STUDIES ON VIRGIN HARDWOOD FOREST: I—DENSITY AND FREQUENCY OF THE WOODY PLANTS OF DONALDSON'S WOODS, LAWRENCE COUNTY, INDIANA

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I. Introduction. Primeval, or "virgin" forests, timbered areas which have never been lumbered or grazed, are rapidly becoming exceedingly rare and of small area in the central hardwoods region. Exact statistical knowledge of the condition of such relics of the widespread forest known to the Indian and the early pioneers is not at hand. The early botanists had the description of new species and matters of distribution to occupy their attention. The overworked foresters, coming into the field later, were largely pressed by economic problems arising from the vast tracts of second-growth hardwood, overgrazed woodlots, abandoned agricultural land and erosion. The magnificent "interminable" forests which played such a commonplace rôle in the lives of our forefathers have practically become extinct, to the wonder and surprise of a later generation gradually becoming "outdoor" conscious, largely through the activities of such organizations as the Indiana Department of Conservation. The recognition of the immediate necessity for detailed study of the few remaining undisturbed forest tracts is spreading. It is to be hoped that the next few years will see the necessary expenditure of time and money by several workers and organizations to enable the satisfactory building up of a botanical picture of the forests our forefathers found necessary to destroy for the advance of civilization.

American students of plant communities have never considered it feasible to undertake as intensive studies as have the European ecologists and plant geographers. Plant sociological concepts as expressed by Braun-Blanquet and Pavillard (2) in their "Vocabulaire de Sociologie Végetále" and Braun-Blanquet (1) in the text "Pflanzensoziologie" are even yet somewhat strange to most, and largely dismissed with some such remark as, "Our flora (American) is so much richer and our territories larger! We could never afford the time to do such work!" The last few years, however, have seen a start in this type of botanical investigation by foresters, for example, Lutz (12, 13), grazing investigators as Hanson (8, 9), Sampson (18), McGinnies (14), and other ecologists as Gleason (6, 7), Kenoyer (10, 11), Nichols (15), Romell (17), and others. In another paper the writer, Cain (4), has presented a general discussion of Braun-Blanquet's concepts with a form for a table which

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will permit the maximum condensation of data. The headings for this table are presented here to show, both the fragmentary nature of the present paper and the possibilities which lie ahead in the plan for a complete description of virgin hardwood communities. The present paper presents data on density, dominance or coverage, here in the aspect of *basal area*, and frequency, i. e., the quantitative analytical aspects of the organization of a community. (Table I; 1 a, b, c).

It is hoped that, when a bulk of data on virgin forests are obtained, light will be thrown on several perplexing problems in ecology. For example, among the several authors who have attempted to map the distribution of the deciduous forest formation, its associations and sub-

TABLE I

Sociologic Résumé												Species List
I Organization									II Synecology		III	
A Analytic							B Syn-thetic		A			
1 Quantitative			2 Qualitative						1 Physiog-nomy		Genetic Sociology	
a	b	c	a	b	c	d	a	b	a	b	a	
Abundance*	Dominance	Frequence	Sociability	Vitality	Periodicity	Stratification	Presence†	Fidelity	Life-form	Leaf-size	Dynamic Behavoir	
1-5	1-5	1-5	1-5	1-3	1-4	1-4	1-5	1-5	1-α	1-α	1-5	Classes

* Abundance, expressed numerically, or as per cent, on a unit area basis is termed "density".

† Presence, expressed numerically or as per cent, on a unit area basis is termed "constance".

Table I. The form for a table which permits the most compact assembling of plant sociological data. No American plant community has been studied sufficiently intensively to permit the construction of such a table.

Note: The quantitative data (1) are derived from quadrats; the analytic data (A) from the study of some one community; the synthetic data (B) from the study of several different examples (stands) of the same community. There are other sociologic concepts but these are the only ones permitting assignment to definite classes of the species composing a community, and hence, tabular presentation.

climaxes, there is considerable discrepancy; Weaver and Clements (22), Schantz and Zon (19), Shelford (20), etc., yet no great attention has been paid to virgin areas, especially in regions of slow physiographic change. Again, as Deam and others have suggested for common weed trees, such as persimmon (Diospyros), sassafras, etc., a tremendous increase in abundance since the clearing of the forests and the later abandonment of wide acreage, especially in hill regions, it occurs to the writer that certain forest trees in partially cut climax woods may enjoy a greater abundance than in primeval conditions. This may be the

Fig. 1. Maple reproduction under beech consociation, near Jasper, DuBois County, Indiana.

case in some instances in the Beech-Maple climax, for the selective cutting of more valuable trees as white oak (Quercus alba), tulip (Liriodendron tulipfera), walnut (Juglans nigra), etc., may have left the way open for maple and beech to rapidly reach a stage where they alone are codominants, or form consociations. Also, in some work in a small tract of virgin forest at Turkey Run State Park, Esten (5) has found evidence which may be interpreted to show that maple is succeeding beech. There is a scattering of very large old monarch white oaks, a strong dominance of beech and a heavy reproduction of sugar maple (Acer saccharum). In DuBois County, about five miles north of Jasper, Indiana, there are several tracts of virgin timber. Figure 1 shows a beech woods with maple undergrowth from this region. So it is that detailed statistical studies will contribute much to the finer aspects of succession and the matter of consociations and of later serial stages in various hardwood regions.

II. The Area. Donaldson's Woods is one of the attractions at Spring Mill State Park, located about three miles southeast of Mitchell, Lawrence County, Indiana. The county is entirely within the unglaciated south-central portion of the state, usually referred to as the "Knobs."

Physiographically the area is in the regional unit known as the Mitchell plain, composed in the main of residual soils formed from the Mitchell limestone. In the soil survey of the county, Bushnell (3), the soils of Donaldson's Woods are referred to the Frederick silt loam. The region of the Park presents a most excellent example of the karst topography, with numerous sinkholes, sinkhole ponds and caves characteristic of underground drainage. The general elevation of the region is approximately 700 feet above sea level.

There is no weather station at the Park, but data from Bedford, about 14 miles to the north, and from Salem, about 25 miles to the southeast, are presented below. The mean annual temperature for Bedford is 55.1 F. and for Salem is 54.2 F., giving an average for the vicinity of Spring Mill State Park of 54.65 F. The mean annual precipitation at Bedford is 40.35 inches and at Salem is 42.67 inches, giving an average for the vicinity of Spring Mill State Park of 41.5 inches. These mean figures are taken from the annual weather report summarizing all available data up to and including 1925. The following figures present monthly precipitation averages. This type of diagram, figure 2, the writer believes was first introduced by Prof. Transeau at the Oxford meeting of the Ohio Academy, 1931.

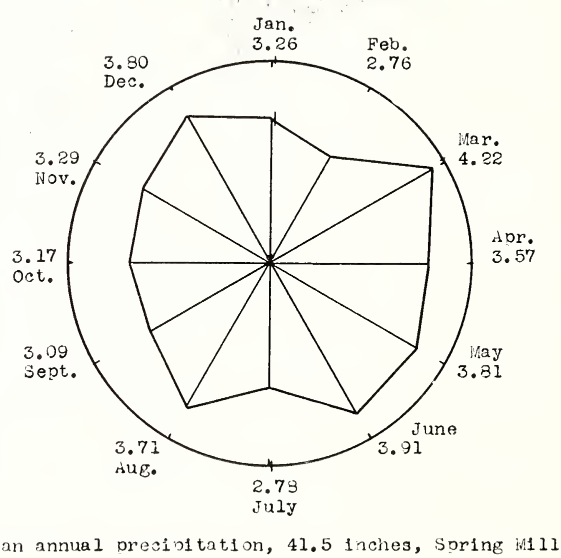

Fig. 2. Precipitation "rose" for the vicinity of Spring Mill State Park, constructed on the basis of monthly means.

III. The Vegetation. A. Methods. The shape and size of the tract to be studied was determined by running a line around the boundary with the aid of a steel tape and a U. S. Forest Service compass mounted on a Jacob's staff. From this outline map the location of the quadrats was determined to give maximum dispersal of twenty-five sets of quadrats well within the limits of the woods. Figure 3. The permanent quadrats consist of twenty-five plots, each 10 x 10 meters, for the study of all woody plants of one inch or more d. b. h. (diameter breast high, i. e., 4.5 feet above the ground). In the northeast corner of each of these quadrats was staked off additional ones 4 x 4 meters for the study by height classes of smaller woody plants. A study of herbaceous plants has not yet been made but the plan is to study one meter quadrats in each of the corners of the larger plots, as indicated in figure 3.

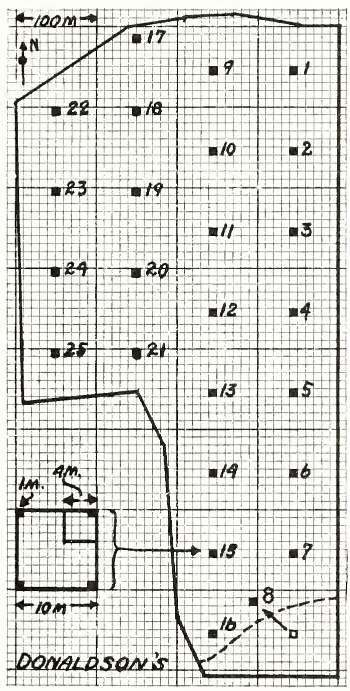

Fig. 3. Outline of Donaldson's Woods showing the position of 25 sets of permanent quadrats.

All quadrats were charted for permanent record. In the 100 meter quadrats the exact location and d. b. h. is given to scale for each stem over one inch. In the 16 meter quadrats the location and height by six inch classes is given, except for seedlings under six inches high, which are tabulated at the bottom of each quadrat sheet. For illustrations of the two types of quadrats see figures 4 and 5. From these data abundance, or rather *density*, which is abundance on a unit area basis, *frequence*, and basal area are computed. No effort was made to estimate *dominance* on a basis of coverage, by crown classes for each species. Collectively, however, the tree stratum would have class 5 coverage, 76-100 per cent. *Basal area*, which can be considered as one aspect of coverage, is computed from the results of the 25 10 x 10 m. quadrats.

Certain of the more important species are presented in a comparative manner by means of *phytographs,* a type of diagram devised by Lutz (12). The four axes of the phytographs are percentage expressions of (1) abundance of stems 10 inches d. b. h. or over, (2) frequency of stems 10 inches or over, (3) size classes in which the species is found (see Table V), and (4) basal area.

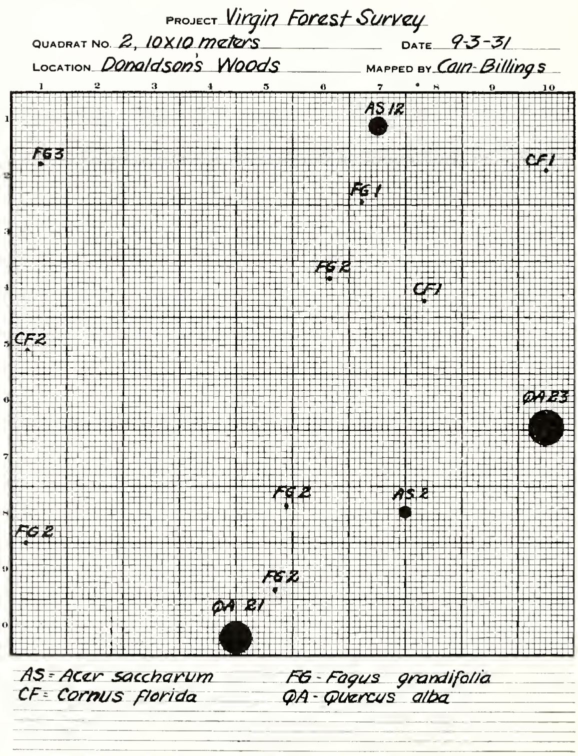

Fig. 4. Sample quadrat sheet in which position and diameters of trees are indicated.

The field work was always done by two men. Exact compass lines were maintained for control, linear measurements and heights were made by metric steel tapes, while diameters were determined by calipers except for stems over 36 inches d. b. h. One man measured and the other recorded or charted as the case required.

B. Results. The results of this statistical study are considered under three headings, density, basal area, and frequency. Table II shows the symbols used in charting the 45 species of woody plants encountered in the survey. There may be a few other species which were unobserved. At the present, however, only *Campsis radicans* and *Celtis pumila* are to be added to the list.

Considering Table III which presents the density of all species encountered in the 25 quadrats, which were 10 x 10 meters in size, by inch classes, we find a total of 309 stems in 2,500 sq. m. area. This survey is approximately 1 per cent of the tract of 61 acres. The one, two and three inch diameter classes contain about 70 per cent of the total number of stems. The following species have stems 10 inches

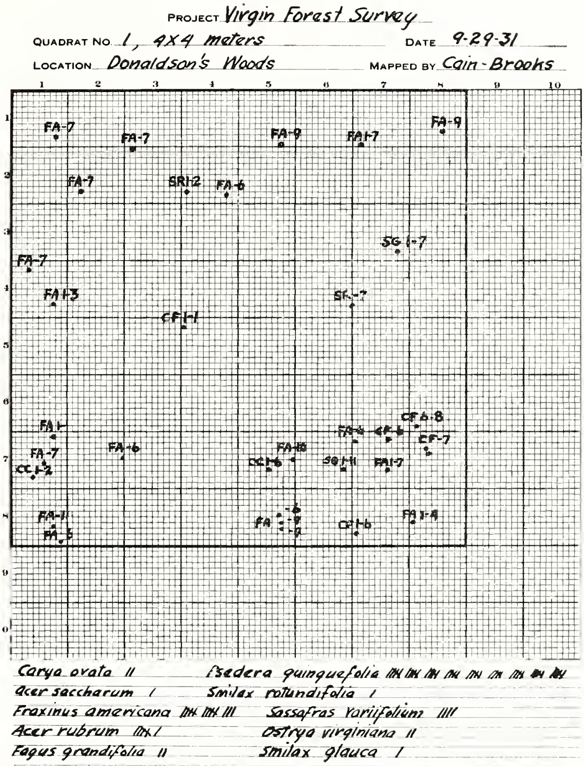

Fig. 5. Sample quadrat sheet in which position and height of woody plants are recorded from permanent quadrat.

d. b. h. or over: *Acer saccharum, Carya glabra, Carya laciniosa, Fagus grandifolia, Fraxinus americana, Liriodendron tulipifera, Nyssa sylvatica Quercus alba, Quercus borealis* var. *maxima, Quercus velutina.* The most consistently represented species in the larger size classes is *Quercus alba,* with a maximum of 47 inches d. b. h. *Liriodendron tulipifera* is next with a maximum of 34 inches, although there were larger trees present in the tract outside the quadrats. Referring to Table IX, the species of greatest density are *Acer saccharum* with 43 stems, *Fagus grandifolia* with 36 stems, *Fraxinus americana* with 36 stems and *Quercus alba* with 26 stems. Among the small trees, *Cornus florida* is the only one of the six species of any abundance, with 98 stems.

TABLE II

Symbols used on quadrat maps for species of Donaldson's Woods

AR —Acer rubrum
AS —Acer saccharum
AC —Amelanchier canadensis
AT —Asimina triloba
BA —Benzoin aestivale
CaC —Carpinus caroliniana
CCd —Carya cordiformis
CG —Carya glabra
CL —Carya laciniosa
CO —Carya ovata
CS —Celastrus scandens
CLO —Celtis occidentalis
CC —Cercis canadensis
CF —Cornus florida
COb —Cornus obliqua
CA —Corylus americana
CR? —Crataegus sp?
EV —Evonymus atropurpureus
FG —Fagus grandifolia
FA —Fraxinus americana
FL —Fraxinus lanceolata
JN —Juglans nigra
LT —Liriodendron tulipifera
MC —Menispermum canadense
MR —Morus rubra
NS —Nyssa sylvatica
OV —Ostrya virginiana
PS —Prunus serotina
PQ —Parthanocissus quinquefolia
QA —Quercus alba
QI —Quercus imbricaria
QM —Quercus Muhlenbergii
QR —Quercus borealis var. maxima
QV —Quercus velutina
RR —Rhus radicans
SV —Sassafras officinale
SG —Smilax glauca
SR —Smilax rotundifolia
SO —Symphoricarpus orbiculatus
UF —Ulmus fulva
VV —Vaccinium vacillans
ViA —Viburnum acerifolium
VP —Viburnum prunifolium
VPD—Viburnum pubescens deamii
VA —Vitis aestivalis

TABLE III

Density of species by inch diameter classes from 25 quadrats, 10 x 10 meters: Donaldson's Woods

In. DBH	AR	AS	CG	CL	CO	CC	CF	FG	FA	LT	MR	NS	OV	QA	QR	QV	SV	VP	VA	Total
1	5	17	5	1	4	1	38	6	21	....	2	1	3	1	1	....	....	1	....	106
2	1	8	3	1	4	2	34	9	10	....	1	2	1	1	....	....	1	....	1	78
3	3	12	....	....	3	....	19	5	4	....	1	1	2	....	....	....	....	....	....	50
4	1	1	....	....	2	....	7	1	....	....	....	....	1	1	....	....	....	....	....	14
5	3	1	1	....	....	....	....	2	....	....	....	....	....	1	....	....	....	....	....	8
6	2	1	....	....	2	....	....	2	....	....	1	....	....	2	....	....	....	....	....	10
7	....	....	....	....	1	....	....	1	....	....	....	....	....	....	....	....	....	....	....	2
8	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2
9	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	1
10	....	1	....	....	....	....	....	....	....	....	....	1	....	1	....	....	....	....	....	3
11	....	....	....	....	....	....	....	1	....	....	....	....	....	....	1	....	....	....	....	2
12	....	1	....	1	....	....	....	....	1	....	....	....	....	1	....	....	....	....	....	4
13	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	1
15	....	....	....	....	....	....	....	....	....	1	....	1	....	2	....	....	....	....	....	4
17	....	....	2	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	3
19	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	1
21	....	....	....	....	....	....	....	....	....	....	....	....	....	2	....	....	....	....	....	2
22	....	....	....	....	....	....	....	....	....	....	....	....	....	3	....	....	....	....	....	3
23	....	....	....	....	....	....	....	....	....	....	....	....	....	2	1	....	....	....	....	3
24	....	....	....	....	....	....	....	....	....	....	....	....	....	2	....	....	....	....	....	2
25	....	....	....	....	....	....	....	....	....	....	....	....	....	2	....	....	....	....	....	2
26	....	....	1	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	2
27	....	....	....	....	....	....	....	....	....	1	....	....	....	1	....	....	....	....	....	2
28	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	1
34	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	1
42	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	1
47	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	1
																				309

[1] The scientific names used in this paper follow Deam's publications on trees and shrubs: Deam, C. C. "Trees of Indiana," Indiana Department of Conservation, 1932. Deam, C. C. "Shrubs of Indiana," Indiana Department of Conservation, 1924.

Table IV presents the density of all species encountered in 25 quadrats, each 4 x 4 meters, by six inch height classes. These include all plants under one inch d. b. h. of a woody nature. Any over 9.5 feet high, yet less than one inch in diameter are put in the last column. The species well represented throughout the height classes are: (AS)

TABLE IV

Density of species by height classes (under 1 inch d. b. h.) derived from 25 quadrats 4 x 4 meters: Donaldson's Woods

Height by Feet

Symb.	.5—	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	plus
AR	106	17	5	2				1											1		1
AS	19	6	3	5	1		1		2	1	1		1		1		2		1		
AC	2																				
AT	6	1	4	2	1		1	1			1					2			1		
BA	32	6	18	1	1	2	1	1	4	1											
CaC	64	13	4	1	1		1	1	2	1											
CCd	4	2	1				2		1				1								
CG	43	15	6	1	8	2	3	2	2	1	1				3						1
CL			2	1		1	1														
CO	3						1														
CS	11	1	1																		
ClO	1																				
CC	27	2	4	2	1				1												2
CF	47	40	21	7	7	2	1		1	1	4			1	1	2	1				
COb	1																				
CA	3		3	5	1	1															
Cr?	2	1						1													
EA	1																				
FG	2	5										2									
FA	93	57	34	12	8	8	6	6	2		4	1	1	1	2	2	1	1	2	1	2
LT	10		1																		
MC	1	1		1																	
MR	5	2	2		2	1	1					1	1		1						
NS	2	1	1	2	2	1								1					1	1	
OV	19	2	1		1					1											
PS	20	3	5	2																	
PQ	1,432	2																			
QA	47	5																			
QR	2	3																			
RR	46	2	1																		
SV	48	3	3																		
SG	15	3	1	1																	
SR	83	6	3	1	1				1				1	1							
SO			2		1																
UF	57	22	7	2			1	1			2						1			1	
VV	9	10	1																		
ViA	21	8	8	4		1															
VP	2	2	2	1		1															
VPD	2		1																		
VA	13	6	5	2	4						1										

Acer saccharum, (CG) *Carya glabra,* (CF) *Cornus florida,* (FA) *Fraxinus americana,* (NS) *Nyssa sylvatica,* (UF) *Ulmus fulva.* In the smallest height class (AR) *Acer rubrum* shows especially heavy reproduction. Beech, (FG) *Fagus grandifolia* is conspicuously low in these small sizes although it holds up well in the larger size classes.

Computing on a common basis of 2,500 sq. m. area the following interesting contrast in density of size classes is found:

Woody plants under 1 in. d. b. h.	7,100
Woody plants from 1 to 9 in. d. b. h.	309
Woody plants 10 in. d. b. h. or over	38

8—47716

TABLE V

Density of 11 species illustrated in the phytographs by five size classes (Based on 25 quadrats, 10 x 10 meters)

Species	up to 1 ft. high	1.5-12 ft. high	1-3 in. D. B. H.	4-9 in. D. B. H.	10 in. and over
Quercus alba	325	....	2	5	19
Quercus borealis var. maxima	31	....	1	....	3
Liriodendron tulipifera	69	....	....	....	3
Fagus grandifolia	44	12	20	6	2
Nyssa sylvatica	25	50	4	....	3
Acer rubrum	800	31	9	7	....
Carya cordiformis	44	25	....	....	....
Carya glabra	400	150	8	1	3
Fraxinus americana	1,150	319	35	....	1
Acer saccharum	175	100	37	4	2
Cornus florida	675	194	91	7	....

The basic figures for the sizes under 1 inch D.B.H. were taken from the 4 x 4 quadrats and multiplied by the figure necessary to make them equal to the density for 10 x 10 m. quadrats.

TABLE VI

Woody plants of Donaldson's Woods according to frequency derived from species 1 inch d. b. h. or over from 25 quadrats 10 x 10 meters each.

Class E, 1 species of 81-100% frequency—
- CF—Cornus florida 92%

Class D, 2 species of 61-80% frequency—
- QA—Quercus alba 72%
- AS—Acer saccharum 68%

Class C, 3 species of 41-60% frequency—
- FG—Fagus grandifolia 48%
- FA—Fraxinus americana 48%
- CO—Carya ovata 44%

Class B, 2 species of 21-40% frequency—
- AR—Acer rubrum 40%
- CG—Carya glabra 24%

Class A, 11 species of 1-20% frequency—
- NS—Nyssa sylvatica 20%
- LT—Liriodendron tulipifera 12%
- QR—Quercus borealis var. maxima.......... 12%
- OV—Ostyra virginiana 12%
- CL—Carya laciniosa 8%
- MR—Morus rubra 8%
- CC—Cercis canadensis 4%
- QV—Quercus velutina 4%
- SO—Sassafras officinale 4%
- VP—Virburnum prunifolium 4%
- VA—Vitis aestivalis 4%

TABLE VII

Woody plants of Donaldson's Woods according to frequency derived from species less than 1 inch d. b. h. from 25 quadrats 4 x 4 meters.

Class E, 4 species of 81-100% frequency—	
FA—Fraxinus americana	96%
CG—Carya glabra	84%
CF—Cornus florida	88%
PQ—Parthenocissus quinquefolia	84%
Class D, 5 species of 61-80% frequency—	
UF—Ulmus fulva	80%
AR—Acer rubrum	64%
QA—Quercus alba	64%
SR—Smilax rotundifolia	80%
SO—Sassafras officinale	68%
Class C, 6 species of 41-60% frequency—	
AS—Acer saccharum	56%
PS—Prunus serotina	48%
CC—Cercis canadensis	56%
VA—Vitis aestivalis	48%
RR—Rhus radicans	44%
ViA—Viburnum aerifolium	44%
Class B, 8 species of 2-40% frequency—	
NS—Nyssa sylvatica	36%
LT—Liriodendron tulipifera	24%
CCd—Carya cordiformis	24%
CaC—Carpinus caroliniana	36%
BA—Benzoin aestivale	28%
MR—Morus rubra	28%
SG—Smilax glauca	28%
OV—Ostrya virginiana	24%
Class A, 17 species of 1-20% frequency—	
FG—Fagus grandifolia	20%
CO—Carya ovata	12%
QR—Quercus borealis var. maxima	12%
CL—Carya laciniosa	8%
ClO—Celtis occidentalis	4%
CS—Celastrus scandens	20%
VP—Viburnum prunifolium	20%
CA—Corylus americana	16%
Cr?—Crataegus sp?	12%
SO—Symphoricarpus orbiculatus	8%
VPD—Viburnum pubescens var. deamii	8%
AT—Asimina triloba	4%
COb—Cornus obliqua	4%
EA—Evonymus atropurpureus	4%
AC—Amelanchier canadensis	4%
MC—Menispermum canadensis	4%
VV—Vaccinium vacillans	4%

On a basis of the 1 per cent survey there are 521 trees per acre one inch D. B. H. or over, while of the sizes less than that there are approximately 23,000 stems. The latter number is greatly increased by the abundance of (PG) *Parthenocissus quinquefolia*, the virginia creeper; (RR) *Rhus radicans*, the poison ivy, etc.

Table V gives the density of the species illustrated by the phytographs at the close of this section, on a basis of five size classes.

The frequence of species is usually expressed by five classes, or directly in percentages. Frequence refers to the number of quadrats in

TABLE VIII

Comparison of frequency of species from 2 sets of quadrats: 25 quadrats, 10 x 10 meters; 25 quadrats, 4 x 4 meters

Species	Frequency Percent			Life Form
	10x10m. 1 in. D. B. H. or over	4x4m. under 1 in. D. B. H.	Difference	
Cornus florida	92%	88%	plus 4	small tree
Quercus alba	72	64	plus 8	tree
Acer saccharum	68	56	plus 12	tree
Fagus grandifolia	48	20	plus 28	tree
Fraxinus americana	48	96	minus 48	tree
Carya ovata	44	12	plus 32	tree
Acer rubrum	40	64	minus 24	tree
Carya glabra	24	84	minus 60	tree
Nyssa sylvatica	20	36	minus 16	tree
Liriodendron tulipifera	12	24	minus 12	tree
Quercus borealis var. maxima	12	12	0	tree
Ostrya virginiana	12	24	minus 12	small tree
Carya laciniosa	8	8	0	tree
Morus rubra	8	28	minus 20	small tree
Cercis canadensis	4	56	minus 52	small tree
Quercus velutina	4	0	plus 4	tree
Sassafras officinale	4	68	minus 64	small tree
Viburnum prunifolium	4	20	minus 16	small tree
Vitis aestivalis	4	48	minus 44	vine

which a species occurs and is expressed in terms of per cent of the total number of quadrats examined in the particular study. For example, if a certain species is found in 10 out of 100 quadrats examined, totally disregarding the abundance of the species, it would have 10 per cent frequence. Again, if it was found in 23 out of 25 quadrats the frequency would be 92 per cent. It has been found more convenient and easier to comprehend if the frequency percentages from all the species in a community analyzed are thrown into five classes. Frequency class 1 contains all species from 1 to 20 per cent frequent, and similarly, F.2 contains those from 21 to 40 per cent; F.3, 41 to 60 per cent; F.4, 61 to 80 per cent, and F.5, 81 to 100 per cent. These classes are sometimes referred to as A>B>C>D<E in which each succeeding class is smaller except the last, Class E being larger than D under normal conditions.

Briefly then, this means that there are more species in a community which will be found to have low frequency. In Table VI, for example, there is only one species in Class E while there are 11 species in Class A. In this table the frequency is computed on a basis of the occurrence of a species in the 25 quadrats, each of 100 sq. m., considering only woody plants of 1 inch d. b. h. or more. Table VII is similar, but considers only woody plants of sizes under 1 inch d. b. h. from smaller quadrats,

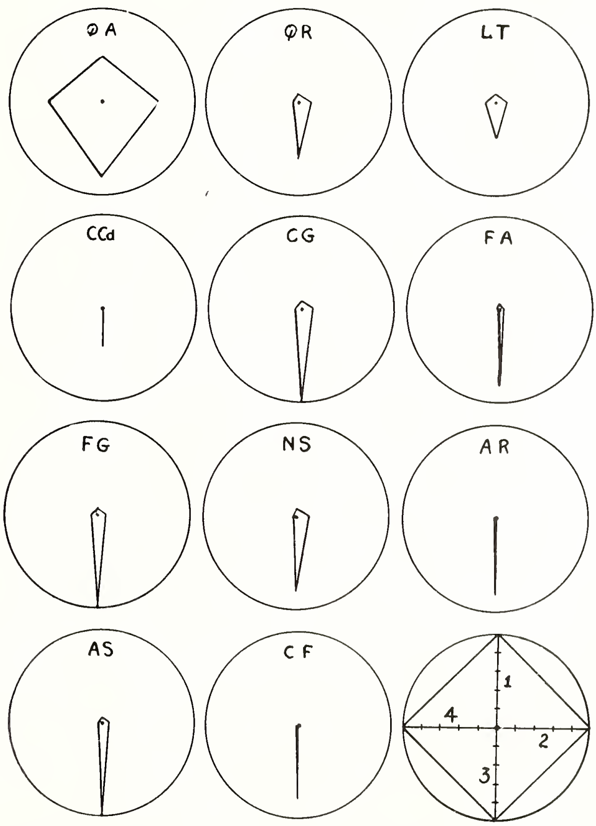

Fig. 6. Phytographs of the more important trees of Donaldson's Woods.

25 of them, 4 x 4 meters. Table VIII presents the differences found from the two computations.

Basal area is the cross-sectional area of a tree or stand, in square feet measured at four and one-half feet above the ground, (d. b. h.) This is obtained from area of circles whose diameters equal those of the trees measured. There is never any attempt to account for the fact that the tree is seldom a circle in cross-section, except to average diameters at right angles when the tree is especially a-symmetrical. Table IX presents the results of the basal area computations from the one per cent survey (10 x 10 m. quadrats) together with similar data from a 10 per cent survey. For the latter, strips connecting the quadrats in a

TABLE IX

Basal Area Study of Donaldson's Woods

SPECIES	1% Survey				10% Survey			
	25 quads 10 x 10 m. .61 acres B.A., sq. ft.	No. stems	Average B. A. per stem	B. A. per acre sq. ft.	10 m. strips	No. stems	Average B. A. per stem	B. A. per acre sq. ft.
Quercus alba	64.904	**26**	**2.500**	**106.40**	380.527	**203**	1.878	**62.38**
Quercus borealis var. maxima	4.475	4	1.119	7.33	69.186	48	1.441	**11.34**
Liriodendron tulipifera	11.510	3	**3.837**	**18.87**	50.905	23	**2.213**	**8.34**
Fagus grandifolia	5.890	**36**	.164	**9.66**	26.838	**209**	.128	**4.40**
Nyssa sylvatica	3.453	7	.493	5.66	18.315	53	.346	3.00
Acer rubrum	1.430	16	.089	2.34	17.635	**104**	.170	2.89
Carya cordiformis					16.856	11	1.532	2.76
Carya glabra	7.077	12	.590	**11.60**	16.551	88	.188	2.71
Fraxinus americana	1.360	**36**	.038	2.23	15.821	**187**	.084	2.60
Juglans nigra					14.110	4	**3.527**	2.31
Acer saccharum	2.947	43	.068	4.83	12.602	**235**	.054	2.07
Carya ovata	1.088	16	.068	1.78	10.389	58	.179	1.70
Carya laciniosa	812	3	.271	1.33	thrown with Carya ovata			
Quercus velutina	4.280	1	4.280	7.01	thrown with Quercus borealis var. maxima			
Quercus imbricaria					3.546	2	1.773	.58
Quercus muhlenbergii					2.890	1	2.890	.48
Ulmus fulva					2.014	22	.091	.33
Celtis occidentalis					.228	3	.076	.04
Prunus serotina					.196	1	.196	.03
Cornus florida	2.478	**98**	.025	**4.06**	18.438	**713**	.025	**3.02**
Sassafras officinale	.022	1	.022	.04	2.759	25	.110	.45
Ostrya virginiana	.222	7	.032	.36	2.758	107	.026	.45
Carpinus caroliniana					1.148	42	.027	.19
Morus rubra	.277	5	.055	.45	.648	17	.037	.10
Cercis canadensis	.049	3	.016	.08	.189	10	.019	.03
Asimina triloba					.020	4	.005	.003
Amelanchier canadensis					.015	3	.005	.002
Viburnum prunifolium	.005	1	.005	.01	.010	2	.005	.001
26 species		318 **521 per acre**		184.14 sq. ft.		2,175 **357 per acre**		112.206 sq. ft.

north-south direction were examined. These strips were 10 m. wide (approximately one-half chain) and were 90 m. between strips. The discrepancy between the two talleys when expressed on an acre basis is difficult to account for. Certainly the ten per cent cruise is the most reliable as a measure of the stand. It may have so happened that especially large trees fell in the 25 quadrats. Both surveys reveal the importance of the following species: *Quercus alba, Liriodendron tulipifera, Fagus grandifolia* and *Acer saccharum*. *Cornus florida* is conspicuously the most important of the small trees.

In Table X is found the data used for the construction of the phytographs. See Figure 6. *Quercus alba* is shown to be especially important, rating high in respect to all four of the criteria, abundance, frequency, distribution through size classes and basal area. For the method of computation of these data see Table X.

C. **Discussion.** In 1927 *Tillotson* (21) said that the Central Hardwood Region included about 40,000,000 acres of woodland in Ohio, Indiana, Illinois, Iowa and Missouri, the southern portions of Michigan, Wisconsin and Minnesota, the eastern edge of Nebraska and Kansas, the northeastern corner of Oklahoma, northern Arkansas and western half of Kentucky and Tennessee. About "three-fourths of the timberproducing acreage is in the form of farm wood lots, generally 10 to 40 acres in extent. Continual cutting of the best species and individuals, forest fires, and heavy pasturing have rendered these stands badly dilapidated and decadent . . . . so that the greater portion of the timber is on a slow but seemingly sure march to extinction. . . . . unless present practices are materially altered. A few virgin stands are still in existence, generally individual pieces of timberland held off the market for personal reasons by the owners, or else stands relatively inaccessible." The Central Hardwood Forest Experiment Station men found it difficult to locate some thirty-odd tracts of virgin timber for scientific studies of soil conditions, etc. *Pegg* and *Thomas* (16), writing in 1909 concerning the advisability of scientifically controlled wood lots for Indiana, remark on the rapid depletion of the timber. "Official records, which begin in 1870, show an acreage of 7,189,334 acres in timbered lands in Indiana. In 1880 only 4,335,000 acres were left. By 1890 over 2,500,000 acres more were cleared, of which 75,000 acres became waste land. Then Indiana ranked fifth with the states of the Union in the total output of lumber. In 1907 she ranked twenty-seventh."

Wherever one reads about forestry conditions one finds essentially the same story, with the exception, however, of an upward look in some states, especially those with classified land taxation. There are two common points of view concerning forest land. The one which held sway too long and completely was that trees are to be cut for their immediate profit, regardless of future consequences, the result being our

TABLE X

Data for Construction of Phytographs: 11 Species

Species	Radius 1: Abundance	Radius 2: Frequency	Radius 3: No. of Size Classes	Radius 4: Basal Area
Quercus alba	50%	56%	4	58%
Quercus borealis var. maxima	8	12	3	4
Liriodendron tulipifera	8	12	2	10
Fagus grandifolia	5	8	5	5
Nyssa sylvatica	8	12	4	3
Acer rubrum	....	....	4	1
Carya cordiformis	....	....	2	....
Carya glabra	8	12	5	6
Fraxinus americana	4	4	4	1
Acer saccharum	5	8	5	3
Cornus florida	....	....	4	2

1—*Abundance:* each species figured as a per cent of the total number of stems 10 inches D.B.H. or over.

2—*Frequency:* each species figured on a basis of the 25 quadrats, 10 x 10 meters, i.e. per cent of quadrats containing stems 10 inches D.B.H. or over.

3—*Size Classes:* each species indicated according to the number of the five size classes in which it is found. See table V.

4—*Basal Area:* each species expressed as a per cent of the total basal area of all species computed on a basis of sq.ft. per acre.

present conditions; the other too sentimental and impractical, that not a tree should be cut. We have people with the latter point of view to thank, however, for the preservation of the few remaining tracts of virgin hardwood in the Central West. Between waste and exploitation, and sentiment, is the rational viewpoint of the forester, considering the forests to be a long-rotation crop, to be utilized, yet perpetuated. One

Fig. 7. One of several handsome specimens of Yellow Poplar, *Liriodendron tulipifera*, found in Donaldson's Woods.

cannot help but wish, at this late date, that seventy-five or a hundred years ago some one had thought of establishing state parks, so that larger areas of primeval forest would have been preserved for recreation, inspiration and as museums and scientific laboratories. The small areas which remain at Turkey Run, Spring Mill, and under private ownership are none the less admirable. It behooves the present generation of botanists and zoologists to study these tracts intensively before they, too, diminish or are modified.

Virgin forests are uneven-aged, over-ripe old monarchs overtopping and choking off the reproduction. When the pioneers first came it was not uncommon to find yellow poplar, oak and other species 150, 175 and almost 200 feet high with a girth of 25 feet. Today such a handsome tree as the poplar in Figure 7 is a monument, and trees five to six feet in diameter worthy of a long pilgrimage to see. Everywhere under these large trees the smaller trees, shrubs and herbaceous plants struggle for light while their root systems undergo severe competition for moisture. A spongy mass of forest litter makes a floor that holds rainfall and yet makes difficult the germination of certain lighter seeds. Very striking, however, is the abundant reproduction in the smaller size classes; seedlings up to a foot or so in height and saplings one to three inches or so in diameter. Everywhere they are waiting for one of the old trees to die and make an opening in the dense canopy into which they can grow in the severe struggle for existence. One needs only to examine the tables in this paper for examples of this situation. Yet to use such data for interpretation of matters of succession is extremely hazardous, for the elements of chance play a large part in what species are present at the right time and place to take advantage of opportunities for survival. For example, on a basis of a single study, such as this one of Donaldson's Woods, it would be unwise to say that white oak and yellow poplar; at present of high dominance, will be replaced by sugar maple, white ash and beech as the dominants die off, simply because of their greater density in the smaller size classes. Something of survival ability in the intermediate ages must be known. Then there is the matter of good and bad seed years for different species. The large number of seedlings of *Acer rubrum*, *Carya glabra*, *Fraxinus americana*, and *Ulmus fulva* may only be a temporary aspect. These are the matters which make the establishment of permanent quadrats important and the study of several comparable stands imperative if any adequate knowledge of virgin forest conditions is to be attained.

IV. Summary and Conclusions. Permanent quadrats have been established in a virgin forest tract known as Donaldson's Woods, located at Spring Mill State Park, where they will be protected and available for future study. Detailed investigation has been made of density, frequency and basal area of the woody plants encountered in the survey, which data, however, are only a fragment of the complete sociological study of the vegetation which it is proposed to complete as rapidly as time permits. Similar studies on other virgin forest tracts are to be undertaken so that data will be comparable and certain synthetic concepts built up. It is hoped that ample facilities will be provided for the larger task.

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