CHAPTER 15

Down Woody Material

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The full range of possible down woody material (DWM) research includes wildlife, nutrient cycling, fungi, fuels, carbon, biomass, water cycling/stream structures, and stand structural diversity. Of studies on DWM by the national Forest Health Monitoring (FHM) Program of the Forest Service, U.S. Department of Agriculture, 80 percent primarily focused on fire-related objectives. The only two remaining studies not focused on fire dealt with the mapping of snags and coarse woody debris, close to the topic of mapping DWM found in many fire studies. The explicit request for Evaluation Monitoring (EM) projects under the Fire EM umbrella has resulted in a dominance of fire-related studies to the exclusion of all other DWM topics. There have been no completed FHM studies explicitly and primarily focused on the DWM topics of wildlife, carbon, or structural diversity (for detailed description of dead wood ecology, please see Harmon and others 1986).

Project INT-EM-99-02; INT-EM-00-02; INT-F-01-03: Fire Risk Rating of FIA/FHM Plots

The Forest Vegetation Simulator (FVS) (Reinhardt and Crookston 2003), with the Fuels and Fire Effects (FFE) and Insect and Pathogen (I&P) extensions, was used to characterize forest fire hazards in Montana. Data from the Forest Inventory Analysis (FIA) Program of the Forest Service were processed through the FVS to characterize current and future fire hazards in Montana. The potential for wildfires to put lives, property, and environmental services at risk is a much discussed and debated topic in recent years, especially in communities across Montana. This study had two main objectives: (1) to develop methods of using FIA data and the FVS, incorporating its FFE and I&P extensions, to characterize current and simulated future forest conditions in Montana, and (2) to use the methods developed to describe the conditions of Montana forests now and in 50 years. Following analysis of all model outputs, a number of conclusions were stated. First, there is an abundance of comingled small- and medium-diameter stands creating an abundance of ladder fuels. Second, there is an abundance of stands with a high potential for crowning fires, especially in extreme fire weather conditions. Third, the stand attributes that resulted in reduced wildfire mortality were fire-resistant species (e.g., ponderosa pine), larger diameter trees, lower crown bulk density, and less stand layering (e.g., complex crown architecture). Future modeling improvements to refine modeling estimates are suggested, such as adding tree species and recalculating growth and mortality functions. For further details, please refer to Atkins and Lundberg (2002).

Project SO-F-01-04: Evaluating Critical Fuel Loading in the Wildland/Urban Interface

Located in coastal Georgia adjacent to the Florida border, Camden County covers more than 403,000 acres, two-thirds of which is forest land. Interstate 95 and U.S. Highway 17 are routed through the middle of the county. Camden County is home to the Kings Bay Naval Base and the Cumberland Island National Seashore, with a number of communities in the interface between suburban/urban development and natural fuel complexes in forest ecosystems. The Georgia Forestry Commission initiated a pilot study to address several wildland/urban interface issues unique to this county. A study was undertaken with the specific objective to develop forest fuel loading values for the palmetto/gallberry fuel type that is the dominant fuel type in the county. The study methods followed a number of logical steps. First, the fire history (e.g., cause, number, and acreage burned) of Camden County (1996-2001) was determined. Second, the forestry commission developed a series of wildfire occurrence maps. Third, forest statistics concerning forest density and extent were developed from FIA data. Finally, all the data layers were combined with a fire hazard rating index for urban interfaces. It was found that wildland fires could occur anywhere in Camden County where forests adjoin grasslands with fire ignition coming from human activities along roadways or lightning strikes. On average, nearly 99 fires occur annually in Camden County. The population of Camden County has more than tripled since 1980, causing a tremendous increase in wildland/urban interfaces and associated increases in fire hazards. Recommendations based on the results of the risk assessment were presented to fire departments, emergency management agencies, the American Red Cross, County Commissioners, and University of Georgia Cooperative Extension Service.

