# Size Structure and Composition of Trees in Oakwood, Ohio: Historical and Environmental Determinants[1]

BETH CANFIELD[2] AND JAMES R. RUNKLE[3], Department of Biological Sciences, Wright State University, Dayton OH 45435

**ABSTRACT. Our goal was to determine whether broad patterns could be identified in the size structure and composition of woody plants in Oakwood, OH, and to determine the influence of both natural and socio-cultural environments. We examined variation in woody species composition for 36 combinations of tree size, position within housing lots, and zones within the city. Parameters considered were development history, topography, a city tree-planting program, species characteristics, and location (front yards, tree lawns, boulevards, wild areas, and parks). Distributional patterns in species composition were examined using ordination (detrended correspondence analysis).**

**Silver maple is the most abundant species in newer sections of Oakwood and is important everywhere. It has a classic, intolerant-species size distribution, with many large individuals from initial city plantings and few replacement trees. Silver maple is being replaced by longer-lived and slower-growing residential or street trees such as sugar maple. Oaks are being planted in some zones, but most large oaks are found in parks. Histories and development times explain most variations between zones. The Johnny Appleseed program, a city-sponsored tree planting program that offers a few carefully selected species per year, was very important in determining the species composition of small trees. Tree composition of this community is both complex and dynamic, responding to its natural and socio-cultural environments.**

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## INTRODUCTION

People have been planting and maintaining trees in urban areas for centuries (de la Chevallerie 1986; Phillips 1993; Schoeneman and Ries 1994; Konijnendijk 1997). Urban trees improve the air quality, property values, appearance, economic attractiveness, and general livability of communities (Phillips 1993; Schoeneman and Ries 1994; MacDonald 1996; Konijnendijk 1999). The care of urban trees traditionally has been done by arborists, whose specialized knowledge includes techniques for pruning, treating disease, and otherwise dealing with the problems of individual trees (Elias and Irwin 1976; Ball 1997; Dunster 1998). A newer approach, becoming important in the 1970s and accelerating since, has been to consider urban trees as part of an ecosystem, interacting with each other, wildlife, people, and fluxes of energy and chemicals (Whitney and Adams 1980; Whitney 1994; Ball 1997; Moll 1997; Konijnendijk 1997, 1999; Schoeneman and Ries 1994). A key to management of the urban forest ecosystem is to understand forest structure (the number, location, size, and condition of the trees) and its relationship to forest functions (Nowak 1994d).

One challenge in studies of the urban forest is to determine how its composition varies under different conditions and what factors determine that variation. The vagaries of individual owner preferences account for much of the variation in tree composition but certain broad patterns are recognizable. For example, Whitney and Adams (1980) found tree species composition in Akron, OH, to be strongly correlated to the income and occupation of the homeowners. Near Chicago, land use, amount of education given to the public about tree planting and maintenance, and management practices influence patterns of current vegetation (Nowak 1994a). Relatively few such studies exist, however, so it is hard to generalize their results to other communities.

The goals of the present study are to understand the components determining tree species composition in Oakwood, a small, compact, residential community near Dayton, OH. Components to be examined include tree size, zone, and habitat. Five physical zones defined geographically vary in topography and human history. Habitats consist of front yards, tree lawns bordering streets, boulevards, city parks, and relatively unmanaged natural areas.

This study addresses three sets of questions. 1) Using stem size distribution as an indicator, how is the species composition changing? Which species are found mostly as large stems (implying that their future importance will decrease)? Which are found well represented among both small and large stems (implying that they will remain constant in importance)? Which are found mostly as small stems (implying either that they will not become large or that they will increase in importance)? 2) For large and small stems, separately, how is species composition influenced by habitat (local environment) and zone (topographic and broader historical features)? 3) Are trends in Oakwood similar to trends elsewhere in the Midwest?

## MATERIALS AND METHODS

### Study Area: Oakwood, Ohio

Oakwood's area was 769 ha and its population was 8957 in 1990 (City of Oakwood 1995). It was incorporated 15 July 1907, and is primarily a residential community,

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[2]Current address: School of Public Health, The Ohio State University, M-120 Starling-Loving Hall, 320 W. 10th Avenue, Columbus, OH 43210

[3]Corresponding Author

with 3149 single-family dwellings, 212 multiple-family dwellings, and 209 business units. It has 88 km of pavement, 74 km of sidewalks, and 14 signaled intersections (City of Oakwood 1995).

Oakwood has had a long history of tree planting, beginning in the 1890s before incorporation (Ronald and Ronald 1983). The city has won several awards recognizing its efforts to preserve its trees and green areas. In 1982 Oakwood received a governor's Arbor Day Award; Oakwood has also been recognized since 1982 by the National Arbor Day Foundation. Oakwood is a Tree City USA (City of Oakwood 1995).Committees established to protect the community's natural beauty include the Oakwood Environmental Committee, Friends of Smith Gardens, and the Oakwood High School Ecology Club, which together volunteered 1258 hours in 1995 (Collins 1995). Oakwood also employs a full-time horticulturist.

