# Effect of Land Use Practices on Composition of Woodlot Vegetation in Greene County, Ohio[1]

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ABSTRACT. **Woody vegetation in 17 woodlots in Greene County, OH was sampled and the owners of the woodlots surveyed and interviewed to reveal relationships between present species composition and land-use histories. Altogether, 4,080 stems in three size-classes were sampled using the point-centered quarter method. Land-use histories and direct observations were used to devise a human activity index (HAI) to rank the woodlots according to the intensity of human use. The HAI values correlated ($P = 0.0072$) with the first DECORANA (detrended correspondence analysis) ordination axis supporting the hypothesis that human land-use practices had an effect on present community structure. Woodlot size, the types of disturbance (e.g., timber harvest, firewood cutting, tree planting, livestock grazing, recreation, and so forth) and time (both duration of the disturbance and subsequent recovery) were key factors influencing the species composition of the present vegetation.**

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## INTRODUCTION

Natural and human disturbances play a major role in influencing plant community structure in many ecosystems (Pickett 1980, Pickett and White 1985). In the American Midwest many forests are changing in species composition and size-class structure faster than concomitant changes in soils, topography, or climate. A common situation is for a forest to have many large oaks in the canopy but little or no oak reproduction, leading to a gradual replacement of oaks by other species (Whitney and Somerlot 1985, McGee 1986, Boerner and Cho 1987, Boerner and Kooser 1991). One explanation for such changes is that often current forests are continuing to recover from past disturbances, which may or may not be related to human activities (Whitney and Somerlot 1985). Although some historical reconstruction of past human activities is possible and fruitful (Whitney and Somerlot 1985), it is impossible to determine the exact influence of people during the early 1800s when large canopy trees of species which currently do not regenerate well got established. The dilemma, therefore, is how to estimate the conditions under which those canopy individuals were established in view of the scant historical record. One approach is to collect as much historical evidence as possible for specific forests. Another approach, the one used here, is to use the diversity of present woodlots in both species composition and history to relate present or recent management practices to present species composition and size-class structure. By determining the conditions under which different species now are reproducing, it is possible to partly reconstruct past conditions under which those species gained dominance.

The primary objective of the present study on small woodlots, therefore, was to identify present patterns of variation in woody vegetation and to determine if part of the variation can be explained by recent management practices. Four major determinants of woodlot vegetation composition are topography, woodlot size, soils, and past human history. Topography was not addressed directly in this study: only upland woodlots were selected. Size and soil type (Garner et al. 1978) were contrasted among woodlots. Past human history is the hardest factor to quantify and to determine. For the present study, an index was constructed to rank different woodlots according to human impacts. A secondary objective of this study was to investigate the usefulness of this derived index to quantify the recent history of human land uses.

## MATERIALS AND METHODS

### Study Area

Research study sites were located in Greene County in southwestern Ohio. This region is generally flat to gently rolling, with some steep slopes found along ravines and creekbeds. Because of the topography and fertile soils, Greene County has been primarily an agricultural region since the arrival of the first white settlers in the early 1800s.

The climate is moderate, with large fluctuations in annual, seasonal, and daily temperatures (Garner et al. 1978). Summers are warm and humid with July temperatures (1936-1965) ranging from 16.6° C to 29.7° C (average daily minimum and maximum). Winters are typically cold (temperatures less than -18° C an average of 4 days per year) and cloudy. Average annual precipitation (1936-1965) is 96.7 cm per year. Greene County is located in the Wisconsin Age glaciated region of Ohio and has many areas of deep, fertile soils. Miamian Series soils formed in medium-textured glacial till were most common for the areas studied, with the Miamian-Eldean-Casco and the Miamian-Russell-Xenia associations most numerous (Garner et al. 1978).

### Site Selection

Particular woodlot sites for this study were selected using the following criteria: 1) a minimum of 1.5 ha (to reduce edge effects), 2) primarily upland locations, and 3) owners willing to supply information on the history of the area and willing to allow on-site data collection.

Consultation with Ohio Department of Natural Resources personnel produced a list of potential woodlots and their owners. Initial contact was made by mail and phone in order to complete woodlot history surveys (Appendix).

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Follow-up interviews were conducted if warranted. Seventeen woodlots fit the above criteria and were chosen for this study.

Topographical maps (USGS 7.5 series, 1968 revised 1975) were used to determine both longitude and latitude as well as the approximate areas of the 17 woodlots. Detailed descriptions of the individual woodlots are given in Ramey-Gassert (1990).

**Sampling Methods**

The 17 woodlots were sampled from mid-April through June 1988. In each of the 17 woodlots, 20 points were sampled using the point-centered quarter method (Cottam and Curtis 1956). Cottam and Curtis (1956) stated that 20 was the minimum number of points necessary to describe a woodlot. At least 10 m in from the edge of the woods, random points were chosen along roughly parallel transects. Occasional problems such as crossing a path or a deep ravine caused slight deviations from randomness. In such cases, the nearest suitable point along the transect was selected.

