Comparison of Donaldson's Woods in 1964 with its 1954 Forest Map of 20 Acres

ALTON A. LINDSEY and DAMIAN V. SCHMELZ[1]
Department of Biological Sciences, Purdue University

Donaldson's Woods is an 80-acre stand of original mixed-mesophytic forest in Spring Mill State Park, Lawrence County, Indiana. Because of many very large white oaks and tulip trees, this is the most impressive forest in the state. Following the growing season in 1954, field data were collected for construction of a two-dimensional model of 20 acres at a scale of 1:36, showing the position and basal area of each tree 4 in. d.b.h. or over. An evaluation of 9 methods of forest sampling (1) was based on this large scale map.

Ten growing seasons after the original mapping, the present writers (2), in late July, 1964, made a tree-for-tree comparison of the 20 acres as of the beginning and end of this interval. Ozalid copies of the tracing linen map sections were used in the woods, and each tree was located and measured with a diameter tape. Individuals that had grown past the 4-in. diameter threshold were added to the map; trees that had died or come down were so recorded. The map sections, assembled later in the laboratory into a flat model 37 x 18 ft., provided data for a study of population dynamics in the mature tree stratum during a decade of forest history during which almost no human disturbance affected the stand.

Trees[2] New to the Record

Since individuals smaller than 4 inches d.b.h. were disregarded both at the beginning and end of the decade, trees growing across the 4-inch d.b.h. lower limit of recorded trees were newly recorded in 1964 in the sizes from 4 to 8 inches. Table 1 gives their numbers and basal area sums for 2-inch size classes having midpoints at 5 and 7 inches, under the heading "new".

Many sugar maples and a moderate number of beech, American ash, and flowering dogwood grew across the 4-inch threshold. But only 4 small white oaks did so. The basal area sum of the new sugar maples was greater than that of the other 24 species combined.

Six individuals (Table 1) that were too small to count in 1954 had entered the 7-inch midpoint size class by 1964. Four of these were sugar maple.

The gross or absolute gain of new trees was 179 in all, or 9.1 individuals per acre, representing a gross increase in basal area of only 1.06 sq. ft. per acre from trees that were less than 4-inch d.b.h. in 1954.

[1]The second-named author is a teaching priest at St. Meinrad College, St. Meinrad, Indiana.

[2]Qa is Quercus alba, Fg Fagus grandifolia, As Acer saccharum, Co Carya ovata, Qr Quercus rubra, Ns Nyssa sylvatica, Ar Acer rubrum, Cg Carya glabra, Fa Fraxinus americana, Qv Quercus velutina, Lt Liriodendron tulipifera, Cl Carya laciniosa, Ov Ostrya virginiana, Cc Carya cordiformis, Cf Cornus florida, and others (less than 1 per cent density in tables) are Fraxinus pennsylvanica, Juglans nigra, Sassafras albidum, Ulmus rubra, U. americana Carpinus caroliniana, Tilia americana, Celtis occidentalis, Ulmus thomasi and Morus rubra.

TABLE 1

Accessions and deaths of trees in 19.57 acres in the two smallest two-inch size-classes, between the 1954 and 1964 studies. Figures for each species show numbers of individuals (No.) and sum of their basal areas. (B.A. sum) in square feet. Species symbols are identified in the earlier footnote.

Species	5 inch class				7 inch class			
	No.		B.A. Sum		No.		B.A. Sum	
	New	Died	New	Died	New	Died	New	Died
Qa	4	13	0.48	1.72	....	9	....	2.27
Fg	23	24	2.66	2.77	1	11	0.25	2.36
As	94	10	10.6	1.24	4	....	0.87	......
Co	1	4	0.10	0.58	....	1	......	0.21
Qr	1	......	0.09	....	....	....	......	......
Cg	3	11	0.37	1.49	....	4	......	0.91
Ns	3	7	0.36	0.87	....	1	......	0.32
Ar	8	4	1.04	0.55	....	4	......	1.18
Fa	13	7	1.50	0.74	1	1	0.20	0.20
Cl	......	2	....	0.21	....	....	......	......
Cc	......	2	....	0.32	....	....	......	......
Ov	6	3	0.59	0.22	....	1	......	0.20
Cf	13	8	1.30	0.92	....	....	......	......
Others	4	6	0.43	0.74	....	1	......	0.28
Totals	173	101	19.4	12.4	6	33	1.32	7.93

Mortality

At least 15 trees died from windthrow in the 19.6 acres since 1954, when their basal area had totaled 36.6 sq. ft., or nearly 2 sq. ft. per acre. Eight of these were white oaks, ranging in d.b.h. from 5.6 to 37.7 in. and having had 29.0 sq. ft. basal area sum. Three windthrown white oaks had exceeded 30 in. d.b.h. A black oak 27.6 in. was windthrown. The 1954 basal area sum of the 7 recognizably windthrown trees other than white oak was 7.66 sq. ft.

