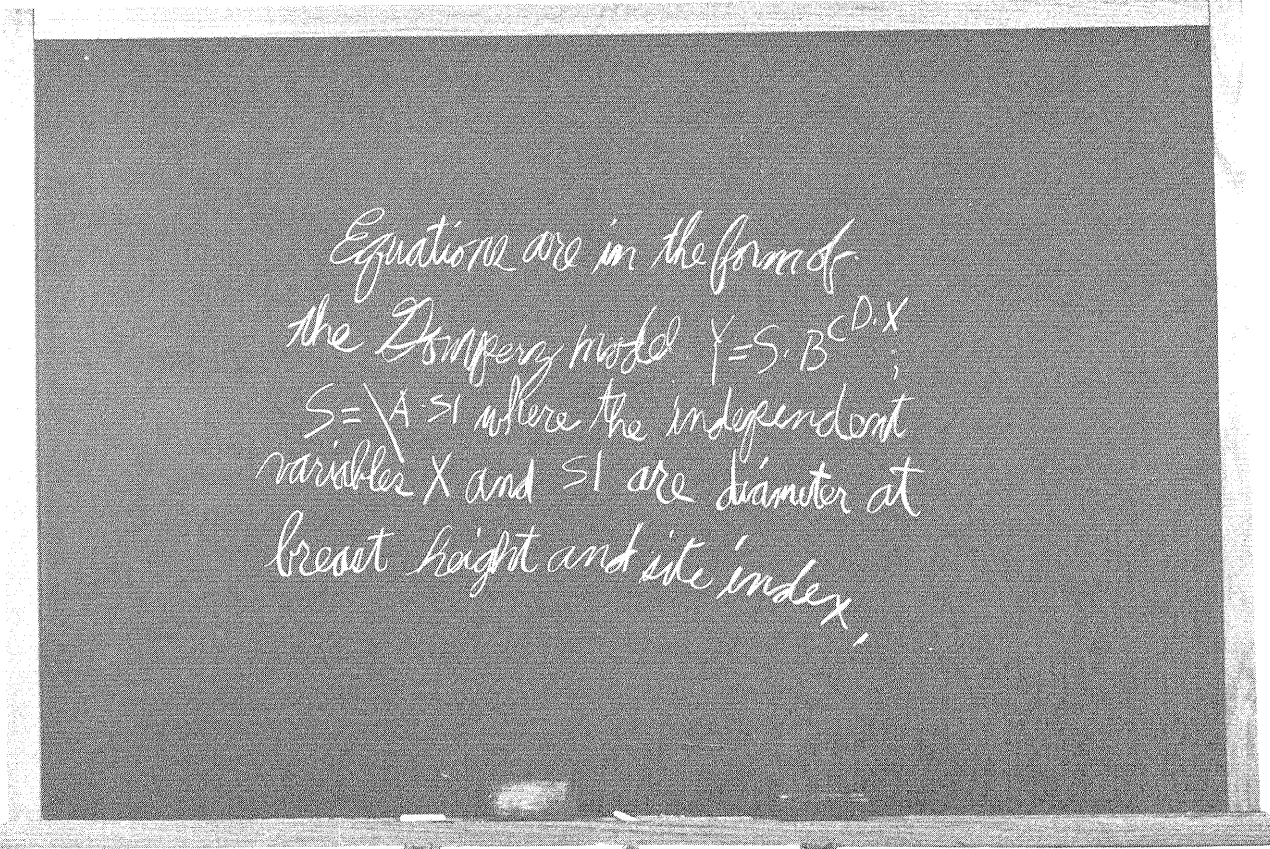


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USDA FOREST SERVICE
GENERAL TECHNICAL REPORT NC-15

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local net volume equations for missouri



Equations are in the form of
the Dampney model $Y = S \cdot B^{CD \cdot X}$;
 $S = \sqrt{A}$ where the independent
variables X and SI are diameter at
breast height and site index.

