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Structure & Composition of a Climax Forest System in Boone County, Kentucky

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STRUCTURE AND COMPOSITION OF A CLIMAX
FOREST SYSTEM IN BOONE COUNTY, KENTUCKY

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STRUCTURE AND COMPOSITION OF A CLIMAX

FOREST SYSTEM IN BOONE COUNTY, KENTUCKY

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STRUCTURE AND COMPOSITION OF A CLIMAX

FOREST SYSTEM IN BOONE COUNTY, KENTUCKY

Michael Edward Held May 1975 41 pages

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The structure and composition of a 52 hectare mature mesic hardwood forest in Boone County, Kentucky was studied during 1973-74. Acer saccharum was the dominant tree species of the entire forest, with Fraxinus americana as the subdominant. In the understory vegetation, Acer and Fraxinus were among the dominant genera, thus this forest system can be described as being at the climax stage of development. A previously cleared area in the forest was also analyzed. It was found that the dominant tree species of the canopy were also dominant in the genera of the understory in the disturbed area, indicating a return to the stable maple-ash system of the entire forest. During the Spring of 1974, tornados moved across Boone County; one of these tornados damaged the forest that was under study. The effects of this wind storm were included in the collection of data. Tornado damage was not limited to any specific species and in this study there was no apparent relationship between root depth and soil type among uprooted trees.

INTRODUCTION

It is apparent that there is a distinct lack of information concerning the forest vegetation of the Commonwealth of Kentucky. Especially lacking are studies of forests before the development and extensive use of the land in Kentucky. Although there is a great amount of general information dealing with the Eastern Deciduous Forest Biome, the author notes that there are few studies dealing with the composition and structure of climax forests in Kentucky.

To contribute to the knowledge of the forests of Kentucky, this study was undertaken in 1973. A wooded area in Boone County, Kentucky, known as Dinsmore's Woods, was selected for an intensive analysis after a preliminary investigation by the author and others indicated this forest to be a relict type.

This project was undertaken to describe the structure and composition of the forest vegetation, to analyze the successional pattern in the forest, and to provide a permanent record of Dinsmore's Woods as a foundation for possible future studies of the structural and functional aspects of forests.

Dinsmore's Woods is located 8 kilometers (km) (5 miles (mi) west of Burlington, the county seat of Boone County, Kentucky, and 3.2 km (2 mi) east of the Ohio River. The forest covers an area of 52.6 hectares (130 acres). The woods is presently owned by Mrs. Martha Breasted. It has been in her family's possession since the 1830's, as evidenced by the grave markers in a small family cemetery by the edge of the forest. The woods is relatively undisturbed; there having been only three recorded removal of trees. Dead chestnuts were logged after the chestnut blight of the late 1930's. A small area at the top of one slope was cleared for a small garden plot, long since abandoned. This section of the forest will be described as the disturbed area. The final removal of trees consisted of those that were damaged by the 3 April 1974 tornado. On that date, a tornado, with winds exceeding 320 km (200 mi) per hour, raked across Boone County. One of the areas damaged was Dinsmore's Woods. This damage and subsequent removal of trees will certainly have a distinct effect on the composition of the forest.

The bedrock of Boone County is primarily Ordovician limestone and shale of Eden, Maysville, and Richmond age (McFarlan, 1943). Along with the parent material, Pleistocene glacial deposits which vary greatly in composition and thickness mantle the northwestern section of Boone County. It is this region that was covered by the Illinoian glaciation but untouched by later glaciers. These glacial deposits are commonly so weathered that they are hard to recognize and classify. They are, therfore, to be considered as one unit and are referred to as "till". These till deposits are well covered by a well-leached layer of loess from the Wisconsin Age, although the Wisconsin glacier did not reach as far south as Kentucky.

Dinsmore's Woods is found on moderate to steep slopes. These slopes are 218 m (700 ft) to 250 m (800 ft) above sea level and some 60 m (200 ft) above the flood plain located in the valley of the Ohio River.

Climatic data for northern Kentucky has been recorded since 1931 at the Greater Cincinnati Airport. This airport is located 3.2 km (2 mi) northeast of Dinsmore's Woods. The maximum temperature mean (24.4°C) occurs in July; the coldest month is January with a mean temperature of 0.1°C. Mean precipitation is highest in July, the time of least mean rainfall is October, with 50.46 cm of the yearly average of 102.89 cm falling from March to July. The growing season between the last frost (April 15) and the first frost (October 22) averages some 190 days.

MATERIALS AND METHODS

The circular plot method (Ohmann, 1973) was employed to determine species composition, relative frequency, and relative density of all size classes of vegetation. Relative dominance, based on calculated basal area, was determined for the tree species. At Dinsmore's Woods, 23 circular plots, each with a size of 1/8 hectare (1/3 acre), were randomly placed throughout the forest. Two transect lines, each 200 m (656 ft) in length, were established through the disturbed area in the forest. One transect went along a North-South line, the other, an East-West line.

The diameter breast height (dbh) of each tree species greater than 10 cm (4 in) dbh was recorded for each 1/8 ha circular plot. Saplings less than 10 cm dbh, but greater than one meter (3.28 ft) in height were sampled in an 1/16 hectare (1/6 acre) circular plot placed within each 1/8 ha plot. Seedlings less than 10 cm dbh and less than one meter in height were counted in an 1/32 hectare (1/12 acre) circular plot inside the 1/16 ha plot. The saplings and seedlings were identified to genus (species if possible). All three plots had the same center point. All woody vegetation that occurred within an area of 30 cm (1 ft) on either side of the transect lines in the disturbed area were sampled following the procedure used in the circular plots. Plant nomenclature follows that of Fernald (1950).

To check the adequacy of the sampling technique at Dinsmore's Woods, a species-area curve was determined for all three size classes of vegetation (Oosting, 1956). Sampling is considered adequate when a ten percent increase in area sampled yielded additional species equal to only five percent of the total number present. This point is equal to the minimum number of circular plots which should be used to obtain an adequate sample of the vegetation.

Within the boundaries of the forest stand three sets of data were analyzed. Separate determinations were made for the vegetation composition of the disturbed area and the tornado damaged trees. The data from those two sets were also included with data analyzed from samples taken to represent the entire forest. Relative density, relative frequency, and relative dominance were calculated and summed to give importance values for each tree species (Curtis and McIntosh, 1951). Relative density and relative frequency were determined for the saplings and seedlings of the forest area sampled. The same calculations were performed for the data of the disturbed area.

For the tornado damaged trees that occurred within any plot, the relative density, relative frequency, and relative dominance were calculated and summed to give importance values. The length of each tree was determined and the extent of the rooting system was measured in all wind-thrown trees.

During the period of research, a lumber company was employed by the owner to clear the woods of all fallen and tornado damaged trees. Stumps left from this work provided a record of annual growth rings. A random sample comprising ten stumps was chosen and analyzed to give an approximation of the age of the stand.

