

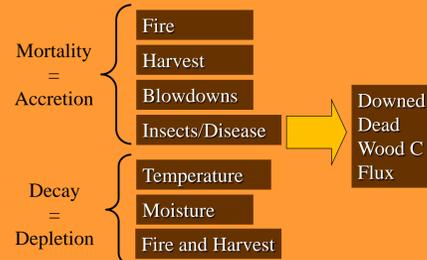
# Does the Nation's Down Woody Materials Inventory Have the Power to Detect Carbon Flux?



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## Detection of Dead Wood Carbon Flux

Flux of downed dead wood carbon (C) pools is the result of a complex accretion and depletion process:



Compared to live tree and organic soil C pools, the flux of downed dead wood C is relatively minor:

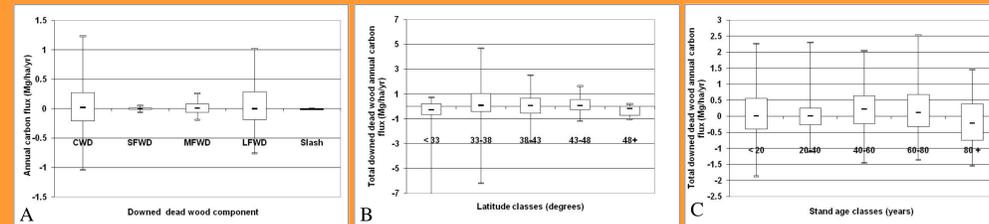
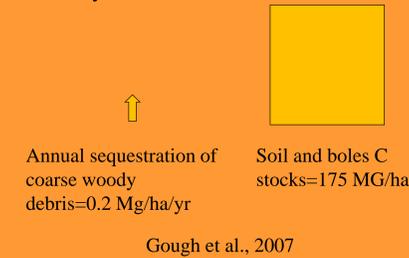


Fig. 1. Box plots (median, Q1, Q2, 5<sup>th</sup>, 95<sup>th</sup>) of average annual C flux of (A) downed dead wood components, (B) total dead wood by latitude, and (C) total dead wood by stand age, eastern U.S. (negative values indicate sequestration)

Using FIA's P3 inventory, the median annual C flux of most downed dead wood components is nearly zero with coarse woody debris and large fine wood debris having the largest range in flux. The distribution of total downed dead wood C flux maybe nearly identical across classes of latitude and stand age. For more information see Woodall In Press.

### Need For Power Analysis:

Given the minimal annual flux of downed dead carbon stocks, what is the probability of detecting a difference of a certain magnitude (1- type II error)? How many P3 plots do we need to detect a sizeable flux of downed dead wood carbon?

Mean annual sequestration of total downed dead wood sampled on FIA P3 plots=0.05 Mg/ha/yr  
Std. Dev. of annual sequestration of total downed dead wood sampled on FIA P3 plots=8.08 Mg/ha/yr

## Methods and Data

Objectives within FIA P3 Network:

- 1) Determine probability of detecting a difference of a certain magnitude (1- type II error) among domains of interest (e.g., state or ownership),
- 2) How many inventory plots needed to detect C flux?
- 3) How much C flux needed for detection by inventory network?

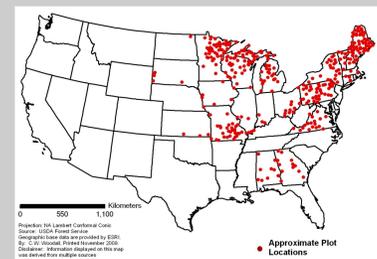


Fig. 1. Approximate plot locations for FIA P3 plots established in 2002 and 2003 with remeasurement in 2007 and 2008

Only fully-forested, single condition FIA P3 plots (DWM) were used in this study which were established in 2002 and 2003 with remeasurement in 2007 and 2008 (n=366).

Average annual flux was calculated as the time 1 stock minus the time 2 stock, divided by the measurement interval (5 yrs). Therefore, a C sequestration is indicated by a negative value.

Power analyses were conducted using SAS Power Procedures with "twosamplemeans" and "pairedmeans" options.

## Testing for Differences Among Domains of Interest

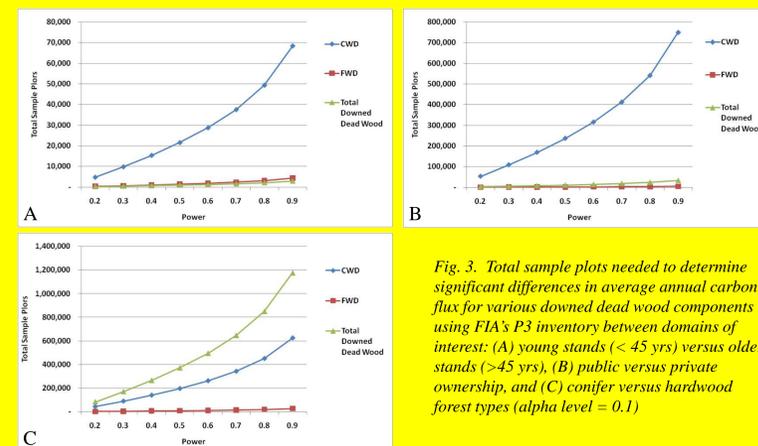


Fig. 3. Total sample plots needed to determine significant differences in average annual carbon flux for various downed dead wood components using FIA's P3 inventory between domains of interest: (A) young stands (<45 yrs) versus older stands (>45 yrs), (B) public versus private ownership, and (C) conifer versus hardwood forest types (alpha level = 0.1)

Using actual means and standard deviations from a regional assessment of downed dead wood C flux (assuming SRS), power analysis indicated that a tremendous number (over a million) of P3 plots would be needed to detect a significant difference in C flux between domains of interest. If there are substantial differences in C flux between domains (e.g., stand age), then only 5,000 plots would be needed to determine significant changes in annual C flux.

