Estimation, Analysis, and Reporting of the Down Woody Materials Indicator

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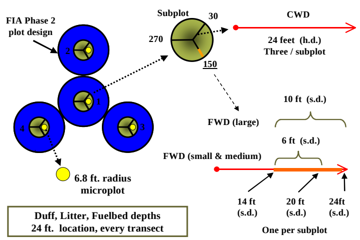
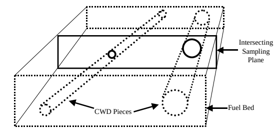
Sample Protocol Theory



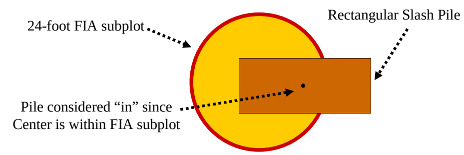
Plot-level Sample Design



The fundamental concept of transect sampling is that sampling of down woody debris occurs along sample planes defined by transect lines. One of the advantages of the transect sampling techniques is that the total volume in a sampled area can be estimated by measuring only the diameter or cross-sectional area of a down woody piece at the point of interception by the transect line. Based on this premise, there have been a number of refinements and field applicability alterations for transect sampling that are reflected in the methods employed by the FIA program.

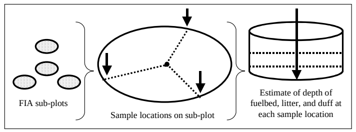
One point of considerable confusion regarding transect sampling is that the properties of the estimators can be derived using both design- and model-based inference. Design-based: Kaiser (1983), Gregoire and Monkevich (1984), Gregoire (1998), Gregoire and Valentine (2003), and Williams and Gove (2003). Model-based: Warren and Olsen (1964), de Vries (1973), Brown (1974), Van Wagner (1982), and Bell et al. (1996). (For citations please see citation list attached below poster)

Transect Sampling



It can be assumed that slash piles are merely conglomerations of woody debris where usage of transect sampling would be impractical and hazardous. If woody debris is packed into a shape sufficient for ocular delineation, then the dimensions of the shape may be recorded along with an estimate of the packing ratio (an estimate of the ratio of wood volume to total volume). Bulk density estimates based on the species composition from transect sampled CWD and estimates of packing ratio may be used in slash pile volume equations to provide estimates of tonnage for sampled slash piles.

Fixed-Area Sampling



The sampling protocol for the down woody material components of litter, duff, and fuelbed involves sampling their depth at various points within FIA sub-plots. Duff, litter, and fuelbed are assumed to be strata of the forest floor such that multiple measurements of their depth may adequately estimate their tonnage and volume with appropriate weight conversion factors.

Simple Random Sampling

Estimation Procedure Examples

Inference for the FWD and CWD may model-based. The assumed model structure is that log locations are distributed within the population according to a uniform distribution and the orientation of each log is also in accordance with a uniform distribution. Thus, both the orientation and location of pieces of FWD and CWD within the population of interest are assumed to be completely random. Each transect that makes up the Y-plot is treated as a non-informative sample, so the four Y-plots that comprise an FIA plot are viewed as a sample of 12 transects for CWD.

One FWD Estimator

$$\bar{y} = (kfac)(\pi^2/8L)\sum_{i=1}^{n} d_i^2,$$

where y is volume per unit area, k is a constant that accounts for unit conversions, f is a constant for converting the estimates to per-acre or per-hectare values, L is the total length of the transect, a is the non-horizontal (lean) angle correction factor for the piece of FWD, c is the slope correction factor, d is the diameter of the piece at the point of intersection, and n is the number of pieces intersected by the transect.

One CWD Estimator

$$\bar{y} = \frac{f\pi}{2L}\sum_{i=1}^{n}(y_i/l_i),$$

where y is a model-unbiased estimator of the attribute of interest per unit area, L is total transect length, y is the attribute of interest for CWD piece, l and is the length of the piece i, and f is used to convert the estimate into a per-acre of per-hectare value.

Fine Woody and Coarse Woody Debris

It is assumed that duff, litter, and fuelbed depths are sampled using simple random sampling (SRS), even though the 12 sampling locations are systematically arranged. The estimate of the mean depth, and its associated variance estimator, are given by:

$$\bar{y} = \frac{\sum_{i=1}^{n_f} y_i}{n_f}, \qquad s_y^2 = \frac{\sum_{i=1}^{n_f} y_i^2 - \frac{(\sum_{i=1}^{n_f} y_i)^2}{n_f}}{n_f(n_f-1)},$$

where y_i is the depth at the ith point, and n is total number of points falling in the forested condition.

