Species Composition of Down Dead and Standing Live Trees: Implications for Forest Inventory Analysis

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Abstract.—The assessment of species composition in most forest inventory analysis relies solely on standing live tree information characterized by current forest type. With the implementation of the third phase of the U.S. Department of Agriculture Forest Service's Forest Inventory and Analysis program, the species composition of down dead trees, otherwise termed coarse woody debris (CWD), is now available to inventory analysts. To evaluate the possible contribution of CWD inventory data to forest ecosystem assessments, the species compositions of standing live and down dead trees for FIA plots across north-central States were compared within the context of forest inventory analysis. Results indicate that CWD species composition data may refine understanding of past tree mortality patterns in the context of stand development and species composition shifts. Further, CWD species composition data provide analysts with an additional categorical unit for inventory reports. Although use of CWD species composition data may be limited by measurement error and sparse sampling intensity, such data complement standing live tree data for a range of inventory analysis procedures.

Introduction

Forest types (FTs), otherwise known as forest cover types, are categories of forest defined by constituent vegetation (Eyre 1980, Helms 1998). The single attribute of forest vegetation often used as a delimiter of FT is the species composition of living forest biomass present in the stand/plot being typed (Eyre 1980, Helms 1998). Additionally, FTs may be defined by current or potential vegetation (Daniel *et al.* 1979). The Forest Inventory and Analysis (FIA) program of the U.S. Department of Agriculture (USDA) Forest Service uses a definition of FT that deals mainly with the species composition of current tree biomass on a plot, "classification of forest land based on the species presently forming a plurality of the live-tree stocking" (Smith *et al.* 2001, 43). FT information has been used as a categorical variable for ecological analyses for decades and forms the basis of numerous forest reports produced by FIA and its cooperators (H. John Heinz III Center for Science 2002, Miles *et al.* 2003, Smith *et al.* 2001, USDA Forest Service 1965). Recent forest resource reports have placed additional emphasis on FT analyses (Heinz Center 2002, Smith *et al.* 2001) because changes in FTs across the United States may indicate effects of urbanization and climatic variations.

Because forest typing procedures usually include only living trees, the identifiable species composition of down dead trees is often omitted in forest inventories and subsequent analyses. Down and dead trees, otherwise known as coarse woody debris (CWD), serve as critical habitat for numerous flora and fauna. Flora use the microclimate of moisture, shade, and nutrients provided by CWD for regeneration establishment (Harmon *et al.* 1986). CWD provide a diversity (stages of decay, size classes, and species) of habitat for fauna ranging from large mammals to invertebrates (Bull *et al.* 1997, Harmon *et al.* 1986, Maser *et al.* 1979). Besides providing assessments of habitat, CWD may contain the history of the species composition of any particular stand, possibly refining understanding of mortality trends over time (i.e., succession). CWD studies to date often quantify only the volumes, sizes, and diameters of CWD with incidental information regarding CWD species composition (Goodburn and Lorimer 1998, Pedlar *et al.* 2002). Given the importance of CWD, a new categorical variable is proposed that may benefit CWD assessments and overall inventory analyses. "Coarse Woody Type" (CWT) may be defined as a

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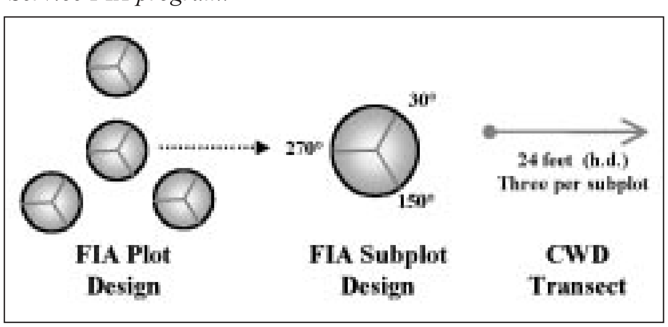
broad categorization of the species composition of the dead tree biomass in a forest stand. Because FIA inventory data may be used to determine both FT and CWT on selected inventory plots, the FT and CWTs may be used separately or in combination to refine understanding of forest attributes and stand dynamics.