In order to avoid any overlapping, particularly of large stems, and to allow sufficient distance between points, an average of 30 m was paced off between adjacent points and quarters were laid out for sampling of three size-classes of woody stems. From the center point in each of the four quarters, the nearest small stem (0.5-2 m in height), subcanopy or medium stem (over 2 m tall but not canopy height), and canopy tree were measured for diameter at breast height (dbh) and distance from the center point. Thus, 12 stems were sampled in three size-classes at each of 20 points in all 17 woodlots.

**Data Analyses**

Distance and dbh measurements were used to calculate stand density and basal area (Cottam and Curtis 1956). Importance values were defined in two ways: 1) The average by species of relative density and relative basal area for medium and large stems and relative density alone for small stems was used for statistical analyses using the SAS statistical package (SAS 1982) and for ordinations. 2) Averaging relative frequency (relative number of points in which a species occurred) with relative density and relative basal area for large and medium stems or with relative density alone for small stems was used to summarize results from all woodlots taken together (Table 1).

Ordination of the resulting 50 species X 17 woodlot matrix was conducted using detrended correspondence analysis (DECORANA; Hill 1979a), which arranges both species and samples along axes of gradually changing composition determined by the program itself. Gauch (1982) considered this procedure to be the most successful in applications to community analysis. Later research (e.g., Peet et al. 1988) continues to support the use of that procedure. Two-way indicator species analysis (TWINSPAN; Hill 1979b), which classifies vegetation into hierarchical divisions according to similar species composition, was also used to determine patterns. The importance values used for both analyses were the averages of the importance values of the three size-classes for each species.

A Human Activity Index (HAI) (Table 2), modified from indices developed by Dony and Denholm (1985), Dorney and Leitner (1985), Wathern et al. (1986), and Domon and Bergeron (1987), was used to give numerical values for the impact of past human-related disturbances in the woodlots. Most of the indices from these articles used present species composition to help determine disturbance history; disturbed stands were ones in which many shade intolerant species, presumed to be indicators of disturbance, were present. We wished to derive an index independent of present species composition which could be used to derive the successional status of different species and communities. In the literature reviewed, as well as in this study, conventional data gathering, visual surveying, and historical information were used to evaluate the present condition of the woodlot.

To calculate HAI, numerical values are assigned subjectively in five categories of disturbance: timber harvesting, firewood cutting, livestock grazing, planting trees, and other activities. The latter category includes hunting, refuse dumping, gathering (e.g., berries, morels), and recreational uses such as hiking, horseback riding, and children playing. No extremely disruptive recreational uses, such as frequent off-road vehicles, were noted in the woods surveyed. These five numbers, ranging from 0.0 for no apparent disturbance to 2.0 (in increments of 0.5) for the most severely disturbed sites observed, are summed together to create an HAI value for each woodlot. Setting a value of 2.0 for the most severe disturbance observed instead of the most severe possible is justifiable because our goal was to rank only the woodlots in our study by disturbance, not to generate an absolute standard for disturbance. Because it is not clear which of these categories is most important, all are assigned an equal weight. To add the effects of time since disturbance a second value, HAIb, was created by subtracting from HAI 0.5 if the last timber harvest occurred before 1978 (i.e., >10 yr before the present study) and 0.5 if the last incident of livestock grazing occurred before 1978. As Dony and Denholm (1985), Dorney and Leitner (1985), and Domon and Bergeron (1987) point out, a value such as the HAI is an attempt to bring objectivity and numerical data into an area which is relatively subjective. Wathern et al. (1986) state that an evaluation technique such as an index will be biased and cannot be value-free. However, if used with non-parametric analytical procedures, ranking past woodlot disturbance by HAI can provide a way to relate vegetation to human land use.

Two indices from the literature were calculated using our data in order to compare them to HAI as a useful measure of human disturbance in a stand. Dorney and Leitner (1985) define their woodland index WI as:

$$WI = \sum_{i=1}^{n} (AV)_i R_i$$

where $AV_i$ is the species adaptation value (1-10) reflecting the shade tolerance of species i relative to *Acer saccharum* (Curtis 1959) and $R_i$ is the rank of the ith species, ranking from last (least important) = 1 to first (most important) = n. They found n=3 to be satisfactory. Species ranks were obtained from our list of species importance values (Table 3). Species adaptation values come from the list in Curtis (1959)