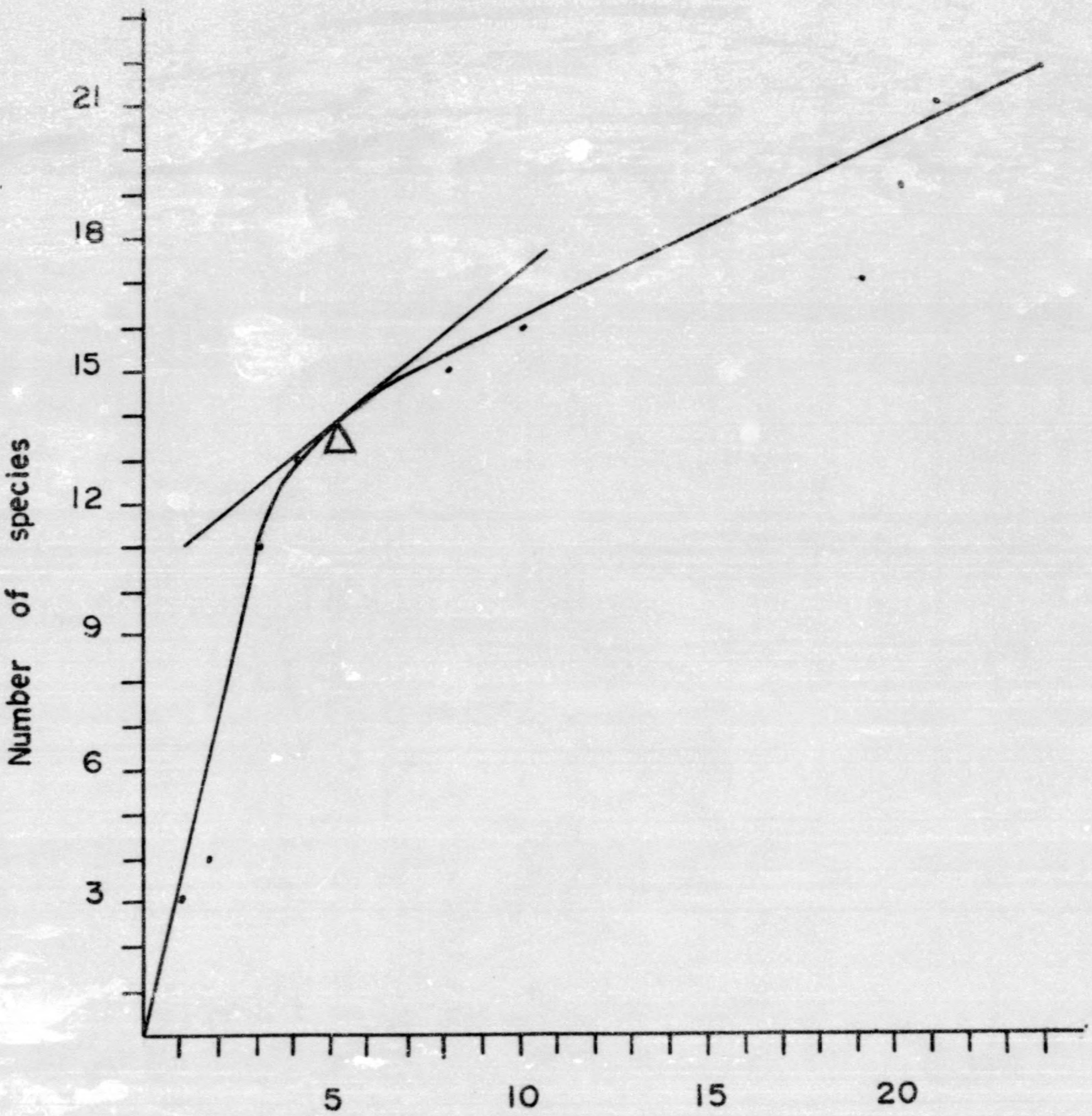
Two soil samples were obtained from each circular plot in Dinsmore's Woods. One was taken at 5 cm (2 in), the other at 15 cm (6 in). A La-Motte Soil Test Kit was used to measure soil pH. Soil texture was analyzed by the hydrometer method of Bouyoucos (1936).

RESULTS

Species-area curves for the tree class of vegetation (Fig. 1), saplings (Fig. 2), and seedlings (Fig. 3) demonstrate that in all size classes of vegetation analyzed, the number of circular plots utilized were more than adequate. Although 23 plots were used for the tree class, five plots of the 1/8 ha size were shown to be the minimum number needed to characterize this vegetation class. In the sapling and seedling classes, 23 plots (1/16 ha and 1/32 ha respectively) were used, whereas for the sapling class, three plots were considered adequate, and for the seedling size range, two plots were the minimum number needed.

In Dinsmore's Woods 21 tree species are included in a sample of 23 circular plots. The tree species for the complete forest are ranked according to their importance values in Table 1. The four predominant tree species, with their importance values, found at Dinsmore's Woods are: Acer saccharum Marsh. (.9194), Fraxinus americana L. (.4448), Celtis occidentalis L. (.2988), and Ulmus rubra L. (.2293). Acer saccharum has the greatest relative density (.3571), relative dominance (.3443), and relative frequency (.2180) of any other tree species at Dinsmore's Woods. It must be noted that by combining the four different species of Quercus, a collective importance value of .3314 was obtained even though no one species of Quercus had a higher importance value of .1787.

Figure 1. Species-area curve of trees from Dinsmore's Woods. The arrow indicates the minimum number of 1/8 hectare circular plots which must be used in order to adequately sample the tree composition.



Number of 1/8 hectare circular plots

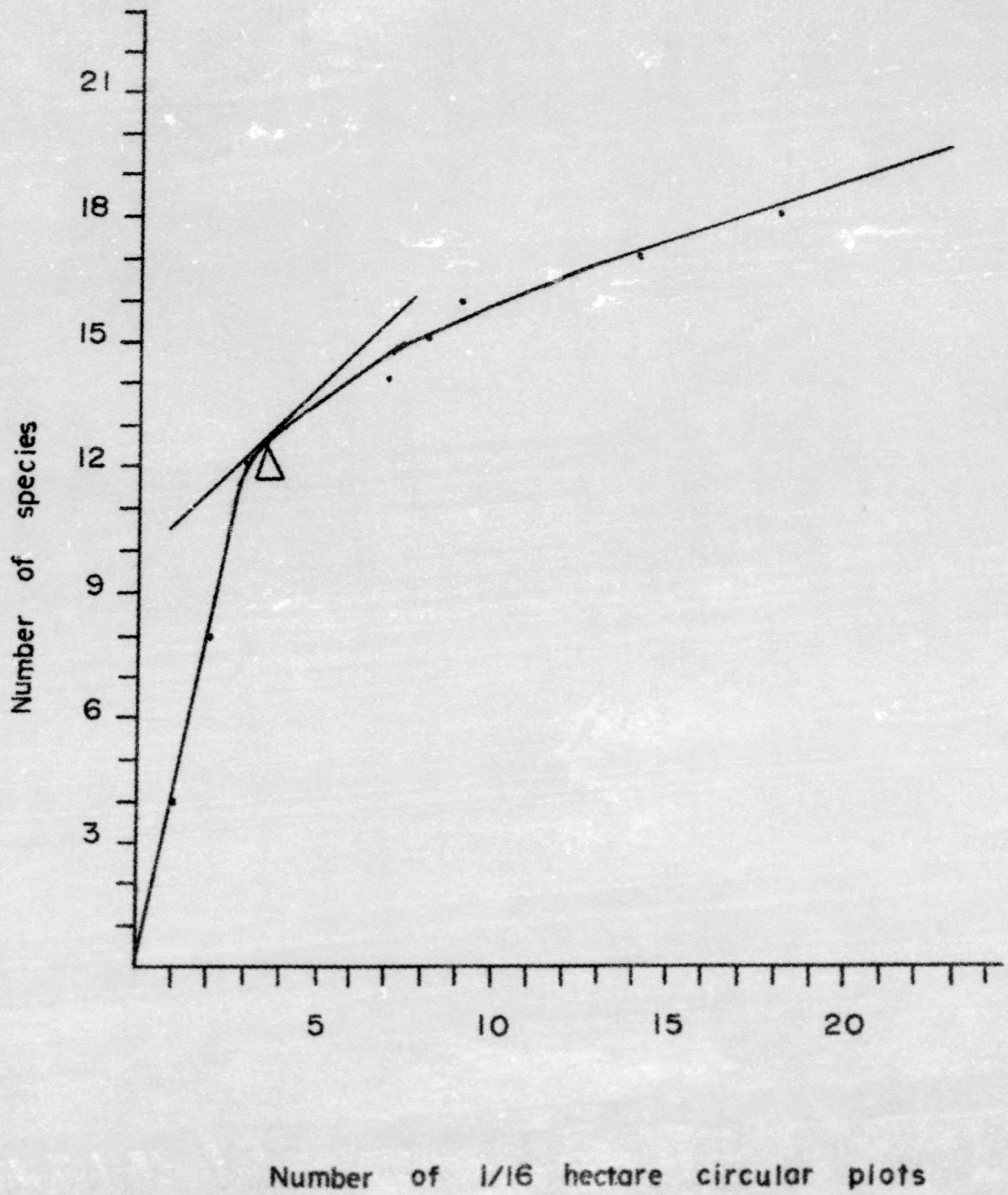
A total of 1585 woody individuals in the three size classes were recorded at Dinsmore's Woods. This corresponds to a density of 566 stems per hectare. In the tree size class, there were 182 individuals, which gives a density of 65 trees per hectare. The trees have a mean diameter of 32 cm (12.6 in) and a total basal area of 28.1 m^2 per hectare (302.35 ft^2 per hectare).

