



Missouri Ozark Forest Ecosystem Project Site History, Soils, Landforms, Woody and Herbaceous Vegetation, Down Wood, and Inventory Methods for the Landscape Experiment

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Edited by Stephen R. Shifley and Brian L. Brookshire

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Analysis of Down Wood Volume and Percent Ground Cover for the Missouri Ozark Forest Ecosystem Project

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Abstract.—Volume and percent ground cover of down wood were estimated on the MOFEP sites from two separate sampling inventories, line transects and fixed-area plots. Line transects were used to sample down wood in the 1990-91 and 1994-95 inventories and fixed-area plots were used in an additional inventory in 1995. Line transect inventories estimated a range in ground cover from 1.2 to 2.9 percent in 1990-91 and from 1.0 to 2.2 percent in 1994-95. Fixed-area plots estimated a range in ground cover from 0.6 to 1.7 percent. Percent ground cover estimated by line transects was significantly higher than estimates based on fixed-area plots. Down wood volume estimates ranged from 190 to 423 ft³ ac⁻¹ for line transect inventories in 1994-95 and from 114 to 463 ft³ ac⁻¹ for fixed-area plots. No significant difference was found for down wood volume estimated by line transects and fixed-area plots.

Dead wood on the forest floor is important as a slow-release nutrient sink in forested ecosystems. This material provides habitat for numerous terrestrial vertebrates and invertebrates and serves as substrate for a variety of fungi. Measurement of down wood collected as part of the MOFEP vegetation sampling protocol is a necessary part of understanding the ecological processes that occur within the oak-hickory and oak-pine forests of the Ozarks. Sampling objectives were to estimate down wood volume and percent ground cover for MOFEP sites. Down wood characteristics were summarized for each MOFEP site and can be linked to other vegetative characteristics measured for individual plots.

METHODS

Volume and percent ground area cover of down wood on MOFEP sites were estimated from two separate inventories. The first inventory used line transects to measure down wood on 645 vegetation plots in 1990-91 and again in 1994-95. The latter inventory included three additional plots for a total of 648. On each plot, four line transect segments were

established extending in cardinal directions from plot center to the four subplot centers (Shifley *et al.* figure 1, this volume). Each transect segment was 56.6 ft (17.2 m) in length. Down logs at least 24 in. (61 cm) in length and 2 in. (5 cm) in diameter were tallied when they intersected the transect line. Coverage was recorded as the length of the transect line covered by down logs. A Biltmore stick was used to record maximum diameter for each down log. Maximum diameter measurements excluded butt swell. In 1995, field crews also recorded minimum log diameter down to 2 in. in diameter. Length of each qualifying log was recorded by size class as shown in table 1. Logs that forked and had several branches were measured as multiple

Table 1.—Size classes for recording log length on MOFEP sites by line transects in sample years 1990-91 and 1994-95. Length is recorded as the longest length the log attains until it has less than a 2 in. (5 cm) diameter.

Size class	Length (feet)
5	$2 \leq x \leq 5$
10	$5 < x \leq 10$
15	$10 < x \leq 15$
20	$15 < x \leq 20$
30	$20 < x \leq 30$
40	$30 < x \leq 40$
50	$40 < x \leq 50$

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pieces with the main trunk as the longest length. Logs crossing two or more transects were recorded in each transect. Leaning snags at least 5 cm in diameter that were supported by another tree and stumps with a 24-in. horizontal length occurring under the line transect were recorded as down wood.

The extent of decomposition was ranked for each piece of down wood using five decay classes defined by Maser *et al.* (1979). Decay class characteristics are described in detail in table 2. Decay class one consisted of newly fallen limbs and trees with little decay; decay class five consisted of logs that were almost completely decomposed.

Table 2.—Decay class descriptions for down wood.

Class	Description
1	Bark intact; twigs present; log intact and elevated on points; round.
2	Bark intact but 10-90% loosened; twigs absent; log intact to partly soft and elevated on points but sagging slightly; round.
3	Trace of bark; twigs absent; log breaking into hard, large pieces and sagging near ground; round; original color to faded.
4	Bark absent; twigs absent; log breaking into small, soft, blocky pieces and in contact with ground; round to oval; faded.
5	Bark absent; twigs absent; log soft and powdery and in contact with ground; oval; faded.

