QUANTIFYING WILDLAND FIRE FUEL LOADING AND FIRE RISK IN COASTAL PLAIN FORESTS

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Abstract

Wildland fuels have been accumulating during at least the past half-century due to wildland fire management practices, policies, and other factors. The additional fuels contribute to intense fire behavior and increase the resistance of fires to control. Existing wildfire risk assessments are based on fire behavior models. These can be improved with additional remotely sensed vegetation/GIS data and the spatial characterization and modeling of live and dead woody biomass. Spatially and temporally explicit estimates of vegetation landcover, canopy density, and biomass need to be assessed to improve wildfire risk assessments. Forest fuel loading biomass estimates can be spatially displayed across the landscape to identify areas of low to high wildfire risk. Additionally, land managers need to identify forest units with the highest need for fuel reductions for prescribed burning permitting and to be able to quantify the effects of land management activities. This study report on the assessment of wildland fire risk utilizing remotely sensed vegetation maps, forest field plot data, and spatial models of live and dead vegetation fuel loading. The vegetation classes were combined with field measurements of standing live and dead trees, down deadwood, understory vegetation, forest floor, and soil carbon biomass using USDA Forest Service Forest Inventory and Analysis (FIA) protocols. Our study incorporates modified National Vegetation Classification System (NVCS) association level vegetation maps created from digital photogrammetry, disturbance history, and FIA data, to accurately capture the structural complexity of fuelbeds in southeastern United States coastal plain forests.

Introduction

Advances in fuel mapping have been driven by the need for better fire control planning (Sandberg et al., 2001). As natural resource and land manager's view of fire and its role in ecosystem management have changed from suppression to prediction and mitigation, fuel mapping strategies were reevaluated to meet the challenges of wildland fire risk. Fire behavior, smoke, and emissions models are becoming increasingly valuable tools in predicting wildland fire risk and in the application of prescribed fire in ecosystem management. An important component of all these models is fuel loading by size and it distribution. Fuel loads include the amount of downed woody debris, duff, litter and live shrub and herbaceous vegetation that can carry a fire. Each of these fuel types is of primary importance when predicting fire behavior.

From the inception of the USDA Forest Service in 1905 until the 1970s, the primary forest management focus has been fire suppression. Wildland fire fuel mapping was based on a system that classified fuels by rate of spread and resistance to control on a stand-by-stand basis. The rate of spread was ranked as low, medium, high or extreme based on statistical analysis of fire reports for similar stand types. Resistance to control was estimated by the amount of time it would take to construct a fire line by a hand crew, using the same ranking system of low to extreme (Sandberg et al., 2001). This classification system was the standard to map fuels until the 1970s and is still in use today. The shift from fire suppression to prediction was a direct result of the information collected on fuel loading and fire behavior in the 1950s and 1960s. In 1972, Rothermel (1972) developed a mathematical model to predict fire spread in homogenous wildland fuels. Rothermel's formulas are the basis for many of the fire spread prediction programs such as Behave (Burgan and Rothermel, 1984), Nexus (Scott, 1999), Farsite (Finney, 1995) and the National Fire Danger Rating System (NFDRS) (Deeming et al., 1978). The NFDRS was developed to provide a national system of fuel models and to standardize fuel models for input to fire spread models. The twenty fuel models that make up the NFDRS are based on the amount and arrangement of fuel by size class. Albini (1976) used the vegetative descriptions in the fuel models from the NFDRS and generalized them into 13 fuel models. Anderson (1982) used these 13 fuel models to develop a photographic and descriptive guide that can be used as an aid in determining fuel loads and fuel models. The guide included pictures, vegetation descriptions, fuel load estimates, and a table to cross walk between the NFDRS and the Anderson's fuel models. These 13 fuel models, however, lack key fire inputs for predictive fire models, such as coarse woody debris (dead woody debris ≥ 3 inches in diameter), and forest floor depth (litter and duff).

