The Forest Types of Indiana and a New Method of Classifying Midwestern Hardwood Forests

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Abstract

Evidence from the plotting of modified importance sums for 3 species-groups of dominant forest trees on a 3 axis, triangular graph supported the classification of 58 outstanding old-growth, relatively undisturbed stands in Indiana into four major forest types: Oak-hickory, Beech-maple, Lowland-depressional and Mixedwoods. Two clearly recognizable subtypes of the latter were well drained mixedwoods *versus* poorly drained mixedwoods.

Other lines of evidence, such as the species association gradient presented herein, and a 3 dimensional ordinational model published elsewhere, corroborate this interpretation.

This classification appears applicable to the hardwood forests of all nearby midwestern states where the forest stands also seem to be dominated in different sites by essentially the same 3 general species-groups, and intermediate mixtures.

The Indiana Natural Areas Survey of 1967-9 provided an opportunity for extensive field work on the old growth forest stands of the state. Detailed descriptions of many such stands were presented in the book on the survey results (5). The best 36 forest stands (i.e., those least disturbed and most nearly in equilibrium with their specific environment) were used for ordination and an intensive comparison of forest types. After completion of this work, the authors jointly developed several simpler, more readily applicable approaches for the classification and comparison of midwestern hardwood forests, using 58 relatively undisturbed stands, including the 36 stands of the Schmelz and Lindsey analysis (7). The best one of these approaches appears worthy of recommendation for use in all midwestern states where 3 essentially similar groups of hardwood tree species attain high importance values; it therefore forms the basis of the present brief paper. The method depends on importance percentage sums of the respective species-groups, plotted on a special triangular graph. It does not require tedious computations, ordination or the construction of three-dimensional models.

The potential usefulness of the present method is not restricted to application by professional forest ecologists. Because of current and probable continuing interest in preservation of natural areas by citizens' groups, state conservation departments, federal agencies and others, an accurate but relatively simple approach to comparison and classification of forest stands should aid in determining priorities for official protection.

Methods and Materials

The 58 forest stands we used (Table 1) were either subjected to full tallies of substantial portions (up to 23 acres complete census) or were intensively sampled by a number of $\frac{1}{2}$ acre strips or $\frac{2}{2}$ acre strips, each

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400 feet in length. The unusually thorough gathering of basic data was prompted by the demonstration by Lindsey, Barton and Miles (3) that a satisfactory level of adequacy depends on quite high intensity of sampling.

In each stand, the following attributes were computed for each species represented by individual stems exceeding 4 inches dbh: density per acre (D_z) , relative density (D_3) , basal area per acre (B_2) , relative basal area (B_3) and importance (V_3) . The latter was obtained by averaging relative density and relative basal area figures. The V_3 for separate selected species within a given stand were summed, to obtain the total importance for each of three basic species-groups which dominated and characterized stands representing particular forest types.

The oak-hickory species-group included the species of upland Quercus and Carya characterizing rather xeric forest sites in Indiana, i.e., white $(Q. \ alba)$, chestnut $(Q. \ prinus)$ and black $(Q. \ velutina)$ oaks, and pignut $(C. \ glabra)$ and shagbark $(C. \ ovata)$ hickories. The lowlanddepressional species-group included 13 species on flood plains or poorly drained depressions—red and silver maples $(Acer \ rubrum, A. \ saccha$ rinum), big shellbark hickory $(C. \ laciniosa)$, hackberry $(Celtis \ occi$ dentalis), green ash $(Fraxinus \ pennsylvanica)$, sweet gum (Liquidam $bar \ styraciflua)$, black gum $(Nyssa \ sylvatica)$, sycamore (Platanusoccidentalis), swamp white oak $(Q. \ bicolor)$, bur oak $(Q. \ macrocarpa)$, pin oak $(Q. \ palustris)$, Shumard oak $(Q. \ Shumardii)$ and American elm $(Ulmus \ americana)$.

The beech-maple group typical of upland mesic sites consisted of *Fagus grandifolia* and *Acer saccharum*.