We hypothesized that the Johnny Appleseed program, in which the city of Oakwood subsidizes the cost of tree planting by homeowners, would be important in determining the types and locations of street trees. In this program about five species are selected each year by the city horticulturalist, with citizen input, and offered to the residents. Altogether, 1529 trees were planted through this on-going program from 1976 to 1995, with 1337 stems still alive (Collins 1995). Approximately 17% of the trees were planted in yards; the rest were street trees (as defined later). Trees usually were about 5 cm dbh (diameter at breast height = 137 cm) when planted. Many species have been offered through this program, with sugar maple and Callery pear the most often planted (Table 1; scientific names are given in Appendix 1).

TABLE 1

*Species composition of Johnny Appleseed trees.*

| Species | Number |
|---|---|
| Sugar maple | 269 |
| Callery pear | 247 |
| Little leaf linden | 181 |
| Northern red oak | 167 |
| Shumard oak | 102 |
| Tulip tree | 89 |
| Sweetgum | 68 |
| White ash | 61 |
| Norway maple | 56 |
| Red maple | 36 |
| Ginkgo | 30 |
| Green ash | 14 |
| Japanese Zelkova | 11 |
| Crabapple | 4 |
| Thornless honeylocust | 2 |
| Total | 1337 |

Original surveyors' notes from 1802, obtained from the Ohio State Auditor's Office in Columbus, were transcribed by J. A. Forrester (personal communication). All descriptions of survey lines (totaling 7 miles or 11 km) through Oakwood refer to the vegetation as oak, hickory, and dogwood. Spicebush was listed for the two lines that traversed the slopes on the north end of town. A wet area was mentioned just southeast of Oakwood on the flat uplands. Sugar maple, ash, and elm were found near that wet area.

We divided Oakwood into five zones, corresponding to differences in topography and history (Table 2). The zones differed in time of initial development, in lot size, in presence or absence of sidewalks and boulevards, and in topography.

TABLE 2

*Descriptions of zones.*

| | Parameter | | | | | |
|---|---|---|---|---|---|---|
| Zone* | Avg lot size | Sidewalks | Blvds | Topography | Developed | Old Trees** |
| 1 | 12 x 38 m | Present | Some | Flat | 1920s-30s | None |
| 2 | 12-21 x 38 m | Present | Many | Flat | 1920s | None |
| 3 | >21 x 38 m | Present | None | Mixed | Mostly 1900s | Some |
| 4 | Variable to large | Few | None | Hilly | Mostly 1900s | Some |
| 5 | 15 x 40-42 m | Present | None | Mixed | 1920s-30s | Some |

*Zones were bordered as follows: for zone 1, East Drive, Far Hills Avenue, Telford Avenue, and Shroyer Road; for zone 2, Telford Avenue, Far Hills Avenue, Patterson Road, Acorn Drive, and Shroyer Road; for zone 3, Patterson Road, Far Hills Avenue, Irving Avenue, Shafor Boulevard, and Acorn Drive; for zone 4, Schantz Avenue, Far Hills Avenue, Park Road, Deep Hollow Road, and west city limits; and for zone 5, Park Road, Far Hills Avenue, Deep Hollow Road, and south city limits.
**Trees originating before development of the city

## Data Collection and Analysis

To answer the research questions, we used data from a city street and park tree survey conducted by ACRT (an acronym for Appraisal Consulting Research Training), a large and well-known professional tree survey company (Phillips 1993). We collected additional data on trees from about 150 front yards.

The ACRT survey was done from February to June 1995 for woody stems over 180 cm tall. We will refer to all such stems as trees because only species with clearly identifiable main stems were sampled. We used two variables from this study: location and diameter at breast height (dbh). Location included zone (as described above) and habitat (street or park). "Street" trees were located on street right-of-ways, which usually ended at the back edge of the sidewalk or, if no sidewalk was present, a specified distance from the middle of the street. "Park" trees were found in public areas. All street trees were identified. Only park trees that represented hazards, were distinctive, or were in high traffic areas were included in the ACRT study.

The ACRT data were used to identify two additional habitats. Boulevard trees were identified along two thoroughfares (Far Hills Avenue and Shafor Boulevard). Here trees were planted in median strips in the center of the roads. They were not removed from the set of street trees because they represented a small fraction of the total and because the data storage system was not easy to manipulate. Woods trees were defined as trees found in the Elizabeth Gardens and Houk Stream natural areas.

We expanded the data set by sampling yard trees from about 6 blocks per zone, picked subjectively. Yard trees were found from the sidewalk or, if no sidewalks were present, from the street to near the edge of the house. Some of these trees also may be included in the street tree data set. Eastern hemlock and juniper were not sampled if they occurred next to a house, in respect for private property. Problems with species identifications arose: cherries were combined with *Prunus* spp. and dogwoods were combined with *Cornus* spp. Most magnolias were identified only to genus ("*Magnolia*, other").

We used percent of total number of stems for a given category to indicate species importance. Altogether we had 36 data sets. The data was separated into large (dbh >30 cm) and small (dbh ≤30 cm) stems data sets. For each size class we recognized 18 data sets, as follows: 3 habitats (street, park, yard) by 5 zones plus boulevard, Elizabeth Gardens, and Houk Stream.

