United States Department of Agriculture

Forest Service

North Central Forest Experiment Station

Research Paper **NC-257**

Diameter Growth, Survival, and Volume Estimates for Trees in Indiana and Illinois

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Smith, W. Brad; Shifley, Stephen R.
Diameter growth, survival, and volume estimates for trees in Indiana and Illinois. Res. Pap. NC-257. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1984. 10 p.

Measurements of more than 15,000 Indiana and Illinois trees were summarized by species and diameter class into tables of mean annual diameter growth, annual probability of survival, net cubic foot volume, and net board foot volume. In the absence of better forecasting techniques, this information can be utilized to project short-term changes for Indiana and Illinois trees, inventory plots, stands, or forests.

KEY WORDS: D.b.h., growth, cubic foot volume, board foot volume, crown class, mortality.

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1992 Folwell Avenue
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Manuscript approved for publication April 4, 1984
September 1984

DIAMETER GROWTH, SURVIVAL, AND VOLUME ESTIMATES FOR TREES IN INDIANA AND ILLINOIS

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ABSTRACT.—Measurements of more than 15,000 Indiana and Illinois trees were summarized by species and diameter class into tables of mean annual diameter growth, annual probability of survival, net cubic foot volume, and net board foot volume. In the absence of better forecasting techniques, this information can be utilized to project short-term changes for Indiana and Illinois trees, inventory plots, stands, or forests.

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During the past three decades many permanent forest inventory plots throughout Indiana and Illinois have been established and maintained by forest managers and researchers from forest industries, universities, and the USDA Forest Service. Individually, these data sets represent many small geographic areas, but collectively they provide a comprehensive picture of average growth and mortality rates and tree volume characteristics found throughout Indiana and Illinois during the time period from 1949 to 1977. This note summarizes average annual growth and mortality rates and average net volumes observed from measurements on more than 15,000 trees from Indiana and Illinois.

Summaries by species and diameter class highlight general trends and serve to guide planners and forest managers when more detailed sources of information are unavailable.

We obtained continuous forest inventory tree growth and mortality data from the following sources:

Tract name	Location	Years of measurement	Number of plots
Indiana demonstration woodlots	Throughout Indiana	1958-1964	718
Hoosier National Forest	South-central Indiana	1966-1976	78
Bottomland hardwood study plots	Throughout Indiana	1966-1977	33
Sinissippi Forest	North-central Illinois	1943-1963	439
Kaskaskia Experimental Forest natural area	South-central Illinois	1958-1973	8

We owe special thanks to W. Lloyd Fix and W. L. Mills, Purdue University; Dieter Pelz and George Gertner, University of Illinois; Dave Stenger, Sinissippi Forest; and Richard Schlesinger, USDA Forest Service, for providing major portions of the data base. Information for tree volume estimates came from nearly 1,000 forest inventory plots that were measured when Indiana's forests were surveyed in the late 1960's (Spencer 1969).

The summary of diameter growth by species group and diameter class shows that mean annual diameter growth rates ranged from 0.05 inch (0.1 cm) per year for noncommercial species to 0.24 inch (0.6 cm) per year for cottonwood (table 1). The mean annual diameter growth rate for all trees was 0.15 inch (0.40 cm). The diameter growth rate for small shortleaf

pines is markedly greater than for hardwood trees of similar size. Shortleaf pine is generally grown in plantations, thus eliminating much of the overstory competition that often diminishes growth rates for small trees growing under natural conditions. Averaged across all species, diameter growth increased with increasing diameter, but this trend was not consistent for each species group individually. Some of the variation in the diameter growth rates both among and within species groups is due to the different number of observations and different sampling error associated with each of the mean values reported. Summaries of diameter growth by crown class, diameter class, and species group clearly show the faster growth associated with trees from dominant and codominant crown classes (table 2).

The mean annual survival rate for sampled trees was 99.1 percent (table 3). Due to the prevalence of Dutch elm disease during the remeasurement period, survival rates for elm were markedly lower than those for other species.