When the saplings are ranked according to relative density plus relative frequency (Table 2), the five important genera are: Acer (.4856), Ulmus (.3916), Asimina triloba (L.) Dunal. (.2084), Fraxinus (.1954), and Celtis (.1313). Relative density plus relative frequency values (Table 3) were determined for the seedlings of the entire forest at Dinsmore's Woods. The top five genera were Acer (.5395), Ulmus (.3512), Fraxinus (.2441), Prunus (.1228), and Carya (.1134). Since it is extremely difficult to make positive identifications of saplings and seedlings of such complex genera as Acer and Quercus no attempt was made to differentiate between species of those two taxa. Thus, in tabulating the data above and elsewhere all of the individuals of those two genera are treated collectively in discussions of saplings and seedlings.

A comparison between the five important genera in all three size classes, found in the complete forest, is shown in Table 4. There were three dominant genera in each class, Acer, which is ranked first in all three size classes, Ulmus and Fraxinus. Celtis was one of the important genera in the tree and sapling classes.

In the disturbed area of Dinsmore's Woods, ten tree species were recorded in an area of four circular plots. This data was included in the

Figure 2. Species-area curve of saplings from Dinsmore's Woods. The arrow indicates the minimum number of 1/16 hectare circular plots which must be used in order to adequately sample sapling composition.


21
18
15
12
9
6
3
Number of species
5
10
15
20
Number of 1/16 hectare circular plots

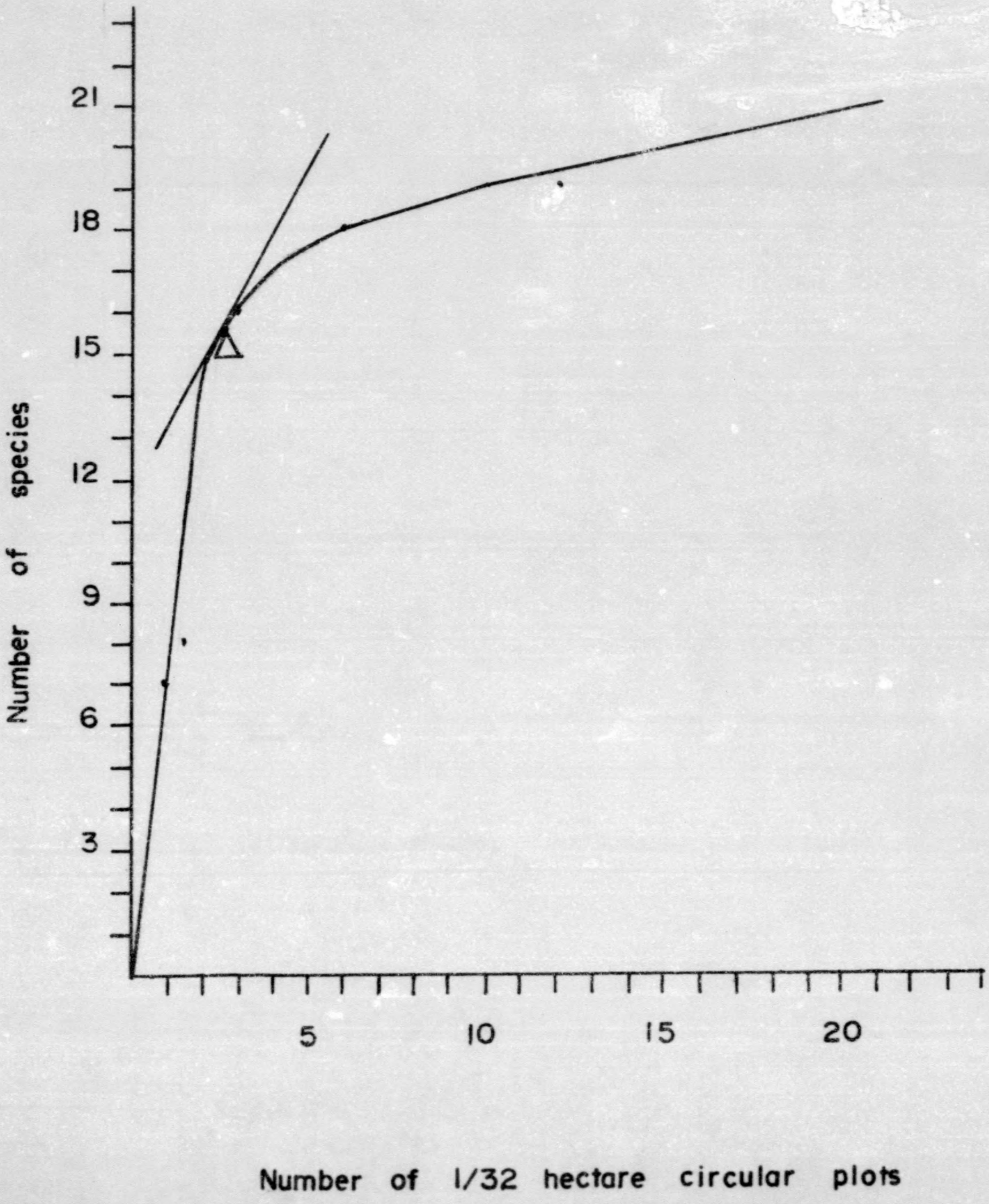
analysis of the complete forest. The tree species of the disturbed area are ranked according to their importance values in Table 5. The five predominant species, with their importance values, are: Celtis occidentalis (.6933), Juglans nigra L. (.3541), Ulmus rubra (.3250), Fraxinus americana (.3250), and Cercis canadensis L. (.2807).

Saplings of the disturbed area are listed according to their relative density plus relative frequency values (Table 6). The five leading genera are Ulmus (.5302), Acer (.4330), Celtis (.2485), Fraxinus (.1845), and Prunus (.1626). In the seedling size class of the disturbed area (Table 7), the five dominant genera, ranked according to their relative density plus relative frequency values, are Fraxinus (.4342), Acer (.3333), Prunus (.2723), Celtis (.2247), and Gleditsia triacanthos (.2133).

Table 8 is a comparison of the five leading individuals of the disturbed area in all three vegetation size classes. Celtis and Fraxinus are found in all three classes; genera found in two classes are Acer, Prunus, and Ulmus.