The use of a graph in the form of an equilateral triangle made it possible to plot, by one dot for each stand, the selected population importance sum for each of the 3 species-groups in a single plane. This graph, reproduced as Figure 1, shows values for the beech-maple species-group increasing upward, i.e., the base of the triangle stands for zero and apex of the triangle would represent 100% beech and/or sugar maple. However, the plotted figures cannot be simply the straight importance percentage sums. The total importance for a stand is actually 100%, but we disregard some species, namely, those not included in any of the three species-group lists above. Because the use of the three-axis graph depends on the 3 values for each plotted point adding up to 100, we converted each species-group figure to a new per cent value, on the basis of a full 100% for the sum of only the 3 species-group importance figures. These adjusted values, then, were plotted for Figure 1.

Such figures for the oak-hickory species-group were plotted on the axis that has values increasing from the entire right-hand side (zero for OH) to the lower left point (100% for OH). Conversely, all along the left side is the zero value for the lowland-depressional species group component of a given stand, while this component increases rightward and downward to 100% LD species at the lower right-hand point. Upon



FIGURE 1. Location of 58 hardwood forest stands on a three-axis graph, plotting sums of the 3 species-group importance percentages per stand (see text) on the triordinates to determine the stand type. The 60 per cent importance level (heavy line) delimits the 3 corners where beech-maple, oak-hiekory and lowland depressional stands occur, while the stands falling eentrally represent the mixedwoods type. (Abbreviated stand names are explained in Table 1. In several cases, one dot represents more than one closely similar stand).

this 3-axis graph, then, we plotted the 3 major components of each of the 58 stands selected for minimal history of disturbance by human activity.

For example, the Bear Creek Valley slope forest (BV in Table 1) contained no lowland-depressional species, hence its dot (BV) fell on the zero LD line that forms the left side of the Figure 1 graph. The figures for the other axes were approximately 20% beech-maple and 80% oak-hickory, as the BV dot in Figure 1 indicates.

Results and Discussion

Since the abovementioned position of stand BV on the graph closely approaches the oak-hickory (lower left) point, this stand doubtless represents the oak-hickory forest type. It would be classed as an oak-hickory stand by the criteria of Crankshaw *et al.* (2) or on any other basis of which we have heard. But how should stand BU (with the same [20%] beech-maple percentage but only 63% oak-hickory, and with 17%