Small trees (Fg 6.2, 6.4 in.; As 4.0; Ar. 5.5; Fp 9.2) killed were seldom directly blown over or broken off, but were borne down by larger windthrown trees or large falling limbs. Figures on mortality by wind were certainly conservative, because windthrow could usually be definitely ascertained only in trees killed fairly late in the decade. Mortality figures are in Tables 1 and 2.

The most striking observation in the field was the surprisingly rapid rate of decay of fallen trees that had been alive and standing in 1954. In several instances, we would have judged that such logs had been lying on the ground for several decades. A prostrate trunk from a tree about 12 in. d.b.h. would usually have been reduced to half its original volume or less. Often little or no sign of a fallen tree of the 6 in. size class remained. The normal annual precipitation of approximately 42 in., and the normal annual temperature mean of 55° F., are high for Indiana.

Use of a bridle trail along the east edge of the study area was begun during the decade. It followed a ridge where tree growth was somewhat more open and a higher proportion of small trees occurred.

Even though no trees were cut for the trail, several small trees died from soil trampling. Nowhere else in the stand was there any disturbance brought about by human activities, since the foot trail (Trail 3) has existed since long before 1954 and has not caused tree mortality recently.

Death of the small trees (Table 1) that had been living in 1954 was generally due to shading and suppression. Data in the table suggest greater shade tolerance for sugar maple than for beech; the latter nearly held its own in the 5-inch class but fell off badly in the next class. White oak of these sizes survived very poorly, and very few new accessions of this species entered these classes. This is probably not entirely due to low tolerance, for a number appeared to be hard hit by the white oak bacterial bark disease.

Table 2 compares deaths within species groups throughout the size-class range. In white oak, mortality accounted for 3.90 sq. ft. basal area per acre. All oak species lost 4.87 sq. ft., all hickories lost 0.82. The combined oak-hickory group had an actual (not net) loss of 5.7 individuals per acre, which had 5.69 sq. ft. per acre of basal area. In contrast, beech and sugar maple combined lost only 2.1 trees per acre with 0.62 sq. ft. per acre. Only one sugar maple over 6 in. d.b.h. died; however, there were very few large sugar maples available.

TABLE 2

Number of individuals lost by death and their actual basal area sums in 19.57 acre stand for all size class of *Quercus alba* (separately) and the species groups *Q. rubra*—*Q. velutina*, all Carya species, and the Fagus—Acer saccharum group. Last column is for all other species combined.

Size	Qa		Qr, Qv		Co, Cg, Cl, Cc		Fg, As		Others	
Class	No.	B.A.	No.	B.A.	No.	B.A.	No.	B.A.	No.	B.A.
5	13	1.72	....	....	19	2.60	34	4.01	35	4.17
7	9	2.27	....	....	5	1.12	11	2.36	8	2.18
9	7	3.06	....	....	2	0.87	1	0.38	6	2.56
11	1	0.67	1	0.66	2	1.19	2	1.28	7	4.70
13	2	1.95	2	1.72	2	1.76	1	0.86	4	3.58
15	4	5.21	1	1.07	....	....	....	....	....	....
17	2	3.08	1	1.67	....	....	2	3.34	....	....
19	....	....	1	2.07	....	....	....	....	....	....
21	....	....	....	....	1	2.36	....	....	....	....
23	1	3.08	....	....	1	3.01	....	....	....	....
25	....	....	....	....	1	3.19	....	....	....	....
27	....	....	3	11.8	....	....	....	....	....	....
29	2	9.18	....	....	....	....	....	....	....	....
31	2	10.1	....	....	....	....	....	....	....	....
33	3	17.4	....	....	....	....	....	....	....	....
35	1	6.49	....	....	....	....	....	....	....	....
37	1	7.75	....	....	....	....	....	....	....	....
47	1	12.25	....	....	....	....	....	....	....	....
	49	84.2	9	19.0	33	16.1	51	12.2	60	17.2

In summary, 10.3 trees died on the average acre in the 10 year period, representing 7.6 sq. ft. of basal area as of 1954. Subtracting 7.6 from the 121.8 sq. ft. which the 118.6 individuals per acre had in 1954, gives 114.2 sq. ft. per acre represented by the 108 surviving trees.