TABLE 1

*Overall species importance.*

| Species[5] | Number[1] of Stems L | M | S | Basal Area[2] L | M | Frequency[3] L | M | S | Importance Value[4] | No. of Woodlots Present |
|---|---|---|---|---|---|---|---|---|---|---|
| *Fraxinus americana* | 21 | 11 | 8 | 20 | 11 | 17 | 10 | 8 | 13.4 | 17 |
| *Acer saccharum* | 11 | 18 | 16 | 9 | 14 | 8 | 13 | 11 | 12.6 | 13 |
| *Prunus serotina* | 7 | 13 | 14 | 5 | 9 | 8 | 12 | 13 | 10.1 | 17 |
| *Ulmus rubra* | 8 | 7 | 5 | 6 | 12 | 8 | 7 | 5 | 7.2 | 13 |
| *Celtis occidentalis* | 3 | 9 | 7 | 3 | 10 | 4 | 9 | 8 | 6.8 | 15 |
| *Ulmus americana* | 5 | 5 | 3 | 4 | 8 | 5 | 6 | 4 | 5.0 | 13 |
| *Carya ovata* | 7 | 3 | 3 | 6 | 6 | 7 | 3 | 2 | 4.6 | 11 |
| *Lonicera* spp. | 0 | 5 | 14 | 0 | 0 | 0 | 6 | 12 | 4.6 | 16 |
| *Quercus alba* | 5 | 1 | 1 | 16 | 2 | 6 | 1 | 1 | 4.3 | 13 |
| *Carya cordiformis* | 5 | 3 | 5 | 4 | 3 | 5 | 4 | 6 | 4.2 | 16 |
| *Juglans nigra* | 8 | 1 | 1 | 7 | 2 | 6 | 1 | 1 | 3.3 | 15 |
| *Quercus rubra* | 4 | 1 | 1 | 6 | 2 | 5 | 1 | 1 | 2.4 | 11 |

[1] As percentages of total number of all stems = 1,360 for each-size class. Values given for large, medium, and small stems, in order.
[2] As percentages of total basal area = 141 $m^2$ for large stems and 3.8 $m^2$ for medium stems. Values given for large and medium stems in order.
[3] As percentages of total number species-point combinations for each size-class. Values given for large, medium, and small stems, in order.
[4] Value given is average of preceding 8 values for each species.
[5] List of other species having average importance values less than 2, in order of importance. *Fraxinus quadrangulata, Acer negundo, Robinia pseudo-acadia, Liriodendron tulipifera, Cercis canadensis, Crataegus* spp., *Aesculus glabra, Viburnum* spp., *Gleditsia triacanthos, Cornus florida, Acer nigrum, Carpinus caroliniana, Quercus muhlenbergii, Quercus bicolor, Sassafras albidum, Ailanthus altissima, Ostrya virginiana, Quercus imbricaria, Lindera benzoin, Carya tomentosa, Sambucus canadensis, Cornus* spp., *Platanus occidentalis, Maclura pomifera, Morus rubra, Asimina triloba, Prunus virginiana, Tilia americana, Nyssa sylvatica, Pinus* spp., *Xanthoxylum americanum, Acer rubrum, Juniperus virginiana, Euonymus atropurpureus, Populus deltoides, Salix* spp., *Catalpa speciosa, Diospyros virginiana.*

TABLE 2

*Woodlot disturbances.*[1]

| Woodlot[2] | Timber Harvest | Firewood Cutting | Livestock Grazing | Planting Trees | Other Activity[3] | HAI |
|---|---|---|---|---|---|---|
| 2 | 2.0 (1987) | 1.5 (1987) | 2.0 (1982) | 2.0 (1932) | 1.5 (1987) | 9.0 |
| 7 | 1.0 (1987) | 2.0 (1987) | 2.0 (1985) | 0.5 (1985) | 2.0 (1988) | 7.5 |
| 13 | 0.5 (1976) | 1.5 (1988) | 2.0 (1956) | 0.5 (1976) | 1.0 (1987) | 5.5 |
| 9 | 1.5 (1985) | 1.0 (1987) | 1.5 (1955) | 1.0 (1987) | 2.0 (1987) | 7.0 |
| 6 | 0.0 | 2.0 (1988) | 2.0 (1963) | 2.0 (1980) | 1.0 (1987) | 7.0 |
| 12 | 0.5 (1981) | 2.0 (1986) | 2.0 (1981) | 1.0 (1982) | 2.0 (1987) | 7.5 |
| 3 | 1.5 (1950) | 1.5 (1988) | 1.0 (1950) | 0.5 (1951) | 1.5 (1988) | 6.0 |
| 14 | 0.5 (1955) | 2.0 (1987) | 2.0 (1976) | 1.0 (1983) | 2.0 (1987) | 7.5 |
| 16 | 1.5 (1986) | 1.5 (1987) | 2.0 (1932) | 2.0 (1932) | 1.0 (1988) | 8.0 |
| 11 | 2.0 (1980) | 1.0 (1985) | 1.5 (1960) | 2.0 (1961) | 0.5 (1987) | 7.0 |
| 10 | 0.5 (1987) | 1.5 (1987) | 1.0 (1930) | 1.5 (1987) | 1.0 (1988) | 5.5 |
| 4 | 2.0 (1987) | 1.5 (1987) | 2.0 (1985) | 0.0 | 1.0 (1987) | 6.5 |
| 17 | 0.5 (1963) | 2.0 (1988) | 2.0 (1980) | 0.5 (1985) | 2.0 (1987) | 7.0 |
| 15 | 1.0 (1979) | 2.0 (1987) | 1.0 (1970) | 0.5 (1987) | 1.0 (1988) | 5.5 |
| 5 | 1.5 (1950) | 1.5 (1988) | 1.0 (1948) | 0.0 | 2.0 (1986) | 6.0 |
| 1 | 0.0 | 1.5 (1988) | 0.5 (1953) | 0.0 | 1.5 (1988) | 3.5 |
| 8 | 1.0 (1982) | 1.0 (1987) | 0.0 | 0.0 | 0.5 (1987) | 2.5 |

