FOREST VEGETATION IN HAMILTON COUNTY, OHIO: A CLUSTER ANALYSIS AND ORDINATION STUDY

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ABSTRACT. —Twenty mature, relatively undisturbed forests in Hamilton County, Ohio were systematically sampled and subjected to cluster analysis. Based on those results eight forest types were identified. These included: silver maple-cottonwood-green ash or black willow on alluvial floodplains; pin oak-red maple in depressions of floodplains; oak-hickory on well-drained slopes >25%; oak-maple-ash on dissected till plains or ridge and slope complexes; mixed mesophytic with tulip poplar on well-drained till plains; mixed mesophytic without tulip poplar on loess or colluvium; maple-ash-beech on residuum, colluvium or well-drained till plains of Illinoian or Wisconsin origin; and beech-maple on lacustrine and loess deposits. Geology, especially the glacial history, soils, topography, and disturbance history appear to influence tree species community patterns.

Introduction

Dr. E. Lucy Braun began her classic studies of forest ecology in southwestern Ohio, in particular, Hamilton County or the Cincinnati Region (Braun 1916, 1936, 1950). Geologically, Hamilton County is at or near the terminus of the Nebraskan, Kansan, Illinoian, and Wisconsin glacial advances (Ray 1974). Phytogeographically, the county is in Braun's (1950) Western Mesophytic Forest Region, but near the junction of her Mixed Mesophytic, Oak-Hickory and Beech-Maple Forest Regions or Kuchler's (1964) Oak-Hickory, Mixed Mesophytic, and Beech-Maple Forests.

Braun (1916) and Diehl (1933) considered topography and soils as two of the most important factors in determining forest types and distribution in Hamilton County. However, bedrock geology and the glacial deposits may have a major influence on local vegetation patterns (Braun 1950, Forsyth 1970).

The majority of the land area of Hamilton County was a part of the original Symmes Purchase of 1788. Following European settlement, changes in the landscape began to appear, first as a result of land clearing and agriculture and later because of urban expansion. Existing forests were reduced in size and fragmented as a series of isolated islands on the landscape. Today, forest remnants occur in parks, nature preserves, and old estates where they have received protection. In recent times some of these remnants have been the basis of ecological studies by Hoye *et al.* (1978), Bryant (1987) and Swanson and Vankat (2000). In a similar way, Levenson (1980, 1981) sampled the parks and woodlots of metropolitan Milwaukee, Wisconsin as biogeographic islands within an agro-urban setting.

The primary goals of the present study were to continue to characterize the mature forest remnants in Hamilton County, Ohio (Bryant 1987) as part of an evaluation of urban forests and to determine the nature, patterns and environmental relationships of the remnants.

The Setting

Hamilton County is located in the extreme southwestern corner of Ohio. The 107,350 ha county is bounded on the west by southeastern Indiana and on the south by the Ohio River and adjacent northern Kentucky. Fenneman (1916) placed Hamilton County in the Till Plains section of the Central Lowland Physiographic Province. However, he found this area to be less typical of the Till Plains of Ohio and Indiana because of its proximity to important drainage lines. Brockman (1998) included portions of Hamilton County in the Outer Bluegrass Region of the Interior Low Plateau and the Illinoian Till Plain of the Central Lowland Province.

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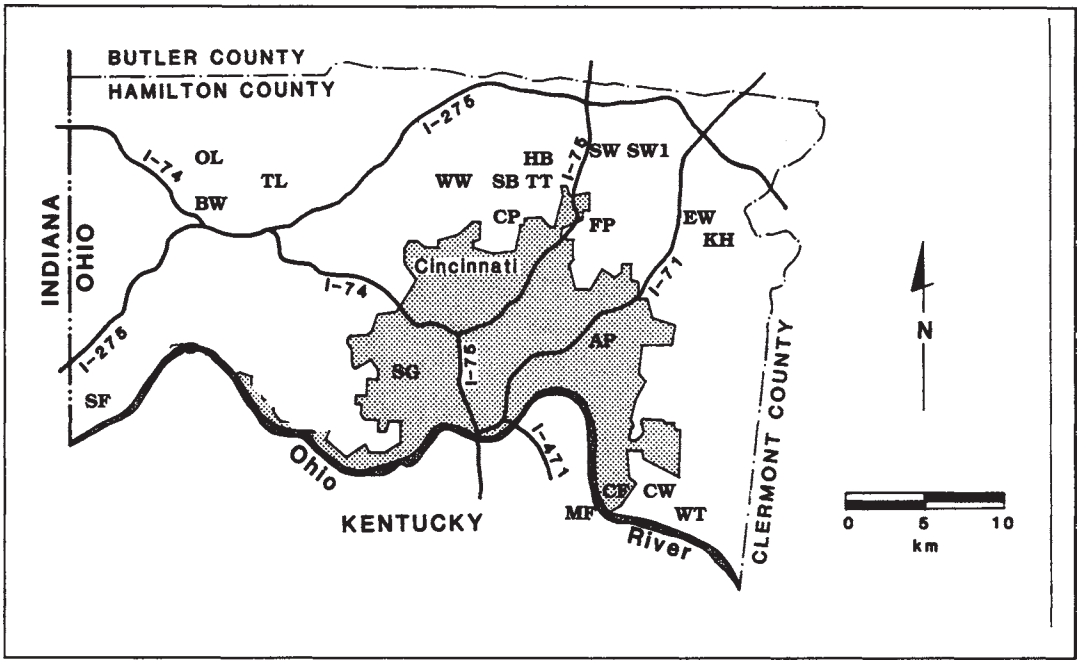

