1988

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FUEL WEIGHT PREDICTION EQUATIONS FOR UNDERSTORY WOODY PLANTS IN EASTERN TEXAS

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ABSTRACT.—Equations were developed for predicting total above-ground fuel weight (ovendry in grams) of 19 understory woody plant species in eastern Texas forests, using logarithmic equations and stem basal diameter. Prediction of woody fuel weight can be used to enhance fire intensity estimates under varying fuel moisture and weather conditions. *Key words*: biomass, fuels; understory species; prediction equations.

Low to moderate intensity fires (wild or prescribed) moving through a forest environment feed on fuel at or near the forest floor, consuming litter, grasses, forbs, and small woody vegetation in the forest understory. Depending on species and burning conditions, living vegetation in the small basal diameter classes (less than 0.6 centimeter) can contribute to the energy output, especially during October through March in eastern Texas forests, when most wildfires occur, and the majority of prescribed fires are planned. If fire managers could accurately evaluate the understory fuel weight present on a designated burn site, they could conduct more efficient and, perhaps, less hazardous prescribed burns (Brown et al. 1982).

Numerous equations for estimating the fuel weight of the small diameter woody plant component of forest ecosystems have been developed for several regions of the United States as Williams and McClenahan (1984) in eastern and southern Ohio; Edwards (1976) in lower Piedmont and Coastal Plain of Georgia; Phillips (1977) in upper Piedmont of Georgia and the mountains of North Carolina; Roussopoulos and Loomis (1979) and Grigal and Ohmann (1977) in northeastern Minnesota; Hitchcock (1978) in Tennessee; Brown and Marsden (1976) and Telfer (1969) in the northern Rocky Mountains; and Franchi et al. (1984) in Alabama and Mississippi.

However, information on understory woody stem fuel weight in eastern Texas forests is not available. Fuel weight prediction equations developed in other regions are not applicable to east Texas because forest conditions affecting understory fuel weight are governed by different plant species, climate, landform, soil, and overstory conditions (Franchi et al., 1984).

In this paper, we present equations to estimate the ovendry weight of the aboveground portion of individual woody stems for 19 species common to the understories of forests in eastern Texas. With this information, along with data on forest litter, fire managers in that region

The Texas Journal of Science, Vol. 40, No. 1, February 1988

TABLE 1. Arthmetic means and ranges of variables used to develop biomass prediction equations.

Species	Number of plants	Basal diameter (mm)		Dry weight (gms)	
		Mean	Range	Mean	Range
Acer rubrum	29	13.2	8-21	63.5	7.6-227.7
Baccharis halimifolia	20	12.2	6-25	68.6	10.6-295.2
Carya tomentosa	21	12.7	5-33	92.6	2.6-528.9
Callicarpa americana	31	10.4	6-17	74.7	4.2-327.7
Cornus florida	39	13.0	5-21	92.2	4.2-250.2
Ilex opaca	31	14.0	7-27	118.4	8.3-519.8
Ilex vomitoria	30	12.2	6-20	126.1	14.5-432.5
Liquidambar styraciflua	35	14.2	6-22	77.6	6.5-249.9
Pinus echinata	29	21.3	12-35	154.6	33.2-438.2
Pinus taeda	32	14.0	7-26	84.7	14.2-421.1
Quercus alba	29	12.2	5-33	99.0	2.3-495.9
Quercus falcata	31	13.2	6-24	81.2	11.7-275.3
Myrica cerifera	34	8.6	3-18	60.6	0.8-256.4
Rhammus caroliniana	27	9.9	4-17	37.6	2.6-147.0
Rhus copallina	30	13.0	5-33	82.4	2.6-528.9
Rhus glabra	29	13.2	7-22	57.1	3.7-195.9
Sassafras albidum	23	13.0	6-22	80.2	3.0-279.2
Vaccinium spp.	22	10.4	6-17	71.0	16.9-172.5
Viburnum dentatum	20	11.2	7-17	85.2	10.2-314.0

can compute total fuel loadings to determine the potential severity of wildfires or estimate the effects of prescribed burns.

Woody Stem Fuel Sampling

Nineteen species commonly occurring in the understory of mixed pine-hardwood forests in eastern Texas were sampled. Data from live stems were collected during the dormant seasons December 1984 to March 1986.

Each selected live woody stem was cut at ground-line. After cutting, basal diameter was measured to the nearest millimeter using a dial-gauge caliper. The above-ground portion of each plant was ovendried and weighed to the nearest 0.1 gram. Table 1 characterizes the data by listing means and ranges for each of the 19 species. Basal diameters for 15 of the 19 species did not exceed 30 mm.

Fuel Weight Prediction

Plottings of observed dry weight (DW) over observed stem basal diameter (D) revealed strong exponential growth trends for each of the 19 species. A logarithmic transformation of the data sets provided excellent linear relationships suitable for simple linear regression analyses. Residual analyses revealed no adverse trends. Fuel weight prediction

TABLE 2. Predicting dry-weight (gms) using basal diameter (mm) of 19 species of understory woody plants in eastern Texas.