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Projects SO-F-01-03; NE-F-01-05: Assessing Contribution of Down and Standing Deadwood Biomass and Decay on Fuels and Wildland Fire Risk Across the Southeastern and Northeastern United States

The study summarized fuel biomass/carbon for Eastern States based on preliminary 2001 and 2002 DWM plots sampled by the FIA program (for details regarding the FIA program's DWM indicator, please see Woodall and Monleon 2008). As this was one of the first regional summaries of DWM based on phase 3 DWM indicators, it found that linkages between the DWM biomass models (estimators) and the FIA database offer a methodology for monitoring DWM that is beneficial for establishing carbon credits, assessing wildlife habitat, managing fire fuels, and understanding other forest health issues related to dead wood and the forest floor. The primary objective of this study was to explore use of the Eastwide FIA database, remotely sensed landcover data, a coarse woody debris model, and a productivity model (PnET) as the basis for developing estimates of live and deadwood biomass for producing fire fuel maps for eastern forests. The study used both FIA phase 2 and phase 3 plots. On average, mass of each DWM component was less than 4.5 tons per acre (10 tonnes/ha). Generally, Northern States had greater amounts per plot than Southern States. An objective was to use these DWM data to estimate DWM for all plots in the eastern half of the FIA database. This was done by developing regression models to predict DWM from available FIA measurements collected on their phase 2 plots.

Project Number NC-F-03-01: Supporting the National Fire Plan with Maps and Digital Data Layers Derived from FIA and FHM Plot Observations

This study brought together phase 2 and phase 3 data, along with pertinent ancillary data (forest/non-forest maps), to map down woody material fuels at large scales (McRoberts and others 2004). This was one of the first studies to postulate and examine using an entire suite of forest monitoring data to produce continuous coverages of fuel loadings. Specific objectives were to (1) construct models of the relationships between phase 3 down wood material observations and the suite of phase 2 observations, (2) determine if augmentation of phase 3 plot observations with phase 2 plot predictions improves fuel maps, and (3) determine if fuel maps are improved by masking out non-forest areas. The following conclusions were derived from this study: (1) augmenting phase 3 plot observations with phase 2 plot predictions improves fuel maps, (2) masking out non-forest portions of the landscape improves fuel maps, and (3) map-based mean per acre fuel tonnage estimates are not significantly different than plot-based estimates, suggesting that the map is unbiased at the spatial scale of most of Bailey's Ecological Provinces (Bailey 1995).

Project Number: NC-F-04-03: Fire Season "Real Time" Estimation of Fuel Moisture Fluctuations in Regional Down Woody Material Inventories During a Fire Season

Although regional-scale forest fuel maps are essential to wildfire management and fire risk mitigation efforts, forest fuel conditions are not static. Regionally assessing the fire season fluctuations of fuel moisture levels has never been undertaken using extensive fuels inventory and mesoscale models. Such effort is crucial to tracking weather-dependent fire hazards across regional forest fuels during critical fire seasons. This study examined the concept of meshing phase 3 DWM data with real-time meteorological data for real-time assessment of fire hazards. This study was one of the first to suggest linking static estimates of fuel loadings with mesoscale models for prediction of real-time fuel moisture to aid rapid response to wildfires. Specific objectives were to (1) employ mesoscale atmospheric numerical model output to modify FIA down woody material data to produce higher temporal resolution information on fuel moisture, (2) produce an assessment of the variations in fuel moisture over the course of a fire season, (3) assess the extent to which fire activity correlates with these simulated fuel moisture variations, and (4) determine if this system can be employed to produce real-time predictions of fuel moisture conditions based on the simulated variations in fuel moisture from the previous year. Products delivered by this study were (1) regional-scale map of fuel moisture weekly/daily/hourly variations across multiple North Central States for a past fire season, (2) assessment of how past fire behavior correlates with the study's fuel moisture maps, and (3) regional-scale real-time prediction and subsequent map production of fuel moisture conditions. For further details, please refer to Woodall and others (2005).

Project SO-F-05-01: Models for Using FIA Data to Assess Impacts of Fire and Fuel Loading on Water Quality

Preliminary analyses have indicated a possible causality between dead and live forest structure and stream pH—particularly for western U.S. forests. DWM in forest ecosystems provide structure and, therefore, may impact water quality. This study had several objectives, including (1) linking

FIA phase 2 data with national Water Quality Assessment (NAWQA) data at the watershed-basin scale (HUC-6), (2) establishing baseline relationships between live and dead forest structure and water quality (i.e., dissolved oxygen, suspended sediment, water temperature, and electrical conductivity), and (3) demonstrating model ability when applied to FIA data to assess impacts of fire and fuels on water quality. Study results indicated that between 7 and 25 percent of examined counties exceed one or more standard deviations from a regional mean for dissolved oxygen, temperature, electrical conductivity, pH, or sediment variables. The Southern United States had the largest percentage of counties with >1 standard deviation from the regional mean for almost all water quality variables. The ordered ranking of variables within each study region demonstrated varying patterns. For example, sediment and winter temperature are upper and lower extremes in the Southern United States, but these variables are opposite in other regions. Overall, it was feasible to merge U.S. Geologic Survey NAWQA data and FIA data for assessing water-quality across large-scales for sustainability assessments. The greatest value for this type of analysis is to establish a 1990s baseline for comparing future deviations. Although this study did not explicitly relate water quality to DWM structure (only biomass), it has established relationships between regional water quality and large-scale estimates of forest standing live tree structure (FIA phase 2 data).