Figure 1.—The location of study sites in Hamilton County, Ohio. Letters indicate the study sites sampled except for Melbourne Forest which is in Campbell County, Kentucky. See Table 1 for abbreviations.

The local physiographic features of importance are uplands, slopes, floodplains, and terraces (Braun 1916, Diehl 1933). Braun equated these features to the soils of the area. Lerch *et al.* (1982) listed prominent topographic features of the county as gently rolling glacial uplands, steep hillsides along the major streams, extensive glacial river terraces and outwash plains, and floodplains. The topographic relief ranges from 139 m to 293 m. Stream dissection has produced many steep-sided valleys on some of the glacial deposits in the county where underlying Ordovician bedrock has been exposed (Forsyth 1970). Soils in the county reflect the glacial and erosional history of southwestern Ohio (Lerch *et al.* 1982).

The climate of Hamilton County is of the continental type with cold winters and hot summers. Annual precipitation is about 101.6 cm with over half of that falling during the growing season.

Description of Study Sites

A total of nineteen sites were selected for sampling from throughout the Hamilton County and one in Campbell County, Kentucky across the Ohio River from southeastern Hamilton County. The sites were selected to provide a representative sample of forests, geology, and soils of the region (fig. 1). Eleven sites were located in Hamilton County Parks and three were in Cincinnati City Parks. The remaining sites located in a Cincinnati Recreation Commission Preserves, in a cemetery, on an older private estate, one was a University preserve, one on the property of the Cincinnati Water Works, and one was on a convent grounds. Many other sites were visited, but were not sampled for various reasons. Mt. Airy Forest, a park of over 400 ha near the center of Cincinnati, was not sampled because it was formerly pasture land that had been reforested by plantings (Braun and Jones 1926). Other sites were generally too small to obtain a random sample or too disturbed.

The forest of Ault Park (AP), California Woods Nature Preserve (CW), Caldwell Park (CP), Winton Woods (WW), Bowles Woods (BW), and Melbourne Forest (MF) were old-growth forests previously described by Bryant (1987). Emery Woods (EW) was thoroughly described by Swanson and Vankat (2000).

California Floodplain (CF) is located on the Ohio River Floodplain. Soils are Genesee-Urban Land complex and are loamy alluvium.

Shawnee Floodplain (SF) has been described as a back swamp area of Shawnee Lookout Park. Jules silt loam on the site is deep, nearly level and well-drained (Lerch *et al.* 1982).

Oak Leaf (OL) is a forest in the Miami-Whitewater Forest. The Bonnell silt loam covers steep (25 – 35%) slopes. These well-drained slopes border the Illinoian till plain.

Timber Lakes (TL) is also located in Miami-Whitewater. Soils are primarily Eden silty clay loam on 25 – 40% slopes. Cincinnati silt loam is a loessial soil over Illinoian till (Lerch *et al.* 1982).

Spring Grove (SG) is within Spring Grove Cemetery where it has been preserved since 1880 (Linder 1995). Soils in the ravine include Urban terraces (Lerch *et al.* 1982).

Kroger Hill (KH) is found on well-drained Illinoian till plain where the rolling land is pitted with sinkholes. Soils are Rossmoyne silt loams which are loess over underlying Illinoian glacial till.

Trillium Trails (TT) is within Winton Woods Park. Soils are residual on hillsides and include the Eden silty clay loam which formed from interbedded limestones and soft calcareous shales.