The goal of this study was to determine if information on down dead tree species composition could be used to refine analytical procedures that have typically used only FT information. Specific objectives were to (1) assess difficulties in developing a CWD typing algorithm, (2) compare FT and CWT paired by individual plot and correlate them with the stand attributes of total stand basal area, stand age, and site index, and (3) link plot-level FT and CWTs to successional and stand development patterns regionally observed for common FTs.

Methods

As defined by the FIA program, CWD are down logs with a transect diameter ≥ 3 in and a length ≥ 3 feet. CWD are sampled during a specific phase of FIA's multiscale inventory sampling design (USDA 2002). CWD are sampled on transects radiating from each FIA subplot center (fig. 1). Each transect is 24 feet long, three per subplot. Information collected for every CWD piece intersected on each of three 24-foot transects on each FIA subplot is transect diameter, length, small-end diameter, large-end diameter, decay class, species, evidence of fire, and presence of cavities (fig. 1). Transect diameter is the diameter of a down woody piece at the point of intersection with a sampling transect. Decay class is a subjective determination of the amount of decay present in an individual log. Decay class 1 is the least decayed (freshly fallen log), while decay class 5 is an extremely decayed log (cubicle rot pile). The species of each fallen log is identified through determination of species-specific bark, branching, bud, and wood composition attributes (excluding decay class 5 CWD pieces). If a CWD piece is too decomposed to identify its species, a hierarchy of species identification is followed: species, species group, conifer or hardwood, or unknown.

Figure 1.—*Line-intercept coarse woody debris sampling design for the Down Woody Materials Indicator of the USDA Forest Service FIA program.*



CWD inventory data, along with corresponding tree and stand information, for this study were obtained from selected forested plots (n = 345) in the north-central States. Plots were sampled during the summers of 2001 and 2002. DeVries' line-intercept estimators were used to determine CWD volume per acre by species (DeVries 1986). A CWT was determined for each sample plot based on the species with the plurality of CWD volume per acre. Although a CWT algorithm may eventually be developed to readily determine CWTs, that objective was beyond the purview of this study. For this study, the CWT for each plot was determined by the species with the most cubic foot volume per acre using decay class, species, and log dimension information (volume per unit area estimators) of individual CWD pieces.

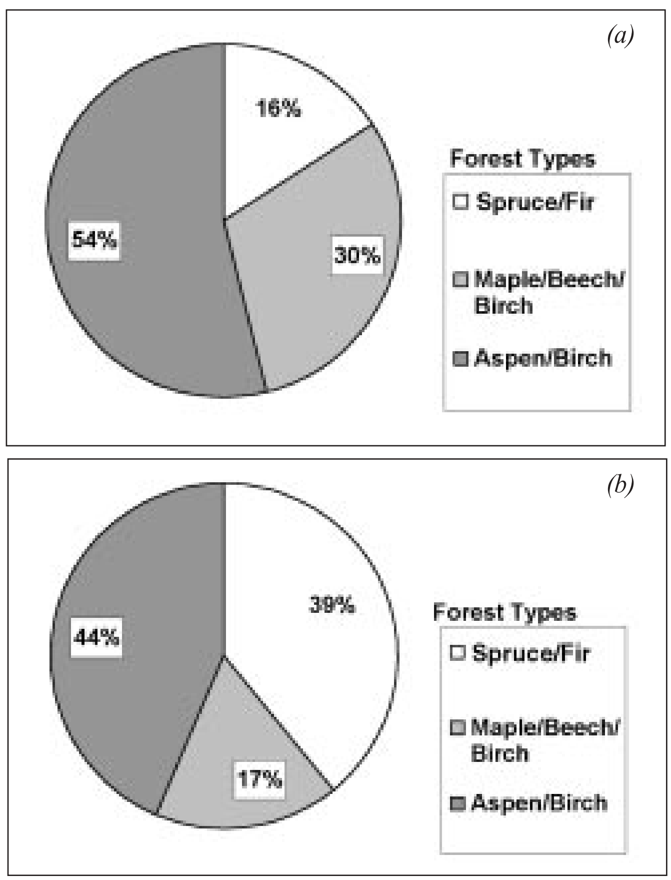
FTs were determined by field crews based on visual observations of the plot (USDA Forest Service 2002). Because numerous FTs may be present on any selected phase 2 plot, the FT for the condition class occupying the greatest proportion of the plot area was selected. If two or more FTs occupied the same area proportion, the FT of the proportion with the most basal area was selected. Both FTs and CWTs were broadly assigned to the following FT/CWT groups: pine, spruce/fir, oak/pine, oak/hickory, elm/ash/cottonwood, maple/ beech/birch, and aspen/birch (Smith *et al.* 2001). To accomplish the second objective of this study, all study plots were stratified into two classes for analysis: (1) plots that had different CWTs and FTs, and (2) plots that had no difference in CWTs and FTs (the species composition of down dead tree biomass is roughly equivalent to the species composition of the standing live tree biomass).