The volume of timber on commercial forest land is commonly reported in two ways; growing-stock volume and sawtimber volume. Both are net volumes of the central stem above a 1 foot stump in live trees of commercial species having no serious defects in quality. Growing-stock volume is measured in cubic feet on trees 5 inches d.b.h. and larger to a variable 4-inch top diameter (outside bark). The U.S. Forest Service measures volume in board feet, International ¼-inch rule, for softwoods 9 inches d.b.h. and larger to a variable 7-inch top (outside bark) and hardwoods 11 inches d.b.h. and larger to a variable 9-inch top (outside bark). Poor form, however, often lowers merchantable height below where the minimum top diameter occurs, so top diameters at merchantable height generally increase as diameter increases. For example, hardwood sawtimber trees greater than 16 inches d.b.h. consistently have top d.o.b.'s in excess of 11 inches.

Net cubic-foot and board-foot volumes by species group and diameter class were averaged from more than 13,000 individual tree observations (tables 4-6). Gross tree volumes for cubic feet and International board feet were calculated using Stone's equation[1], which is a function of observed breast height diameter, merchantable height, and top diameter outside bark. Doyle board foot volumes were computed using Wiant's (1977) equation using diameter breast height and bole length. We corrected gross volume estimates for differences in bark thickness among species, and we applied field estimates of cull volume to gross volume to arrive at net tree volume.[2]

Tables 1-3 can be used to estimate average tree-by-tree growth and survival for Indiana or Illinois inventory plots. Such projections require a tree list that itemizes species, diameter, and perhaps crown class for a representative sample of trees from the stand or stands being considered. Alternatively, total stand growth can be estimated using the stand table projection techniques described by Husch *et al.* (1972). Stand table projections require a summary of the number of trees by species and diameter class.

Although simple inventory projections can be implemented using only a pencil, some paper, and a hand calculator, they are also readily computerized. For example, Moser (1980), Harrison and Rauch (1979), and Pelz (1978) all describe computerized forest data processing programs that summarize current and projected stand and stock tables from forest inventory data. Growth estimates in those programs are usually derived from increment cores taken during the inventory or from user-supplied growth-rate tables. Tables 1-3 provide a basis for estimating growth and mortality rates when no site-specific estimates are available. Moreover, local increment core measurements can be used to adjust the growth rate tables to reflect local conditions. Such an adjustment procedure using remeasurement data is described by Smith (1983).

For any of the above projection techniques, tree and stand volume can be estimated from the tables of mean tree volume presented here. Or, if all the necessary information were available, local volume equations such as those prepared for Indiana by Smith and Weist (1982) could be used.

When using the information in tables 1-6, remember that all reported values are averages for trees responding to a great variety of forest conditions and management regimes. Some average values are based on very few observations, and the values do not account for the effects of site quality, stand density, or stand manipulation on tree growth, survival, and volume. (For example, compare these results with those reported by Schoering and Fischer (1982)). Projections for a period much longer than the 10-year span encompassed by the basic data may be of questionable reliability. These data have been merged with similar information from other Central States to formulate a system of STEMS (Belcher *et al.* 1982) diameter growth and mortality models applicable in Indiana, Illinois, and surrounding States. These computer

[1] *A description of this function can be found in the appendix of: A net volume equation for Indiana (Smith and Weist 1982).*

[2] *Tables of associated merchantable heights, and merchantable top diameters are available from the authors.*

models do account for site quality, stand density, and inter-tree competition to provide more detailed and more biologically realistic projections of tree and stand growth than are possible from the information reported here.

PRINCIPLE TREE SPECIES GROUPS FOR ILLINOIS AND INDIANA[3]

Shortleaf pine ..... *Pinus echinata*
Select white oak
- White oak ..... *Quercus alba*
- Swamp white oak ..... *Quercus bicolor*
- Bur oak ..... *Quercus macrocarpa*
- Swamp chestnut oak ..... *Quercus michauxii*
- Chinkapin oak ..... *Quercus muehlenbergii*

Other white oak
- Overcup oak ..... *Quercus lyrata*
- Chestnut oak ..... *Quercus prinus*
- Post oak ..... *Quercus stellata*

Select red oak
- Cherrybark oak .... *Quercus falcata* v. *pagodifolia*
- Northern red oak ..... *Quercus rubra*
- Shumard oak ..... *Quercus shumardii*