Sharon Woods (SW) is a gorge area of Sharon Woods Park. This area is part of the dissected Wisconsin till plain. The soil complex includes Miami silt loam, Eden silt loam, and Russell-Urban Land.

Sharon Woods (SW1) occurs within the Park just north of the gorge area. This forest is on Wisconsin till plain with little or no dissection. Soil is the Miami-Hennepin.

Hazelwood Botanical (HB) is within the Hazelwood Botanical Preserve managed by the University of Cincinnati. This forest was initially studied by Segelken in 1929. This woods is located on the Illinoian till plain of northern Hamilton County. Soils include the Rossmoyne silt loam. Not long after this forest was systematically sampled, it was destroyed by a tornado.

Spring Beauty Dell (SB) is located with Winton Woods Park. This forest is an old slack water terrace and lacustrine sediments from the Markland silty clay loam (Lerch *et al.* 1982).

French Park (FP) is the site of a former Girl Scout camp. Colluvium covers the lower slopes of the hillsides. This is Pate silty clay loam. Bonnell silt loam is also present. This is a loessial soil over underlying Illinoian glacial till (Lerch *et al.* 1982).

Withrow Woods (WT) is located off 5-mile Road in southeastern Hamilton County. This includes a deep ravine and was part of an old glacial terrace of Illinoian age (Fenneman 1916). Upland soils include the Cincinnati silt loam and the Rossmoyne silt loams Eden soils are prominent on the steep slopes.

Methods

All forests sampled exceeded the minimum size of 3.8 ha that Levenson (1981) considered to be the smallest size at which a mature, mesic forest can perpetuate its interior conditions while sustaining limited random perturbations (Loucks 1980). All sites were sampled in 0.04 ha circular plots spaced at 30 meter intervals throughout the forest interior. All trees ≥10 cm at diameter-breast-height (DBH) were measured in each plot. The number of plots taken per site depended on the size of the forest and/or its homogeneity or heterogeneity. The number of plots sampled/stand ranged from 10 to 45.

Data for each forest were analyzed to relative frequency, relative density, and relative dominance or relative basal area. These values were summed to produce and importance value for each species

Table 1.—Tree density (trees/ha), basal area (m^2/ha), species diversity (H'), and the number of tree species in sample for forests in Hamilton County, Ohio

Forest	Trees/ha	m^2/ha	H'	Species Richness or Number of Species
Ault Park (AP)[1]	313	34.27	2.83	20
Bowles Woods (BW)[1]	279	32.19	1.94	15
Caldwell Park (CP)[1]	199	26.07	3.35	23
California Floodplain (CF)	175	43.92	0.99	6
California Woods (CW)[1]	324	39.16	3.11	20
Emery Woods (EW)[2]	401	42.60	3.68	32
French Park (FP)	287	29.93	2.51	15
Hazelwood Botanical Preserve (HB)	191	28.28	1.99	12
Kroger Hills (KH)	251	31.63	2.01	19
Melbourne Forest (MF)[1]	396	30.19	2.98	17
Oak Leaf (OL)	274	25.71	1.85	10
Sharon Woods Gorge (SW)	294	31.85	2.61	19
Sharon Woods Upland (SW1)	294	27.99	1.78	11
Shawnee Floodplain (SF)	435	16.34	1.00	4
Spring Beauty Dell (SB)	340	28.87	1.82	15
Spring Grove (SG)	314	29.12	2.48	16
Timber Lake (TL)	299	26.77	2.56	15
Trillium Trails (TT)	277	31.01	1.96	12
Winton Woods (WW)[1]	240	28.85	2.18	15
Withrow Woods (WT)	306	37.38	2.97	23

[1]After Bryant (1987)
[2]After Swanson and Vankat (2000)

(Appendix 1). Because of the presence of the invasive Amur honeysuckle (*Lonicera maackii*) throughout the parks (Luken and Thieret 1996), shrubs, saplings and seedlings were not included in this survey. Density (trees/ha), basal area (m^2/ha) and species diversity (Shannon Index or H') were determined for each forest.

Stand relationships were summarized using both the Unweighted Pair Group Mean Average (UPGMA) clustering technique (Kovach 1998) and the Bray-Curtis ordination procedure (McCune and Medford 1999).

Results

There was a total of 47 tree species in the forests samples in Hamilton County, Ohio and environs. Only two species, *Ailanthus altissima* (tree-of-heaven) and *Maclura pomifera* (Osage orange) were not native to the area. We interpreted this to indicate that the forest samples, at least at the tree level, were not greatly disturbed. Tree density, basal area, species diversity, and tree species richness are shown in Table 1. All upland sites sampled fit within the ranges for tree density (trees/ha) and basal area (m^2/ha) reported by Parker (1989) and Martin 1992) for mature mesic forests.