Results/Discussion

Preliminary determination of a CWT by using existing CWD data collected on FIA subplots provides an initial framework for developing a formal CWT algorithm. Many challenges exist to the development of a CWT algorithm using FIA data. First, the CWT for a forested plot may resemble no currently defined FT. For example, plots in the Southern United States may have a significant amount of large chestnut (*Castanea dentata*) down logs present on a plot dominated by standing northern red oak (*Quercus rubra*) trees. Therefore, in this case, the CWT would be chestnut, which no longer exists as a FT in the Southern United States. Second, a hierarchy of species identification may complicate typing algorithms. Field crews may readily identify the particular species of individual CWD pieces but may only identify other CWD pieces as unknown hardwood or conifer because of decay. Third, for decay class 5 logs, no species identification is possible because the logs are too decayed. For some plots, a majority of the CWD volume may be in decay class 5 and, thus, these null values would confound CWT efforts. Fourth, the effects and importance of CWD decay classes on the typing process need to be resolved. The species identification of a freshly fallen (decay class 1) CWD piece is more certain than the identification of a partially rotten (decay class 4) CWD piece. Fifth, latitude and climate may affect decay rates that may cause a spatial bias to CWT algorithms. Plots located in Minnesota or Wisconsin may have older logs of previous FTs that occupied the plot versus plots in Missouri where decay rates are faster with less chance of CWTs differing from that of current FTs. Thus, plots in more northerly latitudes or xeric sites may be more difficult to type. Finally, crew measurement error may affect CWD species identification in certain FTs. Some FTs, such as paper birch (*Betula papyrifera*), may have CWD that decays rather rapidly, while other FTs in adjacent areas may have CWD that is more resistant to decay. Therefore, field crews may have more uncertainty with species identification in paper birch forests than in other forests with more decay-resistant species such as black walnut (*Juglans nigra*).

For all 345 study plots, 52 percent displayed a difference between FT and CWT. The remainder of the plots (48 percent) showed no difference between CWT and FT. When the plots were examined in the context of three common FT groups of the Lake States (spruce/fir, maple/beech/birch, and aspen/birch), distinct differences existed in FT and CWT comparisons between the conifer and hardwood FTs (figs. 2a–b). When considering the distribution of FTs between the two strata of difference/no difference, the proportion of plots in northern hardwood forests (maple/beech/birch and aspen/birch) that had a difference in FT and CWT (61 percent) was less than the proportion of plots with no difference in FT and CWT (84 percent) compared to spruce/fir FTs (figs. 2a–b). For spruce/fir forests, this trend was reversed: the difference in FT and CWT (39 percent) was greater than the proportion of plots with no difference in FT and CWT (16 percent) (figs. 2a–b). These results suggest that spruce/fir forests are more likely to have CWD of a different species from the FT than maple/aspen/birch forests, a result attributable to the regional maturation of aspen/birch FTs and understory development of more shade-tolerant climax spruce/fir forests (Kotar *et al.* 2002).