In order to determine litter and duff weights-per-area estimates, the estimators of mean depth are multiplied by fixed conversion factors to estimate the number of tons per unit areas,

$$\bar{Y}_{DLF} = \bar{y}(BD)(k),$$

where is the y mean depth of duff or litter, BD is bulk density (i.e., weight per unit volume, lbs/ft³), and k is unit-area conversion values (21.78 for tons/acre with depth in feet) (10,000 for kg/ha with depth in meters).

Duff, Litter, and Fuel bed

Since shrubs and herbs are estimated using SRS, mean and variance estimators may be applied in order to determine mean values (i.e. mean maximum live shrub height) per sample unit (condition class or plot-level). As an alternative to reporting mean shrub/herb height and coverage, all these measurements may be incorporated into a single measure of fuel complex height known as the integrated fuel depth. Integrated fuel depth scales the maximum height of all shrub/herb components based on its associated coverage then determines a mean value:

$$\text{Integrated Fuel Depth} = \sum_{i=1}^{n}(h_i(c_i/100))\}/\{(\sum_{i=1}^{n}(c_i))/100\}$$

where n is the number of shrub/herb components, h_i is the height of the ith component, and c_i is the coverage of the ith component.

Shrub and Herbs

Slash or residue pile volumes and weights are determined through estimators provided by Hardy (1996). The first step in estimation is to determine the net volume of the slash pile based on the pile's shape and associated sampled dimensions. Estimates of a pile's net volume may be converted to an estimator of pile weight using:

$$y^{pile} = Vol(BD)(P)(k)$$

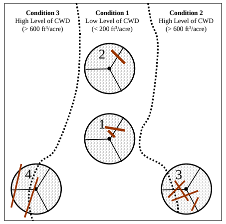
where Vol is the net volume of the pile, BD is bulk density (mass per unit volume, i.e., lbs/ft³), P is the packing ratio or density of the slash pile, and k is a unit conversion constant.

An estimator of the pile weight per unit area for the slash piles found on one FIA sub-plot is

$$\bar{y}^{pile} = \frac{\sum_{i=1}^{n} y_i^{pile}}{a_f},$$

where a_f is the area of the subplot covering forested land in the appropriate units, and y_i^{pile} is the pile weight of the slash pile on the subplot, and i – th is the number of slash piles on the subplot.

Residue Piles



Depiction of FIA plot that covers three different forest conditions. Sub-plots 1 and 2 fall completely within condition class c=1. Sub-plot 3 straddles condition classes c=1 and c=2. Sub-plot 4 falls predominantly in condition class c=1, but a small portion falls in condition class c=3.

First, determine the volume of each piece of CWD.

V ft
0.56
10.14
4.61
1.34
17.15
4.66
1.64
85.34
8.48

The next task is to calculate the total transect length within each condition. This yields

$$\sum_{j=1}^{k(1)} L_j(1) = 224.9, \sum_{j=1}^{k(2)} L_j(2) = 59.5, \quad \text{and} \quad \sum_{j=1}^{k(3)} L_j(3) = 3.4.$$

All that remains is to estimate the volume per acre of CWD on each condition (see CWD estimators), where the per unit area conversion factor is f=43,560, and the length of each pieces, l_{ij}, is given in appropriate data tables. This yields cubic foot volume per acre estimates of $Y(1)$=303.7, $Y(2)$=931.4 and $Y(3)$=30,130.

Population Estimation Example

Analytical Procedure Examples

State	County	Plot	1-hr *	10-hr*	100-hr*	1000-hr*	Duff*	Litter*	Herb/ Shrub (ft)	Slash*	Total Tons*
X	17	385	0.2	0.5	1.9	2.6	5.3	0.7	1.0	0	11.2
X	31	434	0.4	0.5	0.7	1.0	5.6	1.9	0.3	0	10.1
X	31	436	0.5	1.1	2.6	5.0	3.5	1.6	1.3	0	14.3
X	31	439	0.7	1.4	4.1	4.6	9.1	3.3	0.7	0	23.2
X	31	442	0.1	1.3	2.6	3.0	4.9	2.2	0.5	22.7	36.8
X	31	446	1.1	2.6	3.0	5.5	15.6	2.1	5.6	0	29.9
X	31	109	0.9	1.5	9.3	10.4	3.8	3.3	0.8	0	29.2
X	31	120	1.3	0.8	5.5	1.8	4.7	1.5	0.4	0	15.6
X	31	900	0.4	1.4	3.3	3.2	17.8	1.9	2.8	0	28.0

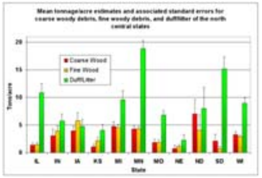
Plot-level core tables provide application and summarization of DWM estimators at the plot-level. Core tables may be produced for three science disciplines: fire, carbon, and wildlife. If analysts prefer use of alternative DWM estimators or wish to add their own refinements to the DWM processing algorithms, then analysts will need to process data independently. There is no single way to process DWM data allowing analysts the freedom to pursue their own scientific explorations.

Plot-Level Table Output

State	County	CWD (tons)	CWD (ft³)	FWD (tons)	Duff (tons)	Litter (tons)
27	12	1287	112,012	895	1501	1203
27	29	2901	189,051	1201	3501	899
27	8	125	70,651	50	502	38
27	21	1802	151,232	895	2003	902
18	10	978	12,523	236	1002	365
18	21	45	895	12	85	52
18	13	1687	201,235	1211	1232	987
18	40	1251	107,235	781	1787	685
29	17	3251	201,563	1200	3001	1023

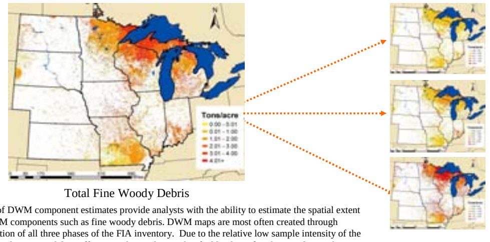
Expansion of DWM plot-level estimates to larger area estimates (i.e., super-county, state, or regional-scales) produces population-level core tables. These type of core tables are of interest to analysts seeking single estimates of DWM components for delineated areas as opposed to the distribution of plot-level values as provided by plot-level core tables.

Population-Level Output



Graphical summarizations of core tables provide more "user-friendly" outputs for interpretation of DWM estimates. The DWM Indicator uses a sampling intensity sufficient to indicate the current status and trends in DWM components across large regions of the US, thus table summarizations should be at larger scales than typically found in state-level phase two inventory reports.

Graphical Output

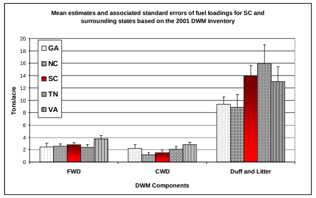


Total Fine Woody Debris

Maps of DWM component estimates provide analysts with the ability to estimate the spatial extent of DWM components such as fine woody debris. DWM maps are most often created through integration of all three phases of the FIA inventory. Due to the relative low sample intensity of the DWM indicator, modeling efforts may be used to predict fuel loadings for phase 2 plots with non-forest masking provided by phase 1 imagery.

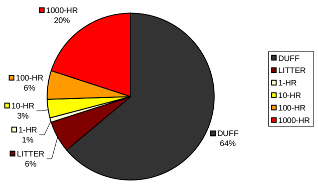
Map Analyses

Comprehensive Reporting Examples



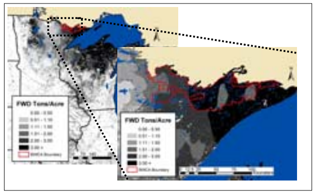
Due to the lingering effects of Hurricane Hugo nearly 11 years prior to this inventory, one might expect a significant difference between SC's coarse woody material tonnages compared to neighboring states. However, based on the preliminary DWM assessment, the tonnage of CWD in SC forests does not significantly vary from that of neighboring states.

South Carolina



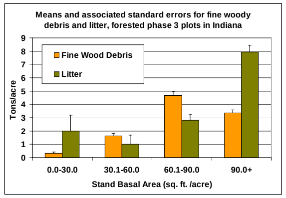
Due to a down woody materials phase 3 sampling intensification in the Allegheny National Forest (ANF), there is sufficient sample size to adequate estimate the fuel components of the forest The phase 3 inventory in the ANF indicates that the majority of fuels are found in the duff layer with fine woody fuels and litter only contributing minimally.

Allegheny National Forest



Down woody material sampling intensification provides multi-scale mapping capability allowing users to zoom in and out of areas of concern.The base sampling intensity of down woody materials provided by the FIA program allows construction of a regional map of FWD, while sample intensification in the Boundary Waters Canoe Area (BWCA), allows creation of a smaller scale fuels. The base phase 3 sample intensity of the FIA program, combined with sample intensification efforts, may empower local-scale decision makers with an empirical basis for fire-hazard mitigation planning.

Boundary Waters Canoe Area Wilderness



Combining phase 2 stand attributes with phase 3 fuel estimates allows examination of fuel:stand dynamics. For Indiana, there is a gradual increase in litter and fine woody debris fuel loadings with increasing stand densities. This trend is a typical result of stand development patterns.

Indiana

For more information and data for this FIA Indicator please visit the web site: http://www.ncrs.fs.fed.us/4801/national-programs/indicators/dwm/