The second down wood estimate, measured in 1995, was based on 99 fixed-area circular plots that were concentric with the overstory vegetation plots (Shifley *et al.*, this volume). These plots were equally distributed among the nine sites (11 plots per site), and plot selection within sites was random. The selected down wood plots occurred on ecological landtypes (ELT) 17 (48 plots), 18 (50 plots), and 23 (1 plot). ELT classifications are described by Miller (1981), Meinert *et al.* (1997),

and Kabrick *et al.* (this volume). This second sample used protocols that matched other down wood inventories in the region, and the results can be directly compared to those from other studies (Shifley *et al.* 1995, 1997a, b; Rebertus *et al.* 1997). Logs or portions of logs ≥4 in. (10 cm) in diameter were tallied within the fixed-area plot. Length, midpoint diameter, and decay class were recorded for each qualifying piece of down wood within the plot. Leaning snags and stumps at least 4 in. in diameter were recorded as down wood.

ANALYTICAL METHODS

Percent Ground Cover

Percent of ground area covered by down wood was computed for all measurement years. For the line transects, percent cover of down wood was computed by simply measuring the proportion of the transect line that was covered by individual pieces of down wood. Coverage was determined as the vertical projection of the log onto the transect measuring tape. For the circular fixed-area (0.25-ac) plots, percent cover of down wood was determined by assuming each piece of down wood covered an area equal to the product of its length and its midpoint diameter. Areas for individual pieces of down wood were summed to obtain the proportion of the plot covered. Values were computed for each plot and averaged to obtain means by site and ELT. Table 3 indicates the number of plots sampled at each site for each inventory and the harvest treatment for each site. Shifley *et al.* (this volume) lists the number of plots and the years they were measured for all sites at MOFEP.

Volume

Volume was computed only for the 1994-95 measurement of line transects and the fixed-area plots. Volume for the line transect sample at each plot was computed using the formula presented by Van Wagner (1968):

$$V = \frac{\pi^2 \Sigma d^2}{8L}$$

where *V* is the volume per acre of down logs (ft³/ft²), *d* is the diameter of each down log (in.) averaged from maximum and minimum diameters, and *L* is transect length (ft). This formula depends on the assumptions that down



logs are cylindrical, horizontal, and randomly oriented. For the 1995 data, we used the average of the maximum and minimum log diameters as diameter for this equation. However, for the 1994 line transect data, only maximum log diameters and log length were measured in the field. Consequently, we assumed a 3.7 percent reduction in diameter per foot of length based on the mean observed taper rate for the 4,334 down logs measured in 1995. Based on this assumed taper rate and the known log length, we estimated the minimum log diameters for the 1994 inventory. We used the average of the maximum log diameter and the estimated minimum log diameter as the average log diameter in the application of the volume equation.

For the fixed-area plots, volume per log was computed from the observed length and midpoint diameter of each log using the formula for the volume of a cylinder with known length and diameter. All volumes were computed by plot and then summarized to obtain means by site and ELT. The number of plots sampled at each site and the harvest treatments for each site are listed in table 3.

Analysis of variance was used to compare mean volume and mean percent ground cover among sites and between ELT's for line transect and fixed-area plot inventories. Tukey's Honestly Significant Difference procedure was used to determine where differences exist among sites for each inventory.

RESULTS AND DISCUSSION

Percent Ground Cover

Ground area covered by down wood ranged from 1.2 to 2.9 percent and from 1.0 to 2.2 percent when estimated by line transects in years 1990-91 and 1994-95, respectively. In sample year 1990-91, significant differences were found for mean percent ground cover between sites 6 and all other sites ($F=11.3$; $P<0.01$) (table 4). Significant differences in mean percent ground cover were found among sites from sample year 1994-95 and are listed in table 4 ($F=6.1$; $P<0.01$). There were no significant differences in mean percent cover between the 1990-91 and 1994-95 line transect inventories ($F=2.6$; $P=0.11$). Ground area covered by down wood for fixed-area plots ranged from 0.6 to 1.7 percent (table 5). Mean percent ground cover for fixed-area plots was significantly different between sites 4 and 6 ($F=2.2$; $P=0.03$) (table 5).

The percent ground cover estimates based on line transects were consistently higher than estimates based on fixed-area plots. These differences were significant with $P<0.001$ ($F=11.3$). This difference was at least partially because line transect inventories included pieces down to 2 in. in diameter, but fixed-area plot inventories included pieces only down to 4 in. in diameter.

Percent ground cover of down wood also differed by ELT. Percent of down wood cover

Table 3.—Summary of MOFEP harvest treatments and number of plots sampled at each site for fixed-area plots in 1995 and line transects during sample years 1990-91 and 1994-95.

Site	Treatment	Number of fixed-area plots for volume and percent ground covered	Number of plots sampled by line transects for volume and percent ground covered	
			1990-91	1994-95
1	No harvest	11	73	76
2	Uneven-aged	11	73	73
3	Even-aged	11	72	72
4	Uneven-aged	11	74	74
5	Even-aged	11	70	70
6	No harvest	11	71	71
7	Uneven-aged	11	71	71
8	No harvest	11	70	70
9	Even-aged	11	71	71
Total		99	645	648

Table 4.—Estimated percent ground cover of down wood for 1990-91 and 1994-95 line transect inventories. Estimated volume of down wood for 1994-95 line transects¹.

Site	1990-1991		1994-1995			
	% ground covered by down wood		% ground covered by down wood		Vol. of down wood (ft ³ ·ac ⁻¹)	
	Mean	SE ²	Mean	SE	Mean	SE
1	1.8 ^a	0.11	1.6 ^{bc}	0.12	234 ^{ab}	21
2	1.5 ^a	0.11	1.2 ^{bc}	0.10	188 ^a	17
3	1.6 ^a	0.14	2.2 ^{ac}	0.25	418 ^b	122
4	1.7 ^a	0.16	1.4 ^{bc}	0.13	227 ^{ab}	27
5	1.7 ^a	0.17	1.0 ^b	0.09	198 ^a	23
6	2.9 ^b	0.19	2.2 ^{ac}	0.22	394 ^{ab}	43
7	1.6 ^a	0.13	1.8 ^{ac}	0.15	291 ^{ab}	32
8	1.6 ^a	0.14	1.8 ^{ac}	0.18	309 ^{ab}	34
9	1.2 ^a	0.11	1.4 ^{bc}	0.15	221 ^{ab}	24
Mean	1.7		1.6		276	

Means with the same letter within columns were not significantly different (Tukey multiple comparison, $P>0.05$).

¹ Volume m³·ha⁻¹ = 0.06997 (volume ft³·ac⁻¹).

² SE = standard error of the mean.

Table 5.—Percent ground cover and volume of down wood by site for fixed-area plots (0.25 ac).

Site	% ground covered by down wood		Vol. of down wood (ft ³ ·ac ⁻¹)	
	Mean	SE ¹	Mean	SE
1	0.9 ^{ab}	0.15	209 ^{ab}	41
2	0.8 ^{ab}	0.11	167 ^{ab}	34
3	1.3 ^{ab}	0.26	345 ^{ab}	92
4	0.6 ^a	0.10	115 ^a	22
5	0.8 ^{ab}	0.12	165 ^{ab}	35
6	1.7 ^b	0.43	463 ^b	139
7	1.1 ^{ab}	0.36	242 ^{ab}	102
8	1.3 ^{ab}	0.20	269 ^{ab}	55
9	1.1 ^{ab}	0.22	382 ^{ab}	84
Mean	1.1		262	

Means with the same letter within columns were not significantly different (Tukey multiple comparison, $P>0.05$).

¹SE = standard error of the mean.



estimated from sample years 1990-91 ranged from 1.1 to 2.5 percent for ELT 17 and from 0.9 to 2.5 percent for ELT 18 (table 6). Line transects sampled in years 1994-95 produced estimates ranging from 1.1 to 2.0 percent for ELT 17 and from 1.2 to 3.1 percent for ELT 18 (table 6). No significant differences were found between ELT's 17 and 18 in the 1990-91 or 1994-95 inventories (table 6). Percent ground cover of fixed-area plots ranged from 0.6 to 1.3 percent on ELT 17 and from 0.5 to 2.4 percent on ELT 18 (table 6). There were no significant differences between ELT 17 and ELT 18 ($F=2.8$; $P=0.11$) (table 6).

Volume

Line transect inventories estimated a range in down wood volume from 190 to 423 $\text{ft}^3\text{-ac}^{-1}$ (13 to 30 $\text{m}^3\text{-ha}^{-1}$) (table 4). Mean volume of down wood on site 3 was significantly greater than on sites 2 and 5 when estimated by line transects ($F=2.6$; $P=0.008$) (table 4). Decay classes three and four made up most down wood on all sites except site 3 where decay class one and two accounted for a slightly higher percent of volume. Decay classes three and four included 72 percent of down wood volume, decay classes two and five each had about 12 percent, and decay class one included 4 percent (table 7). The majority of volume was ranked into decay classes three and four in part because the ranking system was developed for western conifers (Maser *et al.* 1979).

Volume of down wood ranged from 114 to 463 $\text{ft}^3\text{-ac}^{-1}$ (8 to 32 $\text{m}^3\text{-ha}^{-1}$) when estimated using fixed-area plots (table 5). Mean volume of down wood was significantly greater on site 6 compared to site 4 ($F=2.3$; $P=0.03$) (table 5). Most down wood volume on all sites was categorized as decay class three (74 percent) (table 8). Only about 14 percent of the total down wood volume was categorized into decay classes one and two combined, and about 12 percent was categorized into decay classes four and five combined. Mean volume did not differ significantly among sites on fixed-area plots in decay classes one, two, four, and five (table 8). However, site 6 was significantly greater than sites 2 and 4 in decay class three ($F=2.6$; $P=0.01$) (table 8).