Species	Prediction equations	r^2
Acer rubrum	$DW = 0.03OD^{2.842}$	86%
Baccharis halimfolia	$DW = 0.21OD^{2.193}$	96%
Carya tomentosa	$DW = 0.034D^{2.855}$	96%
Callicarpa americana	$DW = 0.008D^{3.735}$	94%
Cornus florida	$DW = 0.205D^{2.328}$	88%
Ilex opaca	$DW = 0.056D^{2.747}$	92%
Ilex vomitoria	$DW = 0.176D^{2.550}$	88%
Liquidambar styraciflua	$DW = 0.059D^{2.638}$	88%
Pinus echinata	$DW = 0.081D^{2.419}$	86%
Pinus taeda	$DW = 0.136D^{2.360}$	90%
Quercus alba	$DW = 0.073D^{2.682}$	96%
Quercus falcata	$DW = 0.176D^{2.269}$	83%
Myrica cerifera	$DW = 0.121D^{2.628}$	96%
Rhammus caroliniana	$DW = 0.027D^{3.010}$	98%
Rhus copallina	$DW = 0.040D^{2.765}$	94%
Rhus glabra	$DW = 0.045D^{2.672}$	79%
Sassafras albidum	$DW = 0.016D^{3.235}$	96%
Vaccinium spp.	$DW = 0.204D^{2.456}$	90%
Viburnum dentatum	$DW = 0.033D^{3.150}$	92%
Composite	$DW = 0.096D^{2.551}$	85%

equations are presented in Table 2 for each of the 19 species. In addition, all data sets for hardwood species were combined into one set, and a composite equation was developed, which should be suitable for undetermined or unspecified components of the forest understory.

APPLICATION

Assume that a land manager would like to run a prescribed fire through a mixed pine-hardwood forest somewhere in east Texas. The purpose of the burn might be to reduce potential fuel loads that could contribute to a damaging wildfire. The manager needs an estimate of fuel loading in order to burn in an effective and safe manner.

A recent forest inventory consisting of various size sampling plots and the planar intersect technique provided estimates of overstory woody stem diameters, understory stem diameters, and species composition, and forest floor material, such as litter, forbs and fallen roundwood. The understory woody plant component for our example consisted of eight species plus several undetermined plants. For each category, the average basal diameter and number of stems per hectare was determined (Table 3). The diameter values were substituted into appropriate equations in Table 2. After multiplying by stems per hectare, an estimate of the fuel load for this component of the forest understory was obtained (Table 3).

TABLE 3. Average basal diameters, number of stems and dry weight per hectare of selected understory woody species in eastern Texas.

Species	Average basal diameter (mm)		Stems per hectare (number)	Dry material per hectare (kg)
Liquidambar styraciflua	14.2		4600	297
Ilex vomitaria	12.2		3950	410
Myrica cerifera	8.6		5100	176
Cornus florida	13.0		1750	141
Acer rubrum	13.2		950	44
Quercus falcata	12.2		425	22
Vaccinium sp.	10.4		1950	125
Pinus taeda	14.0		2800	193
Miscellaneous	12.8		1225	79
		TOTAL	22,750	1487

The dry weight fuel load of woody stem material of 1487 kilograms per hectare in conjunction with an estimated 8400 kilograms per hectare of forest floor material, enables the experienced forester to calculate the potential energy (heat) release for our example. Actually, full potential energy is not usually realized in a forest fire, due to several stand variables—moisture content of the living and dead fuels, size class and arrangement, weather factors and topography (particularly slope).

The living segment of the fuel complex is seldom totally consumed, but if a sufficient litter layer is present to carry a fire, many of the smaller diameter shrubs, trees, and vines will burn and contribute to the fire's energy release. Recent fire behavior modeling (Burgan and Rothermel, 1984) with an emphasis on fuels has resulted in an increased understanding of the interacting factors affecting forest fires. However, accurate fire behavior predictions will continue to be rather elusive due to the unlimited combinations of fuel, topography, and weather conditions.

To complete our hypothetical example, let us assume that the landform is interior Coastal Plain. If a prescribed fire (strip headfire) was run through our forest three days after a 12.50-mm rain, litter and duff layers may average 10 and 20 percent moisture content, respectively. Air temperature is 15°C, relative humidity is 25 percent, and wind speed is 9.5 kilometers per hour. Thus we might expect a fuel reduction of at least 40 percent of the 1480 kilograms of woody stem material with basal stem diameters less than 30 mm and about 60 percent of the 8400 kilograms of forest floor material. Reductions would vary under different site and burning conditions.

These estimates are based on a normal distribution of size classes found in understory species for the calculated basal diameters obtained in field sampling. Forest land managers can benefit from better knowledge of part or all of the biomass data.

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