## TITLE: Carbon Estimation From Soil to Tree Tops in the U.S.

**LOCATION:** Entire U.S.

**DURATION**: 1 year of 1-year project **FUNDING SOURCE:** Base EM

**PROJECT LEADER**: **David C. Chojnacky**, Forest Inventory Research Enterprise Unit, USDA Forest Service, Washington, DC dchojnacky@fs.fed.us (703) 605-5262

**COOPERATORS: Michael C. Amacher**, Research Soil Scientist, Rocky Mountain Research Station, Logan, UT mamacher@fs.fed.us 435-755-3560; **Stephen P. Prisley**, Associate Professor, Virginia Tech University, Blacksburg, VA prisley@vt.edu 540-231-7674

**PROJECT OBJECTIVES:** (1) Publish mass/carbon estimates of forest floor (duff, litter, down woody materials [DWM], and understory) for the eastern U.S. that were developed by linking Forest Inventory and Analysis (FIA) phase 3 (P3) DWM data and phase 2 (P2) plot data; (2) extend methodology from part 1 to the entire U.S. and include soil carbon; and (3) combine soil and forest floor carbon estimates with FIA P2 tree data to obtain a complete assessment of forest carbon from soil to tree tops.

**JUSTIFICATION**: Our proposal focuses on carbon as a key link for evaluating the extent, severity, and/or causes of a variety of forest health problems at various scales. Carbon is critical for healthy forests and forms a useful metric that integrates the life cycle of a forest—from live and dead trees to down and decomposed materials and soil carbon. FIA P3 and P2 plots collect all the necessary pieces for a soil-to-forest carbon assessment but integrating these data for total forest carbon estimates is no trivial task—particularly with all the recent changes and data base developments in the FIA program. The proposed project leader and cooperators have experience integrating P2 and P3 data and feel there is a compelling need to further investigate ways to facilitate the use of existing FHM data for carbon estimation, expanding results from previous regional work to a national scale.

**DESCRIPTION:**

**a. Background**: From previous Forest Health Monitoring grants and other funding, we have linked P2 to P3 data for duff, litter, and down woody materials through regression models for estimates of mass and carbon at the P2 scale. These results were submitted to *Forest Ecology and Management* (Chojnacky and others, in preparation) but are pending revision and submission elsewhere, in part because such work with broad-scale corporate data (like FIA) whose collection was not under direct project control causes problems with traditional scientific publishing paradigms. Further funding support is being sought to deal with these issues and publish the completed results (objective 1).

Additional raw lab data also are available from previous duff and litter studies, to enable us to improve duff and litter carbon estimates for better inference from FHM data. For example, in our specially collected data (2005) we observed that duff layers—particular in hardwood forests near metropolitan Washington, DC—may be declining supposedly due to exotic earth worm activity; ability separate duff from litter data (with our unanalyzed data) might be useful for documenting duff or litter decline. Therefore, analyzing our 2005 data might improve forest floor estimates for objectives 2 and 3.

We would also like to explore an enhancement to FHM soils data. The FHM soils protocol samples to a depth of 20-cm but much of the literature reports soils carbon to 100 cm. We would also study the feasibility of extending the FHM soil carbon estimates to 100 cm by examining

the Natural Resources Conservation STATSGO data base (with which collaborator Prisley has worked) for estimating forest soil carbon to 100 cm for U.S. forests. The might add to improved soils estimates for objectives 2 and 3.

The graph shown in fig. 1 was presented at the 2006 meeting of Ecological Society of America, where there was much interest in why the total carbon estimates are not available for the western U.S—particularly since the Forest Service has collected the data. The DWM numbers in the chart were based on the work mentioned above (pending publication). Tree carbon was based on regional equations (Jenkins and others 2003) applied to the old Eastwide FIA data base. Soil carbon was just a preliminary analysis done for the ESA meeting by using a methodology similar to that used for DWM estimates. We would like to look at updating the chart results for the entire U.S. from the most recent FIA data with well-documented linkage models between P3 and P2 data (objectives 2 and 3).

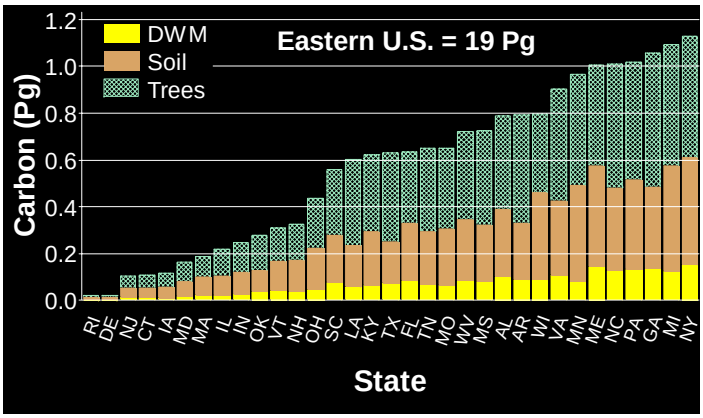
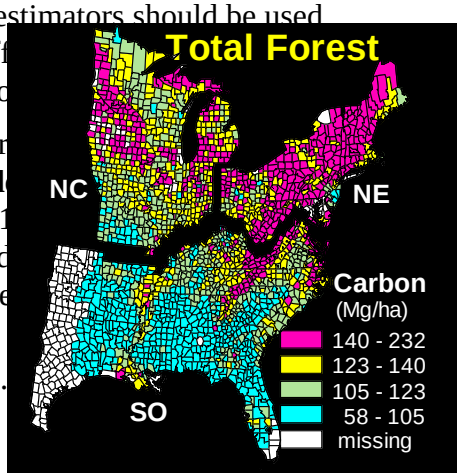



Figure 1. Estimated carbon in soil, trees, and down woody materials in the eastern U.S., by state.