Remote sensing data have become a critical part of natural resource mapping efforts. Landsat Thematic Mapper (TM) has been one of the most widely used tools to classify fuels. Direct fuel mapping with Landsat TM has been used to run prescribed fire simulations with the Farsite model. A second method of fuel mapping uses remotely sensed data is the indirect mapping approach. This methodology uses ecosystem characteristics to map fuels, based on the assumption that there is a correlation between ecosystem structure (i.e. species composition, canopy height, canopy closure, etc.) and fuel loads. Some examples of this indirect method of fuel mapping include Advanced Very High Resolution Radiometer (AVHRR) to map NFDRS fuels for the continental United States (Burgan et al., 1998); and Airborne Visible and Infrared Imaging Spectrometer (AVIRIS) data to map fuels in the State of California (Roberts et al., 1998). In these indirect mapping projects, vegetation types is mapped and then classified into either the Anderson or the NFDRS fuel models. An example of indirect mapping used 1: 80,000 black and white aerial photographs viewed in stereo (Oswald et al., 1999). Forest stands were delineated by stand composition, basal area, and total crown closure and classified into NFDRS fuel model with 90% accuracy. These studies were limited by their reliance on the generalized Anderson or NFDRS fuel models.

A third approach to mapping fuels uses topographic, biological, or geological gradients (Keane et al., 2001) to estimate fuel loads, rather than using standard values associated with specific fuel models. Mickler, et al. (2002) used predicted future net primary production, climate, FIA data and Landsat TM to estimate current and future forest biomass for fuel load mapping in the Southeastern US. Chojnacky et al. (2004) compiled fuel loading data from FIA plots to compute biomass and developed seven regression equations to predict county-level fuel loads based on forest inventory data from FIA's intensive plot network. Fuel loads were compiled for nearly 100,000 FIA plots in the eastern US where fuel load data are not yet available. The FIA Phase 3 plots in particular are used to collect fuel load data by measuring coarse woody debris, fine woody debris, litter and duff, live and dead woody shrubs, and herbaceous ground cover (Woodall, 2002). Although these approaches are not at a spatial scale for use by local land manager, it does provide for state and regional fire risk planning and moves away from the exclusion use of standardized fuel models.

This paper reports on methodology for a quantitative, multi-purpose strategy to map fuel loads. The overall goal of this study was to link vegetation classes with fuel load models. This study reports on the potential for assigning biomass values to detailed vegetation classes. These vegetation classes are based on the association level of the National Vegetation Classification System (NVCS), which is sub-set of the larger International Classification of Ecological Communities (Grossman et al., 1998). The association level vegetation is identified based on the dominant species and accounts for forest structure. The reported advantages of this approach are full screen stereo viewing, "zoom- in" capability, and the ability to delineate vegetation directly into a Geographic Information System (GIS) which reduces the time and error used in previous stereo classification and mapping endeavors (Millinor, 2000, Harrell, 2001 and Koch, 2001).

Materials and Methods

Study areas

A 3,000-acre study site on the coastal plain of North Carolina was used for this project. The site is located in the US Fish and Wildlife Service's Alligator River National Wildlife Refuge and the Department of Defense's Dare County Bombing Range in Dare County, North Carolina, USA. The elevation is 3 m. (9.8 ft) above mean sea level. The site was last disturbed by wildfire, approximately 50 years ago, and by periodic hurricanes. Vegetation at the study sites consists of primarily of pond pine (*Pinus serotina* Michx.), loblolly pine (Pinus taeda L.), red maple (Acer rubrum L.) and loblolly bay (*Gordonia lasianthus* (L.) Ellis) with an understory of fetterbush (*Lyonia lucida* (Lam.) K. Koch) and little gallberry (*Ilex glabra*

(L.) Gray). The site is located on Belhaven, Ponzer, and Pongo muck soil series that consists of very poorly drained soils that formed in highly decomposed organic material underlain by loamy marine sediments.