Twelve species of trees were present ≥ 50% of the stands. American beech (*Fagus grandifolia*) and white ash (*Fraxinus americana*) were the most widely distributed species, occurring in 90% of the forests sampled. Sugar maple (*Acer saccharum*), red oak (*Quercus rubra*), and black cherry (*Prunus serotina*) occurred in 85% [17 of 20] of the stands; slippery elm (*Ulmus rubra*), 80%; bitternut hickory (*Carya cordiformis*), 70%; black walnut (*Juglans nigra*) and hackberry (*Celtis occidentalis*), 65%; shagbark hickory (*C. ovata)* and blue ash (*F. quadrangulata*), 55%; and white oak (*Q. alba*), 50%. These species tend to be indicative of the mesic nature of the county and most stands. A number of other species are more site-specific and restricted in their distribution.

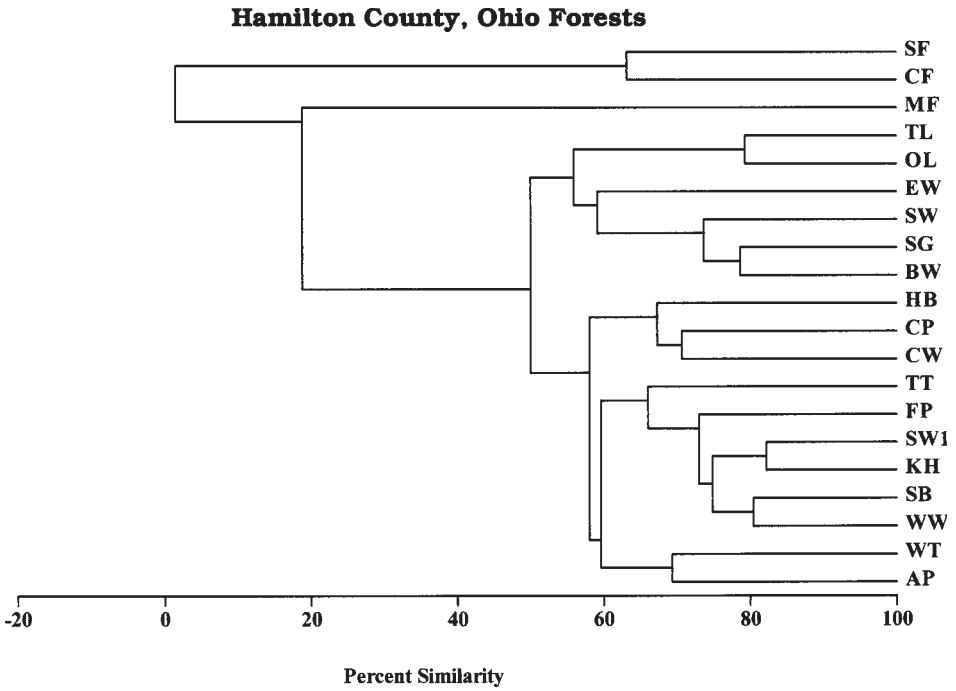

Figure 2.—Cluster analysis dendrogram of the forest sampled in Hamilton County, Ohio.

Twenty-four species accounted for ≥ 5% of the stand basal area in at least one forest. Sugar maple ranked first with 85% [17 of 20 stands] followed by white ash at 60%. American beech and red oak were next with 45%. Tulip poplar (*Liriodendron tulipifera*) at 25% was the only other species to account for as much as 5% of the total basal area in four or more of the forests. This suggested differences in site quality across the county.

Based on the cluster analysis (fig. 2), eight groupings were recognized; however, the mesic associations showed overlap and were the most difficult to distinguish cleanly. Pin Oak-Red Maple (MF) occupied depressions of the Ohio River floodplain and the Silver Maple-Cottonwood-Green Ash or Black Willow (CF and SF) were on the larger floodplains. Mixed Mesophytic forests with the indicator species of this type, *Aesculus octandra* (Yellow Buckeye) and *Tilia heterophylla* (White Basswood) (Braun 1950) sorted out. However, there appeared to be two types of mixed mesophytic forests: those with *Liriodendron tulipifera* (Tulip Poplar) (CW, CP, HB) and those in which Tulip Polar is rare or absent (WT, AP). Oak-Hickory forests (OL, TL) were at the drier end of the moisture gradient. Beech-Maple forests (WW, SB) also represented a distinct type within the mesic grouping. This forest type was mainly on sites underlain with a fragipan. Oak-Ash-Maple forests (SW, SG, BW, EW) and Maple-Ash-Beech forests (FP, KH, TT, SW1) were intermingled with the Mixed Mesophytic and Beech-Maple assemblages and did not separate out easily. For that reason, we considered the latter two species assemblages as Western Mesophytic after Braun (1950) and Gordon (1966, 1969).

