*NIACS Briefing*

# Estimating Carbon Mass in Northern Forests

As forest landowners and managers begin to participate in carbon markets and registries, making accurate calculations of forest carbon stocks will be increasingly important. The purpose of this briefing to provide some guidance on how to make *estimates* of the amount of carbon in forest carbon pools (Table 1) for preliminary scoping activities; resources for making more accurate assessments will also be recommended. Carbon markets typically place the greatest emphasis on the amount of carbon in live trees; other carbon pools may or may not be measured for a particular program.

Table 1. Forest Carbon Pools

| |
|---|
| Live Trees: Live trees with a diameter at breast height (dbh) of ≥2.5 cm (1 in) and including stems, branches, foliage, and coarse roots (minimum root size varies; generally between 2 and 5 mm) |
| Standing Dead Trees: Stems, branches, and coarse roots of standing dead trees with a dbh ≥2.5 cm (1 in) |
| Understory Vegetation: All live vegetation (roots, stems, branches, and foliage) of shrubs and trees <2.5 cm dbh |
| Down Dead Wood: Woody material >7.5 cm in diameter on the ground, stumps, and coarse roots of stumps |
| Forest Floor: Organic material above the mineral soil, including woody material ≤7.5 cm in diameter, tree litter, humus, and fine roots in the organic layer |
| Soil: Belowground carbon including fine roots and all other organic matter not in other pools to a depth of 1 m |
| Harvested Wood: Long-term storage of wood and wood products including: wood and paper still in use that have not been destroyed or in landfills where only a small amount decomposes. |

From: Smith et al. (2006)

## Estimating Carbon Mass from Forest Inventory Data

Forest inventory data can be used to estimate carbon stocks and establish a baseline for accounting. The use of species-specific allometric equations that determine tree mass from inventory measurements (usually dbh and merchantable or total height) will provide the best estimates. Allometric equations have been developed at both the national (Jenkins et al. 2004) and regional (e.g. Hahn 1984, Host et al. 1989) level. When given a choice, high-quality regional biomass equations that have been developed for similar site conditions as the landowner's forest, including site productivity and tree species and size, are generally preferred. Because allometric equations may provide estimates of different tree parts, it is necessary to know whether the calculated value represents the entire live tree (including coarse roots) or only the aboveground (typically above a 1-foot stump) or merchantable portion, as this will determine what carbon pool is being measured and how subsequent calculations are performed.

Where allometric equations are not available or feasible, timber cruise estimates of merchantable volume can be converted to a common unit of cubic feet (Table 2). However, these conversions should be considered as rough estimates because of the differences in the log rules and methods used to compute merchantable volume as well as other factors. The derived values may have a lower degree of accuracy than using allometric equations to directly estimate cubic foot volume.

Table 2. Unit conversions

| | |
|---|---|
| 1 metric ton (Mg) | = 2,200 pounds |
| 1 cord (cd) | ≈ 72 $feet^3$ wood |
| 1 board foot (bf) | ≈ 6.5 $feet^3$ wood |
| 1 $meter^3$ | = 35.315 $ft^3$ |
| 1 Mg Carbon | = 3.67 Mg $CO_2$ |

Source: Reed and Mroz (1997)

Table 3. Ratio of total live tree volume to merchantable tree volume.

| Region | Hardwoods | Softwoods |
|---|---|---|
| Northeast[1] | 2.140 | 2.193 |
| North Central | 2.418 | 2.514 |
| Central | 2.651 | 2.601 |

From: Birdsey (1996) [1]Includes mid-Atlantic region

Region-specific ratios can used to estimate total live tree volume given merchantable volume (Table 3). Once total live tree volume is determined, it can then be multiplied by a conversion factor for the corresponding region and forest type (Table 4) to determine the carbon mass in live standing trees.