Measurement and modeling of down woody debris and fuels

We acquired color infrared (CIR) negatives of stereo aerial photography for the study area. Aerial photos were scanned to generate digital coverages and stereo models for interpretation as well as orthorectified mosaics of the study areas. We incorporated existing GIS vegetation data from the US Fish and Wildlife Service and the US Air Force to classify newly acquired aerial photography (2004 leaf off 1:600 scale color infrared) using onscreen stereoscopic techniques (ERDAS Imagine®, Orthobase and Stereo Analyst) to create a digital vegetation database. Vegetation polygons were classified in 3-D softcopy photogrammetry to produce National Vegetation Classification System (NVCS) association level vegetation maps. After developing stereo models, vegetation boundaries were delineated within each study site using ERDAS Imagine Stereo Analyst®. Vegetation types were identified using the NVCS at the association level (http://www.natureserve.org/explorer/). Specific associations were assigned with the aid of field data. Fire fuel data from field based sample plots, digital photos, and vegetation data were used to develop fire fuel polygons. Additional field data was used to assess the thematic accuracy of the vegetation classification, the positional accuracy of the digital orthophoto mosaic, and the fuel load polygons.

A permanent plot network was established on the Alligator River National Wildlife Refuge and the Air Force Dare County Bombing Range modeled on USDA Forest Service FIA P2 and P3 plots to measure (Figure 1) characterize live biomass and pre- and post-burn down deadwood (DWD). Three plots were randomly assigned within a sampling grid for each vegetation type. We used field protocols based in methods establish by the USDA Forest Service in Field Instructions for Southern Forest Inventory (http://fia.fs.fed.us/library.htm#Manuals). The collection of DWD data uses a line-intersect method to sample down wood along linear transects. Plot-level data on the amount, distribution, and characterization of DWD was related to the detailed attribute data for other ecosystem components on the same plot (i.e., shrub and herbaceous understory, standing dead, and live biomass) (Figure 1.). FIA methodology was augmented with additional data on the vertical distribution of DWD for input into the FARSITE fire behavior model. Down deadwood was characterized as coarse woody debris (woody pieces greater than 3.0 inches in diameter), or fine woody debris (small = 0 to 0.24 inch, medium = 0.25 inch to 0.9 inch,

Figure 1. FIA cluster subplot design with three 24-ft. transects (slope corrected, horizontal distance) established at each subplot location. All subplot clusters are laid out in a fixed pattern regardless of different condition classes and only the transect segments that fall in the forest condition are sampled. The 6.8-ft radius micro plot is used to estimate the percent cover and height of live and dead shrubs, live and dead herbs (includes grasses) and litter. Fuel loading is estimated in accessible forestland conditions on the micro plot.

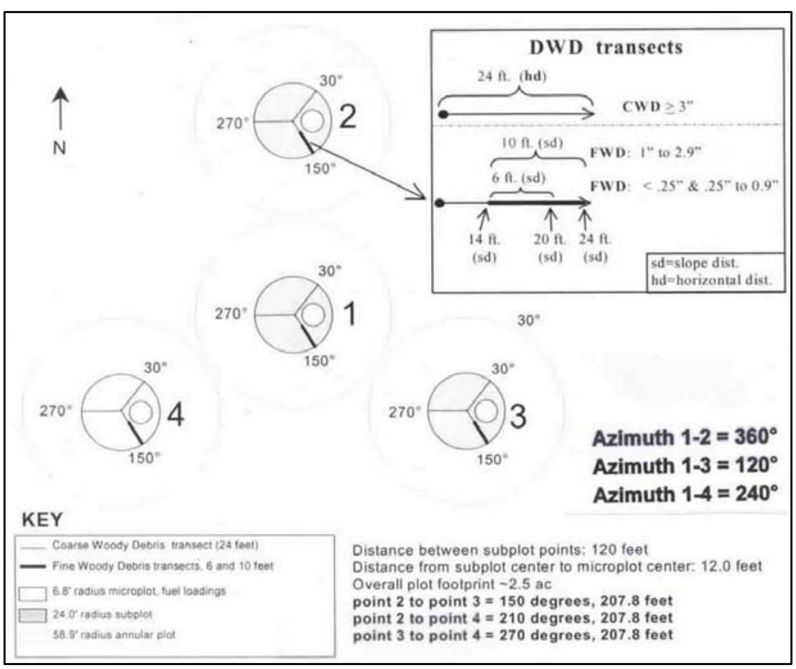


Table 1—Equations for compiling DWM components from transect and plot measurements.