Patterns in species composition were examined by detrended correspondence analysis using the ordination procedure DECORANA (Hill 1979; Peet and others 1988). This procedure separates data sets by overall similarity of the vegetation. Data sets with similar species at similar relative abundances will be close together. Combining species, such as the cherries and dogwoods, makes these comparisons less precise than if each species had been recognized. However, relatively few species were affected and those species had relatively low abundances, so combining species should not significantly affect the pattern. This technique simultaneously orders species and sites. Species and sites with similar ordination values are usually related: the species are important in those sites; the sites contain those species. Positions of some abundant species are graphed.

## RESULTS

The ACRT survey identified 6447 street trees and 648 park trees representing over 90 taxa (a taxon is usually a species but occasionally is a cultivar or a group of related species).

The ordination of all 36 data sets showed clearly that the composition of large and small trees differed (Fig. 1). No overlap in composition between the two size classes occurred except that large stems in boulevards were more similar to small stem groups than to other large stem groups. Species responsible for this result will be discussed later.

The size distributions of the main species followed three patterns (Table 3, Fig. 2). Some species were found more often as small stems. These species either remain

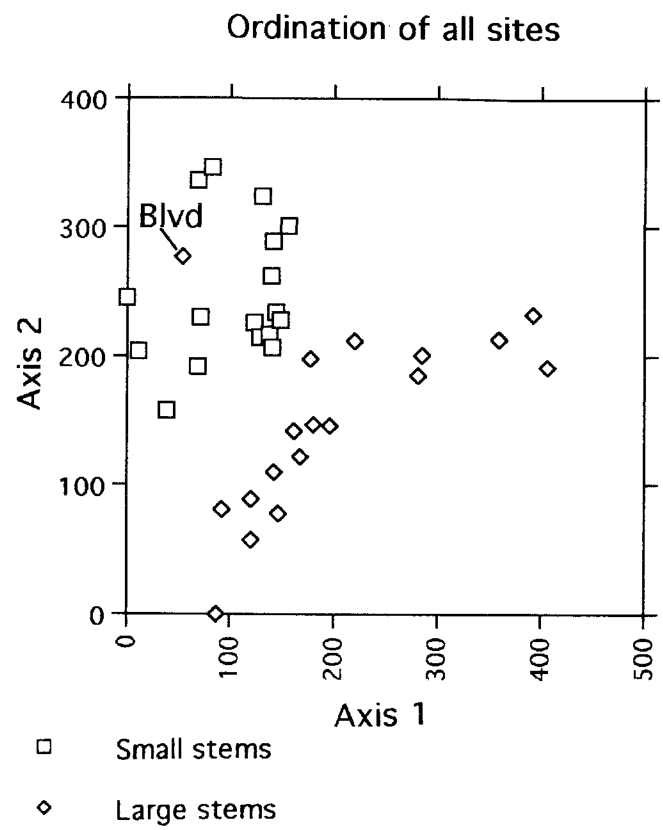


FIGURE 1. Ordination of all sites. Axes 1 and 2 are generated by detrended correspondence analysis.

TABLE 3

*Percent of small and large stems overall.*

| Species | % Small | % Large |
|---|---|---|
| Crabapple | 10 | * |
| Little Leaf Linden | 5 | * |
| Callery Pear | 5 | * |
| Redbud | 4 | * |
| Dogwood | 4 | * |
| Black Cherry | 4 | * |
| Scotch Pine | 4 | * |
| Sugar Maple | 7 | 5 |
| Green Ash | 3 | 4 |
| Norway Maple | 3 | 6 |
| Silver Maple | 3 | 20 |
| Black Locust | * | 8 |
| Hackberry | * | 5 |
| Norway Spruce | * | 4 |
| Black Walnut | * | 4 |
| Siberian Elm | * | 3 |
| Tulip Tree | * | 3 |

*PCN (percent of total for size class) <3

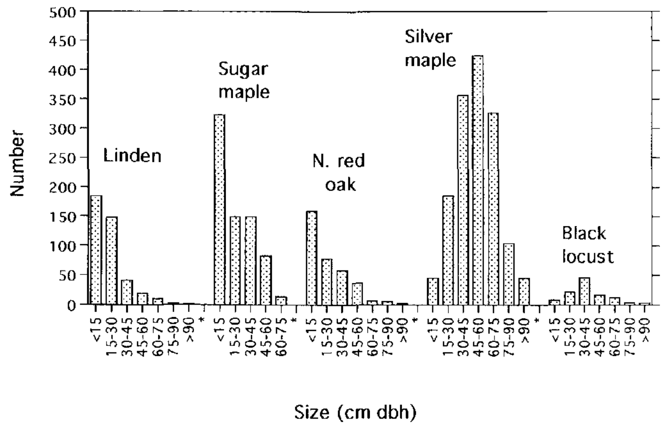


FIGURE 2. Size class distribution of five important species. Axes are total number of individuals in the sample and size (cm dbh). The asterisks on the abscissa separate species.

small (<30 cm dbh) throughout their life span (crabapple, Callery pear, redbud, dogwood) or were planted in large numbers too recently to have reached a greater size (Scotch pine, little leaf linden). Some species were well represented among both small and large stems: sugar maple, green ash, Norway maple, and northern red oak (2.5% of large stems, 2.7% of small stems). These species should continue to maintain their relative importance in the community. Some species were more abundant as large stems than as small stems: silver maple, black locust, hackberry. These species are likely to decrease in relative importance in the future.