[1]Values range from 0.0 to 2.0 where 2.0 is the most severe activity, 0.0 is an absence of the activity. Human activity index (HAI) is the sum of these values. Approximate last date for activity is given in parenthesis.
[2]Woodlots listed in order of first DECORANA axis.
[3]Includes: Hunting, refuse dumping, gathering (i.e., berries, morels, grapevines, etc.), recreation (i.e., hiking, horseback riding, children playing, etc.).

TABLE 3

*Values for large, medium, and small size classes of species with an importance value ≥ 10% for at least one size class in at least one woodlot.*

| Species[1] | Stands in order of DECORANA first axis | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | 7 | 13 | 9 | 6 | 12 | 3 | 14 | 16 | 11 | 10 | 4 | 17 | 15 | 5 | 1 | 8 |
| | L M S | L M S | L M S | L M S | L M S | L M S | L M S | L M S | L M S | L M S | L M S | L M S | L M S | L M S | L M S | L M S | L M S |
| *Robinia pseudo-acacia* | 8.9.6 | 5.1.4 | 15.0.0 | | 16.0.0 | 0.0.1 | 2.0.0 | 1.0.0 | 2.0.0 | | | | | | | | |
| *Quercus bicolor* | 2.7.0 | 0.11.8 | | | | | | | | | | | 2.0.4 | | | | |
| *Acer negundo* | 3.18.21 | | 0.3.3 | 1.3.3 | 0.0.3 | | 0.3.5 | | | 0.2.4 | 0.0.4 | | | | | | |
| *Gleditsia triacanthos* | 5.10.5 | 2.0.4 | 2.0.0 | 3.0.0 | 1.0.0 | | 3.0.0 | 1.0.1 | 0.0.1 | | 3.3.4 | | | | 1.0.0 | | |
| *Liriodendron tulipifera* | | 9.4.1 | 16.10.0 | | 6.1.0 | | | | 7.0.1 | 4.0.0 | 3.4.0 | | | | | | |
| *Lindera benzoin* | | 0.0.1 | | | | | 0.4.18 | | | | | | | | | | |
| *Ailanthus altissima* | 0.1.1 | | | 1.1.4 | 1.0.3 | | | 0.0.3 | | 0.1.16 | 0.1.4 | | | | | | |
| *Crataegus* spp. | 0.2.3 | 1.1.0 | | 1.0.1 | 0.2.8 | 0.0.3 | 0.2.3 | 0.3.0 | | 0.2.0 | | 1.20.4 | 0.1.0 | 0.1.0 | 0.1.0 | | |
| *Juglans nigra* | 59.16.13 | 15.0.0 | 0.2.0 | 17.4.0 | 0.0.1 | 2.0.3 | 1.0.0 | 1.0.1 | 8.0.1 | 7.0.0 | 4.0.0 | | 4.0.1 | 4.0.0 | 3.0.0 | 0.1.0 | |
| *Platanus occidentalis* | | | | 12.1.0 | | | | | | | 1.0.0 | | | | | | |
| *Sassafras albidum* | | | 11.0.0 | | 0.1.1 | 0.4.5 | 2.0.0 | | | 3.1.0 | | | | | | | |
| *Ulmus americana* | 0.1.0 | 12.7.11 | 6.23.0 | 9.5.1 | 2.28.19 | 6.16.6 | 8.3.0 | | 5.4.6 | 2.0.0 | 8.0.3 | 5.9.3 | 1.1.0 | | 5.8.5 | | |