by jerold t. hahn

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1975

LOCAL NET VOLUME EQUATIONS FOR MISSOURI

Jerold T. Hahn

A P P L I C A T I O N

As a part of the 1972 Forest Survey of Missouri, personnel of the Station's Forest Survey Team developed a merchantable tree volume equation and tables of coefficients for four regions of Missouri. This equation and the coefficients can be used on a digital computer by industrial foresters, consulting foresters, or others in need of quick net-volume-per-tree estimates. The equation and coefficients were developed for both board foot (International $\frac{1}{4}$ -inch rule) and cubic foot volumes, for several species and species groups, and for two tree classes, "desirable" and "acceptable."¹

¹Forest Survey classifies live trees as "desirable," "acceptable," "rough," "rotten," or "short-log." Equations were prepared for the first two classes. Forest Survey defines "desirable" trees as live trees that have no serious defects that limit present or prospective use and that have relatively high vigor and contain no pathogens that may result in death or serious deterioration before rotation age. These are trees that would be favored by forest managers in silvicultural operations. "Acceptable" trees are live trees having no serious defects that limit present or prospective use but that have pathogens or damage that may affect quality. The great majority of the trees in Missouri were classed as "acceptable" with very few "desirable" so the forester wishing to use only one equation for woods-run material would be best advised to use the equation for "acceptable" trees.

The only data needed to determine tree volumes in Missouri with the equation and coefficients are species, d.b.h., tree class, and site index.²

To use the equation and coefficients, find on the map the region in Missouri where the trees grow (fig. 1). Next, decide whether you want cubic or board foot volume, and decide what tree class (desirable or acceptable) the trees fall into. Then choose the appropriate table (tables 1 to 4), and the proper region (Survey Unit) within it.

Columns 1 through 6 in the tables contain all the information needed for using the equation except d.b.h. The coefficients (columns 2 through 5) to be substituted in the equation depend on the species group number (column 1), so first obtain this number from table 5. Then substitute in the following equation the appropriate coefficient A (column 2), site index (column 6 if site index was not measured in the field), coefficient B (column 3), coefficient C (column 4), coefficient D (column 5), and d.b.h.

$$\text{Volume} = (A \cdot \text{site index}) \cdot B^C \cdot D \cdot \text{DBH}$$

²If site index measurements have not been taken, the average site index for the observations used in constructing tables 1 to 4 can be used. These average site indexes are found in column 6 of the tables.