The ordination of large stems produced a complex pattern (Fig. 3). The first axis formed a gradient from the boulevard to the newest zones (1 and 2) to the most natural areas. The second axis separated the street trees and some yards (zones 1, 4) and parks (zones 1,5) from the rest of the parks and yards.

Several species were important in generating these patterns (Table 4, Fig. 3). The boulevard was distinctive in having large individuals of usually small species (crabapple, Callery pear) and many conifers. The woods were distinctive in the high abundance of tulip tree, hackberry, and oaks. Parks contained many silver maples and black locusts (zones 1,5) or hackberries (zones 2,3). Street trees were especially heavily influenced by silver maple (40% of all trees) and sugar maple. Yard trees were dominated by silver maple (12%), black locust and Norway maple. Zones also varied. Zone 1, the newest, most uniform zone, was dominated by silver maple (58%) with Norway maple and sweetgum also important. Zone 2 had less silver maple (18%) and Norway maple (11%) but more hackberry and such boulevard species as Norway spruce. Zone 3 was similar to zone 2 though with less silver maple (11%) and Norway maple and more Siberian elm and sugar maple. Zone 4 had the lowest relative abundance of silver maple (9%) and relatively high amounts of black locust, black walnut, sugar maple and American elm. Zone 5, with its mix of small and large lots, contained relatively high numbers of both silver maple (19%) and black locust (19%).

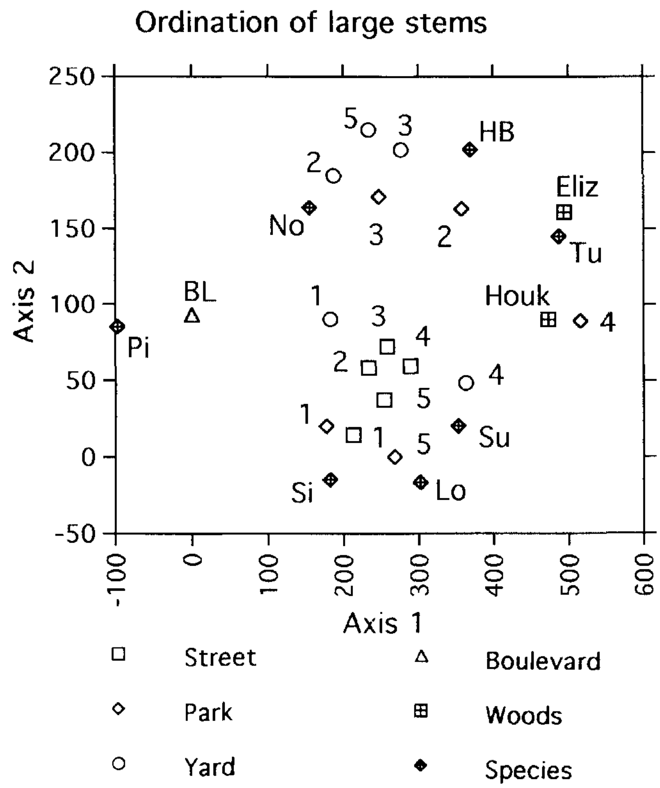


FIGURE 3. Ordination of large stems. Numbers refer to zones. Other site abbreviations are BL = boulevard samples, ELIZ = Elizabeth gardens, HOUK = Houk stream. Species abbreviations are Pi = Scotch pine, No = Norway maple, HB = hackberry, Tu = tulip tree, Su = sugar maple, Lo = black locust, and Si = silver maple. Axes 1 and 2 are generated by detrended correspondence analysis.

The ordination of small stems separated both zones and habitats (Fig. 4). The first axis separated yard trees from other habitats. The second axis expressed differences in the yard trees among zones and clustered street trees from all zones with park trees from zones 1 and 3. The boulevard was distinctive in the high abundance of crabapple and little leaf linden (Table 5, Fig. 4). The woods had high values of native species such as sugar maple, American hornbeam, and black cherry. Park trees contained fairly high abundances of crabapple (15%) and conifers. Small street trees were dominated by sugar maple, Callery pear, Norway maple and others. Yard trees were dominated by ornamental flowering shrubs, such as dogwood, redbud, and magnolia. Zones also differed. Only zone 1 had much silver maple (11%). Zone 2 was diverse with no species over 6% of the total. Zone 3 also was diverse with a maximum relative abundance of 8% for Norway maple. Zone 4 had high values for sugar maple and crabapple. Zone 5 had high values for white ash, dogwood, and Scotch pine.

# DISCUSSION

## Effects of the Johnny Appleseed Program

A major influence on the species composition and size distribution of Oakwood's trees has been the Johnny Appleseed program (Table 1). This program accounts for the high numbers of some species in the smaller size class, including sugar maple, Callery pear, little leaf linden, and northern red oak. Some important