On the ordination (fig. 3), Axis 1 appeared to be a moisture gradient with the floodplain forests and depression forest at the wet end and the Oak-Hickory) at the drier end. All the other forests were intermediate across the moisture gradient. Axis 2 was interpreted to represent a topographic gradient from depressions to floodplains to rolling flats to ravines to slopes and steep slopes. Based on this interpretation, the forests tend to sort out as Depression forests of Pin Oak-Red Maple; Floodplain forests of Silver Maple-Cottonwood-Green Ash or Black Willow; Beech-Maple on the rolling flats or terraces; Mixed Mesophytic in ravines; Western Mesophytic on sites with intermediate slope and moisture conditions; and, Oak-Hickory on exposed hillsides and steeper slopes. Disturbance history of the forests undoubtedly plays a role in this interpretation.

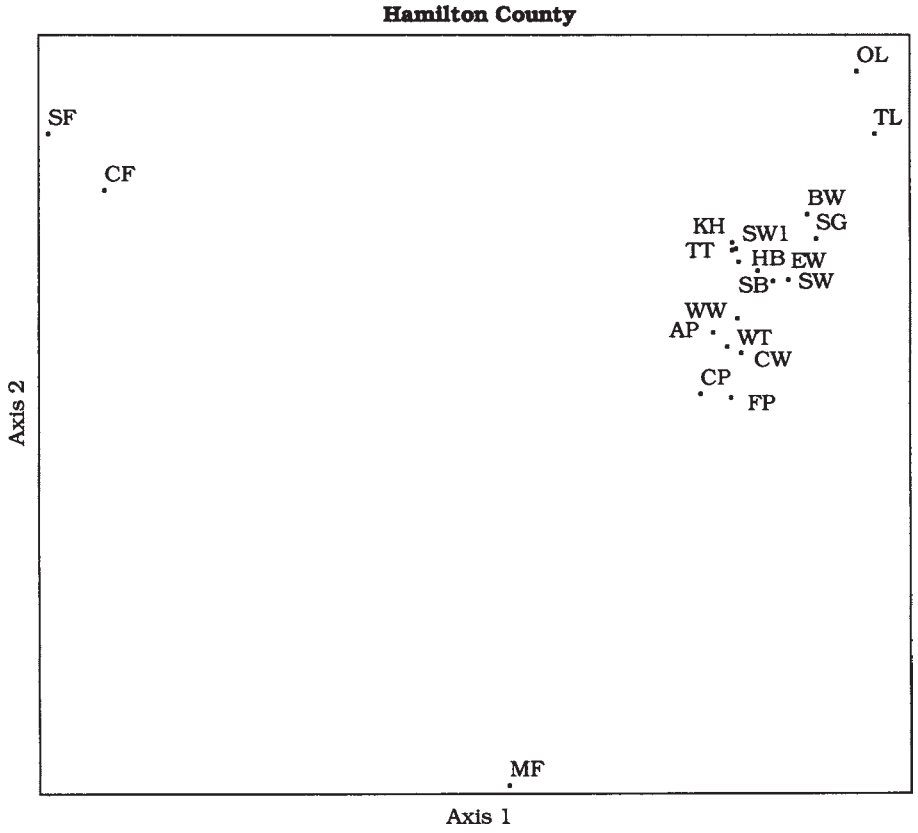

Figure 3.—Ordination of the twenty forests sampled in Hamilton County, Ohio. Axis 1 is a moisture gradient and Axis 2 is a topographic gradient.

Discussion

Even though the forests of Hamilton County, Ohio have been widely studied (i.e., Braun 1916, 1936, 1950; Bryant 1987; Diehl 1933; Hoye et al. 1978; Swanson and Vankat 2000), they are still of great interest. Much of that interest results from the glacial history of the county plus the diversity of soil types and landforms present. Braun's (1950) inclusion of the forests of the county as part of the Western Mesophytic Forest region and the well-known urban history (Wade 1959) of Cincinnati add to that interest.