Data recorded from the two transect lines, which were placed in the disturbed area, is presented in Table 9. The five leading tree species and their relative density plus relative dominance values are: Celtis occidentalis (.4241), Ulmus rubra (.4230), Fraxinus americana (.3379), Robinia pseudo-acacia L. (.3287), and Gleditsia triacanthos (.2396). In the sapling class the three dominant genera, with their relative density values, are Ulmus (.4743), Acer (.1794), and Morus rubra L. (.0769). The three important seedling genera, ranked according to their relative density values are: Ulmus (.3200), Gleditsia triacanthos (.2400), and Fraxinus (.1600).

Figure 3. Species-area curve of seedlings from Dinsmore's Woods. The arrow indicates the minimum number of 1/32 hectare circular plots which must be used in order to adequately sample seedling composition.



21
18
15
12
9
6
3
Number of species
5
10
15
20
Number of 1/32 hectare circular plots

Comparison between Tables 8 and 9 shows that *Celtis occidentalis* is dominant in the tree class of both procedures of analysis. *Fraxinus americana* and *Ulmus rubra* are also found in the top five species in both sets of data. In the sapling class of circular plot analysis data, *Ulmus* and *Acer* are dominant, as they are in the transect method of vegetation determination. In the seedling class, *Ulmus* is first in the transect procedure; however, in the plot analysis *Ulmus* is not in the first five genera. Only *Fraxinus* and *Acer* are dominant in both methods of analysis of the seedling class.

Comparison of Tables 4 and 8 shows that *Fraxinus* is the genus found to be dominant in all six size classes of both the complete forest and the disturbed area. *Acer*, *Ulmus*, and *Celtis* occur as leading genera in the five of the size classes.

In the tornado damaged area, which was included in the complete forest data, there are twelve tree species that occur in five circular plots. Of these twelve species, seven were damaged to some extent by the high winds. All trees of the tornado area and their importance values are presented in Table 10. The five leading species are: *Acer saccharum* (1.0921), *Ulmus rubra* (.3919), *Celtis occidentalis* (.3271), *Tilia americana* (.2165), and *Fagus grandifolia* (.2123). The trees damaged by the tornado and their importance values are listed in Table 11. The five leading species and their importance values are *Acer saccharum* (1.3011), *Fraxinus americana* (.5004), *Cercis canadensis* (.2981), *Celtis occidentalis* (.2898), and *Tilia americana* (.2799). Only three dominant species of all the trees in the damaged area are represented in the list of important damaged trees; they are *Acer saccharum*, *Celtis occidentalis*, and *Tilia americana*.

The length of all trees that were uprooted was recorded to give an approximation of canopy height. The average height was 20 meters (65.6 feet), with the tallest being 34.1 meters (111.8 feet), (Acer saccharum). The dbh was also taken for all uprooted trees. The species, average dbh, and average heights of the uprooted trees were: Acer saccharum, 37.5 cm (14.8 in), 18.5 m (60.6 ft); Ulmus rubra, 56.6 cm (22.3 in), 19.2 m (62.9 ft); Celtis occidentalis, 48.8 cm (19.2 in), 26.7 m (87.5 ft); Gleditsia triacanthos, 15.0 cm (5.9 in), 19.8 m (64.9 ft); and Fraxinus americana, 35.5 cm (14.0 in), 20.3 m (66.5 ft).

Table 12 lists the species, diameter, and number of annual rings counted for ten trees cut during the clearing operation by the lumber company. Also the average diameter and number of rings is given for each species with two or more stumps studied. The largest stump recorded was a Fraxinus americana, which had a diameter of 76.2 cm (30.0 in) and 114 annual rings. This data was helpful in determining the age of the forest community.

The rooting system of all trees that were uprooted within the sample plots was measured. The average length of all species was 2.3632 m (7.75 ft). For individual species, the average lengths were: Acer saccharum, 1.916 m (6.28 ft); Gleditsia triacanthos, 1.700 m (5.57 ft); Fraxinus americana, 2.300 m (7.54 ft); Celtis occidentalis, 2.806 m (9.20 ft); Ulmus rubra, 3.100 m (10.16 ft).

Data of the 46 soil samples, two from each plot, in relation to texture and pH are presented in Table 13. Analysis of the samples taken at 5 cm (2 in) gave a range of pH of 4.6-6.0, with a mean of 5.5. The average soil texture of this level of samples was 7.2% sand, 59.5%

clay, and 33.3% silt. The majority of the 5 cm samples (13) fall within the clay class and the remaining ten samples are classified as being the silty clay type.

For the 15 cm (6 in) samples, the range of pH was 4.4-5.6, with an average of 5.2. The average texture of the soil was determined to be 7.2% sand, 64.1% clay, and 28.7% silt. Eighteen samples fell within the clay texture class, the other five were of the silty clay soil classification.

Table 1. The number (N), relative density (RD), relative dominance (RDo), relative frequency (RF), and importance value (IV), of all tree species over 10 cm dbh at Dinsmore's Woods.

Species	N	RD	RDo	RF	IV
Acer saccharum Marsh.	65	.3571	.3443	.2180	.9194
Fraxinus americana L.	26	.1428	.1570	.1450	.4448
Quercus alba L.	7	.0384	.0733	.0670	.1787
Q. rubra L.	2	.0109	.0432	.0240	.0781
Q. muehlenbergii Engelm.	2	.0109	.0189	.0240	.0538
Q. prinus L.	1	.0054	.0034	.0120	.0208
Celtis occidentalis L.	20	.1098	.0930	.0960	.2988
Ulmus rubra L.	18	.0989	.0464	.0840	.2293
Gleditsia triacanthos L.	9	.0464	.0309	.0490	.1293
Carya tomentosa Nutt.	5	.0274	.0474	.0490	.1238
Ostrya virginiana (Mill.) K. Koch	6	.0329	.0060	.0490	.0879
Fagus grandifolia Ehrh.	2	.0109	.0342	.0240	.0691
Cercis canadensis L.	4	.0219	.0181	.0240	.0640
Juglans nigra L.	4	.0219	.0139	.0240	.0598
Acer negundo L.	4	.0219	.0099	.0240	.0558
Tilia americana L.	1	.0054	.0343	.0120	.0517
Robinia pseudo-acacia L.	2	.0109	.0070	.0240	.0419
Maclura pomifera (Raf.) Schneid.	1	.0054	.0124	.0120	.0298
Prunus serotina Ehrh.	1	.0054	.0041	.0120	.0215
Cornus florida L.	1	.0054	.0007	.0120	.0181
Aesculus glabra Willd.	1	.0054	.0005	.0120	.0179

Table 2. The number (N), relative density (RD), relative frequency (RF), and relative density plus relative frequency value (RD+RF), for the saplings of the complete forest.

Genera	N	RD	RF	RD+RF
Acer spp.	129	.2841	.2015	.4856
Ulmus sp.	111	.2444	.1472	.3916
Asimina triloba (L.) Dunal.	63	.1387	.0697	.2084
Fraxinus spp.	36	.0792	.1162	.1954
Celtis sp.	28	.0616	.0697	.1313
Lindera benzoin (L.) Blume	17	.0374	.0620	.0994
Carya sp.	13	.0286	.0697	.0983
Quercus spp.	11	.0242	.0620	.0862
Prunus sp.	16	.0352	.0465	.0817
Ostrya sp.	8	.0176	.0387	.0563
Cornus florida L.	7	.0154	.0310	.0464
Morus rubra L.	5	.0110	.0155	.0265
Cercis canadensis L.	3	.0066	.0155	.0221
Tilia sp.	2	.0044	.0155	.0199
Fagus grandifolia L.	1	.0022	.0077	.0099
Robinia pseudo-acacia L.	1	.0022	.0077	.0099
Sassafras albidum (Nutt.) Nees.	1	.0022	.0077	.0099
Euonymus americanus L.	1	.0022	.0077	.0099
Liriodendron tulipifera L.	1	.0022	.0077	.0099

Table 3. The number (N), relative density (RD), relative frequency (RF), and the relative density plus relative frequency value (RD+RF), for the seedlings of the complete forest.