TABLE 4

*Percent of large stems by habitat and zone.*

| | Habitat | | | | | Zone | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | Blvd | Woods | Park | Street | Yard | 1 | 2 | 3 | 4 | 5 |
| Crabapple | 21 | * | * | * | * | * | * | * | * | * |
| Scotch Pine | 21 | * | * | * | * | * | * | * | * | * |
| Red Pine | 7 | * | * | * | * | * | * | * | * | * |
| Callery Pear | 4 | * | * | * | * | * | * | * | * | * |
| Little Leaf Linden | 4 | * | * | * | * | * | * | * | * | * |
| Austrian Pine | 12 | * | 4 | * | * | * | * | 4 | * | * |
| Norway Spruce | 18 | * | * | * | 7 | * | 7 | 5 | * | 5 |
| Silver Maple | 11 | * | 17 | 40 | 12 | 58 | 18 | 11 | 9 | 19 |
| Black Locust | * | * | 12 | 5 | 12 | 4 | 6 | * | 16 | 19 |
| Norway Maple | * | * | 4 | 4 | 12 | 16 | 11 | 5 | * | * |
| Siberian Elm | * | * | 3 | 3 | 6 | * | 6 | 10 | * | 3 |
| Black Walnut | * | 4 | 5 | * | 5 | * | 4 | * | 9 | 5 |
| Tulip Tree | * | 13 | 4 | * | * | * | 5 | * | 3 | * |
| Hackberry | * | 10 | 8 | * | * | * | 11 | 4 | * | 5 |
| American Elm | * | * | 3 | * | * | * | 4 | * | 7 | * |
| Sweetgum | * | * | * | * | 6 | 9 | * | * | * | * |
| Thornless Honeylocust | * | * | * | * | 4 | * | 5 | 8 | * | * |
| Magnolia | * | * | * | * | 4 | 4 | * | * | * | * |
| Green Ash | * | 3 | * | 7 | 4 | * | * | 7 | * | 4 |
| Northern Red Oak | * | 4 | * | 4 | * | * | 5 | 4 | * | * |
| Sugar Maple | * | 6 | * | 9 | * | 3 | * | 6 | 9 | * |
| White Ash | * | * | * | 3 | * | * | * | * | * | 5 |
| Chestnut Oak | * | 13 | * | * | * | * | * | * | * | * |
| White Oak | * | 11 | * | * | * | * | * | * | * | * |
| American Sycamore | * | 5 | * | * | * | * | * | * | 6 | * |
| Eastern Cottonwood | * | 4 | * | * | * | * | * | * | 4 | * |
| Ginkgo | * | * | * | * | * | * | * | 5 | * | * |
| London Planetree | * | * | * | * | * | * | * | 3 | * | * |
| Black Spruce | * | * | * | * | * | * | * | * | * | 5 |

* PCN (percent of total for habitat or zone) <3

small species such as crabapple, dogwood, and redbud do not owe their high numbers to the program. Still, the results indicate that a high profile, extended activity, like the Johnny Appleseed program, can have a great influence on the species composition and structure of the urban forest.

## Influence of Habitat

Most cities, like Oakwood, have tree lawns, city parks, boulevards, houses with front yards, and natural (undeveloped, wooded) areas. We found these habitats to differ in tree species composition due to interactions between their environments and human activities.

Street trees (a term often used for trees growing in the tree lawn) form the most visible and abundant class. On the one hand, street trees suffer environmental problems such as salt, dog urine, fertilizer runoff, and proximity to traffic-related pollution (Elias and Irwin 1976; Schroeder and Cannon 1982; de la Chevallerie 1986). On the other hand, their individual and diverse natures are both aesthetically pleasing and functionally useful (as sound barriers and shade providers) (Marshall 1971; Rogers 1981; Schroeder and Cannon 1982). They absorb pollutants (Carney 1975; Nowak 1994b), sequester carbon and save energy (Nowak 1994c; McPherson 1994a; ACRT 1995), and add to the market-values of homes (Anderson and Cordell 1985). Their associated benefits exceed the costs of their planting (McPherson 1994b). A proper scale is important in selecting those trees (Hill 1968): crowns should not be too large for the given space (Elias and Irwin 1976). A frequent goal of planting is to produce a diverse street tree community to

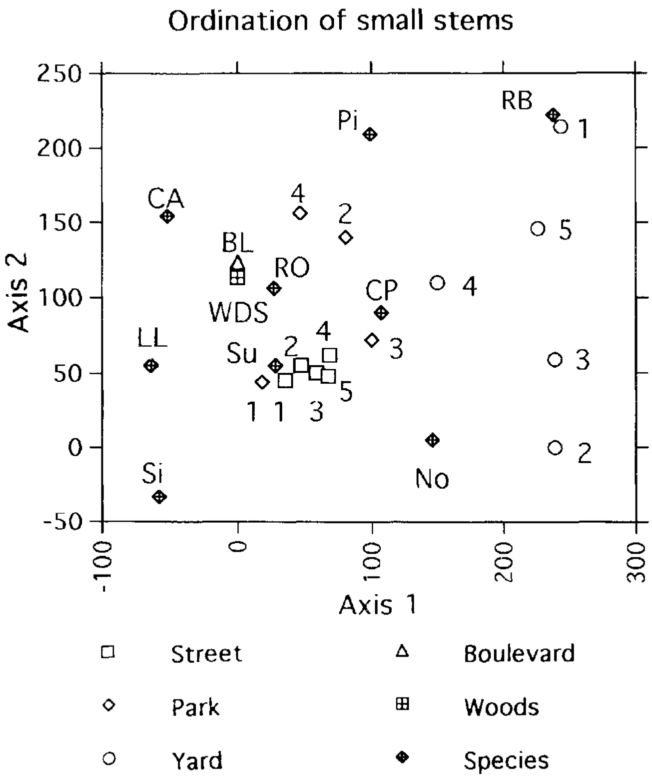


FIGURE 4. Ordination of small stems. Numbers refer to zones. Other site abbreviations are BL = boulevard samples, WDS = woods. Species abbreviations are Si = silver maple, LL = little leaf linden, CA = crabapple, Pi = Scotch pine, RB = redbud, No = Norway maple, CP = Callery pear, RO = northern red oak, and Su = sugar maple. Axes 1 and 2 are generated by detrended correspondence analysis.

avoid catastrophic loss of a single dominant species (Little 1980). Phillips (1993) recommended that no single family make up >10% of trees and no single species make up >5%, based on standards set by the Society of Arborists.