Gross and Net Growth

Since the above-mentioned 9.1 new trees were included in the 117.3 trees per acre found in 1964, the difference of 108.2 trees had survived from the 1954 population. These survivors had a basal area of 127.3 sq. ft. per acre in 1964. Subtracting from this basal area the 114.2 sq. ft. figure for survivors alone, gives 13.1 sq. ft. for the gross growth increment per average acre. In this gross figure, small new trees (of unknown size in 1954) that entered the 1964 record, and trees dropping out from various size classes by death were not included.

In the above discussion, we have segregated the sources of growth changes. In that to follow, the overall balance will be brought out by restricting consideration to net growth. Tables 3 and 4 include information on net growth; the latter integrates several factors affecting tree numbers and basal area, such as new accessions, increment of wood by trees recorded both at the start and end of the decade, and losses by mortality. Basal area produced since 1954 by trees that died during the decade was disregarded since such trees had not contributed to the biomass of the living forest as of the end of the period of change.

Table 3 shows per cent net gain or loss in density and basal area per acre for each 4 in. size class of all species combined. The average stem diameter increased from 11.4 to 11.8 inches. The overall stand basal area (B_9) showed a 5.4 percent net increment, considering the 1954 stand as 100. The decrease in density (D_9), which would be expected to accompany an increase in basal area, was less than 1 percent, however. Obviously, the increased basal area was not brought about by net increase in overall tree number, but rather by tree growth, pri-

TABLE 3

Net changes by size-classes in density per acre (D_2) and basal area per acre (B_2) for the stand, irrespective of species.

Size	Density			Basal Area		
Class	1954	1964	% Change	1954	1964	% Change
6	57.5	52.6	− 8.5	10.3	9.80	− 4.9
10	19.9	22.8	+14.6	10.1	11.6	+14.9
14	11.4	11.9	+ 4.4	11.8	12.5	+ 5.9
18	10.9	9.44	−13.4	19.0	16.7	−12.1
22	7.9	8.33	+ 5.4	21.0	22.0	+ 4.8
26	5.8	6.44	+11.0	21.1	23.3	+10.4
30	3.16	3.83	+21.2	15.1	18.4	+21.8
34	1.23	1.07	....	7.56	6.79	−10.2
38	0.40	0.56	....	3.13	4.27	....
42	0.20	0.20	....	2.02	1.93	....
46	0.05	0.10	....	0.63	1.09	....
Totals	118.6	117.3	− 1.0	121.8	128.4	+ 5.7

marily. The same size classes (Table 3) that underwent a net increase in basal area also increased in density. Not only the direction of change is identical for both, but, curiously, the per cent figures compare quite closely within each size class. Exceptions occur in the largest size classes; they contain very few trees and low basal area sums, and show high variability.

Table 4 compares species, instead of size classes as in Table 3, and reveals the dynamics of net change. In the last column of Table 4 is shown the per cent net gain or loss for the basal area of each species over the decade. This indicates great differences in the response of various species over the 10 year interval. Although white oak had the largest number of deaths (Tables 1 and 2) and had very few new trees entering the record in 1964, this species just held its own in basal area (Fig. 1) due to growth of surviving trees. A disproportionate number of these were medium and large. But the net gain in beech and sugar maple, which had very few medium-sized and no large trees, was 19 and 39 per cent (Table 4), because of the many small trees crossing over the 4 in. threshold and the success of these two species in the well-represented small size-classes (Fig. 2). The combined growth of beech and sugar maple shows a B_2 net gain of 26.8 per cent, contrasting with the combined gain of less than 2 per cent for the six species of Quercus and Carya. Species representing neither beech-maple nor oak-hickory type dominants (Table 4) gained 4.6 per cent basal area in 10 years, comparing closely with the 5.4 per cent for the stand as a whole.