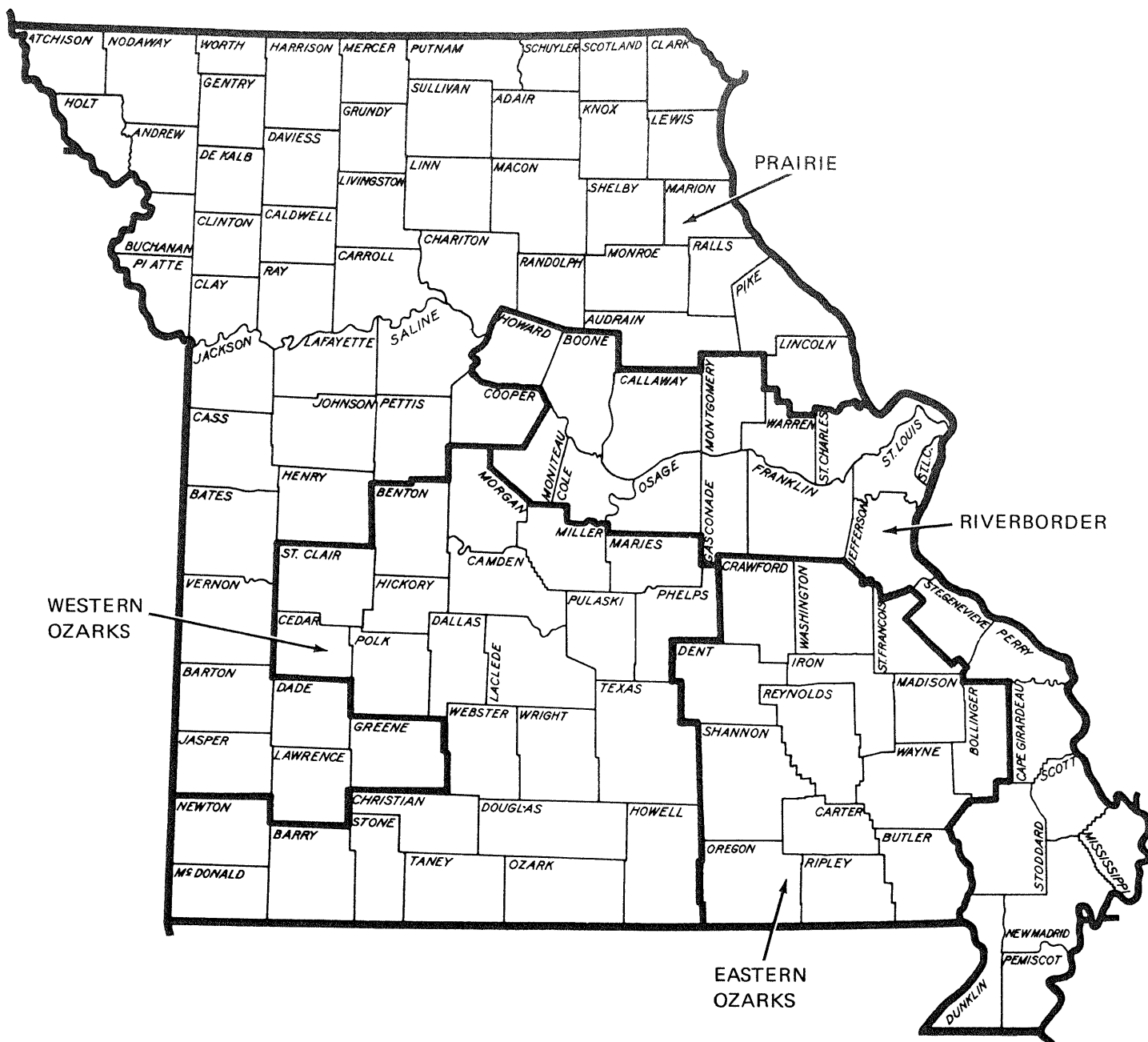


Figure 1.--Regions of Missouri (Forest Survey Units) for which separate sets of equations were derived.

Table 1.--Cubic foot volume regression coefficients for desirable trees,
Missouri, 1972

EASTERN OZARKS UNIT								
Species : group : number : (1) ¹	Coefficient				Average : site : index : (6)	Obser- : vations : (7)	Sampling : error : (8)	R ² : (9)
	A : (2)	B : (3)	C : (4)	D : (5)		No.	Cu. ft.	
1- 5	11.70	0.00076	1.42	-0.15	58	67	4.17	0.89
6- 7	1.24	.00081	1.62	- .27	60	118	2.87	.91
8-10	10.16	.00090	1.38	- .16	63	279	3.95	.87
11-12	1.96	.00124	1.58	- .21	69	32	2.68	.92
13-28	2.50	.00055	1.59	- .22	72	25	4.12	.94
WESTERN OZARKS UNIT								
1- 5	7.42	0.00149	1.41	-0.17	57	12	3.87	0.89
6	1.24	.00074	1.64	- .26	59	42	4.56	.82
7	4.35	.00092	1.48	- .19	54	25	3.60	.90
8-10	1.63	.00137	1.58	- .23	64	85	3.87	.90
11-12	2.79	.00294	1.49	- .20	61	15	4.64	.87
13-27	9.28	.00259	1.36	- .15	69	31	6.68	.95
PRAIRIE UNIT								
6-12	5.53	0.0042	1.37	-0.16	61	39	12.50	0.86
13-27	7.57	.0009	1.35	- .18	80	41	10.45	.84
RIVERBORDER AND BOTTOMLANDS UNITS								
1- 5	3.50	0.00033	1.48	-0.19	79	29	7.25	0.98
6- 7	3.30	.00465	1.46	- .19	51	145	6.15	.84
8-10	28.25	.00052	1.31	- .15	57	76	8.38	.92
11-12	1.54	.00086	1.63	- .24	65	36	6.92	.88
13-26	9.64	.00080	1.42	- .15	81	78	7.83	.92

¹Numbers in parentheses are the column numbers.