Diehl (1933) recognized six forest types in Hamilton County, Ohio. These were: Pin Oak-Red Maple; Beech; and Beech-Maple on uplands and terraces; Mixed Mesophytic and Oak-Ash-Maple on slopes; and Willow-Cottonwood-Silver Maple on recent alluvium of floodplains. Diehl (1933) correlated these forest types to soils and/or slopes. Bryant (1987) reported four types of old-growth forest remnants including Oak-Hickory, Beech-Maple, Depression Forests, and Mixed Mesophytic. A number of these forest types are site specific.

In the Cincinnati region, the forests of the floodplain are two types: the depression forest and "typical" floodplain forest (Braun 1916). She reported the depression forest to be uncommon and limited to undrained situations on the floodplain. The dominants of the depression forest include pin oak (*Quercus palustris*), red maple (*Acer rubrum*), and swamp white oak (*Q. bicolor*) (Braun 1916). She noted that the depression forests of the uplands, i.e. on the Illinoian Till Plain, are similar to those of the floodplains. Diehl (1933) recognized this upland type, however, the Pin Oak-Red Maple type is more common east of Hamilton County (Braun 1916, 1936).

Many forests on the Ohio River floodplain have also been destroyed or seriously disturbed by man. Braun (1916) listed the following species as "typical" of floodplains: willows (*Salix nigra* and *S. alba*), cottonwood (*Populus deltoids*), white elm (*Ulmus Americana*), silver maple (*Acer saccharinum*), boxelder (*A. negundo*) and sycamore (*Platanus occidentalis*). These vary in abundance in different parts of the association. Early descriptions of these floodplain sites in Cincinnati (Glazer 1999) note that, "along the [Ohio] river edge was a marshy beach bottom spotted with an assortment of sycamores, cottonwood, and water maples…This low-lying riverfront area extended approximately eight feet to the north, where a short but very steep slope marked the line of a higher plateau where beech, yellow poplar, and hickory trees receded into the distance". Those early descriptions resemble the California floodplain. The presence of black willow (*S. nigra*) on the Shawnee Lookout floodplain indicates site a back swamp area where alluvial silt deposition is a common event (Potter 1996). The low basal area of the SF site reflects its successional nature.

Mixed mesophytic forests with the indicator species, yellow buckeye (*Aesculus octandra*) and white basswood (*Tilia heterophylla*) (Braun 1950) were found in a number of dissected areas and ravines. Braun (1950) reported that dissected areas of Illinoian glaciation and adjacent northern Bluegrass are contiguous at the east with typical mixed mesophytic forests of the Mixed Mesophytic Forest region. This dissected zone affords favorable sites for mixed mesophytic forest to extend westward as a narrow band (Braun 1950). Forsyth (1970) found that mixed mesophytic forests in Hamilton County are confined to some of the deep, steep-sided valleys produced by stream dissection. In these valleys, where a great variety of moisture conditions support many tree species, a tree association best described as mixed mesophytic occurs (Forsyth 1970). These associations tend to correlate with the occurrence of Kansan drift in Ohio (Forsyth 1970). Mixed mesophytic forests also occur on Kansan deposits in adjacent northern Kentucky (Bryant 1978). The presence or absence of tulip poplar (*Liriodendron tulipifera*) in these mixed mesophytic associations may be related to sand content of the soils, although this was not determined.

Beech-Maple forests have been reported for Hamilton County (Diehl 1933, Bryant 1987); however, Braun (1950) suggested that her Beech-Maple forest region was entirely within the area covered by the last or Wisconsin ice sheet, one that just entered the county. Vankat *et al.* (1975) considered Hueston Woods in southwest Ohio, but north of Hamilton County, to be at the southern extent of the Beech-Maple region. Bryant (1987) described Beech-Maple south of the terminus of the Wisconsin in Hamilton County on soils of mixed glacial origins and underlain with a fragipan. Lindsey *et al.* (1965) also reported Beech-Maple on Illinoian deposits well south of the Wisconsin glacier border in Indiana. The high importance of white ash (*Fraxinus americana*) in the Beech-Maple stands of Hamilton County is unlike those stands to the north and may be a reason that the Beech-Maple stands ordinate with western and mixed mesophytic stands.

Oak-Hickory forests were primarily in the western portion of Hamilton County, especially on slopes and hillsides where erosion had removed much of the glacial materials. White oak (*Quercus alba*), black oak (*Q. velutina*), shagbark hickory (*Carya ovata*), and pignut hickory (*C. glabra*) were predominant in the Oak-Hickory stands. Schmelz and Lindsey (1970) placed red oak (*Q. rubra*) and bitternut hickory (*C. cordiformis*) with their upland mesic group not with Oak-Hickory. We agree with that interpretation. However, sugar maple (*Acer saccharum*) was an important subcanopy member and was gaining importance in the canopy. Over much of the eastern North America, sugar maple has been found to be increasing in importance, especially where fire cycles have been halted (Loucks 1970).