**b. Methods:** Objective 1 would involve manuscript revision, journal evaluation, and standard submission procedures. Objectives 2 and 3 would entail two critical elements: (1) obtain necessary FIA P2 and P3 data and (2) link P3 data to P2 for the broadest-scale inference possible. We will have little control over data access but if the NIMS-FIADB database continues to evolve as it has this past year, a national carbon assessment at some scale is possible. We say "some scale" because with FIA's switch to annual inventory, we will likely decide on a state-by-state basis whether to use annual P2 data for states with partially completed inventory cycles or default to the last periodic inventory. If the annual inventory data become too cumbersome to deal with, we will default to Eastwide and Westwide data for final application of results.

The linking of P3 and P2 will also be affected by data availability because all available P3 data must be matched with P2 for model development. Our aim is to use P3 data from 2001 onward but this again will depend upon what is available in NIMS-FIADB around March 2007. Regression methodology will be used as a first step for linking P3and P2 but consideration will be given to other methods pending availability of variables. Previous modeling explained only 15 to 30 percent of the variation, at best, but a full suite of P2 variables rarely was available.

Because P3 plots are a systematic subset of the P2 plot grid, ratio estimators (which are equivalent to regression estimators with $R^2$=0) can be used should problems be encountered linking P2 and P3 data with regression models. For FIA data, the value of regression estimators over ratio estimators is related to scope of inference. Ratio or low $R^2$ estimators should be used only for state-level or regional estimates; estimators with higher $R^2$ off
smaller area estimation for finer scale county or management area resc




**c. Products: (1) Publication** of results from previous FHM funded pr
(Chojnacky and others, in preparation). **(2)** Regression or similar **mod**
estimating carbon from P2 plots for soil (at least 0–20 cm, perhaps 0–1
materials, and all trees (including roots). **(3)** Equations will be applied
database for county-scale **mapping** similar to preliminary work for the

results will include entire U.S. (including Alaska, Hawaii, and Puerto Rico if data are available).
**(4) Presentation and publication** of new results as funding permits, depending on what complications are encountered with data acquisition or editing/ compilation issues.

## d. Schedule of Activities:

| | |
|---|---|
| Publish complete analysis on down woody materials for Eastern U.S. | Feb 2007 |
| Complete analysis on previous special data collection for duff and litter | Mar 2007 |
| Obtain latest FIA P2 and P3 data for soils, down woody materials, and tree measurements for entire U.S. | Jun 2007 |
| Construct models for linking P3 and P2 data | Aug 2007 |
| Map county-scale carbon results | Sept 2007 |
| Draft manuscript(s) | Oct 2007 |

## f. References:

Figure 2. Total forest carbon, eastern U.S.

Chojnacky, D.C.; Amacher, M.C.; Perry. C.H. 2005a. Estimating carbon in forest-floor duff and litter from FIA data. Poster presented at: 11th Annual Forest Health Monitoring Working Group Meeting. Miami, FL, Jan. 2005; http://fhm.fs.fed.us/posters/posters05/est_carbon_fiadata.pdf

Chojnacky, D.C.; Amacher, M.C.; Perry. C.H. 2005b. Monitoring the forest floor for duff and litter carbon sequestration. Presented at: Sustainable Forestry In Theory and Practice: Recent Advances In Inventory and Monitoring, Statistics and Modelling, Information and Knowledge Management, and Policy Science. Edinburgh Scotland, UK, April 2005.

Chojnacky, D.C. 2005. Estimating forest-floor duff and litter from FIA data in eastern U.S. Presented at: Southern Mensurationists Conference. Wilmington, NC, July 2005.

Chojnacky, D.C.; Amacher, M.C. 2005. Use of FIA P3-soils data for estimating carbon in forest-floor duff and litter: experiences and data availability. Presented at: 7th Annual Forest Inventory and Analysis Symposium. Portland, ME, October 2005.

Chojnacky, D.C.; Amacher, M.C. 2006a. Estimating carbon in forest-floor duff and litter from FIA data, 2005 update. Poster presented at: 12th Annual Forest Health Monitoring Working Group Meeting. Charleston, SC, January 2006.

Chojnacky, D.C.; Amacher, M.C. 2006b. From soil to trees: estimating carbon with FIA data in eastern U.S. forests. Presented at: Ecological Society of America 91st Annual Meeting. Memphis, TN, August 2006.

Chojnacky, D.C.; Myers, J.A.; Amacher, M.C.; Gavazzi, M.J.; McNulty, S.G..[*in preparation*]. Estimating forest floor mass and carbon in eastern U.S. forests.

Jenkins, J.C.; Chojnacky, D.C.; Heath, L.S.; Birdsey, R.A. 2003. National-scale biomass estimation for United States tree species. Forest Science 49(1): 12–35.

## COSTS:

| | Item | Requested FHM EM Funding | Other-Source Funding* | Source |
|---|---|---|---|---|
| **YEAR 2006** | | | | |
| **Administration** | Salary | 33,275 | | |
| | Overhead | 6,225 | | |
| | Travel | 2,000 | | |
| **Procurements** | Contracting/students | 7,500 | | |
| | Equipment | | | |
| | Supplies/Misc | 1,000 | | |
| **TOTAL** | | **50,000** | | |