Species	N	RD	RF	RD+RF
Acer spp.	336	.3532	.1863	.5395
Ulmus sp.	210	.2208	.1304	.3512
Fraxinus spp.	120	.1261	.1180	.2441
Prunus sp.	46	.0483	.0745	.1228
Carya sp.	37	.0389	.0745	.1134
Lindera benzoin (L.) Blume	53	.0557	.0559	.1116
Celtis sp.	36	.0378	.0683	.1061
Asimina triloba (L.) Dunal.	38	.0399	.0496	.0895
Quercus spp.	26	.0273	.0621	.0894
Gleditsia tricanthos L.	18	.0189	.0310	.0499
Sassafras albidum (Nutt.) Nees.	12	.0115	.0310	.0425
Cornus florida L.	4	.0042	.0248	.0290
Ostrya sp.	6	.0063	.0186	.0249
Tilia sp.	3	.0030	.0186	.0216
Cercis canadensis L.	2	.0021	.0124	.0145
Fagus grandifolia L.	2	.0021	.0062	.0083
Juglans sp.	1	.0010	.0062	.0072
Morus rubra L.	1	.0010	.0062	.0072

Table 4. Comparison of the five dominant tree species, sapling and seedling genera, with their importance or relative density plus relative frequency values, at Dinsmore's Woods.

Tree		Sapling		Seedling	
Species	IV	Genera	RD+RF	Genera	RD+RF
Acer saccharum Marsh.	.9194	*Acer* spp.	.4856	*Acer* spp.	.5395
Fraxinus americana L.	.4448	*Ulmus* sp.	.3916	*Ulmus* sp.	.3512
Quercus spp.	.3314	*Asimina triloba* (L.) Dunal.	.2084	*Fraxinus* spp.	.2441
Celtis occidentalis L.	.2988	*Fraxinus* spp.	.1954	*Prunus* sp.	.1228
Ulmus rubra L.	.2293	*Celtis* sp.	.1313	*Carya* sp.	.1134

Table 5. The number (N), relative density (RD), relative dominance (RDo), relative frequency (RF), and the importance value (IV), for trees over 10 cm dbh in the disturbed area at Dinsmore's Woods.

Species	N	RD	RDo	RF	IV
Celtis occidentalis L.	12	.3243	.2975	.0714	.6933
Juglans nigra L.	4	.1081	.1031	.1428	.3541
Ulmus rubra L.	5	.1351	.0470	.1428	.3250
Fraxinus americana L.	3	.0810	.1705	.0714	.3230
Cercis canadensis L.	3	.0810	.1282	.0714	.2807
Gleditsia triacanthos L.	3	.0810	.0638	.0714	.2163
Acer negundo L.	3	.0810	.0626	.0714	.2151
Acer saccharum Marsh.	2	.0540	.0159	.1428	.2128
Maclura pomifera (Raf.) Schneid.	1	.0270	.0924	.0714	.1908
Robinia pseudo-acacia L.	1	.0270	.0184	.1428	.1883

Table 6. The number (N), relative density (RD), relative frequency (RF), relative density plus relative frequency value (RD+RF), for the saplings of the disturbed area at Dinsmore's Woods.

Species	N	RD	RF	RD+RF
Ulmus sp.	27	.3802	.1500	.5302
Acer spp.	13	.1830	.2500	.4330
Celtis sp.	7	.0985	.1500	.2485
Fraxinus spp.	6	.0845	.1000	.1845
Prunus sp.	8	.1126	.0500	.1626
Carya sp.	2	.0281	.1000	.1281
Morus rubra L.	4	.0563	.0500	.1063
Quercus spp.	2	.0281	.0500	.0781
Robinia pseudo-acacia L.	1	.0140	.0500	.0640
Lindera benzoin (L.) Blume	1	.0140	.0500	.0640

Table 7. The number (N), relative density (RD), relative frequency (RF), and relative density plus relative frequency value (RD+RF), for the seedlings in the disturbed area of Dinsmore's Woods.

Species	N	RD	RF	RD+RF
Fraxinus spp.	33	.3142	.1200	.4342
Acer spp.	14	.1333	.2000	.3333
Prunus sp.	16	.1523	.1200	.2723
Celtis sp.	11	.1047	.1200	.2247
Gleditsia triacanthos L.	14	.1333	.0800	.2133
Ulmus sp.	8	.0761	.1200	.1961
Quercus spp.	2	.0190	.0800	.0990
Carya sp.	2	.0190	.0400	.0590
Fagus grandifolia L.	2	.0190	.0400	.0590
Lindera benzoin (L.) Blume	2	.0190	.0400	.0590
Morus rubra L.	1	.0095	.0400	.0495

Table 8. Comparison of the five dominant tree species, sapling and seedling genera, with their importance or relative density plus relative frequency values, in the disturbed area at Dinsmore's Woods.

Tree		Sapling		Seedling	
Species	IV	Genera	RD+RF	Genera	RD+RF
Celtis occidentalis L.	.6933	*Ulmus* sp.	.5302	*Fraxinus* spp.	.4342
Juglans nigra L.	.3541	*Acer* spp.	.4330	*Acer* spp.	.3333
Ulmus rubra L.	.3250	*Celtis* sp.	.2485	*Prunus* sp.	.2723
Fraxinus americana L.	.3230	*Fraxinus* spp.	.1845	*Celtis*	.2247
Cercis canadensis L.	.2807	*Prunus* sp.	.1626	*Gleditsia triacanthos* L.	.2133

Table 9. Analysis of data, collected using the line transect method, for all three vegetation size classes in the disturbed area at Dinsmore's Woods.

Tree Class

Species	N	RD	RDo	RD+RDo
Celtis occidentalis L.	4	.2356	.1885	.4241
Ulmus rubra L.	5	.2941	.1289	.4230
Fraxinus americana L.	2	.1176	.2203	.3379
Robinia pseudo-acacia L.	1	.0588	.2699	.3287
Gleditsia triacanthos L.	2	.1176	.1220	.2396
Acer saccharum Marsh.	2	.1176	.0269	.1445
Juglans nigra L.	1	.0588	.0431	.1019

Sapling Class			Seedling Class		
Species	N	RD	Species	N	RD
Ulmus sp.	37	.4743	*Ulmus* sp.	8	.3200
Acer spp.	14	.1794	*Gleditsia triacanthos* L.	6	.2400
Morus rubra L.	6	.0769	*Fraxinus* spp.	4	.1600
Celtis sp.	4	.0512	*Acer* spp.	3	.1200
Cercis canadensis L.	4	.0512	*Robinia pseudo-acacia* L.	2	.0800
Gleditsia triacanthos L.	3	.0384	*Prunus* sp.	2	.0800
Prunus sp.	3	.0384			
Asimina triloba (L.) Dunal.	1	.0128			
Unknown	1	.0128			

Table 10. The number (N), relative density (RD), relative dominance (RDo), relative frequency (RF), and importance values (IV) of all trees in the tornado plots at Dinsmore's Woods.