Forests that we first recognized as Oak-Ash-Maple or Maple-Ash-Beech were lumped together as the Western Mesophytic type. Gordon (1966, 1969) mapped much of Hamilton County as mixed mesophytic-western type after Braun's (1950) recognition of the Western Mesophytic Forest region. She noted that the major vegetation types occurring in the region form a complex mosaic that is the result of present influences as well as past influences operative within recent enough time that their effects on vegetation have not yet been eliminated. She recognized that the underlying bedrock had a major influence on the vegetation and that was evidence of the lack of "complete climate" control.

Braun (1950) considered the Western Mesophytic Forest region to be a transitional region. Under similar environmental conditions in adjacent southeastern Indiana, Lindsey *et al.* (1965) identified a western mesophytic forest type in which *Fagus-Quercus-Acer-Carya* and *Fraxinus* showed a tendency to mix rather than segregate. Later. Schmelz and Lindsey (1970) identified the following forest types for Indiana: Beech-Maple, Oak-Hickory, Mixed Woods, Western Mesophytic, and Lowland-Depressional. In another paper, Lindsey and Schmelz (1970) listed Beech-Maple, Oak-Hickory, Lowland-Depressional and Mixed Woods for Indiana. In the latter paper, they combined the Western Mesophytic and Mixed Woods types. The transitional nature of forests of southern Indiana and also those of Hamilton County is further supported by earlier forest surveys. Bryant (1987) analyzed the 1788 Symmes Purchase survey, which includes most of present-day Hamilton County. In this paper, Bryant (1987) found that species in five genera: *Quercus* (20.12%), *Acer* (18.43%), *Carya* (14.90%), *Fraxinus (*14.13%), and *Fagus* (12.75%), accounted for over 80% of the trees recorded. Species of *Juglans*, *Aesculus*, *Ulmus* and *Celtis* accounted for another 12.75% of the trees. Additionally, Drake (1815) listed beech, white oak, sugar tree, walnut, hickory, and ash as the most numerous trees in the Miami River area of southwestern Ohio. He included other important timber trees, namely, wild cherry, yellow popular, and blue ash. Those two early surveys add support to the mesic-transitional nature of the original forests that were recognized by Braun in 1950 and is still recognizable today.

Braun (1950) found that a mosaic of unlike climaxes tended to characterize the Western Mesophytic region similar to our findings for Hamilton County, Ohio. Braun considered the region to be a tension zone where the compensating effects of local environments permit unlike climaxes to exist close to one another. It is not possible that all of these are in equilibrium with the regional climate and that their presence is indicative of past events (Braun 1950). We agree that locally Hamilton County is a tension zone and that only where environmental conditions are distinct (site specific) do clear-cut community types occur. The strong relationship between site environment and stand composition is best observed at the ends of the various environmental gradients or determined by other specific environmental features.

Acknowledgments

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Literature Cited

1916. **The physiographic ecology of the Cincinnati region**. Columbus, OH: Ohio Biological Survey 2: 113 – 211.

Braun, E. L. 1936. **Forests of the Illinoian Till Plain in southwestern Ohio**. Ecological Monographs 6: 90 – 149.

Braun, E. L. 1950. **Deciduous Forests of Eastern North America**. Philadelphia, PA: Blakiston Company. 596 p.

Braun, E. L.; Jones, L. 1926. Ohio. Pp. 354 – 372 In: Shelford, V. E. ed. **Naturalist's guide to the Americas**. Baltimore, MD: The Williams and Wilkins Company: 354 – 372.

Bryant, W. S. 1978. **Vegetation of the Boone County Cliffs Nature Preserve, a forest on a Kansan outwash deposit in northern Kentucky.** Transactions of the Kentucky Academy of Science 39: 12 – 22.

Bryant, W. S. 1987. **Structure and composition of the old-growth forests of Hamilton County, Ohio and environs**. In: Hay, R. L.; Woods, F. W. and DeSelm, H., eds. Proceedings of the 6th Central Hardwoods Forest Conference, Nashville, TN: 317 – 324.