Project WC-F-05-05: Pre- and Post-Fire Fuel Loads: Empirical Versus Simulated Results for Mixed-Conifer Forests of the Cascade Range

This FHM-funded study took advantage of an opportunity created by the 2004 McDonald Ridge wildfire on the Gifford Pinchot National Forest in Washington. The McDonald fire burned more than 200 acres through a research area where forest vegetation and fuels had previously been measured (in 2001) as part of a larger, landscape silviculture study in the Gotchen Late Successional Reserve (LSR) (15,000 acres, 6 070 ha). The 2001 data were used to simulate forest structural dynamics associated with fire, insects, and pathogens, and with stand density reduction treatments over a 30-year period for LSR (e.g., Hummel and Calkin 2005). The objective of the 2005 FHM-funded study (WC-F-0-05) was to compare the simulated fire effects with those actually observed. This required remeasuring the burned and unburned plots within the perimeter of the 200-acre (81-ha) fire; the fieldwork was completed 1 year post-fire, in August 2005. Plot measurements included the height, diameter, and species of all live and standing dead trees, plus transects on which down fuels were tallied. Of the 20 original plots in the sample polygon, 10 were within the fire perimeter and, of these 10, three were burned.

A comparison of predicted and actual fire effects was done using the east Cascades variant of a forest vegetation and fire/fuels simulation model (U.S. Department of Agriculture Forest Vegetation Simulator-Fire and Fuels Extension models; Reinhardt and Crookston, 2003). Study results were the subject of a poster displayed at the 2006 International Association of Wildland Fire (IAWF) conference in Portland, OR (Hummel and Bouchard 2006). Results suggest that the FVS-FFE model did well in the plots that burned, but that on an area basis (when plots were pooled), it over-predicted fire-related tree mortality.

Project NC-F-05-03: Multi-Scale Modeling and Mapping Coarse Woody Debris

FIA/FHM programs provide important data that have been used to map dead and down woody material for multi-state regions. The dead and down woody material maps generated based on FIA/FHM plots are too coarse to describe variation at small spatial scales because of the low sampling intensity [about 1 phase 2 and phase 3 plot per 6,178 acres (2 500 ha) and 98,840 acres (40 000 ha), respectively]. The resultant maps, therefore, are insufficient for regional resource management and planning to evaluate fire risk or wildlife habitat suitability (e.g., at the scale of a national forest or other sub-State region). Generally, dead and down woody material is relatively scarce and varies dramatically at small spatial scales such as plots/stands, even when the plots/stands are similar in many other respects (Shifley and Schlesinger 1994). This is due to the spatially stochastic nature of disturbance agents (Shifley and others 2000) and the resultant tree mortality and decay process. Research on other rare forest attributes (e.g., cavity trees) has indicated that they are predictable within a tolerable range of errors at relatively small spatial scales (e.g., 50-acre (20-ha) blocks). The prediction/estimation error of such models may be reduced by employing an ensemble of related models rather individual component (e.g., height and diameter) models (e.g., simple linear regression models; Fan and others 2004). The scale-dependent statistical/computer models and ensembles of predictive models can be developed by using boot-strapping techniques to combine groups of FHM plots and create virtual landscapes of various sizes where the coarse woody debris (CWD) characteristics are known. These can be linked with other data sources such as remote sensed imagery, GIS layers, or other sources of existing data (e.g., Shifley and Brookshire 2000) to map dead and down woody material at finer scales than previously reported for the Midwest. Other sources of CWD data for the region (Spetich and others 1999, Shifley and others 1997) serve as an additional benchmark against which to compare findings from FHM data. Products delivered by this study were (1) an identified set of hierarchical stand and site factors and/or computed composite variables statistically associated with dead and down woody material, (2) a set of statistical/computer models applicable for estimating CWD at multiple spatial scales, and (3) dead and down woody material maps for Missouri based on models or ensembles applied at different scales. These also serve as prototypes for extension of the methods to other geographic regions.