In Oakwood, the application of these principles has varied over time. Silver maple was widely planted following housing development as a hardy and fast growing tree and still dominates the larger size classes of street trees at levels much higher than recommended by Phillips (1993). Widely planting a fast-growing species may have been driven by economics. Street trees add greatly to property value. Street and park trees in Oakwood were worth an estimated $8.2 million in 1995 (ACRT 1995). Further, large trees are worth proportionally more than small trees. ACRT (1995) estimates that trees are worth $4/sq cm basal area. Thus, the pressure to plant fast growing trees is strong. Once the initial set of trees establishes a wooded presence, replacement trees can be selected to meet other criteria. The Johnny Appleseed program, as mentioned above, has provided one means to diversify street trees. The large number of small street tree species (Table 5) is a sign of the success of this program, although maples are still overly represented. Many trees dominating the small size class are slow growing or short statured, fitting well with the space available, both in the ground and above the streets.

Yard trees have different environments and selective pressures. They are less exposed to street-related pollution and stresses than street trees. They are even less likely to consist of large species that may harm the house. They are less likely to have messy fruits that require cleaning, such as crabapple, sweetgum, and sycamore. Their composition also has been influenced by the Johnny Appleseed program, although to a lesser extent than street trees. Flowering shrubs (dogwood, redbud, magnolia) are relatively common. Some exceptions to those trends occur for houses with very large yards that have room for such species as black locust and black walnut.

Boulevard trees are more strongly under the influence of the city horticulturalist. This habitat has many species with striking flowering displays (crabapple, Callery pear); the city has the resources to clean up the fruits. This habitat also has the space available for large conifers, which provide a distinctive look and block noise and views across streets.

Park trees have some unique problems such as vandalism and trampling (Loeb 1987) but often are removed from street pollution. Some park trees are purposefully planted by the horticulturalist; others establish and grow without help. Thus, they include a mix of planted species such as silver maple, Norway maple, crabapple, and conifers and naturally established species such as black locust and hackberry.

The wooded areas include some areas that had trees when Oakwood was developed. The large stems include some species rare elsewhere but fitting the Oak-Maple forest type present in Oakwood before Euroamerican settlement (Gordon 1969): chestnut oak, white oak, sugar maple and tuliptree. Other species are most strongly associated with the wooded areas because they are found near streams, which are not found elsewhere in town: American sycamore, eastern cottonwood, and American hornbeam. Some invasion of the understory by introduced species has been occurring, such as by crabapple, little leaf linden, and Scotch pine. The scarcity of small oaks despite the importance of large ones is consistent with general trends occurring throughout the Midwest (Whitney and Somerlot 1985, Hobbs 1988). Rudnicky and McDowell (1989) also found reproduction by cherry and maple but not oak in a wooded remnant within New York City sampled in 1937 and 1985.

## Influence of Zone

Tree composition varies with broader patterns of topography and settlement history, even for a small community like Oakwood, which went from scattered houses to almost full development within 30 years. The pattern of building in Oakwood went from the lower, flat areas nearer the city of Dayton to the slopes leading away from Dayton and then to the flat upland area. The flood of 1913 in the central city and increasing population both led to this movement upslope, with the greatest population increase occurring in the 1920s (Ronald and Ronald 1983).

Zones 3 and 4 were the first developed, starting about 1900, though with somewhat different patterns. Zone 4 was mostly hilly with some extant trees. It was developed as large estates taking advantage of natural