Other red oak
- Scarlet oak ..... *Quercus coccinea*
- Northern pin oak ..... *Quercus ellipsoidalis*
- Southern red oak ..... *Quercus falcata* v. *falcata*
- Shingle oak ..... *Quercus imbricaria*
- Blackjack oak ..... *Quercus marilandica*
- Water oak ..... *Quercus nigra*
- Pin oak ..... *Quercus palustris*
- Willow oak ..... *Quercus phellos*
- Black oak ..... *Quercus velutina*

Select hickory
- Pecan ..... *Carya illinoensis*
- Shellbark hickory ..... *Carya laciniosa*
- Shagbark hickory ..... *Carya ovata*
- Mockernut hickory ..... *Carya tomentosa*

Other hickory
- Water hickory ..... *Carya aquatica*
- Bitternut hickory ..... *Carya cordiformis*
- Pignut hickory ..... *Carya glabra*
- Black hickory ..... *Carya texana*

Basswood ..... *Tilia americana*
Beech ..... *Fagus grandifolia*
Hard maple
- Black maple ..... *Acer nigrum*
- Sugar maple ..... *Acer saccharum*

Soft maple
- Red maple ..... *Acer rubrum*
- Silver maple ..... *Acer saccharinum*

Elm
- Winged elm ..... *Ulmus alata*
- American elm ..... *Ulmus americana*
- Siberian elm ..... *Ulmus pumila*
- Slippery elm ..... *Ulmus rubra*
- Rock elm ..... *Ulmus thomasii*

White ash ..... *Fraxinus americana*
Sycamore ..... *Platanus occidentalis*
Cottonwood ..... *Populus deltoides*
Sweetgum ..... *Liquidambar styraciflua*
Blackgum and tupelo
- Blackgum ..... *Nyssa sylvatica*
- Tupelo ..... *Nyssa aquatica*

Black cherry ..... *Prunus serotina*
Black walnut ..... *Juglans nigra*
Yellow poplar ..... *Liriodendron tulipifera*
Other hardwoods
- Boxelder ..... *Acer negundo*
- Ohio buckeye ..... *Aesculus glabra*
- River birch ..... *Betula nigra*
- American chestnut ..... *Castanea dentata*
- Northern catalpa ..... *Catalpa speciosa*
- Hackberry ..... *Celtis occidentalis*
- Flowering dogwood ..... *Cornus florida*
- Black ash ..... *Fraxinus nigra*
- Green ash ..... *Fraxinus pennsylvanica*
- Blue ash ..... *Fraxinus quadrangulata*
- Honeylocust ..... *Gleditsia triacanthos*
- Butternut ..... *Juglans cinerea*
- Osage-orange ..... *Maclura pomifera*
- Red mulberry ..... *Morus rubra*
- Bigtooth aspen ..... *Populus grandidentata*
- Quaking aspen ..... *Populus tremuloides*
- Black locust ..... *Robinia pseudoacacia*
- Black willow ..... *Salix nigra*
- Sassafras ..... *Sassafras albidum*

[3] *The common and scientific names of tree species are based on: Little, Elbert L., Jr. Checklist of United States Trees (Native and Naturalized). Agric. Handb. 541. Washington, DC: U.S. Department of Agriculture, Forest Service, 1979. 375 p.*

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Table 1.--Mean annual diameter growth by species group and diameter class, Indiana and Illinois[1/]

(In inches)