Project Number: SO-F-06-01: Fuel Characteristics in the Southern Appalachian Mountains—A Test of FIA Down Woody Material Indicator for Regional Fuel Estimation

Both the National Fire Plan and the Healthy Forest Initiative call for reduction of hazardous fuels. Consequently, estimations of forest fuel loading at various scales become necessary. With objectives such as fuel reduction, site preparation, wildlife habitat improvement, and maintaining extant populations of threatened and endangered species, prescribed fire has become an increasingly widespread management tool in the Southern Appalachian Mountains. However, fuel loading information is not readily available to fire managers in this region. The FIA program is currently assessing the FHM indicators at its phase 3 plots. Within this assessment, DWM sampling occurs every 96,000 acres (38 851 ha). This study compared DWM estimates from two sources: extensively sampled FIA phase 3 plot data and more-intensively sampled fuels information collected specifically for this study. With estimates from two levels of sampling intensity, the study found a large discrepancy, with the FIA phase 3 estimates much smaller (by 47 to 73 percent, depending on study area). Differences in sampling methods were not the cause of the discrepancy observed between the two estimates. In addition, the two methods also used the same equations to determine DWM estimates from field data. Based on the new data collected in this study, total DWM estimates varied from 10.85 to 15.58 tons per acre among the four study areas (24.2 tonne/ha to 34.7 tonne/ha, respectively). Litter and duff accounted for 36.5 to 61.7 percent of the total DWM. Fine woody debris (FWD) (for definition, see Woodall and Monleon 2008) usually accounted for approximately 20 percent while coarse woody debris (CWD) (for definition see Woodall and Monleon 2008) accounted for 20 to 30 percent of the total DWM except for Tennessee (44 percent). Litter and FWD accounted for about 40 percent of the total DWM. Except for litter, the ranges for individual DWM attributes were quite large, particularly for CWD and duff. The study also examined whether regional fuel estimations derived from the FIA phase 3 plots could capture multiple and distinct fuel complexes of forests at its current sampling intensity [approximately one plot per 96,000 acres (38 851 ha)]. Results suggest that FIA phase 3 sampling intensity is appropriate at regional scale when fuel loading is averaged over a large area [more than 2 million acres (809 388 ha)]. However, fire events often occur at a much smaller spatial scale. Fuel estimates obtained over such a large area may not provide much useful information for fire management decisions that have to be made at stand or landscape level. At a smaller scale (i.e., individual county or individual national forest/park scale), the FIA phase 3 sampling intensity would likely be too sparse to generate reliable fuel loading estimates.

Project WC-F-06-05: Estimating Snag Densities and Down Wood with Aerial Survey Data

An important aspect of dead wood analyses is ascertaining the current status (e.g., stage of decay, size, and presence/absence of cavities) of snags and down wood in the vicinity of the analysis area. Aerial survey data can aid managers in developing a picture of the current situation for the incidence and condition of snags and potentially down wood across a landscape. Recent development of the Decayed Wood Advisor (DecAID) has provided an important tool for analyses considering dead and decaying wood. DecAID is an Internet-based synthesis of published scientific literature, research data, wildlife databases, forest inventory databases and expert judgment and experience. It addresses current vegetative conditions (unharvested and managed); provides relevant summaries of snags and down wood; and presents information on wildlife use of snags and down wood. It also provides information on insects and pathogens and their role in creating and retaining dead wood. The following objectives were tackled in this study: (1) assess the impact of bark beetle-caused mortality on the accretion of standing dead and down fuels; (2) assess the ability of aerial surveys to estimate snag and large tree densities and distributions at watershed scales; (3) evaluate fuel loading for selected sub-watershed, and investigate possible correlations with aerial survey recorded mortality; and (4) develop and assess plot-based derived (FIA) conversion factors for aerial survey data relative to dead wood metrics identified in the DecAID. Annual cooperative insect and disease aerial detection surveys have recorded current year disturbance events since 1947. Forest land managers interested in managing for healthy forests in the context of ecosystem management may evaluate effects of forest conditions and existing or proposed management activities on organisms that use snags, down wood and other wood decay elements. Methods included user available spatial and tabular data summaries based on aerial survey data for intersection with hydrologic unit codes (i.e., watersheds) and user defined wildlife habitat types. Information will assist managers in forest and project planning by generating current conditions histograms for comparison with ideal unharvested condition histograms generated from forest inventory plots. Study findings indicated that aerial survey data can provide an extremely conservative estimate of snag densities, sometimes < 10 percent of the actual snag densities. However, aerial data may provide cost effective methodology for snag surveys at fifth-order watersheds (i.e., county-level scale or larger) for some wildlife applications. Due to mapping thresholds and other environmental variables, estimates of snag densities in some habitat types based on aerial survey data are too variable.