TABLE 5

*Percent of small stems by habitat and zone.*

| Species | Habitat | | | | | Zone | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Blvd | Woods | Park | Street | Yard | 1 | 2 | 3 | 4 | 5 |
| Crabapple | 41 | 15 | 15 | 6 | * | 8 | 4 | 8 | 12 | 3 |
| Little Leaf Linden | 17 | 10 | 3 | 8 | * | 8 | 4 | 3 | * | * |
| Scotch Pine | 7 | 5 | 6 | * | * | * | 5 | * | * | 8 |
| Hawthorn | 7 | * | 3 | * | * | 4 | 4 | * | * | * |
| Green Ash | 6 | 5 | * | 6 | * | * | 3 | * | * | * |
| Sugar Maple | * | 10 | 3 | 13 | 5 | 5 | 6 | 6 | 14 | * |
| American Hornbeam | * | 25 | * | * | * | * | * | * | * | * |
| Black Cherry | * | 25 | * | * | * | * | 5 | * | * | * |
| White Ash | * | * | 7 | * | * | * | * | * | * | 9 |
| Austrian Pine | * | * | 7 | * | * | 5 | 4 | * | * | * |
| Callery Pear | * | * | 5 | 9 | 4 | 10 | 4 | 7 | 5 | 3 |
| Silver Maple | * | * | 5 | 6 | * | 11 | * | * | * | * |
| Hackberry | * | * | 4 | * | * | * | * | 6 | * | * |
| Black Locust | * | * | 4 | * | * | * | * | * | * | 5 |
| Northern Red Oak | * | * | * | 7 | * | * | 4 | * | 4 | 4 |
| Sweetgum | * | * | * | 6 | * | * | * | * | * | * |
| Tulip Tree | * | * | * | 4 | * | * | 4 | * | * | * |
| Red Maple | * | * | * | 3 | * | * | 3 | * | * | * |
| Norway Maple | * | * | * | 8 | 4 | * | * | 8 | * | 5 |
| Dogwood | * | * | * | * | 11 | 5 | 3 | 3 | * | 8 |
| Redbud | * | * | * | * | 10 | 4 | * | 5 | 7 | 6 |
| Magnolia | * | * | * | * | 9 | 3 | 4 | 5 | * | 3 |
| Colorado Blue Spruce | * | * | * | * | 8 | 6 | * | * | * | 5 |
| Thornless Honeylocust | * | * | * | * | 4 | * | 4 | 4 | * | * |
| Eastern Hemlock | * | * | * | * | 4 | * | * | * | * | * |
| Norway Spruce | * | * | * | * | 3 | * | * | * | * | * |
| Cherry, Other | * | * | * | * | 4 | * | * | * | * | * |
| American plum | * | * | * | * | * | * | * | 3 | * | * |
| Black walnut | * | * | * | * | * | * | * | * | 4 | * |

* PCN (percent of total for habitat or zone) <3

streams and hillsides. As such it has high concentrations of streamside species, such as cottonwood and sycamore, and of species regenerating naturally, such as sugar maple, black locust, and black walnut. It has very few silver maples. Zone 3 includes one section on the flat, lower area that has more sidewalks and somewhat smaller houses and lots. Zone 3 also includes a sloped area leading upward from Dayton. It has low levels of silver maple but large amounts of Siberian elm, ginkgo, honey locust and green ash.

Zone 5 is a mix of hilly areas with large estates as found in Zone 4 and plats with smaller houses and lots as found in Zones 1 and 2. The high proportion of black locust is due to the large yards in which some natural regeneration is occurring. The large amount of silver maple and black spruce are found on the smaller lots. The low levels of crabapple and Callery pear may come from the lack of boulevards and scarcity of areas under the charge of the city horticulturalist.

Zones 2 and 1 are on the level upland part of Oakwood. Zone 2 was developed earlier and contains most of the city's planted boulevards. Zone 1 was developed most recently. Both sections are characterized by smaller houses and lots than the other sections and by the highest proportions of sidewalks. The boulevards help make Zone 2 the most diverse section in Oakwood. Zone 1 was developed rapidly and shows a homogeneous preference by the plat's developers for silver maple. Norway maple and sweetgum also are well represented in this section. The goal in planting trees here apparently was the development of a crown cover as soon as possible. That first generation of rapidly growing, shade intolerant species (especially silver maple) is beginning to die now, releasing space for slower growing, longer lived species such as those emphasized in the Johnny Appleseed program. A general increase in tree diversity over time is occurring. The senescing and deteriorating trees are important for wildlife such as cavity-nesting birds and mammals (Dunster 1998).

## Comparison with Other Studies of Midwest Urban Forests

The trees of Newark, in central Ohio, were studied using techniques similar to those of our study except that only street trees were sampled (ACRT 1993). The four most common species (percent of total number sampled) in Newark were silver maple (22%), sugar maple (22), red maple (6), and Norway maple (6) versus, for Oakwood, silver maple (23), sugar maple (11), Norway maple (6), and little leaf linden (6). At the genus level Newark had the highest representation of maple (57%), spruce (5), pine (5), and dogwood (4) whereas Oakwood had maple (44), ash (8), linden (7), oak (6), and flowering pear (5). The size distributions showed similar percents of stems <15 cm dbh (26% Newark, 28% Oakwood), more intermediate stems (15-60 cm dbh) in Oakwood (60% versus 48% for Newark) and more large stems (>60 cm dbh) in Newark (25% versus 11% for Oakwood). Differences between the cities may be associated with the Johnny Appleseed program that led to an increased number of common species (all the genera listed above for Oakwood have been represented by Johnny Appleseed trees) and to a large number of intermediate-sized stems (the biggest difference between the cities was for stems 14-30 cm dbh, which were much better represented in Oakwood).

Whitney and Adams (1980) described patterns in woody composition of street trees in the Akron, OH, area, based on a more heterogeneous sample than ours. They also found vegetation to vary with age of area, representing changing patterns of taste and fashion, as well as with various socio-economic variables. Oakwood vegetation is most similar to Akron's maple and mixed suburban community types. The most important species in their maple community type were Norway maple, silver maple, sugar maple, black locust, eastern white cedar, Norway spruce, white mulberry, and black oak. The mixed suburban community contains more species, with fewer dominants. Some important species were flowering dogwood, silver maple, Colorado blue spruce, eastern white cedar, and eastern hemlock. All these species were found in Oakwood, although many were less common than in Akron. The importance of silver maple was common to both sites, however. Their analysis of past horticultural guidebooks (1844-1968) concluded that silver maple was a recommended species in the earlier catalogs but since 1899 has been "recommended with reservation." More recently, Phillips (1993) considered silver maple to be "undesirable," due to its weak wood and aggressive, shallow roots.