Table 2.--Board foot volume regression coefficients for desirable trees,
Missouri, 1972

EASTERN OZARKS UNIT									
Species : group :	Coefficient				Average : site :	Obser- : vations :	Sampling : error :	R ²	
number :	A :	B :	C :	D :	index :				
(1) ¹ :	(2) :	(3) :	(4) :	(5) :	(6) :	(7) :	(8) :	(9) :	
						No.	Bd. ft.		
1- 5	168.15	0.00021	1.23	-0.23	59	53	31.83	0.84	
6- 7	10.49	.00118	1.36	- .34	61	53	24.32	.78	
8-10	123.30	.00038	1.23	- .23	64	174	29.74	.76	
11-12	31.05	.00040	1.29	- .29	72	20	20.68	.87	
13-27	12.00	.00006	1.40	- .37	74	16	36.12	.84	
WESTERN OZARKS UNIT									
1- 5	261.90	0.00029	1.26	-0.17	59	10	19.14	0.94	
6- 7	4.00	.00005	1.70	- .40	55	37	27.25	.65	
8-10	10.06	.00090	1.46	- .28	64	54	28.74	.82	
11-12	5.07	.00024	1.60	- .35	65	11	32.30	.73	
13-27	39.20	.00073	1.34	- .21	72	23	48.90	.94	
PRAIRIE UNIT									
6-12	162.77	0.0012	1.18	-0.18	63	30	103.18	0.73	
13-27	232.56	.0002	1.20	- .20	80	37	67.94	.93	
RIVERBORDER AND BOTTOMLANDS UNITS									
1- 5	10.55	0.00002	1.56	-0.24	90	15	61.18	0.94	
6- 7	14.70	.00578	1.31	- .29	52	111	38.38	.75	
8-10	120.13	.00078	1.22	- .22	57	61	51.53	.90	
11-12	11.09	.00040	1.32	- .41	68	21	32.30	.53	
13-27	48.35	.00031	1.31	- .23	82	75	90.23	.88	

¹Numbers in parentheses are the column numbers.

Table 3.--Cubic foot volume regression coefficients for acceptable trees,
Missouri, 1972

EASTERN OZARKS UNIT									
Species : group number	Coefficient				Average : site index	Obser- : vations	Sampling : error	R ²	
(1) ¹	A :	B :	C :	D :	(6)	(7)	(8)	(9)	
	(2)	(3)	(4)	(5)					
1- 5	1.89	0.00085	1.56	-0.23	60	No. 597	Cu. ft. 1.92	0.93	
6	23.38	.00065	1.34	- .12	60	955	4.75	.86	
7	1.47	.00261	1.51	- .22	55	382	2.58	.90	
8	18.91	.00095	1.34	- .13	60	84	6.89	.84	
9	1.41	.00077	1.58	- .25	63	1,555	5.74	.79	
10	1.16	.00144	1.61	- .24	56	67	2.02	.93	
11	1.49	.00038	1.62	- .25	63	144	2.52	.89	
12	.86	.00038	1.73	- .27	60	240	2.80	.86	
13-23	32.35	.00019	1.34	- .14	73	107	11.20	.90	
24-25	1.37	.00216	1.56	- .22	65	44	3.09	.88	
26-27	4.19	.00075	1.45	- .19	64	83	3.23	.89	
WESTERN OZARKS UNIT									
1	4.99	0.00071	1.47	-0.19	58	216	2.50	0.89	
4	21.11	.00022	1.39	- .16	43	40	1.24	.68	
6	1.34	.00092	1.62	- .24	57	530	4.02	.86	
7	1.45	.00183	1.57	- .22	52	569	3.14	.84	
8	13.50	.00046	1.38	- .16	58	95	4.28	.95	
9	3.41	.00189	1.45	- .18	61	862	5.60	.87	
10	2.54	.00155	1.48	- .20	56	94	3.85	.93	
11	3.65	.00154	1.44	- .18	65	78	3.05	.95	
12	2.22	.00092	1.54	- .21	55	139	2.18	.94	
13-17	1.17	.00054	1.66	- .25	68	29	3.83	.88	
18-21	18.74	.00070	1.33	- .14	67	50	6.07	.95	
22-25	3.61	.00149	1.44	- .18	65	63	3.13	.96	
26-27	14.33	.00042	1.36	- .15	58	34	3.54	.78	
PRAIRIE UNIT									
1- 5	1.27	0.0013	1.78	-0.21	72	--	--	--	
6	2.12	.0028	1.56	- .18	56	361	6.57	0.86	
7	.81	.0009	1.69	- .28	52	71	2.71	.85	
8	2.54	.0005	1.58	- .20	59	42	5.98	.95	
9	4.33	.0011	1.33	- .24	53	137	3.30	.96	
10	4.32	.0007	1.44	- .18	76	96	6.68	.93	
11	1.12	.0022	1.57	- .23	66	104	3.64	.88	
12	1.16	.0021	1.58	- .22	64	51	1.37	.76	
13-14	3.82	.0013	1.45	- .18	78	69	8.01	.95	
15-17	--	--	--	--	--	--	--	--	
18	1.83	.0005	1.59	- .22	70	66	3.45	.93	
19	44.09	.0002	1.31	- .13	75	34	14.90	.96	
20	19.57	.0009	1.32	- .13	81	48	6.54	.98	
21-23	5.10	.0009	1.42	- .17	83	43	4.53	.99	
24-25	.84	.0008	1.67	- .25	66	91	2.91	.90	
26	10.84	.0006	1.35	- .15	71	66	6.11	.94	
27	1.65	.0010	1.53	- .22	65	68	5.41	.86	
RIVERBORER AND BOTTOMLANDS UNITS									
1- 3	3.50	0.00033	1.48	-0.19	79	29	7.25	0.98	
4	1.27	.00133	1.79	- .21	41	129	1.47	.88	
6	1.69	.00160	1.59	- .23	49	1,124	5.65	.80	
7	2.93	.00257	1.48	- .19	43	437	3.38	.84	
8	3.56	.0095	1.49	- .20	54	196	9.34	.87	
9	6.76	.00136	1.41	- .16	58	439	6.29	.91	
10	4.74	.00108	1.51	- .15	60	52	3.51	.98	
11	4.13	.00113	1.46	- .19	58	193	5.09	.97	
12	5.09	.00094	1.45	- .19	56	142	3.33	.95	
13-15	5.21	.00290	1.37	- .16	59	85	3.48	.94	
16-17	.53	.00126	1.55	- .36	73	37	5.18	.79	
18	44.36	.00037	1.31	- .12	64	120	7.65	.92	
19	7.97	.00006	1.56	- .16	78	59	13.15	.92	
20-21	9.53	.00045	1.47	- .15	92	96	16.84	.98	
22-25	.73	.00045	1.68	- .30	64	78	4.58	.76	
26	25.84	.00029	1.28	- .14	68	98	9.41	.97	
27	1.43	.00009	1.82	- .22	86	243	5.81	.89	

¹Numbers in parentheses are the column numbers.

Table 4.--Board foot volume regression coefficients for acceptable trees,
Missouri, 1972