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	County	U.S.G.S. quad	Town	Range	Section
BEECH-MAPLE					
Allee (Al)	Parke	Montezuma	16N	8 W	3
Bendix (Bx)	St. Joseph	Lydick	37N	1 W	11
Caster (Ca)	Montgomery	Shannondale	19N	3 W	34
Cring (Cr)	Jay	Portland	23N	14E	10
Haves (Ha)	Wayne	New Paris	14N	1 W	35
Hoot (Ho)	Owen	Patricksburg	9N	4 W	6
Jackson (Jk)	Ripley	Milan	7 N	12E	18
Logansport (Lo)	Cass	Anoka	27N	2E	33
Manlove (Mu)	Fayette	Connersville	15N	12E	29
Meltzer (Crosby) (MC)	Shelby	Rays Crossing	12N	8E	7
Nature Conservancy (NC)	Montgomery	Alamo	17N	6W	2
Officer's North (ON)	Jefferson	Volga	4 N	9E	22
Pine Hills (PH)	Montgomery	Alamo	17N	6 W	1
Pioneer Mothers (PM)	Orange	Paoli	1 N	1E	7
Potzger (Po)	Ripley	Milan	7 N	12E	20
Rocky Hollow (RH)	Parke	Wallace	17N	7 W	27
Rosbrugh (Ro)	Kosciusko	Leesburg	33N	$6\mathbf{E}$	30
Rush (Ru)	Montgomery	Alamo	18 N	6 W	27
S. LaPorte (SL)	LaPorte	LaPorte East	36N	3 W	2
Spurgeon (Sp)	Noble	Ligonier	35N	9E	18
Warren (Wr)	Berrien (Mich)	Three Oaks	7S	1 W	27
Weaver (Wv)	Fayette	Connersville	15N	12E	30
Wygant (Wy)	Huntington	Majenica	27N	10E	3
OAK-HICKORY					
Beall (Upland) (BU)	Wabash (Ill.)	Mt. Carmel	2S	13W	11
Bear Creek Plateau (BP)	Fountain	Stonebluff	21N	8 W	33
Bear Creek Valley (BV)	Fountain	Stonebluff	20N	8 W	4
Dunes (Xeric) (DX)	Porter	Dune Acres	37N	6 W	13
Fox Island (FI)	Allen	Fort Wayne W.	30N	11E	25
Johnson (Jo)	Posey	Wabash Is.	17S	14 W	32
Lilly-Dickey (Ly)	Brown	Nashville	9N	3E	8
Ross Reserve (RR)	Tippecanoe	Otterbein	23N	6 W	26
Wing Haven (Wi)	Steuben	Angola E	38N	13E	35
LOWLAND-DEPRESSIONAL					
Andrus (An)	Knox	E. Mt. Carmel	18	12W	11
Beall (Bottom) (BB)	Wabash (Ill.)	Mt. Carmel	2S	13W	11
Beckville (Bk)	Montgomery	Shannondale	18N	3 W	11
Davis 1 (Dv)	Randolph	Redkey	21N	12E	23
Giants (WG)	Vermillion	Perrysville	18. 19N	9 W	3. 34
Hemmer (Hm)	Gibson	Lynnville	38	9 W	24
Independence (IB)	Tippecanoe	Otterbein	22N	6 W	3
Kramer (Kr)	Spencer	Owensboro W.	88	7 W	12
Little Cypress (LC)	Knox	E. Mt. Carmel	1S	12 W	14
Meltzer (Brookston) (MB)	Shelby	Ray's Crossing	12N	8E	7
Paramecium Is. (PI)	White	Buffalo	28N	3 W	1
Pin Oak (PO)	Gibson	E. Mt. Carmel	1S	12W	34
Sigmoid Is. (SI)	Carroll	Brookston	25N	3 W	15, 16
Terrace Is. (TI)	Tippecanoe	Brookston	24N	3 W	17
Tippecanoe (Upper) (TU)	Pulaski	Bass Lake	31N	1 W	18, 19
Wesselman (Ws)	Vanderburgh	Evansville	6S	10 W	22, 23
MIXED WOODS					
Big Walnut (BW)	Putnam	Roachdale	15N	3 W	29.31.32
Botany Glen (BG)	Grant	Gas City	23N	8 E	11. 14
Bradford (Br)	Morgan	Mooresville W	13N	1E	5
Clifty (Cl)	Montgomerv	Alamo	17N	6W	ĭ
Conboy (Cy)	Jennings	Vernon	6N	9E	10
Donaldson's (Dn)	Lawrence	Mitchell	3N	iĒ	4
Dunes (Mesic) (DM)	Porter	Dunes Acres	37N	6W	13
McCormicks Cove (McC)	Owen	Gosport	10N	3W	22
Officer's (South) (OS)	Jefferson	Volga	4N	9E	22
Tippecanoe (Lower) (TL)	Pulaski	Bass Lake, Winamac	31N	ĩW	18, 19

TABLE 1. Names, symbols, forest types and locations of the 58 stands considered herein.

lowland-depressional), be typed? An inspection of the distribution of all the stands on the graph aids in establishing improved criteria for stand classification.

The 58 original or very old growth stands utilized do not appear as a continuum throughout Figure 1 since intergradation between the two sides (OH *versus* LD) appears lacking not only along the zero BM (base) line but throughout a large central region and high up toward the BM apex. The intergradations can be traced instead from LD with high available moisture supply, through BM with median moisture and drainage (mesic sites), to OH with limited moisture and excessive drainage. Although these old stands must at present be relatively stabilized and in balance with their sites and overall environments in accord with current polyclimax interpretation, reading the graph upward from either the OH or LD corner parallels the successional trend in Clementsian theory from moisture extremes to optimum conditions for the beech-maple type on mesic sites. This conforms with the results shown by the much less direct approach (through 3-axis ordination technique) of Schmelz and Lindsey (7) based on a more stringently selected 36 stands of these 58.

An area of some selected size subtending each point of the triangle will serve to delimit or define the major forest types for Indiana in a revised type classification. Any criteria adopted are somewhat arbitrary, as were those of Crankshaw et al. (2) and Lindsey et al. (4) in earlier papers. The present authors consider that the information in Figure 1 supports recognition of 4 major hardwood forest types, when each "point" is delimited at the 60% cross line of the graph, as shown by heavier lines. The 3 forest types occupying the extreme site conditions, near the points of the triangle (Lowland-depressional, Beech-maple and Oakhickory) are defined by having at least a 60 (adjusted) importance percentage sum for the one dominant species-group, hence 40% or less for the other two species-group sums taken together. Stand BU, having 63% upland OH species, is therefore placed in the oak-hickory type. Obviously, the three importance sums are sufficient to designate forest types (without plotting stand positions on a graph) once a quantitative criterion is accepted. The graph facilitates broad comparisons.