Species group[2/]	Number of observations	Diameter class (inches at breast height) 1.0-2.9	3.0-4.9	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-22.9	23.0-24.9	25.0-26.9	27.0-28.9	29.0+	Average all classes
Shortleaf pine	132	.198	.168	.128	.120	.139	.120	--	.082	.050	--	.109	--	--	--	--	.142
Select white oak	3,476	.052	.041	.086	.089	.105	.132	.154	.172	.183	.202	.199	.193	.215	.237	.260	.134
White oak	3,313	.055	.037	.085	.089	.106	.132	.153	.172	.182	.204	.200	.183	.207	.241	.236	.134
Bur oak	124	--	--	--	.087	.091	.115	.160	.159	.170	.200	--	.445	.273	.214	--	.130
Other white oak	249	.077	.100	.107	.115	.118	.122	.133	.140	.189	.138	.113	.082	--	--	--	.124
Chestnut oak	228	.049	.100	.112	.124	.123	.126	.136	.140	.189	.138	.113	.082	--	--	--	.128
Select red oak	1,090	.048	.036	.204	.132	.166	.178	.196	.213	.219	.249	.236	.245	.279	.259	.224	.202
N. red oak	1,090	.048	.036	.204	.132	.166	.178	.196	.213	.219	.249	.236	.245	.279	.259	.224	.202
Other red oak	2,111	.045	.117	.116	.147	.147	.165	.174	.179	.181	.196	.179	.210	.262	.242	.237	.166
Scarlet oak	229	--	--	.129	.120	.206	.168	.193	.207	.181	.194	.207	.219	.294	.235	.270	.192
Black oak	1,803	.045	.117	.112	.147	.143	.163	.169	.171	.181	.190	.175	.225	.262	.256	.214	.161
Select hickory	473	.014	.039	.089	.111	.103	.109	.115	.142	.131	.152	.116	.208	.082	--	--	.109
Shagbark hickory	435	.008	.024	.101	.123	.105	.108	.117	.146	.130	.133	.116	.208	--	--	--	.112
Other hickory	702	.023	.060	.071	.077	.099	.115	.137	.150	.145	.143	.187	.131	.053	.130	--	.116
Bitternut hickory	106	--	.126	.088	.107	.102	.134	.135	.166	.176	.125	.179	.040	--	--	--	.126
Basswood	196	--	.360	.100	.209	.181	.191	.188	.176	.189	.228	.143	.189	.217	.275	.421	.192
Beech	615	.044	.033	.081	.108	.142	.163	.146	.158	.175	.152	.157	.146	.128	.122	.102	.150
Hard maple	1,626	.047	.072	.107	.140	.152	.158	.155	.158	.166	.154	.156	.129	.162	.160	.120	.138
Soft maple	340	.123	.158	.158	.193	.189	.190	.245	.184	.227	.215	.364	.211	.303	.114	.283	.202
Red maple	126	.123	.158	.165	.214	.171	.221	.332	.201	.325	.191	.436	.136	.209	--	.283	.205
Silver maple	214	--	--	.027	.097	.193	.184	.227	.182	.188	.219	.352	.223	.350	.114	--	.200
Elm	324	.041	.144	.109	.104	.166	.160	.160	.181	.185	.172	.238	.141	.271	.110	.282	.157
American elm	130	.016	.097	.087	.099	.134	.163	.169	.171	.250	.188	.117	.100	.300	--	--	.143
Slippery elm	189	.064	.223	.159	.127	.188	.158	.154	.186	.169	.144	.272	.152	.243	.110	.282	.170
White ash	567	.054	.044	.160	.152	.146	.145	.185	.158	.201	.195	.199	.178	.141	.233	.135	.152
Sycamore	159	--	--	.194	.129	.179	.183	.213	.198	.195	.225	.188	.238	.135	.195	.161	.191
Cottonwood	479	--	--	--	--	.224	.242	.222	.224	.253	.265	.281	.259	.263	.364	.253	.240
Sweetgum	84	--	--	.400	.080	.120	.095	.116	.145	.160	.093	.180	.210	--	--	--	.125
Black cherry	142	.092	.236	.210	.103	.143	.119	.136	.123	.076	.092	--	--	--	--	--	.127
Black walnut	216	.018	.040	.087	.077	.176	.127	.125	.120	.124	.137	.180	--	--	.360	--	.132
Yellow poplar	189	.101	.145	.226	.184	.166	.228	.268	.208	.219	.202	.185	.300	.094	.201	.189	.208
Other hardwoods	648	.065	.087	.133	.177	.134	.137	.164	.161	.185	.067	.135	--	.153	.060	.221	.131
Sassafras	202	.083	.093	.115	.131	.113	.112	.155	.147	.133	.133	--	--	.200	--	--	.113
Noncommercial	188	.045	.064	.063	.096	.065	.110	--	.067	--	--	--	--	--	--	--	.052
All hardwoods	13,874	.053	.075	.120	.120	.132	.149	.166	.176	.188	.194	.194	.192	.196	.216	.210	.151

[1/] Growth rates were calculated using as many observations as were available; some rates are based upon one observation. Growth rates for each diameter class larger than 20 inches were usually computed using fewer than 2 percent of the total number of observations for a given species group.

[2/] Indented entries designate individual species within a group that have 100 or more observations. Entries for the total species group are not indented and they include data for all species in that group regardless of whether information for one or more of the individual species in the group is reported separately.

Table 2.--Mean annual diameter growth by species group, crown class, and diameter class, Indiana and Illinois

(In inches)

Species group	Crown class	Number of observations	Diameter class (inches at breast height) 1.0-2.9	3.0-4.9	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-22.9	23.0-24.9	25.0-26.9	27.0-28.9	29.0+	Average all classes
Select white oak	Dominant	649	--	--	.103	.136	.148	.140	.152	.157	.154	.190	.172	.157	.229	--	.266	.152
	Codominant	1,331	.180	--	.121	.112	.110	.119	.130	.142	.154	.197	.155	.277	.220	--	.118	.120
	Intermediate	441	.025	.030	.076	.066	.078	.098	.099	.118	--	--	--	--	--	--	--	.079
	Overtopped	91	.053	.050	.048	.056	.050	.057	.157	--	--	--	--	--	--	--	--	.053
Select red oak	Dominant	239	--	--	--	.080	.213	.187	.194	.216	.212	.252	.210	.167	.232	.155	.161	.208
	Codominant	263	.182	--	.231	.182	.150	.153	.162	.158	.203	.276	.271	.255	--	--	--	.166
	Intermediate	53	--	--	.142	.094	.105	.114	.214	--	--	--	--	--	--	--	--	.112
	Overtopped	13	.022	.036	--	.320	.100	.093	--	.164	--	--	--	--	--	--	--	.086
Other red oak	Dominant	535	--	--	--	.229	.186	.189	.187	.186	.207	.203	.208	.207	.259	.336	--	.191
	Codominant	751	--	.191	.154	.152	.142	.154	.166	.170	.165	.217	.160	--	--	--	--	.152
	Intermediate	146	--	.073	.081	.105	.105	.103	.104	.150	--	--	--	--	--	--	--	.102
	Overtopped	14	.045	.045	.063	.064	.045	.071	--	--	--	--	--	--	--	--	--	.051
Other hickory	Dominant	82	--	.160	.100	.134	.112	.132	.130	.156	.155	.210	.191	.127	--	.130	--	.130
	Codominant	164	--	.023	.104	.114	.091	.099	.107	.119	.155	--	--	.136	.082	--	--	.100
	Intermediate	63	--	.070	.055	.071	.056	.130	.100	.209	--	--	--	--	--	--	--	.069
	Overtopped	39	.020	.047	.079	.032	.039	.036	--	--	--	--	--	--	--	--	--	.033
Hard maple	Dominant	23	--	--	--	--	.190	.226	.180	.196	.170	--	--	.145	--	.080	.100	.179
	Codominant	70	.191	.097	.164	.165	.143	.151	.161	.154	.120	.131	.173	--	--	--	--	.150
	Intermediate	35	.182	.118	.117	.173	.112	--	.178	--	--	.127	--	--	--	--	--	.142
	Overtopped	61	.048	.079	.089	.040	--	.036	--	--	--	--	--	--	--	--	--	.058
Other hardwoods	Dominant	403	.387	.325	.214	.150	.172	.193	.190	.170	.177	.210	.189	.250	.172	.233	.203	.188
	Codominant	891	.241	.213	.169	.149	.151	.161	.200	.168	.203	.178	.266	.172	.218	.230	.261	.174
	Intermediate	268	.091	.071	.109	.141	.111	.120	.154	.158	.206	--	.259	--	--	--	--	.118
	Overtopped	186	.058	.046	.096	.093	.095	.094	.108	.049	--	--	.279	--	--	--	--	.076

Table 3.--Mean annual probability of survival by species group and diameter class, Indiana and Illinois[1/]

(In inches)

Species group	Number of observations	Diameter class (inches at breast height) 1.0-2.9	3.0-4.9	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-22.9	23.0-24.9	25.0-26.9	27.0-28.9	29.0+	Average all classes
Shortleaf pine	152	.955	.970	.994	1.000	.995	--	--	--	--	--	--	--	--	--	--	.986
Select white oak	3,595	.936	.971	.997	.994	.996	.999	1.000	.999	.999	1.000	.997	1.000	.994	--	.981	.997
Other white oak	274	.893	--	1.000	.993	.990	.996	.998	1.000	.981	--	--	--	--	--	--	.991
Select red oak	1,139	--	--	.991	.989	.989	.996	.996	.997	.998	.999	.997	1.000	--	1.000	--	.996
Other red oak	2,264	.944	.983	.997	.989	.992	.995	.996	.995	.993	.997	.989	1.000	1.000	--	--	.994
Select hickory	501	.944	.951	.980	.998	.998	1.000	.998	.996	.993	--	--	--	--	--	--	.993
Other hickory	743	.942	.980	.997	.988	.996	.998	.995	.997	.996	1.000	.983	--	--	--	--	.992
Basswood	205	--	--	--	--	.994	.989	.995	1.000	1.000	.990	--	--	--	--	--	.992
Beech	636	.992	--	--	--	1.000	1.000	1.000	.989	.992	.994	.996	.994	.990	--	.977	.995
Hard maple	1,703	.987	.995	.996	1.000	.998	.997	.995	.990	.996	.998	1.000	1.000	--	--	--	.994
Soft maple	378	.978	--	.991	.992	.987	.990	.993	.984	.995	.987	--	--	--	--	.987	.989
Elm	635	.924	--	.956	.983	.908	.896	.900	.924	.849	.861	.925	--	--	--	--	.912
White ash	627	.958	--	.989	.995	.991	.998	.995	.997	.995	1.000	1.000	--	--	--	--	.988
Sycamore	171	--	--	--	--	1.000	.987	.987	.994	.994	.987	.978	.990	--	--	--	.992
Cottonwood	484	--	--	--	--	.998	.998	.998	1.000	1.000	1.000	1.000	1.000	--	--	--	.998
Sweetgum	85	--	--	--	--	1.000	1.000	1.000	1.000	--	--	--	--	--	--	--	.998
Black cherry	167	--	--	--	.973	.977	.998	.996	--	--	--	--	--	--	--	--	.984
Black walnut	223	--	--	--	1.000	.995	1.000	1.000	.994	.991	--	--	--	--	--	--	.996
Yellow poplar	197	.970	--	1.000	.986	1.000	1.000	1.000	.996	.993	--	--	--	--	--	--	.996
Other hardwoods	776	.967	.972	.979	.988	.987	.987	.997	.986	.989	.971	--	--	--	--	--	.981
Noncommercial	240	.978	.974	.974	--	--	--	--	--	--	--	--	--	--	--	--	.978
All hardwoods	15,043	.971	.979	.989	.992	.993	.995	.995	.994	.992	.994	.993	.994	.987	.989	.981	.991

[1/] All values based upon at least 10 observations.

Table 4.--Average net merchantable volume per tree to a variable 4-inch top d.o.b.[1/] by species group and diameter class, Indiana and Illinois

(In cubic feet)

Species group	Number of observations	Diameter class (inches at breast height) 5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-22.9	23.0-24.9	25.0-26.9	27.0-28.9	29.0+
Shortleaf pine	210	2.3	5.8	10.1	17.1	25.4	--	--	--	--	--	--	--	--
Select white oak	2,012	2.4	5.4	10.6	16.7	24.1	33.1	43.6	53.3	69.6	85.4	94.2	112.8	163.5
Other white oak	518	2.7	5.7	10.7	17.0	22.6	30.9	42.4	51.2	68.7	69.0	94.5	69.6	318.8
Select red oak	909	2.8	5.9	10.9	16.6	24.1	33.6	43.3	52.8	66.6	85.7	93.6	109.7	153.1
Other red oak	1,545	2.3	5.5	10.1	16.0	23.7	31.6	42.3	55.6	70.5	84.7	98.3	126.2	174.0
Select hickory	792	2.2	5.9	10.7	16.8	24.5	33.1	46.2	62.3	72.7	93.8	121.3	--	189.0
Other hickory	850	2.4	5.7	10.5	17.7	25.3	34.3	42.4	58.2	63.1	97.9	113.3	179.2	159.3
Basswood	121	2.3	6.2	10.1	15.2	24.5	29.2	41.5	49.0	71.8	82.6	--	131.5	117.5
Beech	431	2.7	6.0	10.5	18.3	26.2	34.6	43.6	58.0	68.8	79.0	110.4	117.1	137.6
Hard maple	1,074	2.7	6.5	11.4	18.6	26.1	34.6	45.4	57.3	64.7	74.7	83.5	106.2	164.1
Soft maple	437	2.6	6.2	11.5	18.6	26.2	35.9	43.4	58.7	71.2	87.7	108.2	127.4	215.1
Elm	370	2.4	5.9	10.1	17.3	25.5	31.4	41.5	53.1	67.8	68.8	114.6	--	--
White ash	767	2.4	5.6	9.8	16.1	23.8	31.7	43.0	53.6	57.8	87.4	102.7	79.7	171.3
Sycamore	411	2.4	7.0	11.3	17.9	27.2	37.5	55.5	67.7	82.9	93.4	122.4	131.0	209.4
Cottonwood	190	1.9	6.2	10.9	18.2	27.0	38.2	47.9	57.4	76.6	91.8	101.2	124.7	203.1
Willow	69	2.2	4.8	7.6	13.9	20.2	28.5	37.3	43.3	47.6	50.5	88.1	--	--
Hackberry	87	2.5	5.2	9.8	15.6	23.7	31.3	47.3	63.4	74.5	--	107.1	163.3	170.6
Bigtooth aspen	75	2.8	6.5	11.6	19.6	27.1	37.5	58.8	73.2	82.4	--	--	--	--
River birch	42	2.7	4.7	10.0	14.6	22.9	--	36.8	50.8	37.0	--	94.9	112.3	--
Sweetgum	183	2.1	5.0	10.5	17.2	26.3	36.0	43.6	56.3	88.3	73.4	103.0	125.2	110.4
Blackgum & tupelo	66	1.7	5.1	8.5	14.1	20.7	29.7	43.2	63.8	66.8	--	137.8	--	143.9
Black cherry	201	3.1	6.9	12.1	18.9	27.2	34.3	41.9	51.7	58.1	89.1	85.9	--	--
Black walnut	298	2.9	5.9	10.5	17.0	22.9	33.6	40.0	53.4	53.1	--	--	--	--
Butternut	25	2.5	6.0	10.6	16.1	31.0	27.2	--	--	--	--	--	--	--
Yellow poplar	628	2.6	6.2	11.8	18.8	26.6	38.4	53.3	65.4	79.5	96.7	139.9	121.0	186.6
Other hardwoods	495	2.1	4.7	9.2	14.5	23.3	28.3	40.0	46.9	50.2	66.7	113.9	--	154.7
All hardwoods	12,596	2.4	5.8	10.6	17.1	24.7	33.4	44.3	56.4	69.9	85.9	101.8	118.5	175.8

[1/] Average top diameter tends to increase with increasing d.b.h. due to poor form in the upper bole of large trees.

Table 5.--Average net merchantable volume per tree to a variable 9-inch top d.o.b.[1/] by species group and diameter class, Indiana and Illinois

(In board feet)[2/]