Table 3. Factors to convert tree volume (cubic feet) to carbon content (pounds).

| Region | Hardwoods | Softwoods | Region | Hardwoods | Softwoods |
|---|---|---|---|---|---|
| *Northeast & Mid-Atlantic* | | | *North Central & Central* | | |
| Bottomland Hardwoods | 14.96 | 17.99 | Aspen-Birch | 12.03 | 14.45 |
| Maple-Beech-Birch | 12.48 | 18.65 | Bottomland Hardwoods | 14.96 | 17.99 |
| Oak-Hickory | 12.16 | 19.76 | Maple-Beech-Birch | 12.09 | 17.90 |
| Pines | 12.29 | 16.87 | Oak-Hickory | 13.52 | 19.64 |
| Spruce-Fir | 12.00 | 16.31 | Pines | 13.69 | 16.47 |
| | | | Spruce-Fir | 11.41 | 14.92 |

The conversion factor equals the weight of a cubic foot of water (62.5 lb) multiplied by the specific gravity and the percent carbon for each forest type. From: Birdsey (1996)

## ADDITIONAL RESOURCES

*Methods for calculating forest ecosystem and harvested carbon with standard estimates for forest types of the United States (Smith et al. 2006; full citation above)*

This document provides complete details on how to determine the amount of carbon in forest ecosystems and wood products, including look-up tables that provide regional values for specific forest types. The estimates and methods in this report are consistent with national and international guidelines for greenhouse gas reporting. An electronic copy of the file can be obtained from the U.S. Forest Service through Treesearch <http://treesearch.fs.fed.us/> and electronic files of the tables are accessible from the USFS Northern Research Station at <http://www.nrs.fs.fed.us/carbon/tools/>.

*Carbon OnLine Estimator (COLE)*

The COLE program allows users to derive carbon estimates for a geographic area of interest by defining states and/or counties of interest. COLE queries USFS Forest Inventory and Analysis field data to determine growing stock volume and stand density, which are then converted to carbon estimates for forest ecosystem pools, including live and dead trees, understory, coarse woody debris, forest floor, and soil. <http://ncasi.uml.edu/COLE/>

*Forest Vegetation Simulator (FVS) Fire and Fuels Extension (FFE)*

Current FVS users can use FFE to produce carbon reports along with traditional FVS output. Management activities, including timber harvests and prescribed fire, can be assessed to evaluate potential effects on forest carbon pools, including live and dead trees, understory, down dead wood, and others. <http://www.fs.fed.us/fmsc/fvs/>

*How to estimate carbon sequestration on small forest tracts (Hoover et al. 2000; full citation above)*

This paper provides a more in-depth description of how forest carbon sequestration can be calculated at the management unit level and also examines how management activities can alter carbon pools. An electronic copy of the file can be obtained from the U.S. Forest Service through Treesearch <http://treesearch.fs.fed.us/>.

**EXAMPLE 1 – Calculation of Carbon Content from Inventory Data**
An inventory of a sugar maple-beech-yellow birch (northern hardwoods) stand in the northeastern US shows a standing volume of 3,500 bd ft and 30 cd per acre.

*Step 1 – Determine merchantable volume in cubic feet:*
3,500 bd ft/ac ÷ 6.5 $ft^3$/bd ft = 538.5 $ft^3$/ac     30 cd x 72 $ft^3$/1 cd = 2,160.0 $ft^3$/ac

*Step 2 – Convert merchantable volume to total volume:*
2,698.5 $ft^3$/ac x 2.418 = 6,525.0 $ft^3$/ac

*Step 3 – Calculate carbon content of total volume:*
6,525.0 $ft^3$/ac x 12.48 lbs C/ $ft^3$ = 81,432.0 lbs C/ac = 37.0 Mg C/ac

**EXAMPLE 2 – Calculation of Carbon Content for Harvested Volume**
From the standing volume in the previous example, 1,000 bd ft and 8 cd per acre were harvested.

*Step 1 – Determine merchantable volume in cubic feet:*
1,000 bd ft/ac ÷ 6.5 $ft^3$/bd ft = 153.8 $ft^3$/ac     8 cd x 72 $ft^3$/1 cd = 576.0 $ft^3$/ac

*Step 2 – Convert merchantable volume to total volume of harvest:*
729.8 $ft^3$/ac x 2.418 = 1,764.7 $ft^3$/ac

*Step 3 – Calculate carbon content of total harvest volume:*
1,764.7 $ft^3$/ac x 12.48 lbs C/ $ft^3$ = 22,023.5 lbs C/ac = 10.0 Mg C/ac

**References**

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**Briefing contributor**

M.K. Janowiak
Northern Institute of Applied Carbon Science
410 MacInnes Drive, Houghton, MI 49931
**www.nrs.fs.fed.us/niacs/**