Given the relatively small flux of dead wood C stocks and lack of difference among domains of interest...substantial numbers of P3 plots are needed to achieve an appreciable level of statistical power.

## How Many Plots? What Flux Detection is Possible?

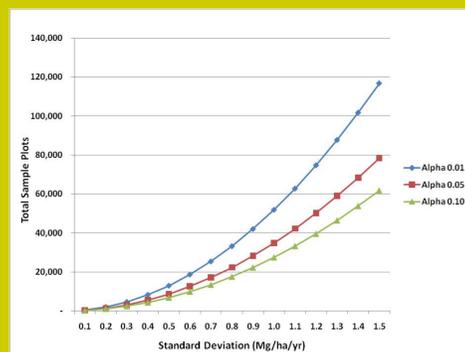


Fig. 4. Number of inventory plots needed to determine a significant difference in coarse woody debris average annual C flux between young and old stands at statistical power of 0.8 (1-type II error) by standard deviation and alpha level, eastern U.S.

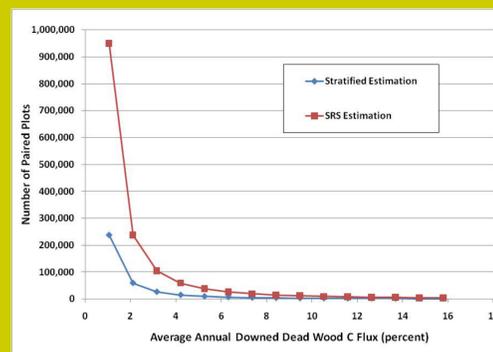


Fig. 5. Number of remeasured inventory plots needed to determine a significant difference in coarse woody debris average annual C flux between time 1 and time 2 (stat. power = 0.8; alpha=0.1) based on standard deviation from SRS versus stratified population estimation based on values from eastern U.S.

The number of plots needed to ascertain a significant difference in coarse woody debris C flux between domains of interest is highly dependent on an analyst's desired alpha level and standard deviation. Assuming simple random sampling, average annual coarse woody debris C flux had a standard deviation exceeding 1.0 Mg/ha/yr such that >50,000 plots would be needed to detect changes in flux between domains even at an alpha level of 0.1 and statistical power of 0.8. Perhaps the most efficient way to increase statistical power would be to reduce population estimate variance through refined stratified estimation procedures in addition to possibly increasing sample intensity.

Assuming FIA's current P3 base sample intensity (1/39,000 ha) and level of downed dead wood C flux seen in the eastern U.S. (< 1% per year), one would need over 20x more plots to statistically verify changes in typical flux at a national scale. With full implementation of FIA's base P3 sample intensity nationally (>10,000 plots), an annual carbon flux in excess of 5% would need to occur for statistical detection. For a state with 250 forested P3 plots, a 32% percent average annual change in total downed dead wood would need to occur for statistical detection. In this example, stratified estimation was assumed to reduce standard deviation by 50% as compared to SRS.

## Conclusions

- 1) Across large-scales, average annual downed dead wood C flux is very minimal compared to standing live tree stocks. Additionally, downed dead wood C stocks do not vary substantially between classes of stand age, forest types, or ownership. Given these aspects of dead wood populations, a tremendous number of inventory plots are needed to attain adequate statistical power for C flux hypothesis testing.
- 2) Efforts to reduce the variation associated with estimates of downed dead wood C stocks, may more efficiently increase the statistical power of the P3 inventory than increasing the sample intensity.
- 3) Given the estimates of downed dead wood C stocks/fluxes and associated variances in the eastern U.S., along with current base P3 sample intensity, it can be assumed that a C flux 5x and 30x greater than average would need to occur for statistical detection at the national and state level, respectively (assuming state with national average of forest land area).
- 4) FIA's current P3 base sample intensity can detect moderate to extreme downed dead wood C flux at the national level, but most likely can only detect catastrophic disturbances at the regional/state level (e.g., hurricanes and widespread wildfires).

Literature Cited/Additional Reading:

- Bechtold, W.A., Randolph, K.C., Zarnoch, S.J. 2009. The power of FIA Phase 3 crown-indicator variables to detect change. In 2008 FIA Symposium. RMRS-P-56CD. Ft. Collins, CO: U.S. department of Agriculture, Forest Service, RMRS.
- Bradford, J.B., Weishampel, P., Smith, M.L., Kolka, R., Birdsey, R.A., Ollinger, S.V., Ryan, M.G. 2009. Carbon pools and fluxes in small temperate forest landscapes: Variability and implications for sampling design. Forest Ecology and Management.
- Conkling, B.L., Hoover, C.M., Smith, W.D., Palmer, C.J. 2002. Using forest health monitoring data to integrate above and below ground carbon information. Environmental Pollution. S221-S232.
- Gough, C.M., Vogel, C.S., Kazanski, C., Nagel, L., Flower, C.E., Curtis, P.S., 2007. Coarse woody debris and the carbon balance of a north temperate forest. Forest Ecology and Management. 244, 60-67.
- Woodall, C.W. In Press. Carbon flux of down woody material in forests of the north central United States. International Journal of Forestry Research.

For more information with regards to the FIA program please refer to: <http://fia.fs.fed.us/> For more information please email lead author at [cwoodall@fs.fed.us](mailto:cwoodall@fs.fed.us)