ESTIMATING FOREST FLOOR FUELS IN EASTERN U. S. FORESTS

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1. INTRODUCTION

The Forest Inventory Analysis (FIA) program (U.S. Department of Agriculture, Forest Service) systematically samples the nation's forests and currently measures variables related to down woody material (DWM) on a subsample of its plots in the third phase of a 3-phase sampling design. This paper focuses on: (1) compiling estimates of DWM within limitations of existing FIA measurements; (2) modeling available data for spatial application of the DWM to FIA's large sample of phase-2 plots across the eastern U.S.; and (3) discussing potential improvements to FIA measurements that would enhance estimates of DWM across the region.

Keywords: down deadwood, coarse woody debris, CWD, Forest Inventory and Analysis (FIA), carbon

2. SCIENCE AND TECHNOLOGY SUMMARY

Data and Methods

The Forest Inventory and Analysis (FIA) program of the U.S. Department of Agriculture, Forest Service, conducts annual surveys of all forest land within the U.S. by using a systematic design of rotating panels where plots are remeasured on 5- to 10-year cycles. The FIA design includes three phases: P1, a remote sensing phase for determining the forest land sampling frame; P2, a systematic grid across all forest land at about 5 km-grid intervals for field sampling; and P3, a 1/16th subsample of phase 2 for more intensive forest health and ecology measurements. FIA data for this study included: (1) P3 down woody material (DWM) measurements sampled from 771 plots in 2001 and 2002; (2) P2 tree measurements from the same plots sampled from 1988 to 2002, of which 68 percent was older than 2001; and (3) duff and litter data—also from P3 plots but part of soils survey sampling.

DWM Definitions

Foresters commonly separate the forest floor or down woody materials (DWM) into 3 successive layers: (1) branches and logs (fine and coarse woody material); (2) litter; and (3) duff. Live and dead understory shrubs and herbs can also be included with forest floor DWM measurements. Duff includes the dark, partly decomposed organic material (*unrecognizable* plant forms) above mineral soil. On top of duff is litter, which includes *recognizable* plant parts such as leaves and flowers but not branches. Branches are separated into 3 size classes of fine woody material (FWM)—<6, 6–25, 26–76 mm diameter—corresponding to 1-hour, 10-hour, and 100-hour fire fuel classes. Coarse woody material (CWM) includes all logs >76 mm diameter and corresponds to the 1,000-hour fuel class.

The objective of this work was to link P3 to P2 data by modeling DWM components as functions of FIA plot variables and auxiliary climate data, and to evaluate this experience for making recommendations to FIA's P3-to-P2 data linkage.

This work started in 2001, and details of compiling DWM data have already been published (Chojnacky and others 2003, Chojnacky and others 2004). The compilation for most DWM components involves summing material sampled along transects by using standard line-intercept methods. However, transects can be of variable lengths because FIA subdivides plots along forest condition boundaries within plots, which greatly complicates the compilation. The complexity is due in part to incomplete FIA database structure where exact transect lengths are not logically recorded along with DWM measurements. Therefore, complex data merging is needed to put data pieces back together.

Because initial models have already been developed for 2001 DWM plots (Chojnacky and others 2003, Chojnacky and others 2004), this study merely updates these with an additional 190 plots sampled in 2002 from the South for coarse woody material (CWM), fine woody material (FWM), and understory vegetation. The 2002 plot data—unlike 2001 data—included all raw P2 plot measurements for fuller exploration of P3-to-P2 plot linkage. Updated modeling of 2001 duff and litter data was not done because better duff and litter weigh samples have since become available for FIA P3 soils sampling. Methods for modeling duff and litter data will be reported elsewhere (Chojnacky and others [in preparation]); only results of the models will be reported here.

Updated modeling of CWM, FWM, and understory vegetation reconsidered previous variable selection from stepwise regression; the same variables generally were selected again except for a few changes. Variable choices generally were statistically significant (at the 0.05 probability level) but some arbitrary restrictions were made to be more or less consistent with previous variable selection. Because none of the models explained more than 20 percent of the variation ($R^2 < 0.20$), it seemed pointless to make major model variable changes based 1 or 2 percent changes in the R^2-statistic. Final models estimated mass of DWM components.

For the duff and litter model, carbon instead of mass was estimated because carbon was more correlated to available predictor variables than was mass. However, carbon-to-mass conversions also were developed. One difference from previous work was that duff and litter were combined for modeling because FIA does not separate duff from litter layers when collecting these samples in field. However, a ratio model was developed for separating duff from litter, using those few samples that were either all litter or mostly duff.

The 2002 data (including the 190 plots from the South with a full suite of P2 tree variables) were used to explore model improvements. Likewise, a full suite of P2 variables were available for the duff and litter modeling.

Results

Table 1 includes the updated equation parameters for estimating mass (Mg/ha) for CWM, 3 sizes of FWM, and understory vegetation. The models are functions of data from either FIA P2 plot-level variables or 30-year averages of county-scale climate variables (Climate Source 2001). The climate data were available in 4-km grid cells, and the cell that coincided with county centroid was applied to all FIA plots within that county. Model relationships were rather weak, with R^2 statistics ranging from 0.04 to 0.17 (table 2).

Table 1—Regression model for estimating coarse woody material (CWM), fine woody material (FWM), and shrub/herb understory for eastern U.S.

