project involved obtaining densities. Since (as stated before) we could not take samples from the plots, we took samples from around the plots from the five main species we encountered: red oak, chestnut oak, black birch, red maple, and yellow birch, as well as some unidentified samples and from those decay classes we encountered the species in on the plots. We never measured any specimens that were class 5; by definition, class 5 is too decayed to measure.

Step 2

We measured and weighed the samples to obtain volume and wet weight.

Step 3

We then proceeded to take a smaller piece from each sample. In order to calculate the density of each species relative to decay class, it is necessary to obtain each specimen's dry weight. The samples, however, will not fit into the oven. It is thus necessary to obtain the smaller portions of the samples in order to determine their dry weight and then the total dry weight of the specimen. We could have initially taken samples small enough to fit into the ovens, however, taking these smaller portions of the larger samples and determining their percentage of the entire specimen, according to volume and mass, provides a method to determine the accuracy of the volume calculations. The volume calculations are estimates, but the mass is much more accurate.

Step 4

By obtaining a percentage of the whole according to both volume and mass, the mass percentage being the most accurate, you will be able to determine the inaccuracy of the volume calculations and make an overall statement regarding the accuracy of the data for the project.

Determine the absolute value of the difference between the smaller portion's two percentages of the whole: the percentage relative to volume and the percentage relative to mass. This absolute value is <u>one way to estimate</u> the percent error. Determine and record an average percent error.

Step 5

Next, to eliminate the percentage of the weight that was water we dried the smaller samples in an oven (set to "4") and weighed them again. We repeated this process until their weight remained constant (some samples required as many as 6 dryings and weightings).

Step 6

By knowing the smaller samples' dry weights and each one's percentage relative to their respective larger sample, we were able to calculate the larger samples' dry weight ("total dry weight"), or mass, using the following formula: where x is the total dry weight

$$\frac{\text{Sample wet weight \%}}{100\%} = \frac{\text{sample dry weight}}{x}$$

Step 7

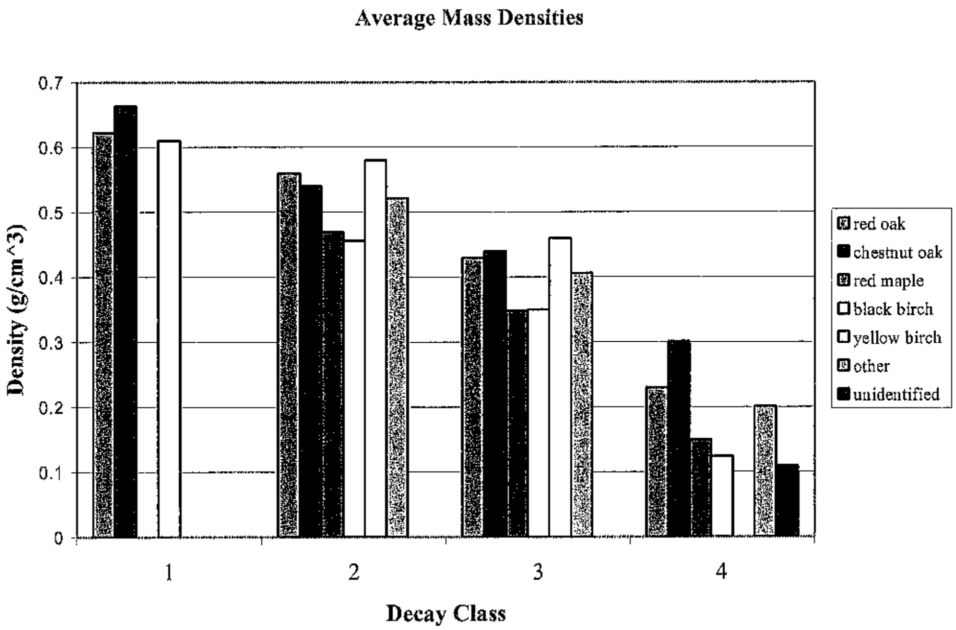
With these values along with the total volumes, we were able to calculate a density for each piece by using the formula: **d = m/v**. We categorized the densities according to decay class and species and then obtained an average for each category (a few outliers were removed). See Figure 2. To calculate additional density averages we needed but had been unable to obtain samples for, we used numbers from the USDA's 1940 Wood Handbook by Luxford and Trayer. See **Figures 3A, B.**