Volume estimates based on line transects were larger on sites 1, 2, 3, 4, 5, 7, and 8, and volume estimates based on fixed-area plots were larger on sites 6 and 9 (tables 4, 5). There was no significant difference between mean volume estimates for fixed-area plots and line transects ($F=0.1$; $P=0.76$).

The mean volume of down wood estimated by line transects in 1994-95 was 249 and 314 $\text{ft}^3\text{-ac}^{-1}$ (17 and 22 $\text{m}^3\text{-ha}^{-1}$) for ELT's 17 and 18, respectively (table 9). There were no significant differences between ELT's 17 and 18 ($F=3.0$; $P=0.10$). The mean volume of down wood on fixed-area plots was 200 $\text{ft}^3\text{-ac}^{-1}$ (14 $\text{m}^3\text{-ha}^{-1}$) on ELT 17 and 324 $\text{ft}^3\text{-ac}^{-1}$ (23 $\text{m}^3\text{-ha}^{-1}$) on ELT 18 (table 9). No significant differences occurred between ELT's 17 and 18 ($F=3.2$; $P=0.09$) (table 9).

Table 6.—Percent ground cover of down wood for ELT's 17 and 18 by site for fixed-area plot and line transect inventories. *P*-values are tests of differences among ELT 17 and ELT 18.

Site	Percent ground cover of down wood					
	Fixed-area plot		Line transects 1990-1991		Line transects 1994-1995	
	ELT 17	ELT 18	ELT 17	ELT 18	ELT 17	ELT 18
1	1.0	1.4	1.1	0.9	1.6	1.8
2	1.1	0.7	1.5	1.4	1.1	1.3
3	0.7	0.8	1.1	1.4	1.7	3.1
4	0.9	1.9	1.4	1.6	1.2	1.5
5	0.6	0.5	1.4	1.5	1.1	1.2
6	0.8	0.7	1.5	1.5	1.8	2.8
7	0.9	2.4	2.5	2.5	2.0	2.0
8	0.7	1.6	1.3	1.7	1.7	2.2
9	1.3	1.4	1.4	1.5	1.4	1.3
Mean	0.9	1.2	1.5	1.6	1.5	1.9
<i>P</i> -value	0.11		0.66		0.13	

Table 7.—Percent of down wood volume by decay class for the 1994-95 line transect inventory. Decay classes are defined in table 2.

Site	Percent of down wood volume Decay class				
	1	2	3	4	5
1	0.0	7.3	39.7	33.1	19.9
2	0.2	10.1	34.6	39.9	15.2
3	28.0	26.1	21.0	17.5	7.4
4	5.3	11.4	31.4	36.7	15.1
5	<0.1	5.4	44.1	38.7	11.7
6	0.1	11.4	39.3	34.7	14.5
7	0.8	13.2	45.5	31.7	8.8
8	0.2	8.7	55.0	27.4	8.8
9	3.7	14.9	53.7	20.6	7.1
Total	4.3	12.1	40.5	31.1	12.0

Table 8.—Percent of down wood volume by decay class for fixed-area plots (0.25 ac). Decay classes are defined in table 2.

Site	Percent of down wood volume Decay class				
	1	2	3	4	5
1	2.6	4.7	74.8	15.5	2.4
2	0.3	5.5	70.8	22.6	0.7
3	32.0	4.1	58.2	5.7	0.1
4	0.0	8.8	72.2	18.6	0.5
5	0.0	3.3	86.4	9.8	0.6
6	0.1	5.2	90.1	4.4	0.2
7	22.0	17.2	54.4	6.2	0.1
8	2.0	7.6	76.3	12.8	1.3
9	5.5	9.0	81.7	3.8	0.0
Total	7.2	7.3	73.9	11.0	0.7



Table 9.—Volume of down wood for ELT's 17 and 18 by site for the fixed-area plot and the 1994-95 line transect inventories.

Site	Volume of down wood (ft ³ ·ac ⁻¹)			
	Fixed-area plots		Line transects 1994-1995	
	ELT 17	ELT 18	ELT 17	ELT 18
1	250	174	240	247
2	162	174	202	209
3	194	525	256	395
4	126	106	207	264
5	207	140	174	279
6	120	670	330	502
7	120	390	260	379
8	257	259	350	323
9	283	502	223	239
Mean	200	324	249	314
P-value	0.09		0.10	

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