Material (Mg/ha)	Regression Coefficients										
	β_0	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9	β_{10}
CWM	-12.4361	6.5882	0.0485	0.1412	0	0	0.2025	0	0	0.0496	0
FWM (25-76 mm)	-14.4497	0	0	0.0407	0	-0.0598	0.3644	-4.0305	-2.3623	0	0
FWM (6-25 mm)	1.7655	0	0.0101	0	0	0	0	-0.2753	0	0	-0.0052
FWM (< 6 mm)	0.5523	0	0	0	0.1082	0.0067	0.0074	0	0	0	-0.0007
Shrub/ Herb	7.5887	0	-0.0217	0	0	0.0283	-0.0307	0	-0.6398	-0.0121	0

$$\text{Material} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_{10} X_{10}$$

where

Material = dry weight biomass of down woody and understory components (Mg/ha)

X_1 = proportion of dead trees (≥ 12.7 - cm dbh) tallied on FIA plot

X_2 = total basal area of live trees (≥ 12.7 - cm dbh) on FIA plot (m^2/ha)

X_3 = quadratic mean diamter of live trees (12.7 - cm dbh) tallied on FIA plot (cm)

$$X_4 = \begin{cases} 1 \text{ if forest typ e is coniferous forest} \\ 0 \text{ otherwise} \end{cases}$$

X_5 = longitude of county center assigned to all FIA plots in that county (decimal degrees)

X_6 = latitude of county center assigned to all FIA plots in that county (decimal degrees)

$$X_7 = \begin{cases} 1 \text{ if plot is located in north central state (IA, IL, IN, KS, MI, MN, MO, NB, ND, SD WI)} \\ 0 \text{ otherwise} \end{cases}$$

$$X_8 = \begin{cases} 1 \text{ if plot is located in northeast state (CT, DE, MA, MD, ME, NH, NJ, NY, OH, PA, RI, VT, WV)} \\ 0 \text{ otherwise} \end{cases}$$

X_9 = average number of days rain or snow fell for county center assigned to all FIA plots in that county (No./yr)

X_{10} = average monthly - mean dew point temp erature of county center assigned to all FIA plots in that county (° C)

Table 2—Regression model statistics for CWM, FWM, and shrub/herb, eastern U.S.

Material	Mean (Mg/ha)	n	R^2
CWM	5.6	759	0.17
FWM (25-76 mm)	4.1	746	0.06
FWM (6-25 mm)	1.7	756	0.04
FWM (< 6 mm)	0.3	756	0.07
Shrub/Herb	2.2	758	0.15

Results for modeling duff and litter were taken from another concurrent study (Chojnacky and others [in preparation]): where carbon was modeled:

$$\text{carb}_{dl} = 14.0108 - 0.9053\,Y_1 + 1.3817\,Y_2 - 3.5278\,Y_3 - 5.2229\,Y_4 + 1.8980\,Y_5$$

where

carb_{dl} = duff and litter carbon (Mg/ha)

Y_1 = average monthly mean dewpoint temperature of county center assigned to all FIA plots in that county (° C)

$$Y_2 = \begin{cases} 1 \text{ if FIA stand size class} = 3 \text{ (9 - 20 in. for conifer or 11 - 20 in. for hardwood)} \\ 0 \text{ otherwise} \end{cases}$$

$$Y_3 = \begin{cases} 1 \text{ if FIA plot in county of non mountinous Oceanic Eastern Broadleaf province (221)} \\ 0 \text{ otherwise} \end{cases}$$

$$Y_4 = \begin{cases} 1 \text{ if FIA plot in county of non mountinous Continental Eastern Broadleaf province (222)} \\ 0 \text{ otherwise} \end{cases}$$

$$Y_5 = \begin{cases} 1 \text{ if FIA plot in county of Outer Coastal Plain Mixed Forest province (232)} \\ 0 \text{ otherwise} \end{cases}$$

This model explained 25 percent of the variation (R^2=0.25) for 805 plots sampled in southern and northeastern U.S. In addition to FIA and climate variables, ecological province was used, which has been cross-walked to county scale for use with FIA data (Rudis 1998). Duff and litter carbon can be converted to mass by multiplying times 3 (Chojnacky and others [in preparation]).

The mean calculated DWM for eastern U.S. FIA plots was 27.0, 6.1, 6.0 and 2.2 Mg/ha for duff/litter, fine woody material, coarse woody material, and shrub/herb cover, respectively. The total of all DWM components accounted for about 25 percent total aboveground forest mass (160 Mg/ha), which included 119 Mg/ha for trees.

Because models predicted rather poorly, it seemed worthwhile to explore model improvement with all available variables and not limit to only those variables available for application to FIA P2 data. For example, the inclusion of some rough classification of "low or high" amount of CWM on each FIA plot could greatly improve the model (from explaining 17 percent to over 50 percent of variation). Likewise, the duff and litter model can be improved (from explaining 25 percent to explaining over 60 percent of variation) by adding duff and litter depth measurements as predictor variables.

Conclusions

Our method to compile DWM for the nearly 100,000 FIA plots in the eastern U.S, using crude regression models to link available DWM data the FIA plots, could be improved if FIA made some simple changes. First, better design of FIA's database structure for DWM is needed to maintain transect lengths throughout data tables for all data collected; at present, the combination of subsetting plots (and transects) for changing forest conditions ("mapped design") and incomplete database structure requires much programming to compile Mg/ha estimates for DWM data. Second, more study is needed to identify stronger covariates for modeling that could be easily measured on P2 plots. Lastly, FIA could provide more complete and timely availability of P3 data and associated P2 data collected on those plots. Such improvements would enable research energy to focus on data analysis rather than data issues. For example, the data for this study were 75 percent available (from previous compilation efforts), yet data acquisition and preparation for the additional 25 percent consumed two-thirds of total study time.

3. REFERENCES

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