Component	Equation
Coarse woody material > 76 mm diameter (CWM)	$\text{CWM} = \sum_{i=1}^{n} \frac{f\ \text{dia}_i^2 \rho_c\ d_c\ \text{s}}{\text{L}}$
Fine woody material < 76 mm diameter (FWM)	$\text{FWM} = \sum_{j=1}^{3} \frac{f\ \text{T}_j\ dclas_j^2\ \rho_f\ d_f\ \text{s}\ a}{\text{L}_j}$
Litter (*recognizable* plant material on forest floor)	$\text{Litter} = f'\ \text{D}\ \rho_{ld}$
Duff (*unrecognizable* plant material below litter and above mineral soil)	$\text{Duff} = f'\ \text{D}\ \rho_{ld}$
Shrub (live and dead shrubby plant material attached to main plant and still standing upright)	$\text{Shrub} = \frac{109.0 - (2.161\ \text{C}_\text{S}) + (0.1078\ \text{C}_\text{S}^2)}{100}$
Herb (live and dead herbaceous plant material attached to main plant and still standing upright)	$\text{Herb} = \frac{13.66\ \text{C}_\text{H}}{1000}$

Equation variables:

a = 1.13, which is an average correction factor for FWM not lying flat on ground

C_H = horizontal projection of live or dead herb cover above plot surface (%)

C_S = horizontal projection of live or dead shrub cover above plot surface (%)

d_c = decay class deduction (for conifer : class 1 = 1.0, class 2 = 0.84, class 3 = 0.71, 4 = 0.45, class 5 = 0.35; for hardwood : class 1 = 1.0, class 2 = 0.78, class 3 = 0.45, 4 = 0.42, class 5 = 0.35), from Waddell (2000) personal communication

d_f = 0.9, which assumes some decay

$dclas_1^2$ = 0.0151 , diameter (inches) squared for < 6 mm FWM

$dclas_2^2$ = 0.2890, diameter (inches) squared for 6 - 25 mm FWM

$dclas_3^2$ = 2.7600, diameter (inches) squared for 25 - 76 mm FWM

dia = log diameter (to nearest inch) at transect intersection of logs > 76 mm (small end) for decay classes 1 to 4 and logs > 127 mm (small end) for decay class 5; see Chojnacky and others (In press) for decay class definitions

D = litter or duff depth (ft)

f = units conversion factor : $\left(\frac{(11.64)(2000)}{(2.2046)(0.404686)(1000)}\right) = 26.09366$

f' = units conversion factor : $\left(\frac{43560}{(2.2046)(0.404686)(1000)}\right) = 48.82473$

i = CWM piece intersected by transect

j = 3 diameter classes of FWM : < 6 mm, 6 - 25 mm, 25 - 76 mm

L = transect length (ft)

n = total pieces of wood sampled on transect

ρ_c = specific gravity of wood species, from Forest Service, Forest Products Laboratory