| *Celtis occidentalis* | 16.17.10 | 4.13.11 | 1.0.0 | 11.15.10 | 0.3.0 | 3.5.6 | 4.10.9 | | 2.10.11 | 1.1.5 | 0.2.1 | 3.7.8 | 0.22.18 | 7.38.21 | 0.3.3 | 1.4.5 | |
| *Carpinus caroliniana* | | 0.1.0 | 0.1.0 | 1.2.1 | | | 0.1.1 | 0.2.0 | | | 1.19.5 | | 1.1.0 | 0.4.1 | | | |
| *Prunus serotina* | 4.2.5 | 4.1.9 | 28.5.5 | 8.22.18 | 14.14.15 | 9.33.18 | 2.12.24 | 6.29.66 | 0.3.5 | 7.29.6 | 1.7.5 | 3.1.21 | 0.19.18 | 14.3.10 | 0.7.8 | 9.2.6 | 0.1.4 |
| *Lonicera* spp. | 0.4.39 | 0.0.1 | 0.21.88 | 0.2.4 | 0.1.16 | 0.1.8 | | 0.4.9 | 0.5.18 | 0.0.1 | 0.3.9 | 0.3.19 | 0.1.5 | 0.0.4 | 0.2.16 | 0.1.8 | 0.0.1 |
| *Fraxinus americana* | 2.13.6 | 16.0.0 | 19.6.0 | 6.0.0 | 52.41.23 | 38.26.20 | 17.11.13 | 49.3.8 | 47.0.4 | 7.4.3 | 10.4.5 | 30.37.21 | 3.16.14 | 13.1.1 | 17.4.10 | 8.14.4 | 24.4.0 |
| *Carya cordiformis* | | 5.3.9 | 0.0.1 | 4.7.5 | 1.0.1 | 2.1.9 | 17.4.4 | 2.3.3 | 2.4.9 | 1.7.11 | 7.6.5 | 0.0.3 | 0.0.3 | 5.7.8 | 18.9.9 | 3.0.1 | 2.0.1 |
| *Carya ovata* | | 0.1.0 | | | | 12.0.1 | 9.8.0 | 21.40.0 | 1.0.1 | 10.19.36 | | 11.0.3 | 28.13.3 | | 8.5.1 | 2.0.0 | 3.0.0 |
| *Quercus alba* | | 1.2.0 | | | | 13.0.3 | 16.0.0 | 11.0.0 | 6.16.0 | 31.1.4 | | 30.0.1 | 30.0.4 | 4.0.0 | 16.6.0 | 3.0.1 | 2.0.0 |
| *Acer saccharum* | | 17.48.33 | 1.20.3 | 22.25.35 | 0.0.1 | | | | 7.37.34 | 0.7.4 | 25.10.18 | 2.3.10 | 0.0.1 | 19.31.24 | 1.0.0 | 45.58.53 | 30.49.53 |
| *Cercis canadensis* | | | | | | | 0.15.1 | | 0.1.1 | | 0.23.14 | | | 0.1.0 | 0.13.4 | 0.1.0 | |
| *Quercus muehlenbergii* | | | | | 0.0.3 | | | | | | 5.3.14 | | 6.0.1 | | | 1.0.0 | 4.0.0 |
| *Ulmus rubra* | | | 1.5.0 | | 1.5.0 | 14.12.5 | 3.23.13 | 1.9.6 | 7.7.1 | 25.22.3 | | 15.19.3 | 4.20.20 | 32.4.11 | 6.18.19 | 3.1.4 | 5.0.4 |
| *Viburnum* spp. | | 0.1.3 | | | 0.0.1 | 0.1.3 | 0.0.6 | | 0.1.1 | 0.0.1 | 0.2.1 | | 0.2.6 | 1.11.4 | 0.1.11 | | 0.2.1 |
| *Quercus rubra* | | 1.1.0 | | | | | 6.0.0 | 7.3.4 | 5.0.0 | 23.1.3 | 23.1.3 | 0.2.0 | 11.0.0 | 1.1.1 | 6.7.1 | 7.0.0 | 17.7.0 |
| *Fraxinus quadrangulata* | | | | 0.4.1 | 1.0.0 | | | | | | 1.1.3 | 0.1.3 | | 2.1.0 | 13.4.6 | 17.11.15 | 4.0.1 |
| *Aesculus glabra* | | | | | 3.1.6 | | | | | | 4.3.3 | | | | 0.0.1 | 0.0.1 | 1.16.14 |
| *Acer nigrum* | | | | | 0.0.1 | 0.2.6 | | | | | | | | | | 2.4.1 | 0.17.14 |