Summary of Key Findings

- Fire behavior and stand growth models may be combined with FIA inventory data to inform landscape-scale fire hazard mitigation/management efforts.
- Western forests, such as those in Montana, have high probabilities of crowning fires as opposed to the mixed-severity fire regimes (e.g., torching/surface fires) typical of pre-European settlement forest ecosystems in this region.
- FIA data may be combined with fire burn history information and wildland/urban interface information at the county level to inform local emergency response planning efforts.
- Regression models may be used to estimate DWM attributes for all FIA phase 2 plots; however, continued research is suggested especially when applying models to assess carbon stocks and fuel loadings at local/State scales.
- Combining phase 2 information with phase 3 fuel information may reduce fuel estimate variance over using phase 3 fuels alone.
- Real-time fire weather assessments (e.g., wind and humidity) may be combined with regional assessments of forest fuels to provide real-time estimates of fluctuating fire hazards.
- The FVS-FFE model adequately predicts post-burn tree attributes, a modeling strategy used in numerous FHM studies. However, the model may overestimate fire-induced tree mortality in some cases.
- Data from FIA inventory phases may be combined with USGS water quality data for assessing impacts of fire/fuels on water quality.
- DWM data analysis results presents a conundrum: at large scales, it does not provide useful information for fire management decisions, while, at smaller scales, the sample density is so sparse as to disallow reliable local-scale fuel loading estimates.
- Only in the most optimum conditions can aerial surveys provide a reliable estimate of forest ecosystem snag densities.

Utilization of Project Results

As most studies investigated novel applications of FIA DWM inventory during its early implementation, there has been scant direct application of study results to on-the-ground management efforts. Instead, the avenues of dead wood research explored by the various EM projects have indirectly informed both State and National reporting efforts. At the State level, DWM analyses are routinely included in 5-year forest inventory reports. At the national level, DWM data are incorporated into National greenhouse gas inventory reports. Perhaps the greatest applied finding from EM projects on dead wood is that the strategic-scale FIA DWM inventory is best suited for State and National monitoring efforts, while forest health issues at sub-State scales requires inventory intensification, ancillary data, or well-developed models. As an example, the DWM inventory has found its greatest strength not in monitoring fuel loadings at county scales but in monitoring tenuous carbon pools at multi-State or National scales (see Woodall and Liknes 2008).

Suggestions for Further Investigation

To provide a more cohesive approach to filling the most relevant DWM knowledge gaps in the future through the FHM program EM grants, a number of items are suggested. First, perhaps more overall strategic goals for fire projects are needed. Are there overarching knowledge gaps we are trying to fill? Currently, past fire/fuels projects appear to be randomly assigned to random regions with little prioritization of topics or regions. Individually, these fire/fuels projects do fill certain knowledge gaps, but with holistic reflection do not serve to advance science at a national scale. Explicitly developing a fire/fuels FHM research plan might better allocate and recruit fire/fuels projects that synch with each other. Second, there is a lack of diversity regarding DWM studies. Perhaps the explicit fire focus of the FHM project is a reason; however, there are hardly any studies examining fungi, wildlife, or structural diversity. Third, there is a disconnect between DWM research as funded by FHM and phase 3 reporting in inventory reports/special analyses. Perhaps the most immediate method for applying research results might be to require principal investigators to facilitate incorporation of their study results into FHM national technical reports or 5-year FIA reports. Fourth, personnel retirements, lack of project reporting in earlier years (2001 or earlier), and lack of follow-up in project deliverables meant that information may have been lost or misplaced. Most projects demonstrated valid and timely study objectives; however, a preponderance of studies did not present their promised deliverables. Perhaps more oversight of study deliverables would ensure both study completion and dissemination of results. Overall, the capacity for worthwhile DWM research has been demonstrated by the reviewed studies. This capacity could be refined or enhanced through more robust study management and incorporation into program reporting requirements.

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