Figure 2.—*Percentage of study plots by selected FT for North Central States (USDA Forest Service, FIA program) by study strata of (a) no difference between forest and coarse woody types and (b) differences between forest and coarse woody types.*



For Lake State forests in particular, differences between FTs and CWTs may help elucidate successional and mortality trends occurring between maple/aspen/birch and spruce/fir forests. To determine if differences between FTs and CWTs were due to recent disturbances, the proportion of study plots in the two study strata were examined. As related to recent stand disturbances identified by field crews, 81 percent of plots that had a difference between FTs and CWTs showed no evidence of recent stand disturbances, and 83 percent of plots that had no FT and CWT differences had no recent stand disturbances. Due to the scarcity of recent stand disturbance events across a region, CWTs may not fluctuate in short time frames, especially within the sample plot sizes (24-ft radius) the FIA program uses. Rather, CWTs may potentially quantify species composition changes during extended years of stand development (FTs of the past, deceased forests in general). In addition, mature or old spruce/fir FTs are often maintained through small-scale, wind-, and disease-related gap dynamics (Frelich and Reich 1995), with remnant early successional species possibly comprising the CWD found on the forest floor. As stand development progresses in a northern hardwood FT, gap dynamics characterized by small windfall events perpetuate shade-tolerant species, such as sugar maple, that may have been present at stand initiation (Frelich 2002), resulting in the same CWT and FT over time. Both of these disturbance types are relatively small scale and may not be observed by field crews.

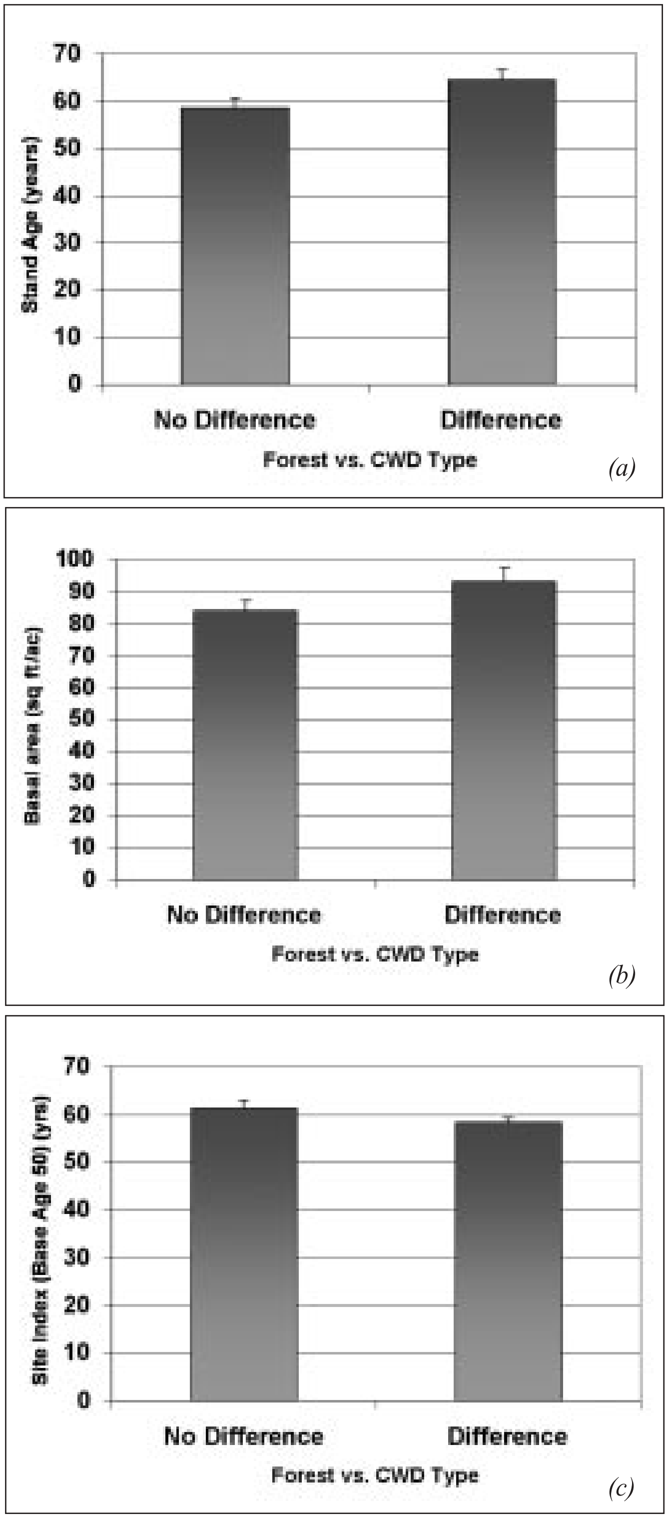
Mean proportions of plots having differences in FTs and CWTs among north-central States were examined (table 1). Northern latitude States (Minnesota, Wisconsin, and Michigan) showed more of a difference between FTs and CWTs than more southerly forests (i.e., Missouri). These results may be due to two reasons: (1) successional trends in spruce/fir forest climax types in Northern States, and (2) regional climatic gradients. For forests in high latitude/elevation and/or xeric regions of the United States, slow decay rates may preserve CWD pieces for decades thus exacerbating differences between down dead and standing tree species compositions. The results in table 1 also support the concept of successional shifts in Lake States forests causing differences in FTs and CWTs by FT. Shifts in CWTs and FTs, as suggested by results in this study, may not be related to recent stand disturbances but rather to long-term successional shifts. For FT groups in this study, the successional pathways of the hardwood forests of maples, aspen, and birches succumbing over time to developing spruce/fir forests may be evidenced by the prevalence of spruce/fir study plots having differences in their respective CWTs and FTs (figs. 2a–b).