Species	N	RD	RDo	RF	IV
Acer saccharum Marsh.	16	.4571	.4128	.2222	1.0921
Ulmus rubra L.	5	.1428	.0825	.1666	.3919
Celtis occidentalis L.	3	.0857	.1303	.1111	.3271
Tilia americana L.	1	.0285	.1325	.0555	.2165
Fagus grandifolia Ehrh.	1	.0285	.1283	.0555	.2123
Quercus rubra L.	1	.0285	.0386	.0555	.1226
Q. alba L.	1	.0285	.0040	.0555	.0880
Fraxinus americana L.	3	.0857	.0121	.0555	.1533
Gleditsia triacanthos L.	2	.0571	.0131	.0555	.1257
Carya tomentosa Nutt.	1	.0285	.0363	.0555	.1203
Acer negundo L.	1	.0285	.0056	.0555	.0896
Cercis canadensis L.	1	.0285	.0033	.0555	.0873

Table 11. The number (N), relative density (RD), relative dominance (RDo), relative frequency (RF), importance value (IV), and the number uprooted (NU), of damaged species in tornado plots at Dinsmore's Woods.

Species	N	RD	RDo	RF	IV	NU
Acer saccharum Marsh.	10	.4761	.4404	.3846	1.3011	8
Fraxinus americana L.	3	.1428	.1263	.2307	.5004	3
Celtis occidentalis L.	2	.0952	.1177	.0769	.2898	2
Tilia americana L.	1	.0476	.1554	.0769	.2799	0
Ulmus rubra L.	1	.0476	.0758	.0769	.2001	1
Cercis canadensis L.	1	.0476	.0531	.0769	.1776	0
Gleditsia triacanthos L.	1	.0476	.0057	.0769	.1302	1

Table 12. Annual ring analysis for ten randomly selected stumps.

Species	dbh (cm)	Number of rings
Fraxinus americana L.	76.20	114
Fraxinus americana L.	48.76	91
Fraxinus americana L.	46.99	94
Fraxinus americana L.	41.40	92
Fraxinus americana L.	36.06	77
Fraxinus americana L.	33.02	83
Acer saccharum Marsh.	46.73	82
Acer saccharum Marsh.	40.64	50
Quercus alba L.	38.10	96
Prunus serotina Ehrh.	34.79	62

Average of stump dbh and number of rings for species with two or more stumps in sample.

Species	dbh (cm)	Number of rings
Fraxinus americana L.	47.06	92
Acer saccharum Marsh.	43.68	66

Table 13. Texture and pH of forty-six soil samples from Dinsmore's Woods.[1]

Plot	Depth (cm)	%Sand	%Clay	%Silt	pH
001	5	12.82	44.03	43.14	4.6
	15	11.72	46.74	41.52	4.4
002	5	3.90	86.96	9.12	5.6
	15	3.46	70.08	26.45	5.6
003	5	5.78	76.11	18.09	6.0
	15	6.20	59.79	33.99	5.6
004	5	20.09	63.29	16.60	5.2
	15	.33	82.70	16.97	5.0
005	5	4.37	47.53	48.09	5.0
	15	11.38	78.94	9.67	5.2
006	5	9.91	61.54	28.53	5.2
	15	1.64	64.62	33.72	5.6
007	5	12.06	43.04	44.88	5.2
	15	2.59	71.09	26.30	6.0
008	5	1.55	55.51	42.93	5.8
	15	14.06	68.75	17.17	4.4
009	5	1.21	90.35	8.43	5.8
	15	10.08	74.14	15.77	5.6
010	5	8.42	51.57	40.00	4.8
	15	6.96	61.32	31.71	5.0
011	5	4.17	55.17	40.64	5.4
	15	2.34	59.10	38.54	5.2
012	5	7.31	72.24	20.44	5.2
	15	8.03	88.31	3.65	5.2
013	5	5.28	81.70	13.00	5.6
	15	8.60	59.55	31.83	5.0
014	5	6.01	55.12	38.86	4.8
	15	1.99	90.20	7.80	5.4

Table 13. (continued)

Plot	Depth (cm)	%Sand	%Clay	%Silt	pH
015	5	10.99	53.54	35.45	5.8
	15	6.74	61.38	31.87	5.6
016	5	6.39	73.84	19.75	5.6
	15	.85	52.25	46.89	5.2
017	5	3.27	50.90	45.81	5.2
	15	3.62	58.32	38.04	5.6
018	5	7.50	53.95	38.54	6.0
	15	6.58	55.51	37.89	4.8
019	5	5.10	46.80	48.09	6.0
	15	12.30	48.42	39.27	4.8
020	5	12.48	58.69	28.81	6.0
	15	7.67	62.20	30.12	5.8
021	5	5.56	45.42	49.01	5.8
	15	11.85	64.34	23.79	5.6
022	5	7.69	46.96	45.34	5.6
	15	6.93	49.08	43.97	4.8
023	5	4.17	55.74	40.08	6.0
	15	20.16	45.73	34.10	5.2

[1]Plot codes: 001-008 represent soil samples on west slopes of the forest; 009-011, from southwestern slopes; 012, northwest slope; 013-017, soil samples from east facing slopes; 018-019, southeast aspect samples; 020-022, from south facing slopes; and 023, from a ridge top in the forest.

DISCUSSION AND CONCLUSIONS

The data presented in Table 1 show that *Acer saccharum* has the highest relative density, relative frequency, and relative dominance of all tree species recorded at Dinsmore's Woods. *Fraxinus americana* was ranked second in all three categories of analysis. *Quercus* spp., as stated before, did not individually have high importance values, but, collectively their importance value was third in decreasing order. Therefore the forest at Dinsmore's Woods may be classified as a sugar maple system, subdominant species being white ash and the oaks. Accessory species were *Celtis occidentalis* and *Ulmus rubra*.

Braun (1916) stated that on more mesophytic slopes near large streams, such as the Ohio River, *Acer saccharum* is the dominant species. Keith (1968) in his analysis of the canopy trees of Boone County, showed that in five of thirteen forest sample sites, *Acer saccharum* was dominant, and in six sites *Acer saccharum* and *Fraxinus americana* were the leading species. The sites analyzed by Keith in 1968 are approximately 2.4 to 16 km north and somewhat east and west of Dinsmore's Woods.

Data presented in Table 4 indicate that the two dominant species in the tree class, *Acer saccharum* and *Fraxinus americana*, are present in the five important genera of the sapling and seedling classes. This evidence of reproduction of the dominant canopy species is seen developing in the smaller vegetation size classes, which indicates a stable and climax system.

The various *Quercus* species, which collectively are present as a leading dominant of the tree class, are not represented as important genera in the sapling and seedling classes of the complete forest. Keever (1973) points out that *Quercus alba* L., found in southeastern Pennsylvania, is shade intolerant and shows low reproduction under a closed canopy. Beals and Cope (1964) state that in cleared areas of forest in southeastern Indiana, white oak seedlings are shaded out by the fast growing maple saplings and seedlings. Therefore the dominant oak species is not reproducing in great numbers and thus the combined density of the oak saplings and seedlings is greatly reduced. But some oaks are present in the understory; *Q. rubra* L., *Q. muehlenbergii* Engelm., and *Q. prinus* L. and these species are considered to be shade tolerant.

In the sapling class, *Asimina triloba*, and in the seedling class, *Prunus* sp., are dominant, but would not be expected to replace the dominant species since they are usually restricted to the understory layer of a forest system.

In the disturbed area of Dinsmore's Woods, *Celtis occidentalis* was the leading dominant tree species. It possessed the highest density and greatest basal area of all tree species recorded in the disturbed area. Accessory species were *Juglans nigra*, *Ulmus rubra*, and *Fraxinus americana*. *Acer saccharum*, the dominant species in the complete forest, is ranked among the least important species in the tree class of the disturbed area. However, in the comparison between the three classes of disturbed area vegetation (Table 8), *Acer* spp. is the second leading dominant in both classes of understory growth. In the sapling class, the three dominants, Ulmus, Acer, Fraxinus, of the complete forest are present, and in the seedling class, Fraxinus and Acer are dominant. These data indicate that although this area was once disturbed, as shown by the species of the tree class, the dominants of the complete forest are predominant in the understory genera. Therefore this disturbed area is returning to the stable system that is characteristic of the complete forest.