Dawson and Khawaja (1985) examined street tree samples in Urbana, IL, from 1932 and 1982. The 1932 sample was dominated by, in decreasing order, American elm, red elm, eastern cottonwood, silver maple and sugar maple. The 1982 list, in decreasing order, was silver maple, sugar maple, sycamore, hackberry, and Siberian elm. One major factor underlying this change was the spread of Dutch elm disease, to which American and red elms are very susceptible but Siberian elm is not. Looking at individual trees, silver maple had the highest survival rates and the largest growth rates. Despite this successful growth, the town has banned new plantings of silver maple because it easily loses branches to wind and because of its very success; one goal of recent actions has been to increase the diversity of street trees.

A large study of the Chicago, IL, area found the most important tree taxa to be Norway maple and honey locust in the city, silver maple and ash in the suburbs, and ash and Norway maple in the rural areas (Nowak 1994a). Large trees (>46 cm dbh) were dominated overall by silver maple, white oak and American elm. Small trees (<7 cm dbh) were dominated by buckthorn, an introduced, small species. These results also overlap substantially with those of our study, except that buckthorn is not important in our area.

Dorney and others (1984) studied the street trees of Shorewood, WI, which is similar in area (406 ha) and population (14000 in 1980) to Oakwood. The populations of both cities grew most rapidly during the 1920s. Shorewood has a more heterogeneous population with more rental housing. Dorney and others (1984) found that single family lots had more trees and a higher species diversity than multiple dwellings. Overall American elm was the most abundant species, consisting of 72% of "parkway" trees (equivalent to our "street" trees) although only 12% of front yard trees. Elm mortality was high due to the Dutch elm disease, but treated individuals plus plantings of disease-resistant saplings maintained its high dominance. Other important front yard species groups were sugar/Norway maple (both trees and saplings) and silver/red maple (trees only). Ash also is well represented as sapling and large stems, in both parkways and yards.

Just as the distribution of trees in Oakwood represents both cultural history and environment, so do the urban forests described above. All sites were dominated by species able to grow rapidly, taking advantage of the abundant sunlight and lack of competition of urban sites. These species grow naturally in open, moist sites in which abundant water, nutrients, and light favor trees able to grow rapidly. Elms were more abundant in the Illinois and Wisconsin sites although were decreasing in importance due to the effects of the Dutch elm disease. Maples everywhere were important, with silver maple the most important except in Shorewood, WI. Changing fashions and a desire to increase street tree diversity are leading to a decrease in the expected future importance of silver maple in most sites, with increases by sugar maple and other species. Programs like the Johnny Appleseed program are useful mechanisms for increasing tree diversity.

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### Appendix 1

*Scientific names (ACRT 1995).*

| Common name | Scientific name |
|---|---|
| Norway maple | *Acer platanoides* |
| Silver maple | *Acer saccharinum* |
| Sugar maple | *Acer saccharum* |
| Red maple | *Acer rubrum* |
| American hornbeam | *Carpinus caroliniana* |
| Hackberry | *Celtis occidentalis* |
| Redbud | *Cercis canadensis* |
| Dogwood | *Cornus* spp |
| Hawthorn | *Crataegus* spp |
| White ash | *Fraxinus americana* |
| Green ash | *Fraxinus pennsylvanica* |
| Ginkgo | *Ginkgo biloba* |
| (Thornless) honeylocust | *Gleditsia triacanthos* |
| Black walnut | *Juglans nigra* |
| Sweetgum | *Liquidambar styraciflua* |
| Tulip tree | *Liriodendron tulipifera* |
| Magnolia | *Magnolia* spp |
| Crabapple | *Malus* spp |
| White mulberry | *Morus alba* |
| Norway spruce | *Picea abies* |
| Black spruce | *Picea mariana* |
| Colorado blue spruce | *Picea pungens* |
| Austrian pine | *Pinus nigra* |
| Red pine | *Pinus resinosa* |
| Scotch pine | *Pinus sylvestris* |
| London planetree | *Platanus acerifolia* |
| American sycamore | *Platanus occidentalis* |
| Eastern cottonwood | *Populus deltoides* |
| Cherry | *Prunus* spp |
| American plum | *Prunus americana* |
| Black cherry | *Prunus serotina* |
| Callery pear | *Pyrus calleryana* |
| White oak | *Quercus alba* |
| Chestnut oak | *Quercus prinus* |
| Northern red oak | *Quercus rubra* |
| Shumard oak | *Quercus schumardii* |
| Black oak | *Quercus velutina* |
| Buckthorn | *Rhamnus* spp |
| Eastern white cedar | *Thuja occidentalis* |
| Little leaf linden | *Tilia cordata* |
| Eastern hemlock | *Tsuga canadensis* |
| American elm | *Ulmus americana* |
| Siberian elm | *Ulmus pumila* |
| Red elm | *Ulmus rubra* |
| Japanese zelkova | *Zelkova serrata* |