Species group	Number of observations	Diameter class (inches at breast height)									
		11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-22.9	23.0-24.9	25.0-26.9	27.0-28.9	29.0+
Shortleaf pine	71	66	56	--	--	--	--	--	--	--	--
Select white oak	1,608	72	115	157	212	255	330	413	412	471	604
Other white oak	441	68	111	159	212	266	366	289	474	348	1,471
Select red oak	780	75	122	174	224	272	329	450	502	549	690
Other red oak	1,305	74	121	158	218	285	353	413	497	547	730
Select hickory	542	79	121	162	236	333	389	465	584	--	784
Other hickory	555	82	124	181	222	313	274	417	451	1,023	555
Basswood	92	76	118	154	201	227	347	399	--	748	829
Beech	372	81	124	174	211	271	330	409	568	464	609
Hard maple	719	78	124	163	220	263	325	393	389	524	675
Soft maple	300	74	116	158	191	258	283	390	444	469	776
Elm	206	79	112	143	195	286	322	209	519	--	--
White ash	481	68	112	157	224	260	304	451	523	304	714
Sycamore	340	68	114	160	269	327	360	403	621	577	1,005
Cottonwood	163	73	130	179	250	287	345	508	487	643	929
Willow	48	55	87	135	150	209	232	230	359	--	--
Hackberry	65	71	104	148	264	265	301	--	784	827	606
Bigtooth aspen	47	89	127	183	326	397	542	--	--	--	--
River birch	29	63	85	--	186	183	166	--	530	539	--
Sweetgum	120	70	111	163	207	247	460	327	471	623	520
Black gum & tupelo	46	53	98	162	223	347	377	--	600	--	829
Black cherry	125	84	127	157	184	201	335	362	255	--	--
Black walnut	195	81	112	166	236	261	226	--	--	--	--
Butternut	16	71	105	106	--	--	--	--	--	--	--
Yellow poplar	510	85	129	194	272	340	420	515	715	500	817
Other hardwoods	239	67	98	128	192	216	262	362	535	--	740
All hardwoods	9,344	75	118	163	221	279	339	423	495	535	747

[1/] Average top diameter tends to increase with increasing d.b.h. due to poor form in the upper bole of large trees.

[2/] International 1/4-inch rule.

Table 6.--Average net merchantable volume per tree to a variable 9-inch top d.o.b.[1/] by species group and diameter class, Indiana and Illinois

(In board feet)[2/]

Species group	Number of observations	Diameter class (inches at breast height)									
		11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-22.9	23.0-24.9	25.0-26.9	27.0-28.9	29.0+
Shortleaf pine	71	33	41	--	--	--	--	--	--	--	--
Select white oak	1,608	34	64	98	144	177	252	326	324	368	474
Other white oak	441	33	62	99	138	183	283	95	339	185	1,294
Select red oak	780	34	66	108	150	196	248	332	407	447	578
Other red oak	1,305	34	66	131	147	200	268	318	442	468	425
Select hickory	542	34	65	81	152	229	294	344	451	--	795
Other hickory	555	37	66	107	144	210	111	323	357	726	646
Basswood	92	32	61	96	137	160	241	320	--	707	709
Beech	372	32	58	90	122	174	224	264	394	310	484
Hard maple	719	32	60	90	135	175	205	283	306	419	548
Soft maple	300	31	60	93	125	179	205	264	362	398	582
Elm	206	34	58	84	103	188	235	76	406	--	--
White ash	481	31	63	97	149	179	206	361	441	353	709
Sycamore	340	28	58	86	169	220	265	278	454	434	821
Cottonwood	163	33	74	117	179	219	262	430	416	537	862
Willow	48	23	49	91	90	171	203	189	319	--	--
Hackberry	65	31	59	94	181	216	203	--	627	757	557
Bigtooth aspen	47	37	62	111	222	300	400	--	--	--	--
River birch	29	32	32	--	136	146	88	--	471	623	--
Sweetgum	120	34	63	106	132	146	340	237	476	539	204
Black gum & tupelo	46	21	56	102	152	259	231	--	518	--	767
Black cherry	125	34	63	89	126	144	268	240	252	--	--
Black walnut	195	32	55	94	156	178	172	--	--	--	--
Butternut	16	26	53	59	--	--	--	--	--	--	--
Yellow poplar	510	36	67	114	169	228	294	375	504	376	644
Other hardwoods	239	30	52	75	137	144	219	264	476	--	811
All hardwoods	9,344	33	63	102	145	193	246	313	396	428	587

[1/] Average top diameter tends to increase with increasing d.b.h. due to poor form in the upper bole of large trees.

[2/] Doyle rule.

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