Table 1.—*Percentage of CWD plots showing a difference in FT and CWT by North Central State (2001–02).*

States	Plots with FT and CWT difference (%)
Indiana	7
Iowa	23
Kansas	33
Michigan	81
Minnesota	81
Missouri	34
Nebraska	13
Wisconsin	54

The means and associated standard errors for stand-level variables of stand age (yrs), basal area (ft^2/ac), and site index (base age of 50 yrs) were compared between the two study strata of FT and CWT differences/no differences. Plots that had a difference between standing live and down dead tree species composition were generally older stands, had greater basal area, and were on poorer quality sites than plots that had no difference in FTs and CWTs, although incorporation of summary statistics might alter those conclusions (figs. 3a–b). First, older stands (fig. 3a) are more likely to have disturbance and successional related mortality. These results may be justified by the fact that older stands have a longer time to accumulate CWD from a variety of species that may or may not be present in the current forest. Second, forests with greater levels of stand basal area (fig. 3b) may be more susceptible to density-related mortality. With greater levels of mortality over time, the greater the chance that the species composition of the CWD of a stand may not resemble the standing tree species. Third, forests on higher quality sites may have faster decay rates for CWD, less accumulation of CWD over time, and therefore less chance for a difference between FTs and CWTs. If a particularly high-quality site can grow trees faster (Assman 1970), the site may be able to grow more fungi and microbes to decompose CWD at faster rates. Overall, if stand and site attributes (density, site quality, or stand age) partially control the accumulation and decay of CWD, the hypothesis may be promulgated that examination of CWTs may indicate the past influence of stand/site attributes in forest stands.

Figure 3.—*Means and associated standard errors for the stand-level attributes of (a) stand age, (b) basal area, and (c) site index for the study strata of no difference between forest and coarse woody types and differences between forest and coarse woody types.*



Conclusions

Despite obvious difficulties and hurdles to developing CWD species composition typing algorithms, CWTs may afford inventory analysts with another categorical variable of analysis. Study results suggest that comparisons between FTs and CWTs may serve as an indicator of successional change at landscape scales. Additionally, FTs and CWTs may refine analysis of the complex relationships between stand/site factors and stand development. If the thesis statement—that CWD species composition indicates the historical mortality patterns of any particular stand—is correct, CWTs may afford opportunities to refine our understanding of CWD and its role as an indicator of forest health.

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