When comparing the data collected for the disturbed area, using both methods of analysis, it must be noted that the area of ground surveyed by each method varies greatly. The transect area covered 328 m^2 or 3.28% of a hectare. This area was kept constant when analyzing the three classes of vegetation. When using the plot method, three different areas were covered. For the tree class, using four 1/8 hectare plots, 5000 m^2 or 50% of a hectare was studied. In the sapling class, utilizing four 1/16 hectare plots, 2500 m^2 or 25% of a hectare was the amount of forest surface studied. Finally, for the seedling class, an area of 1250 m^2 or 12.5% of a hectare was used. Therefore in any discussion of the comparison between size classes of vegetation in the disturbed area, it must be stated that the area covered by the transect line is very small even when it is compared to the smallest area (seedling class) studied by the plot method. Hence the discussion concerning the vegetation analyzed by the two methods is not a direct numerical comparison but one of a qualitative aspect. Therefore, in this discussion only calculations that are used for both methods will be utilized for this comparison.

In the tree class of the disturbed area, using the plot method, the leading dominants, and their relative density plus relative dominance values, are Celtis occidentalis (.6218), Fraxinus americana (.2515), Juglans nigra (.2112), Cercis canadensis (.2092), and Ulmus rubra (.1821). Using the transect method, the five leading tree species, and their relative density plus relative dominance values, are Celtis occidentalis (.4241), Ulmus rubra (.4230), Fraxinus americana (.3379), Robinia pseudo-acacia (.3287), and Gleditsia triacanthos (.2396). As shown by the data, there are three common species, which are found to be dominant using both methods. These species are Celtis occidentalis, Ulmus rubra, and Fraxinus americana.

In the sapling size class, the three leading dominants, and their relative density values, in the transect area are, Ulmus (.4743), Acer (.1794), and Morus rubra (.0769). Using the circular plot method, the important genera are Ulmus (.3802), Acer (.1830), and Celtis (.0985). There is agreement between the two methods on the dominants of the sapling class of disturbed area vegetation. The transect data confirms the assertion that the dominants of the complete forest are found to be important genera in the smaller size classes of vegetation of the disturbed area, indicating a trend toward stability.

Analysis of the seedling class points out differences between dominant genera recorded using both methods. The leading genera of the seedling class, and their relative density values, of the transect method are Ulmus (.3200), Gleditsia triacanthos (.2400), and Fraxinus (.1600). Whereas the important individuals of the plot method are Fraxinus (.3142), Prunus (.1523), and Acer (.1333). This points to the inadequacy of the amount of area covered by the transect. The parcel of land studied was not large enough to provide an adequate sample for analysis. With a small number of organisms, a genus with only a few individuals recorded will possibly be given a large relative density, as evidenced in the seedling class of the transect method. With an adequate sample, the relationship between the number of individuals in the genera of the sample will be better reflected in the relative density values. There is also another problem that arises using a limited area of study. The relative dominance of tree species does not reflect the true importance of a species in the system. Within a sample of a few organisms one species may have many small individuals, or another species may have only one representative with a large basal area, thus these two extremes would possibly be given nearly equivalent relative dominance values. In an adequate sample the possibility of this situation occurring is reduced due to the greater number of individuals studied.

Data presented in Table 10 is a summary of the analysis of the tree class vegetation of the tornado damaged plots. It includes all trees, both damaged and undamaged, in those plots that were affected by the high winds. Similar to the complete forest, the major important species is Acer saccharum. Two other complete forest dominants, Ulmus rubra and Celtis occidentalis, are important species in these plots. Quercus species and Fraxinus americana are among the least important in these five plots, whereas they are dominants in the entire forest community.

A summary of the data analysis of only the trees damaged by the tornado is presented in Table 11. The leading dominant species damaged was Acer saccharum. Fraxinus americana was the next important species that was damaged. It is to be noted that F. americana was not a leading dominant in the five tornado plots, but it is in the complete forest. Cercis canadensis is the third dominant of the damaged trees. It is ranked last of all trees in the five tornado plots and is one of the least important trees in the complete forest. The opposite situation occurs with Ulmus rubra. It is the second leading dominant of all trees in the tornado plots and is an important tree in the complete forest, but it is one of the least dominant trees in the damaged group.

A survey at this site completed by the Kentucky Department for Natural Resources and Environmental Protection, Division of Forestry during April 1974, found 309 trees, over 25 cm (10 in) dbh damaged. The dominant species were Fraxinus americana, Juglans nigra, and Acer saccharum.

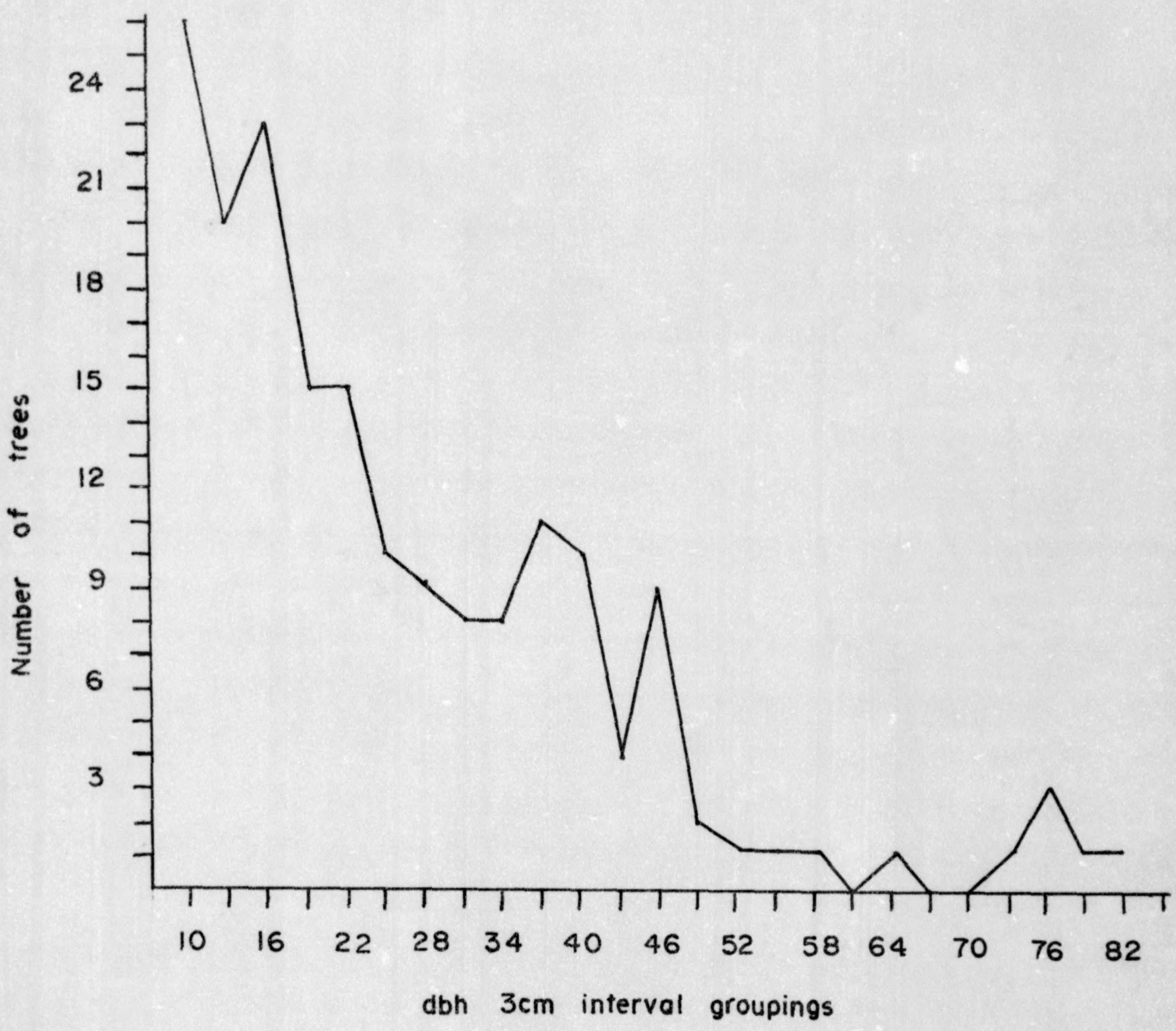
From the evidence obtained in this research and from the Division of Forestry survey, it can be concluded that in the case of natural catastrophes, such as high winds, the destructive force of these events causes damage to all vegetation that is in the path of the tornado. All species are susceptible to destruction or damage, and the effect caused is haphazard and lacks a logical and orderly pattern.

Root length data show that all species' root lengths were within 29% of the average (2.4 m). Within the path of the tornado trees were both uprooted and damaged, some having a section of the bole broken or bent. In this area it appears the effect of the high wind was different on each individual organism, depending on its place in the community, interrelating topography, and the direction of the tornado path. From root length data, it appears that the depth of penetration by the roots into the soil was not a determining factor for trees to withstand the high velocity and force of the tornado winds. In Dinsmore's Woods the average root depth is much greater than the depth in another woods in Pennsylvania struck by a tornado in 1950 (Goodlett, 1954). The Pennsylvania study, one of the few known that correlates tornado damage with forest composition, revealed that the average root depth was .80 meters.

The data presented in Table 13 show that the soil of Dinsmore's Woods is predominantly clay and slightly acidic. This classification of soil type disagrees with that put forth by the United States Department of Agriculture in their soil survey of Boone County (Weisenberger, et al, 1973). This survey places the soil of Dinsmore's Woods, from 0 - 10 cm, into the flaggy silty clay class, and those soils 10 - 45 cm from the surface in the flaggy silty clay loam type. The pH range as determined by the USDA was near neutral. A possible cause of the differences found between the USDA study and that carried out during this research may be due to the fact that the government study is the result of analyses of many samples collected over a large parcel of land and at preselected points. But in the Dinsmore's study there were many soil samples collected randomly over a smaller area. Therefore any differences found are due to the method of sample collecting, not the method of sample analysis. Analysis of the plots and soil texture groupings indicates no correlation of species composition with specific soil types and pH range.

Figure 4 shows the distribution of diameter sizes at Dinsmore's Woods. As pointed out by Martin (1974), the closer the diameter curve approaches the theoretical inverted J curve, the older and maore stable the forest system. The curve of Dinsmore's Woods approximates the inverted J curve with some variations. The bumps in the curve are possibly caused by the inclusion of data of the disturbed area or human error. The greatest number of trees is found in the smaller diameter classes, and each increasing size class has, in theory, a smaller number of individuals

Figure 4. Diameter distribution of tree class individuals from Dinsmore's Woods. Three centimeter (7.5 in) diameter groupings were utilized.


Number of trees
24
21
18
15
12
9
6
3
10
16
22
28
34
40
46
52
58
64
70
76
82
dbh 3cm interval groupings

represented. Usually after the curve reaches zero in the larger diameter size classes there is a minor uplift, indicating a few trees present possessing very large diameters.

Most researchers (Braun, 1936, 1950; McCoy, 1939; Shanks, 1953; and Beals and Cope, 1964) consider the forest of the Illinoian till plain to be comprised mainly of beech, or an association of beech and maple. However, Acer saccharum is regarded as the predominant species on more mesophytic slopes of the ravines and valleys that dissect the till plain (Braun, 1916, 1936, 1950; Beals and Cope, 1964).

A search of the literature indicates a distinct lack of forest ecosystem analyses in the northern region of Kentucky. A floristic checklist prepared by Nelson (1918), and the work of Keith (1968) are the only recorded studies of the forest vegetation of Boone County completed before this project was undertaken. It is hoped that this study will contribute to the ever increasing botanical knowledge of the Commonwealth. The lack of such studies was noted by Meijer in 1970.

The forest composition of Dinsmore's Woods is unique when compared to the other regions of the state since it is located on upland glacial till. Only a small portion of the state near the Ohio River, between Cincinnati and Louisville, was affected by the Illinoian glacier, whereas the rest of the state is considered to be unglaciated. Most of the other forest studies have been done on forests of the unglaciated regions. Martin (1973), in his analysis of Lilley Cornett Woods in Letcher County near the Virginia border, found that Fagus grandifolia Ehrh. and Acer rubrum L. were the dominant species. The predominance of Fagus grandifolia was also noted by Braun in 1942. Braun (1950) classifies that forest as being a Mixed Mesophytic Forest. However, in one of the coves of the woods, Acer saccharum is dominant. Thus this area can be considered more mesic than the other sections of Lilley Cornett Woods. Therefore, in the major forest regions of Kentucky, at least in the more mesic regions, Acer saccharum is a leading species.

Braun (1950) points out that it is apparent that the mesic forests of the glaciated area of Eastern North America are closely related to the mesic forests of the coves and valleys of the southern Appalachians and the Ozarks with Acer saccharum being a dominant species. Curtis (1959) states that this relatively great floristic homogeneity of the American mesic forests is a rare phenomenon not duplicated by any other major community. He counts both the long geologic history of the areas and the evolution of great shade tolerance of the dominant species as major factors in this homogeneity.

Bougher and Winstead (1974), in their study of a forest in Barren County in south-central Kentucky showed that the dominant species was Quercus alba. Acer saccharum was one of the least important species. The woods, known as Bonayr Forest, is located on a level portion of land in the upland of Barren County. This region is considered to be part of the Western Mesophytic Forest, as is Boone County (Braun, 1950). Therefore it is interesting to note that the various forest types that are combined to form the Western Mesophytic Forest lack a single pre-dominant climax type, and give this region a mosaic pattern, which is the result of present and past influences that operate in a region within recent time so that their effects on vegetation are still apparent (Braun, 1950).

One point that stands out in several studies of forest areas in Kentucky and Indiana is the similarity of total basal area per hectare. In Dinsmore's Woods it is 28.1 m^2 per hectare; in Lilley Cornett Woods, the total basal area was 30.0 m^2 per hectare (Martin, 1973a) for the area where Acer saccharum was dominant; and in Barren County, the total was 31.8 m^2 per hectare for trees over 5 cm dbh (Bougher and Winstead, 1974). When revising the data presented by Bougher and Winstead (1974), using only trees greater than 10 cm dbh, the total basal area is 30.2 m^2/hectare. In Donaldson's Woods, a climax forest in southern Indiana, the basal area was 28.7 m^2 per hectare (Lindsey, et al, 1958). Robinson Forest in Breathitt County, Kentucky which was logged prior to 1923 shows 29.766 m^2/hectare basal area on North Facing Slope dominated by Tulip Poplar, Magnolia and Black Locust (Hutchens, 1972). This parameter of forest ecosystems, the total basal area approximately 30.0 m^2 per hectare, may possibly be used to indicate and classify stable, climax forest communities. A search of the literature shows no reference to total basal area as a tool in the analysis of forest systems.

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