Figure 3A **Average Densities**

Red Oak	Chestnut Oak	Unident Oaks	Black Birch	Red Maple
DC 1 = 0.622	DC 1 = 0.664		DC 1 = 0.61	
DC 2 = 0.56	DC 2 = 0.54		DC 2 = 0.456	DC 2 = 0.469
DC 3 = 0.43	DC 3 = 0.44	DC 3 = 0.435	DC 3 = 0.35	DC 3 = 0.348
DC 4 = 0.23	DC 4 = 0.301	DC 4 = 0.266	DC 4 = 0.124	DC 4 = 0.15

Yellow Birch	Others/ Partial IDs	Unidentified
DC 2 = 0.58	DC 2 = 0.521	DC 4 = 0.109
DC 3 = 0.46	DC 3 = 0.4056	
	DC 4 = 0.2013	

Figure 3B



Part 3: Biomass and Carbon Content

With our average mass densities, we were able to calculate the biomass of every specimen on the long-term plots. To obtain carbon values in kilograms, we multiplied by 0.498. The carbon content of live tree biomass is 49.8% (need a better reference) and it is unlikely that this amount drops dramatically as a tree decomposes. Also, according to the USDA Forest Inventory and Analysis Program, the average carbon to biomass ratio in CWD is about 50%.

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For the snags whose biomasses we determined from the BRF databases, we had to make adjustments in order to account for the loss of leaves, and varying amounts of twigs, branches, bark, and stem relative to their decay classes. Thus, we calculated their dead AGB by subtracting the following from the live AGB numbers:

DC 1, leave as is (use live AGB)
DC 2: subtract **1.5%**;
DC 3: subtract **34.2%,**
DC 4: subtract **60%**

These numbers were obtained by taking averages from data from the Hubbard Brook Ecosystem Study: Forest Biomass and Production (Whittaker et al. '93).

When we had our final biomasses, we multiplied them by 0.498 to get the carbon content for each specimen. We added these together to get the total carbon in the CWD on each plot. We also calculated the carbon per hectare in CWD according to each plot. From BRF data we obtained the total biomass in kilograms per hectare of AGB according to each plot.

Carbon Percentages in Coarse Woody Debris in the 8 Long Term Plots of BRF

	AGB (kg/ha)	Total Carbon in AGB (kg)	Total Carbon (kg/ha)	Total BM of CWD (kg	Total Carbon in CWD (kg)	Total Biomass of CWD (kg/ha)	Total Carbon in CWD (kg/ha)	% of Total Carbon in CWD
MM C	309822.99	154291.85	462875.55	620.79724	309.157	15122.621	7531.065	1.63%
MM T	226557.66	112825.71	338477.15	2181.974	1086.623	53720.2	26752.66	7.90%
BM C	222637.56	110873.51	332620.52	1508.3151	751.1409	16169.138	8052.231	2.42%
BM T	212135.38	105643.42	316930.26	1343.0018	668.8149	13456.878	6701.53	2.11%
AB C	293279.27	146053.08	438159.23	3596.916	1791.264	40465.305	20151.72	4.60%
AB T	324531.76	161616.82	484850.45	2367.5774	1179.054	33075.056	16471.38	3.40%
WO C	176058.77	87677.27	263031.8	2498.938	1244.471	65422.197	32580.25	12.39%
WO T	221085.33	110100.49	330301.48	1651.3644	822.3794	40805.214	20321	6.15%
Average of Carbon in AGB = 123635.27 (kg/ha)				Average of Carbon in CWD = 17320.22895 (kg/ha)				Avg : 5.08%

We used this data to calculate the total ecosystem carbon per hectare according to each plot by first adding 18.5% of the biomasses to themselves because the equations used for biomass do not account for the stump and roots of the tree and therefore only account for 81.5% of the tree's biomass. Secondly we tripled the new total biomasses, because as stated before, trees make up for 33% of the total carbon in the forest's ecosystem (Schuster). Now we had the total carbon per hectare for each plot, and to get the CWD's percentage of the whole we divided the CWD carbon per hectare by the total plot carbon per hectare. We also calculated the average carbon per hectare in AGB on the plots as well as the average carbon per hectare in CWD.