EASTERN OZARKS UNIT									
Species : group : number : (1) ¹ :	Coefficient				Average : site : index :	Obser- : vations :	Sampling : error :	R ²	
(1) ¹ :	A :	B :	C :	D :	(6) :	(7) :	(8) :	(9)	
						No.	Bd. ft.		
1- 5	18.73	0.00069	1.38	-0.26	61	301	14.74	0.90	
6	83.50	.00160	1.19	- .19	61	336	40.43	.68	
7	40.86	.00331	1.20	- .20	58	122	26.01	.71	
8-10	6.14	.00063	1.46	- .32	63	691	48.62	.55	
11-12	11.76	.00794	1.27	- .27	61	103	29.10	.32	
13-27	18.16	.00032	1.21	- .41	73	75	35.44	.79	
WESTERN OZARKS UNIT									
1- 5	42.61	0.00042	1.36	-0.23	59	109	19.91	0.84	
6	7.54	.00082	1.47	- .28	57	249	33.58	.64	
7	22.29	.00322	1.31	- .20	52	206	25.91	.56	
8	38.18	.00102	1.32	- .20	60	50	49.18	.80	
9	10.53	.00191	1.39	- .25	60	395	48.27	.68	
10	9.90	.00112	1.42	- .26	60	24	44.93	.85	
11	3.98	.00167	1.52	- .31	69	22	15.66	.90	
12	5.13	.00005	1.62	- .31	61	29	21.03	.84	
13-23	37.59	.00033	1.34	- .21	67	30	58.99	.87	
24-27	34.79	.00081	1.31	- .20	67	38	33.73	.87	
PRAIRIE UNIT									
1- 5	5.78	0.0012	1.39	-0.40	80	--	--	--	
6	10.79	.0036	1.30	- .29	55	211	43.53	0.76	
7	6.74	.0261	1.27	- .29	51	21	24.52	.07	
8	17.70	.0002	1.39	- .26	58	25	36.17	.56	
9	13.39	.0005	1.39	- .27	60	64	37.51	.83	
10	9.07	.00009	1.57	- .24	80	61	48.56	.80	
11-12	106.40	.0014	1.17	- .18	76	32	37.15	.37	
13-14	13.12	.0051	1.18	- .36	80	39	48.76	.89	
15-17	--	--	--	--	--	--	--	--	
18	7.43	.0000009	1.51	- .37	71	21	21.24	.90	
19	135.82	.0006	1.19	- .21	76	29	67.10	.97	
20	35.11	.0007	1.18	- .35	82	43	77.98	.87	
21-23	10.09	.0014	1.21	- .41	82	23	38.08	.96	
24-25	3.95	.0002	1.37	- .48	70	36	30.24	.55	
26	12.59	.0003	1.19	- .49	75	29	65.95	.78	
27	4.32	.0001	1.39	- .43	71	22	61.52	.43	
RIVERBORDER AND BOTTOMLANDS UNITS									
1- 3	10.55	0.00002	1.56	-0.24	90	15	61.18	0.94	
4	5.78	.00116	1.39	- .40	45	39	16.06	.56	
6	17.48	.00573	1.32	- .22	50	624	61.49	.59	
7	4.92	.00122	1.28	- .57	45	117	32.84	.45	
8	8.46	.00004	1.36	- .45	54	125	55.56	.72	
9-10	30.67	.00267	1.24	- .24	59	222	56.95	.77	
11	12.63	.00096	1.32	- .32	64	66	51.18	.91	
12	195.92	.00044	1.20	- .20	64	38	41.80	.83	
13-17	33.93	.00249	1.22	- .22	71	47	39.61	.76	
18	373.89	.00012	1.18	- .19	65	50	70.87	.90	
19	219.21	.00015	1.15	- .27	80	44	47.58	.95	
20-21	37.82	.00083	1.26	- .26	96	71	185.75	.90	
22-25	5.82	.00300	1.35	- .34	69	40	39.11	.58	
26	5.13	.00095	1.39	- .34	77	19	19.94	.96	
27	8.15	.00003	1.34	- .44	91	110	34.40	.80	

¹Numbers in parentheses are the column numbers.