[1]Species listed in order of first DECORANA axis scores for average size-class importance.

for southern upland forests, if possible. Species not listed in Curtis (1959) were assigned the adaptation value of a species having the same shade tolerance (Daniel et al. 1979).

Domon and Bergeron (1987) found the sum of importance values of shade intolerant species in the canopy to be highly correlated with a stand's disturbance history. We used importance values (from Table 3) for species with shade tolerance ratings (Daniel et al. 1979) of intolerant and very intolerant to calculate this value, symbolized as DB. Neither species adaptation values nor tolerance ratings are completely objective and universally agreed upon but, like HAI, represent an effort to subjectively rank an important attribute of a species or stand.

Spearman rank-order correlation coefficients were computed to analyze relationships among DECORANA axes (computed separately for all, large, medium, and small size-classes), the human activity index, stem densities and the basal areas for the three size-classes, and indices from the literature.

Nomenclature for species names follows Gleason and Cronquist (1963).

## RESULTS

### Overall Species Composition

Fifty woody species were sampled in this study (Table 1). Forty-four species were recorded in two or more locations each. An average of 20 species (range 14-26 species) were found per woodlot. *Fraxinus americana* had the highest average importance value with 13.4%. It was found in all 17 woodlots and had 548 stems of all size-classes. Although it was well represented in this study, it had relatively more large stems than small ones, thus indicating some tendency toward nonreplacement. *Acer saccharum* showed the second highest average importance value (12.6%) and the highest density (603 stems), 14.8% of the stems sampled. The large average IVs for all three size-classes indicate that its populations were effectively self-replicating. *Prunus serotina* was present in all woodlots and had the third highest average IV of 10.1%. It had a total of 457 stems in all size-classes, 11.2% of the stems sampled, and was well represented in all size-classes. *Quercus alba* was found in 13 of the woodlots with 114 stems sampled in all three size-classes, 2.8% of the total. It was second in total basal area for the large size-class, but its average importance values were much smaller in the medium and small size-classes, thus indicating it was not replacing itself in these woodlots.

Species ranged from very shade-intolerant pioneers such as *Cercis canadensis*, *Robinia pseudo-acacia*, *Prunus serotina*, *Liriodendron tulipifera*, *Sassafras albidum*, and *Gleditsia triacanthos*, through more shade-tolerant, secondary-stage species such as *Fraxinus americana*, *Ulmus americana*, *Carya cordiformis*, *Ulmus rubra*, *Juglans nigra*, *Carya ovata*, and *Quercus rubra*, to shade-tolerant species, such as *Acer saccharum*, *Aesculus glabra*, and *Acer nigrum*. Several non-native species also were present, including *Ailanthus altissima*, *Rosa multiflora*, *Lonicera* spp., and *Pinus* spp.

### Individual Woodlot Variation

The woodlots selected varied in size, soils, and vegetation structure. None of these factors were obviously or significantly related to overall species composition as summarized by the first DECORANA axis. Basal area ranged from 12-37 $m^2$/ha for large stems and 0.9-7.1 $m^2$/ha for medium stems. Density (number of stems/ha) ranges were 140-700 for large, 600-3,300 for medium, and 1,100-9,800 for small stems. Woodlot size varied from 3 to 29 ha. Woodlots varied in their history of human use (Table 2). All woodlots had been used by their owners in a variety of ways, although the intensity and types of uses varied greatly. All woodlots were used to at least some extent, and recently for firewood and recreation. Most also had been impacted by commercial timber harvests, livestock grazing, and/or tree plantings. Some of these impacts were recent, some as long ago as 1932. Grazing livestock in woods was common in most woodlots at some time, and occurred in 5 woodlots as recently as 1980 or later. Disturbance, as relativized by HAI, did show an obvious relationship to the DECORANA ordering of woodlots: high HAI values were associated with low DECORANA scores and vice versa. The Spearman rank-order correlation coefficients for DECORANA axis woodlot scores with other stand characteristics (Table 4) showed several significant results. HAI was highly correlated ($P \leq 0.01$) with the first DECORANA axis using all size-classes together, thus indicating that disturbance history has had an important effect on the present vegetation patterns. HAI also was negatively correlated with the densities of medium and small stems, indicating that high levels of past human activity result in fewer small and medium sized stems. Human activity was not related to the density of large stems, however. Similarly, probability values for correlations with HAI went from 0.0796 for large stems to 0.0182 for medium stems to 0.0001 for small stems. That is, recent human impact is increasingly important on smaller size-classes of stems.

Large woodlots had higher densities of large and

TABLE 4

*Summary of Spearman rank-order correlations.*

| Woodlot Variables⁺ | HAI | Woodlot Size | All RA1 |
|---|---|---|---|
| RA1 ALL | -.63** | -.09 | 1.00 |
| L | -.44 | -.19 | .86** |
| M | -.56* | .20 | .30 |
| S | .84** | -.15 | -.53* |
| DEN total | -.55* | .55* | .16 |
| L | -.24 | .56* | -.05 |
| M | -.56* | .68** | .16 |
| S | -.54* | .46 | .19 |

⁺ RA1 = First DECORANA axis score, based on ALL size classes or just large (L), medium (M), or small (S) stems.
DEN = Density (#/ha) of all, large, medium, or small stems.
* $0.01 < P \leq 0.05$
** $P \leq 0.01$

medium stems than did small woodlots (Table 4). Large stems showed a probability value of 0.0184, and medium stems showed a 0.0025 probability value related to the size of the woodlots. Densities of small stems showed a lower correlation ($P = 0.0611$) with woodlot size.

The ordination of large stems (all species combined) showed no significant correlations with the ordinations of medium or small stems. If site characteristics (soils, topographic position, etc.) were the dominant influence on vegetation, it would be expected that all ordinations would be similar. They were not, implying that some other factor (e.g., human or natural disturbance history) was important.