Brockman, C. S. 1998. **Physiographic Regions of Ohio [map].** Columbus, OH: Division of Geological Survey, State of Ohio

Diehl, G. A. 1933. **Forest types of Hamilton County, Ohio.** Cincinnati, OH, University of Cincinnati, M. S. Thesis.

Drake, D. 1815. **Natural and statistical view or picture of Cincinnati and the Miami Country.** Cincinnati, OH: Looker and Wallace.

Fenneman, N. M. 1916. **The geology of Cincinnati and vicinity.** Columbus, OH: Ohio Geological Survey Bulletin 9.

Forsyth, J. L. 1970. **A geologists looks at the natural vegetation of Ohio.** Ohio Journal of Science 70: 180 – 191.

Glazer, W.S. 1999. **Cincinnati in 1840**. Columbus, OH: The Ohio State University Press.

Gordon, R. B. 1966. **Natural Vegetation of Ohio, at the time of the earliest surveys [map].** Columbus, OH: Ohio Biological Survey.

Gordon, R. B. 1969. **The natural vegetation of Ohio in pioneer days.** Columbus, OH: Ohio Biological Bulletin, New Series III, No. 2

Hoye, M. E.; Perrine, J. V.; Perkins, C. H. 1978. **Secondary vegetation and successional sequence within Shawnee Lookout Park, Hamilton County, Ohio.** Castanea 44: 208 – 217.

Kovach, W. L. 1998. **MVSP-A multivariate statistical package for Windows, Version 3.0.** Pentraeth, Wales, United Kingdom: Kovach Computing Services.

Kuchler, A. W. 1964. **Potential natural vegetation of the coterminous United States.** New York, NY: American Geographic Society, Special Publication No. 36.

Lerch, N. K.; Hale, W. F.; Lemaster, D. D. 1982. **Soil survey of Hamilton County, Ohio**. Washington, DC: United States Department of Agriculture

Levenson, J. B. 1980. **The southern mesic forest of southeastern Wisconsin: Species composition and community structure.** Milwaukee, WI: Contributions to Biology and Geology; Milwaukee County Public Museum.

Levenson, J. B. 1981. **Woodlots as biogeographic island in southeastern Wisconsin**. In: Forest Island Dynamics in Man-dominated Landscapes. Burgess, R. L.; Sharpe, D. M., eds. New York, NY: Springer-Verlag.

Linder, B. M. E. 1995. **Spring Grove: Celebrating 150 years**. Queen City Heritage 53 (1 & 2): 1 – 141.

Lindsey, A. A.; Crankshaw, W. B.; Qadir, S. A. 1965. **Soil relations and distribution map of the vegetation of presettlement Indiana**. Botanical Gazette 126: 155 – 163.

Lindsey, A. A.; Schmelz, D. V. 1970. **The forest types of Indiana and a new method of classifying midwestern hardwood forests**. Proceedings of the Indiana Academy of Science 79: 198 – 204.

Loucks, O. L. 1970. **Evolution of diversity, efficiency, and community stability.** American Zoologist 10: 17 – 25.

Luken, J. O.; Thieret, J. W. 1996. A**mur honeysuckle, its fall from grace.** Bioscience 46: 18 – 23.

Martin. W. H. 1992. **Characteristics of old-growth mixed mesophytic forests**. Natural Areas Journal 12: 127 – 135.

McCune, B.; Medford, M. J. 1999. **PC-ORD for Windows (Version 4.17):** Multivariate Analysis of Ecological Data. Gleneden Beach, OR: MJM Software.

Parker, G. R. 1989. **Old-growth forests of the central hardwood region.** Natural Areas Journal 9: 5 – 11.

Ray, L. L. 1974. **Geomorphology and quaternary geology of the glaciated Ohio River Valley – a reconnaissance.** Washington DC: United States Department of the Interior, Geological Survey Professional Paper 826.

Schmelz, D. V. and A. A. Lindsey. 1970. **Relationships among the forest types of Indiana**. Ecology 51: 620 – 629.

Segelken, J. G. 1929. **The plant ecology of the Hazelwood Botanical Preserve.** Columbus, OH: Ohio Biological Survey Bulletin 21.

Swanson, A. M.; J. l. Vankat. 2000**. Woody vegetation and vascular flora of an old-growth mixed mesophytic forest in southwestern Ohio.** Castanea 65: 36 – 55.

Vankat, J. L.; Blackwell, W. W.; Hopkins, W. E. 1975. **The dynamics of Hueston Woods and a review of the question of the successional status of the southern beech-maple forest**. Castanea 40: 290 – 308.

Wade, R. 1959. **The urban frontier.** Cambridge, MA: Harvard University Press.