Table 5.--Species and species group numbers for Missouri trees

Species or species group	Scientific name	Number	Species or species group	Scientific name	Number
Softwoods					
Shortleaf pine	<i>Pinus echinata</i>	1	Soft maple	<i>A. rubrum</i> var. <i>rubrum</i> . .	14
Other yellow pines	<i>P. elliottii</i>	2		<i>A. saccharinum</i>	
	<i>P. palustris</i>		Beech	<i>Fagus grandifolia</i>	15
	<i>P. rigida</i>		Sweetgum	<i>Liquidambar styraciflua</i> .	16
	<i>P. virginiana</i>				
Cypress	<i>Taxodium distichum</i> var.		Tupelo and	<i>Nyssa aquatica</i>	17
	<i>distichum</i>	3	blackgum	<i>N. sylvatica</i> var.	
Eastern red cedar	<i>Juniperus virginiana</i> . . .	4		<i>sylvatica</i>	
				<i>N. sylvatica</i> var.	
All other softwoods		5		<i>biflora</i>	
			Ash	<i>Fraxinus americana</i>	18
				<i>F. pennsylvanica</i>	
				<i>F. quadrangulata</i>	
Hardwoods					
White oak A	<i>Quercus alba</i>	6	Sycamore	<i>Platanus occidentalis</i> . .	19
	<i>Q. macrocarpa</i>		Cottonwood	<i>Populus deltoides</i>	20
	<i>Q. michauxii</i>		River birch	<i>Betula nigra</i>	21
	<i>Q. muehlenbergii</i>		Yellow-poplar	<i>Liriodendron tulipifera</i> .	22
	<i>Q. bicolor</i>				
	<i>Q. lyrata</i>		Basswood	<i>Tilia americana</i>	23
White oak B	<i>Q. stellata</i> var.		Black walnut	<i>Juglans nigra</i>	24
	<i>stellata</i>	7	Black cherry	<i>Prunus serotina</i>	25
Red oak A	<i>Q. falcata</i> var.		Elm	<i>Ulmus alata</i>	26
	<i>pagodaefolia</i>	8		<i>U. americana</i>	
	<i>Q. rubra</i>			<i>U. rubra</i>	
	<i>Q. shumardii</i>			<i>U. thomasi</i>	
Red oak B	<i>Q. coccinea</i>	9	All other	<i>Acer negundo</i>	27
	<i>Q. falcata</i>		hardwoods	<i>Aesculus glabra</i>	
	<i>Q. velutina</i>			<i>Betula papyrifera</i> var.	
Red oak C	<i>Q. imbricaria</i>	10		<i>papyrifera</i>	
	<i>Q. marilandica</i>			<i>Catalpa speciosa</i>	
	<i>Q. nigra</i>			<i>Celtis laevigata</i>	
	<i>Q. nuttallii</i>			<i>C. occidentalis</i>	
	<i>Q. palustris</i>			<i>Cornus florida</i>	
	<i>Q. phellos</i>			<i>Diospyros virginiana</i>	
Hickory A	<i>Carya illinoensis</i>	11		<i>Gleditsia triacanthus</i>	
	<i>C. laciniosa</i>			<i>Gymnocladus dioica</i>	
	<i>C. ovata</i>			<i>Juglans cinerea</i>	
	<i>C. tomentosa</i>			<i>Maclura pomifera</i>	
Hickory B	<i>C. aquatica</i>	12		<i>Magnolia acuminata</i>	
	<i>C. cordiformis</i>			<i>Morus rubra</i>	
	<i>C. glabra</i>			<i>Robinia pseudoacacia</i>	
	<i>C. texana</i>			<i>Salix nigra</i>	
Hard maple	<i>Acer nigrum</i>	13		<i>Sassafras albidum</i>	
	<i>A. saccharinum</i>		Noncommercial hardwoods		28

DOCUMENTATION

Data collected on 13,136 trees in the State were used to develop these volume equations. Measurements taken were site index, tree class, d.b.h., merchantable height, and diameter of the stem at merchantable height. For sawtimber-size trees (9.0+ inches d.b.h. for softwoods, 11.0+ inches for hardwoods), measurements were taken at both the sawtimber and pulpwood limits of merchantability. The field crews also measured and estimated the volume of cull material (both in cubic feet and board feet) in each tree.

The net volume in these trees was then calculated using equations developed by Robert N. Stone³ based on S. R. Gevorkiantz's "Composite Volume Tables for the Lake States."⁴ Stone's equations compute gross volume in a tree from the three measurements--d.b.h., merchantable height, and diameter of the stem at merchantable height. This volume is then corrected for differences in bark thickness between species and the field estimate of cull volume is subtracted to arrive at net volume. If tree heights are tallied while making a local cruise, it

would be advisable to measure bark thickness at the same time and to use either the tables from Gevorkiantz and Olsen (1955) or Stone's equations.

Experience in working with volume-d.b.h. relationships suggested that the best mathematical model for this type of data was the "Gomperz" function $Y = S \cdot B^{C \cdot X}$, where the dependent variable Y is tree net volume, the independent variable X is d.b.h., and the asymptote S is a function of site index ($S = A \cdot SI$). Work with test data and previous State surveys confirmed this belief and the model was used with the Missouri data.

The species groups used in the tables were primarily determined by number of observations available for a group (a minimum number of observations are necessary to form an equation using least-squares estimates) and similarity of bole form of the species within a group. The number of observations, the sampling error, and the R^2 for each regression estimate are shown in columns 7 through 9 (tables 1 to 4).

³Unpublished data on file at the North Central Forest Experiment Station, St. Paul, Minnesota.

⁴S. R. Gevorkiantz and L. R. Olsen. Composite volume tables for timber and their application in the Lake States. Lake States Tech. Bull. 1104, 51 p. 1955.

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Plant a tree...trees give oxygen.