**Species Patterns**

Species were ordered by the first DECORANA axis (Table 3). The more highly disturbed woodlots contained species in the upper portion of the table. *Robinia pseudo-acacia*, a pioneer species, was present in eight of the nine woodlots on the more disturbed end of the ordination. Its importance, particularly for small stems, decreased as the severity of the disturbance decreased. *Juglans nigra* was the most important species in woodlot 2, where it was planted in the 1930s. Woodlots 7 and 9, though in the highly disturbed group of woodlots, had *Acer saccharum* as the highest IV in the large size-class. Woodlot 9 also was distinctive in that no oaks were found there in this survey. *Prunus serotina*, another pioneer species, had the highest importance values for large stems in woodlot 13. The next several woodlots (6, 12, 3, 14,16) were dominated by *Fraxinus americana*. Woodlot 3 had *Carya cordiformis* equal to *Fraxinus americana* in importance. Woodlots 11, 4, and 17 had the highest large-stem IVs for *Quercus alba*. In woodlot 17, *Carya ovata* was important. Woodlot 10 was included in this group even though *Acer saccharum* (considered a climax species) was the species with the highest IV, but with a value of only 17%. In the remaining four woodlots, *Ulmus rubra* had the highest IV in woodlots 15 and 5, *Carya cordiformis* and *Fraxinus americana* had higher IVs for large stems than for smaller stems, and in woodlots 1 and 8 *Acer saccharum* had its highest importance values for large stems of any of the woodlots surveyed. TWINSPAN ordered woodlots similarly to DECORANA except that it combined woodlots 9 and 10 with 1 and 8, all of which were dominated by *Acer saccharum*.

Several species had significant correlations (positively or negatively at $P = 0.05$) with HAI and with the first axis of the DECORANA ordination, based on average species importance of all three size-classes. *Fraxinus quadrangulata* correlated positively (large and small stems and average values) with the first axis and negatively with HAI: it was found in relatively undisturbed woodlots. *Cornus florida* correlated positively (medium stems and average) with the first DECORANA axis and negatively (medium stems) with HAI indicating that it also appears more often in woodlots with little disturbance. *Quercus rubra* (large stems and average) and *Quercus muehlenbergii* (large stems) were positively correlated with the first DECORANA axis. *Aesculus glabra* (small stems and average) and *Acer saccharum* (large stems) were negatively correlated with HAI, a finding consistent with the first TWINSPAN sorting of groups using these as indicator species for relatively undisturbed sites.

The following species were negatively correlated with the first DECORANA axis, positively correlated with HAI, and generally found in the highly disturbed woodlots: *Robinia pseudo-acacia*, *Ulmus americana*, *Acer negundo*, *Gleditsia triacanthos*, *Crataegus* spp., *Juglans nigra*, and *Quercus bicolor*. The correlations between species, the first DECORANA axis, and HAI reinforce the conclusion that human activities have had a large impact on present woodlot species composition.

To summarize the results dealing with the relationship between species composition and disturbance, the most disturbed sites had the most shade-intolerant species and the most planted species. The shift diagonally in the species composition gradient, from pioneer invaders to more shade-tolerant climax species, continued as the intensity of past disturbances declined.

Some species were also significantly related to woodlot size. *Acer nigrum* (small stems and average of all sizes in importance) and *Acer saccharum* (also small stems and average) were positively correlated with woodlot size. Small woodlots, on the other hand, had greater importance of medium *Crataegus* spp., small *Cornus* spp., small *Ulmus rubra*, medium *Carya ovata*, and large *Quercus alba*.

Comparing importance values for the three size-classes (Table 3) indicates which species were replacing themselves, shown by large values for each size-class (e.g. *Acer saccharum*, *Fraxinus americana*, and *Prunus serotina*), and which species were not, as evidenced by high values for the large size-class and low for the other size-classes (e.g., *Quercus alba* and oaks, in general).

**Comparison of Indices**

Of the indices tested, WI was clearly the least successful for predicting overall vegetation composition or disturbance history of a woodlot (Table 5). It was not significantly correlated to ordination axis scores (RA1), to HAI, or to DB, the fraction of intolerant species based on importance values. Three species (as used to calculate WI) were apparently too few for this part of the country, at least without locally generated species adaptation values.

TABLE 5

*Spearman rank-order correlations among indices related to a woodlot's disturbance history.*

| Index | Index: HAI | HAIb | DB | WI |
|---|---|---|---|---|
| RA1 | -.63** | -.63** | -.85** | .11 |
| HAI | | .97** | .48 | -.22 |
| HAIb | | | .43 | -.15 |
| DB | | | | -.36 |

*0.01 < $P$ < 0.05
**$P \leq 0.01$

The index DB was even more strongly correlated with ordination scores (RA1) than was HAI (Table 5), probably because both DB and RA1 were calculated from species importance values. On the other hand, HAI was more strongly correlated with RA1, which reflects overall vegetation composition, then with DB, which is based on only two tolerance classes in the largest size-class. The relationship between HAI and DB was of borderline significance ($P = 0.0513$). These results indicate that DB may summarize both vegetation and disturbance; revising tolerance classes to make them more appropriate for the study area might make it more useful.

Modifying HAI to decrease the influence of older disturbances had little impact: HAI and HAIb had similar correlations with the other variables (Table 5).