Stands that are not conspicuously dominated by a single speciesgroup fall within the remaining central hexagonal figure. We term this hardwood type as Mixedwoods. This fourth type is subdivided rather clearly (within the stands examined, at least) into well drained and poorly drained subtypes, at the left-center and right-center respectively, and without intergradation between them within the Mixedwoods Type. The latter includes, basically, both the Mixed Woods and Western Mesophytic Types of Schmelz and Lindsey (7) (both these types representing the well-drained Mixedwoods subtype) plus the poorly-drained mixedwoods subtype represented here by TL, OS and Cy at the right. The latter show very low oak-hickory representation, because low-ground oaks like pin and swamp white oaks are not included in the (upland) oakhickory species-group. However, these 3 stands have moderate amounts of beech and/or sugar-black maple; this raises them above the lowland

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depressional type, into the Mixedwoods Type, as the subtype of the latter which lies intermediate between Beech-maple and Lowland-depressional rather than between Beech-maple and Oak-hickory.

Since about 87% of Indiana was covered by forest in presettlement times (6), all substrate conditions paralleling the forest type triangle in Figure 1 probably supported forests in this state originally. The large central blank space appearing on the graph represents, by and large, the vegetation of sites without extremes of ponding or droughtiness, steep slope or excessive internal drainage. Since these median sites have been chiefly cleared for agricultural utilization, fine present-day forests tend to be restricted to sites less favorable for farming. It seems reasonable that mixedwoods were somewhat more prevalent in the original vegetation of Indiana than in that of today, not so much as an extensive mappable type as on some isolated median sites within the regions mapped (4, 5, 6) as beech-maple or oak-hickory. The portions of southern Indiana mapped previously (4, 5, 6) as "western mesophytic" we now prefer to consider Mixedwoods, in part because Aesculus octandra and Tilia heterophylla which Braun (1) considered mesophytic indicators do not extend very far northward in Indiana.

Data on soil requirements-tolerances of certain Indiana tree species were published by Crankshaw, Qadir and Lindsey in 1965 (2). We have arranged those species according to the ecological affinities shown in Table 2 into a gradient from black oak at the xerophytic end through black ash at the hydrophytic extreme. They fall clearly into the 3 groups roughly corresponding with the 3 apical regions of our Figure 1 graph and with the 3 extreme positions on the ordination model (of 36 stands) published by Schmelz and Lindsey (7). The upland oak-hickory type (upper third of Table 2) prefers high per cent sand, whereas high silt content characterizes the sites of the dominant tree species of beech-maple forests, and high per cent clay favors lowland-depressional stands. Highly leached soils, low pH and low available nitrogen are compatible with oak-hickory. The lowland depressional species are favored by high available water, neutrality of reaction, high clay content and at least 4 of them by high per cent nitrogen in the soil.

TABLE 2. Gradient of influence of the most important soil factors on treespecies in the presettlement Indiana forest. Plus sign indicates high valuefavors species under natural competition. Minus sign indicates that lowvalue is favorable or well tolerated. A reworking of certain data fromCrankshaw, Qadir and Lindsey (2).

	Avail. H₂O	Leach- ing	$_{\rm pH}$	% N	% Sand	% Silt	% Clay
Black Oak		+	_		+		
Chinquapin Oak		+		_	+		
White Oak			6.1	_	+	—	
W. B. Cherry			6.1		+		
Shingle Oak					+		
Post Oak		+	_		_		
Upl. Hickories		+		_	_	+	
Red Oak		+					
Tulip Tree		+				+	
Sugar Maple			+	+		+	
Basswood	+		+	+			
White Ash		\longleftrightarrow		+			+
Beech		\longleftrightarrow				+	
Bur Oak		+				+	
Sweet Gum		+	_				+
Amer. Elm			7				+
Bl. Walnut	+		7		+		
Buckeye	+		+	+	•		+
Hackberry	+	0	7	+			_
Cottonwood	+	0	7	+			
Honey Locust	+	\longleftrightarrow	7	$\leftarrow \rightarrow$			
Sycamore	+		7				+
Black Ash	+		7	+			+

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