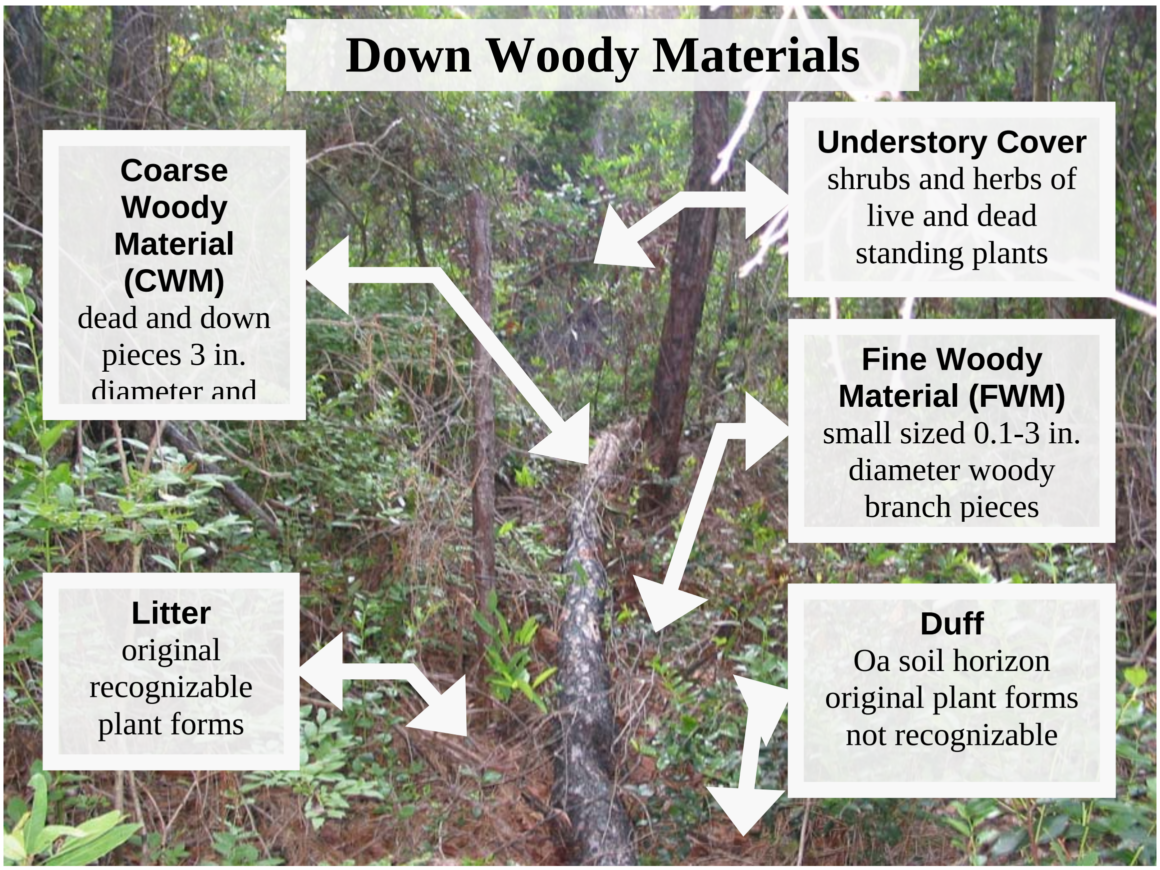
ρ_f = 0.46, which is median specfic gravity of all U.S. tree species

ρ_{ld} = material density for litter = 0.9 and for duff = 2.0 (lbs/ft^3) [source : minimum values from western U.S. forest data, Woodall 2002, personal communication]

$\text{s} = \sqrt{1 + \left(\frac{\text{slope percent}}{100}\right)^2}$, from Brown (1974)

T_j = tally of FWM pieces in each diameter class and large= 1 inch to 2.9 inches, which correspond to 1-hour, 10-hour, and 100-hour fuels, respectively.) (Figure 2). The depth of the duff layer, litter layer, and overall fuelbed was taken at the 24-foot location on each transect. These components were used to estimate fire behavior, fire spread, fire effects, and smoke production. Plot-level per-unit-area sums were expanded by the area associated with the inventory plot or averaged across the plots to produce a mean per-unit-area biomass value. The measurements were combined with material density (specific gravity) values in linear equations (Table 1) to compile dry-weight mass (Mg/ha) for each DWM component. Fuel class biomass algorithms were developed for additional forest species and decay classes in the forest types. Additional micro plots were established for destructive sampling of shrub and herbaceous vegetation to develop biomass equations. Previous equations were developed primarily for western US species (Brown et al, 1982).

Figure2. Coarse and fine woody material, litter, duff, and shrub and herbaceous fuels.



Results and Discussion

Estimating historical forest biomass

Forest inventory data are available for the last half of the 20th. The data have been compiled for years 1953, 1963, 1977, 1987, 1992, and 1997. The USDA Forest Service has a detailed plot-level database for the forest inventory data compiled for the years 1987, 1992, and 1997. For the other years, only forest statistics aggregated across the landscape are available (Smith et al., 2001). Historical tree carbon mass have been based on: (1) generalized tree biomass equations (Jenkins et al., 2003); (2) tables of volume distributed among diameter classes and forest areas (Smith et al., 2001) aggregated across the landscape; (3) effects of ownership and forest type on carbon content from the databases associated with the 1987 and 1997 U.S. forest statistics (Waddell et al., 1989, Smith et al., 2001); and (4) the equations of Smith et al. (2003). Carbon density of forest growing stock was estimated from average tree volumes, diameter distributions, and biomass equations. Estimates of carbon in non-growing stock and standing dead trees were based on similar relationships and data in the detailed 1987 and 1997 databases. The other non-standing-tree carbon pools are estimated based on relationships for live-tree carbon pools from the 1987 and 1997 data, and on forest floor equations in Smith and Heath (2002), and understory vegetation information in Birdsey (1992, 1996).

Southern forests presently contain 5,810 Mt of above-ground C on 87 million ha. Forests of the conterminous U.S. contain 20,340 Mt of aboveground C on 250 million ha. Thus the South accounts for approximately 29 percent of aboveground forest carbon stock in the conterminous U.S. Allocation of this stock among forest ecosystem pools is shown in Table 2. The sum of standing carbon in live and dead trees is provided in Table 3, by forest type and ownership. The majority of carbon is in privately owned forests and in hardwood forest types.

Table 2--Mean aboveground carbon density (Mg C per hectare) of productive Southern forests (timberlands), by to forest type and carbon pool, 1997.

Carbon pool	**Softwood forests**	**Mixed forests**	**Hardwood forests**
	Mg C ha^{-1}	Mg C ha^{-1}	Mg C ha^{-1}
Live trees	37.7	55.4	56.0
Standing dead trees	1.7	3.0	3.1
Understory vegetation	2.9	2.2	2.9
Down dead wood	3.3	7.4	7.5
Forest floor	9.3	7.6	5.7

Vegetation classification and current forest biomass

Land managers in the Coastal Plain of the eastern US recognize four general fuel types on organic soils (i.e., low pocosin, high pocosin, open cane, and overstoried cane). Past fuel and fire behavior research has resulted in only qualitative measures of fuel loads and rates of spread. A more detailed fuel classification based on species composition, standing dead and down deadwood, fuel size classification, understory vegetation, and vertical distribution of fuels would have much more utility than the broad fuel model classification system now in use. Fire in the organic soil areas of the Coastal Plain centers around the frequent and costly blowup wildfires occurring there and the use of fire as a fuel reduction and habitat management tool. Wildfires in this area can under certain combinations of fuel and weather, grow from a low intensity burn to a virtually uncontrollable burn until weather conditions change or the fire has run out of fuel. Control efforts are often hampered by inaccessibility, poor soil trafficability on wet organic soils in the area, and fires that tend to burn deeply into the organic soils. A better understanding of the behavior of fires and the role of fuel loading in fire behavior in the pocosins, especially the factors that contribute to the occurrence of major fires, will contribute to the control of wildfires and the use of prescribed fire as a management tool in the region.

Five NVCS associations were identified on the research site 1. These associations were (1) pond pine woodland (2) pond pine woodland (overstocked), (3) mixed pine/hardwood forest, (4) maple forest, and (5) loblolly pine forest. Preliminary trends in biomass in relation to forest structure across the study area are shown in Figures 3-5. The large component of biomass was found in the Oa horizon of the organic soils. The quantity of carbon ranged from 1,150 to 424 Mg C/ha. The litter layer held the second largest pool of carbon. Values ranged from 80 to 16 Mg C/ha. Additional carbon pools are shown in Figures 3-5.

Fuel classification during the last 75 years has evolved from a fire control planning focus to the beginning of predictive fire behavior modeling in the 1970s. Current fuel classification models have focused on the rate of spread, resistance to control, and the flame length of fires in surface fuels. Fire behavior is predicted by land managers with thirteen stylized fuel models (Rothermel, 1972; Albini, 1976). Decision support systems such as FARSITE and the National Fire Danger Rating system are based on the Rothermel's fire spread model and are the basis of predicting fire behavior today. Land managers recognize that these models are limited in their ability to predict extreme fire behavior, persistent fires, and fuel consumption. Some of these limitations are currently being addressed by a fuel characteristic classification (FCC) research project funded by the JFSP (Sandberg et al., 2001). But of the 53-fuelbed types with detailed or general information currently in the FCC, only one forest type found in Dare County has been identified for inclusion in the FCC database.

The availability of fire-spread models has increased the need for quantitative fuel field data. A line-intersect method developed by Brown (1974) has been widely adopted to quantify fuel-loading inputs. The USDA Forest Service Forest Inventory and Analysis (FIA) program recognized the need for extensive information on fuels across the landscape. Fuel field protocols were piloted by the former Forest Health Monitoring Program between 1998 and 2000, and implemented in 2001 on a 1/16th subset of the standard base FIA grid. These FIA methods generally partition the forest ecosystem into pools for live trees, down deadwood, standing dead trees, understory vegetation, forest floor materials, and soil. Estimating site-specific fuels from this database has been particularly problematic. The data is not consistently available from the largest inventory data source, FIA, and there is little data on fuel pools in the scientific literature. Additionally the biomass algorithms are based nationally on data collected primarily on western US tree, shrub, and herbaceous species and associated wood density for decay classes.

Table 3--Mean aboveground tree carbon mass of Southern forests, by forest type and ownership classifications, 1997. The carbon pool includes aboveground portions of live and standing dead trees. Mean annual carbon change between 1953 and 1997 is calculated as the net change in carbon stock divided by the number of years.

Forest type	**Mean annual C change 1953-1997**	**Total tree C**	**C density**	**Forest area**
	Mt C y^{-1}	Mt C	Mg C ha^{-1}	1000 ha
	PRIVATELY OWNED FORESTS			
Miscellaneous conifer	0.1	14	74.1	193
Longleaf-slash pine	-1.8	148	33.2	4,468
Loblolly-shortleaf pine	0.8	721	39.4	18,286
Oak-pine	6.0	486	45.1	10,767
Oak-hickory	23.4	1,686	59.3	28,445
Oak-gum-cypress	6.4	734	70.8	10,356
Elm-ash-cottonwood	0.3	52	61.5	851
Maple-beech-birch	0.3	28	71.5	397
Other Eastern types (including non-stocked)	0.4	23	8.9	2,541
Total Privately Owned	35.8	3,892	51.0	76,303
	PUBLICLY OWNED FORESTS			
Miscellaneous conifer	0.1	6	66.7	86
Longleaf-slash pine	0.2	34	38.8	883
Loblolly-shortleaf pine	0.3	97	48.8	1,988
Oak-pine	1.1	75	52.9	1,418
Oak-hickory	3.8	229	71.6	3,198
Oak-gum-cypress	1.0	113	71.9	1,572
Elm-ash-cottonwood	0.1	8	74.9	102
Maple-beech-birch	0.1	6	83.7	72
Other Eastern types (including non-stocked)	<0.1	6	5.8	1,025
Total Publicly Owned	6.6	574	55.5	10,343
Total South	42.4	4,466	51.5	86,646

Figure 3. Fine Woody Material (FWM) (Mg/ha) by National Vegetation Classification System (NVCS) association level vegetation type.

Vegetation Type	Plot	Duff	Litter	Total FWM	Small FWM	Medium FWM	Large FWM
loblolly pine forest	2	672.4	52.6	7.9	0.6	3	4.4
loblolly pine forest	8	424.7	60.5	11.6	0.6	5.6	5.3
loblolly pine forest	10	424.7	52	11	0.6	4.5	5.9
maple forest	5	672.4	10.7	6.9	0.9	2.3	3.7
maple forest	7	424.7	12.7	4.3	0.7	2.7	0.9
maple forest	9	424.7	16.6	9.8	0.6	2.7	6.5
mixed pine/hardwood	6	424.7	22.3	8.3	0.9	3	4.4
mixed pine/hardwood	14	424.7	32.9	7.1	0.7	3.3	3.1
mixed pine/hardwood	15	424.7	52.6	16.2	1.6	7.8	6.8
overstocked pond pine	11	424.7	49.1	7.1	0.9	3.7	2.5
overstocked pond pine	12	424.7	53.6	10.4	0.9	4.5	5
overstocked pond pine	4	672.4	80.9	8.4	0.3	3.5	4.7
pond pine woodland	3	1150.2	60.9	10.9	0.5	3.9	6.5
pond pine woodland	13	424.7	55.1	9.2	0.5	4	4.7
pond pine woodland	1	1150.2	75.9	5	2	2.1	0.9

Figure 4. Live and dead shrub and herbaceous biomass) (Mg/ha) by National Vegetation Classification System (NVCS) association level vegetation type.

Vegetation Type	Plot	Live Shrub	Dead Shrub	Live Herb	Dead Herb
loblolly pine forest	2	5.21	0.98	0.00	0.00
loblolly pine forest	8	5.13	1.03	0.01	0.00
loblolly pine forest	10	4.59	1.52	0.00	0.00
maple forest	5	2.65	0.98	0.00	0.00
maple forest	7	3.42	1.19	0.05	0.00
maple forest	9	1.00	0.27	0.00	0.00
mixed pine/hardwood	6	5.26	1.12	0.00	0.00
mixed pine/hardwood	14	4.72	1.04	0.00	0.00
mixed pine/hardwood	15	3.32	1.44	0.00	0.00
overstockedpond pine	11	1.13	2.00	0.00	0.00
overstockedpond pine	12	4.54	2.68	0.00	0.00
overstockedpond pine	4	1.33	0.98	0.01	0.00
pond pine woodland	3	1.54	0.27	0.21	0.02
overstockedpond pine	13	1.22	0.76	0.02	0.00
pond pine woodland	1	8.29	1.16	0.00	0.00

Figure 5. Coarse Woody Material (Mg/ha) by National Vegetation Classification System (NVCS) association level vegetation type.

Vegetation Type	Plot	Coarse Woody Material
loblolly pine forest	2	9.15
loblolly pine forest	8	8.27
loblolly pine forest	10	0.00
maple forest	5	8.84
maple forest	7	17.90
maple forest	9	15.04
mixed pine/hardwood	6	3.11
mixed pine/hardwood	14	23.19
mixed pine/hardwood	15	92.49
overstockedpond pine	11	3.24
overstockedpond pine	12	0.00
overstockedpond pine	4	0.00
pond pine woodland	3	5.04
pond pine woodland	13	3.85
pond pine woodland	1	2.97

Conclusions

The methodology of using modified ICEC association level vegetation maps, created from digital photogrammetry and FIA P3 data, shows promise as an approach to fuel mapping.

(1) Softcopy photogrammetry, coupled with ground truthing, provides a high level of accuracy for mapping to the association level of the ICEC system.
(2) Fuel loads generated from the FIA P3 plots differ from fuel loads estimated using the standard fire models. These differences could have an impact on the prediction of fire spread and behavior.
(3) Fuel loads within fuel size classes did vary between the modified association level classifications. Disturbance history appears to play a significant role in explaining why fuel loads differ and could help in creating more accurate fuel maps.

Research of this nature may lead to use of FIA P3 plot data to generate an index of fuel load by ICEC association level vegetation classification. This could lead to a valuable multi-purpose tool for land managers and researchers for use in predicting, preventing and managing forest biomass for wildfire.

Acknowledgement

Support for this project was provided by the USDA Forest Service Forest Health Monitoring Program, US Air Force Air Combat Command, Legacy Resource Management Program, and the Joint Fire Science Program.

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