## DISCUSSION

The list of species dominating the woodlots in the present study is nearly identical to the list of species which Gordon (1969) reported to characterize the oak-sugar maple forests which dominated western Greene County when the original land surveys were completed about 1802-1803. The effect of human activities has been to shift the relative importance of species already present rather than to result in a complete change in vegetation. The only introduced species among the 12 most important overall was *Lonicera* spp. (Table 1). However, shifts in relative importance undoubtedly have occurred.

Relatively few studies characterizing the woody vegetation of disturbed woodlots have been done in this part of the country. Most studies have concentrated on comparatively undisturbed old-growth remnants (e.g., Weaver and Kellerman 1981, Boerner and Cho 1987).

Two studies have been done to examine woodlots in southwestern Ohio. Bell (1978) examined 54 sites from Greene County and southward. The composition of his woodlots agreed with ours in basal area (mean 24 $m^2$/ha, range 13-40 $m^2$/ha). Unfortunately, he did not list importance values by species, but those species sufficiently important for him to graph match our list of important species, except that they did not include *Prunus serotina*, *Ulmus rubra*, or *Celtis occidentalis*. Hoye et al. (1979) examined stands aged 3, 9, 25, 80, and over 120 years after land abandonment. Ranking the species on their list by age of stand of occurrence, after weighting by a scale of abundance, results in a list very similar to that in the present study (Table 3), confirming our interpretation of the ordination axis as a successional/disturbance gradient. Hoye et al. (1979) found dominant species to be *Acer negundo*, *Crataegus* spp., and *Robinia pseudo-acacia* in the youngest stands; *Celtis occidentalis*, *Fraxinus americana*, *Juglans nigra*, *Prunus serotina*, and *Ulmus rubra* widely distributed in stands of all ages; and *Acer saccharum*, *Carya cordiformis*, *C. ovata*, *Quercus rubra*, and *Tilia americana* found primarily just in the oldest stand.

Comparisons with studies of woodlots in northeastern Ohio (Whitney and Somerlot 1985) and southeastern Wisconsin (Levenson 1981) also show many similarities in relative importance of species. Differences include the absence of *Lonicera* in northeastern Ohio and the absence of *Celtis occidentalis* from both other sites. Data in the present study confirm those of Whitney and Somerlot (1985) that *Ulmus americana* is maintaining itself in the upland forests despite its elimination from some locations by disease.

Our data support the idea that *Quercus* is generally not replacing itself: it is far more important in the canopy than in the smaller size-classes. However, it was present in our smallest size-class in at least a few woodlots (Table 3), which suggests that some regeneration is still taking place given the appropriate disturbance regime and site characteristics. Further studies of these situations may help us understand why oak was so successful regenerating in the past and why, in general, it is not so successful today. Oaks presented a problem for vegetation-based indices of a stand's disturbance history. Although oaks are generally classified as intolerant species (Daniel et al. 1979), in the study area oak dominance can characterize older stands. Stands in the process of changing may be dominated by intolerant species (e.g., *Robinia pseudo-acacia*) after some sorts of disturbance, but by tolerant species (e.g., *Acer saccharum*) if the change is away from oak dominance.

The present study supports the use of indices like HAI to provide a systematic method for ranking woodlots according to their apparent history of human impact. In combination with nonparametric tests showing relationships among variables, such indices can begin to allow understanding of vegetation patterns obviously influenced by human activities, which often are poorly documented and difficult to quantify. Use of this index provided a relatively fast and efficient way to survey a variety of woodlots in a short time and to relate their vegetation to past human uses. It provided an index of woodlot disturbance independent of the present vegetation of that woodlot. Calculating the index values also made it clear that most woodlots are simultaneously affected by people in many different ways. As a consequence, it would be difficult to determine the effects of any one management practice (e.g., grazing) by itself.

HAI could be improved. It did not incorporate a time factor into characterization of past disturbance. The time since disturbance, duration of disturbance, and intensity of disturbance all should influence the impact on the vegetation. The difficulty with incorporating those factors into the index may explain why the relationship between HAI and ordination scores was striking for vegetation extremes but not clear for intermediate stands.

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## APPENDIX

*Questions for woodlot owners and managers.*

1. How long have you owned/managed the woodlot?

2. Has it changed? Smaller? Larger? Shape?

3. What types of management practices (if any) have you used?
   ____ grazing ____ firewood ____ cutting/thinning
   ____ bushhogging ____ refuse dump
   ____ recreational use ____ hunting ____ other
   How much of the woodlot?

4. If animals were grazed there, what? how many?
   for how long?

5. Have you had any professional advice? when? who?
   Did you follow up on it?

6. Were there any fires? natural or set? insect damage?

7. The wood that was cut, was it firewood?
   timber harvesting? selective cutting/culling?
   how much? how often? when?

8. What types of trees?

9. How do you view the woodlot? nice to look at?
   enjoy? too much work to clear?
   good for firewood, etc.? other?

10. What are your future plans for the woodlot?

COMMENTS: