COMPARING MEASURED AND NFDRS FUEL MODEL ESTIMATES OF DEAD FUEL LOADS IN THE PIEDMONT AND COASTAL PLAIN OF NORTH CAROLINA

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1. INTRODUCTION

The potential for wildfires in southern US urban areas has increased with regional population growth. Land managers need ways to identify wildfire risk areas while complying with the President's Healthy Forests Initiative. Fuel loads are one of the major factors associated with wildfire risk. A recent report by the U.S. Government Accountability Office identified the need for improved fuel data as a prerequisite to meeting the goal of reducing wildfire risk (GAO, 2005). The report concluded that fuel loads need to be reduced if wildfire risk to ecosystems and communities is also to be reduced.

Since 1964, the USDA Forest Service has employed a National Fire Danger Rating System (NFDRS) in an effort to identify areas at high risk to wildfire and plan suppression tactics (USDA, 1964, Deeming and Brown 1975). The original NFDRS was comprised of just two fuel models, but increased to 9 models in 1972 and to 20 models by 1978. In 1988, revisions were made to address shortcomings in previous model predictions of fire danger. However, few changes were made to the dead fuel loading parameters defined in the 1978 version of the NFDRS (Burgan, 1988). Currently, land managers in the U.S. have few applicable fuel models to choose from when rating fire danger in their respective regions. Land managers will need more site specific fuel models to accurately rate fire danger.

Dead fuel load, or down deadwood (DDW) is delineated into 1-, 10-, 100- and 1000-hour fuel classes, and each class is defined by the amount of time, or time lag, that it takes a fuel to reach moisture equilibrium with the environment. The1- to 100- hour fuels (<7.6 cm in diameter) are termed fine woody material (FWM). The 1000-hour fuels ($\geq$ 7.6 cm in diameter) are termed coarse woody material (CWM). While the role of CWM in forest ecosystems has been well documented, there are few studies available in the literature that attempt to quantify the DDW biomass in different forest ecosystems.

With the creation of the National Fire Plan in 2000, greater emphasis has been placed on quantifying down deadwood in an effort to identify areas that are at high risk of wildfire and better understand the temporal dynamics of forest fuels. Federal and state agencies, such as the USDA's Forest Inventory Analysis and the multi-partnered LANDFIRE project, are working to provide fine resolution data that will aid this effort. While it will be years before this data can be considered for incorporation into the NFDRS, it is an important step toward improving our ability to rate fire danger. The objective of this paper is to quantify and compare DWM across three important North Carolina forest ecosystems.

2. METHODS AND MATERIALS

This research was conducted in North Carolina's Alligator River National Wildlife Refuge (ARNWR), Croatan National Forest (CNF) and Uwharrie National Forest (UNF). Each of these forests is managed with prescribed fire to reduce understory fuels. Study sites included two pond pine woodlands (commonly called high pocosins) at ARNWR, two longleaf pine stands at CNF (one burned annually and the other burned every 4 years) and an oak-hickory and loblolly pine stand (each burned every 4 years) at UNF. Dead forest fuels were measured at each site as part of a larger study to identify areas in the southern US that are at a high risk of wildfire.

DDW measurements followed the protocols used by the USDA Forest Inventory and Analysis Program to measure down woody debris and fuels

(Phase 3, March 2002 Field Guide). Each field plot consisted of four 7.3 m radius clustered subplots 35.6 m apart and 0, 120 and 240 degrees from the central subplot. Three 7.3 m transects in each subplot at 30, 150 and 270 degrees were used to estimate fine and coarse woody material, litter and duff biomass. FWM included three classes equating to 1-hour fuels that are < .6 cm in diameter, 10-hour fuels that are .6 to 2.5 cm in diameter and 100-hour fuels that are 2.5 to 7.6 cm) in diameter. CWM included all down deadwood 7.6 cm and greater in diameter at any of the line intersects. FWM less than 2.5 cm diameter was tallied along a 1.8 m length of each transect and FWM 2.5 to 7.6 cm diameter was tallied along a 3.1 m length of each transect. A piece of CWM was tallied if any part of it intersected one of the transects. Species, decay class, length and long and short end diameters were recorded for each piece of CWM. Species decay was classified on a 1 to 5 scale, 1 for undecayed CWM and 5 for heavily decayed CWM. Litter depth was measured at the 7.3 meter point on each transect and included undecomposed foliage in the A_e soil horizon. Duff was measured at the same point below the litter layer and was defined as partially decomposed litter below the A_e horizon.

Down deadwood biomass was combined with litter and duff to compare the measured dead fuel load to NFDRS fuel model estimates. The one-hour fuels included litter biomass to a depth of .6 cm and 10-hour fuels included litter biomass from a depth of .6 to 1.9 cm. 100- and 1000-hour fuels included litter and duff from a depth of 1.9 to10.2 cm and from below 10.2 to 30.5 cm, respectively. These criteria were derived from definitions used in the NFDRS as described by Schlobohm and Brain (2002) and Deeming, Burgan and Cohen (1977). In situations where the litter depth did not exceed 1.9 cm, duff biomass was classified as a 100-hour fuel.

Biomass was calculated based on line intercept theory derived by Van Wagner (1968) and DeVries (1973) and later improved upon by Howard and Ward (1972) and Brown (1974). The basic concept, as detailed by Waddell (2002), is that multiple attributes can be summed across transects to estimate per-unit-area volume. FWM and CWM biomass were calculated using formulas developed by Brown (1974) and used in Western ecosystems. Site- and species-specific variables were substituted where appropriate, and included wood specific gravity, average diameter for each FWM class and reduction factors for each decay class. Litter and duff biomass were calculated by multiplying average depth by site-specific bulk density. All biomass estimates were calculated using SAS statistical software.

NFDRS fuel model dead fuel load estimates and measured fuel load were analyzed by comparing each class of fuel and determining if NFDRS estimates were within a 95% confidence interval of the measured fuel load. This same method was also used to determine if there was a best-fit fuel model for each study area.

3. RESULTS AND DISCUSSION

The NFDRS fuel model estimates of dead fuel load did not compare well with measured estimates when analyzed by site and fuel class. The general trend was that the NFDRS estimates were higher for 1-hour fuels and lower for 10-, 100- and 1000-hour fuels. This was particularly true for 100- and 1000-hour fuels and the magnitude was greatest on sites with deep litter and duff layers. Duff and litter biomass accounted for 56 to 92% of the dead fuel load in the 100-hour fuel class across all sites and over 90% of the dead fuel load on the ARNWR sites.

The ARNWR sites are characterized by a deep litter layer and a duff layer that exceeds 2 meters. While a high water table often minimized the potential for these fuels to ignite, drought conditions and ditching can combine to make them a viable threat. None of the NFDRS fuel models compared well with measured estimates of dead fuel load on these sites. All NFDRS models associated with the ARNWR forest types overestimated 1-hour fuels 21 to 50% and underestimated 100- and 1000-hour fuels by 500 to 7000% and 2300 to 2500 %, respectively. Only Model O 10-hour fuel load, used in high pocosins with an understory greater than 1.8 m and southeastern forests with dense brush, was comparable to measured dead fuel load. All other models underestimated the fuel load in this fuel class from 150 to 700%.

Model E, used in oak-hickory and mixed southeastern forests and Model P, used in southern pine plantations, 1-hour fuel load estimates compared well with measured fuel load on both UNF sites. However, these and other models applicable to both sites underestimate 10-hour fuels by 20 to 400% and 100-hour fuels by 85 to 4500%. Model R, added in 1988 to account for hardwood forests in summertime underestimated 1-hour fuel load by 90%, 10-hour fuel load by over 300%, and 100-hour fuel load by over 1700% on both study sites.

The annually burned CNF site showed the best agreement with NFDRS fuel models applicable to the forest types present. Model O estimates of 100- and 1000-hour fuels compared well with measured estimates of dead fuel load, but overestimated 1-hour fuel load by 75%, and 10-hour fuel load by 67%. Model D, used in low pocosins with less than 1.2 m of brush, and Model P, used in southern pine plantations, provided reasonable estimates of 10-hour fuels on this site, but both overestimated 1-hour fuel load by 75% and 50%, respectively, and Model P underestimated 100- hour fuel loads by 380%. Model C, used in longleaf and slash pine forests, provided reasonable estimates of 1- and 10-hour fuels, but does not provide an estimate for 100-hour fuels. Like many of the other fuel models, including Models D and P, Model C has no estimate for 1000-hour fuels. Model C provided a reasonable estimate of 1-hour fuels on the CNF site burned every 4 years, but this model, along with Models P and D, underestimated 10-hour fuels by 58%, and 100-hour fuels by nearly 1400%. Model O overestimates 1-hour fuels by 67% and 10-hour fuels by 47%, and underestimates 100-hour fuels by 160% and 1000-hour fuels by 215% on this site.

4. CONCLUSIONS

The biggest difference between NFDRS fuel model estimates and measured dead fuel load was found in 100- and 1000-hour fuels. Part of this difference is due to the lack of data for 1000-hour fuels in many of the NFDRS fuel models, but even when data was presented it generally underestimated fuel load in both of these classes. This was true even when litter and duff were not included in measured dead fuel load estimates. The NFDRS also tends to overestimate 1-hour fuel load and underestimate 100- and 1000-hour fuel loads. While there was no best-fit model for any of the study sites, the annual burn site at CNF showed the best agreement with fuel model estimates of dead fuel load. Even though no one model was a best fit, Model C reasonably estimates 1- and 10-hour fuels and Model O reasonably estimates100- and 1000-hour fuel loads. If land managers are going to use the NFDRS to rate the risk of wildfire, dead fuel loads may need to be estimated on a more site-specific basis.

5. REFERENCES

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