Unlike white oak, red and black oaks increased appreciably in basal area (Fig. 1) while holding steady in importance value. Red maple declined in all attributes shown, whereas white ash increased in all.

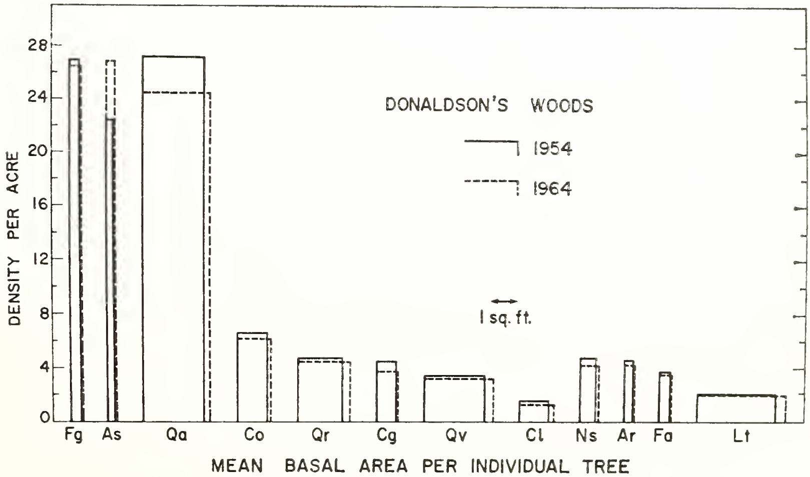

Fig. 1. Comparison of beginning and end of decade by species as to density per acre, basal area per tree, and basal area per acre. The latter, being the product of the other two, is represented by the area of the bar.

TABLE 4

Comparison of species attributes between 1954 and 1964, and percent net gain (+) or loss (—) of basal area (B_2) per acre by species over the decade. Species symbols were identified in the long footnote preceding first table.

Species	Density per acre		Relative Density		Basal Area per acre (B_2)		Relative Basal Area		Importance (V_3)		Percent change in B_2
	1954	1964	1954	1964	1954	1964	1954	1964	1954	1964	
Qa	27.08	24.47	22.8	20.8	62.05	62.32	50.94	48.54	36.9	34.7	+ 0.44
Fg	26.93	26.47	22.7	22.6	9.99	11.92	8.20	9.28	15.4	15.9	+19.3
As	22.53	26.93	18.9	22.9	5.95	8.29	4.88	6.46	11.9	14.7	+39.3
Co	6.59	6.08	5.56	5.18	7.44	7.69	6.11	5.99	5.84	5.58	+ 3.4
Qr	4.75	4.49	4.00	3.83	8.04	8.74	6.60	6.81	5.30	5.32	+ 8.7
Ns	4.70	4.19	3.96	3.57	2.85	2.79	2.34	2.17	3.15	2.87	—21.1
Ar	4.65	4.29	3.92	3.66	1.67	1.57	1.37	1.22	2.64	2.44	— 6.0
Cg	4.55	3.78	3.84	3.22	3.24	3.11	2.66	2.42	3.25	2.82	— 4.0
Fa	3.58	3.78	3.02	3.22	1.68	1.90	1.38	1.48	2.20	2.35	+13.1
Qv	3.42	3.27	2.88	2.79	7.95	8.51	6.53	6.63	4.70	4.71	+ 7.0
Lt	1.94	1.89	1.64	1.61	5.87	6.33	4.82	4.93	3.23	3.27	+ 7.8
Cl	1.58	1.48	1.33	1.26	1.78	1.91	1.46	1.48	1.39	1.37	+ 7.3
Ov	1.53	1.64	1.29	1.40	0.21	0.23	0.17	0.18	0.73	0.79	+ 9.5
Cc	1.33	1.18	1.12	1.00	1.60	1.54	1.31	1.20	1.22	1.10	— 3.8
Cf	1.28	1.53	1.08	1.30	0.13	0.16	0.11	0.12	0.59	0.71	+23.1
Others	2.15	1.84	1.80	1.55	1.35	1.40	1.12	1.10	1.46	1.32	+ 3.7
	D_9				B_9						B_9
	118.6	117.3			121.8	128.4					+5.4

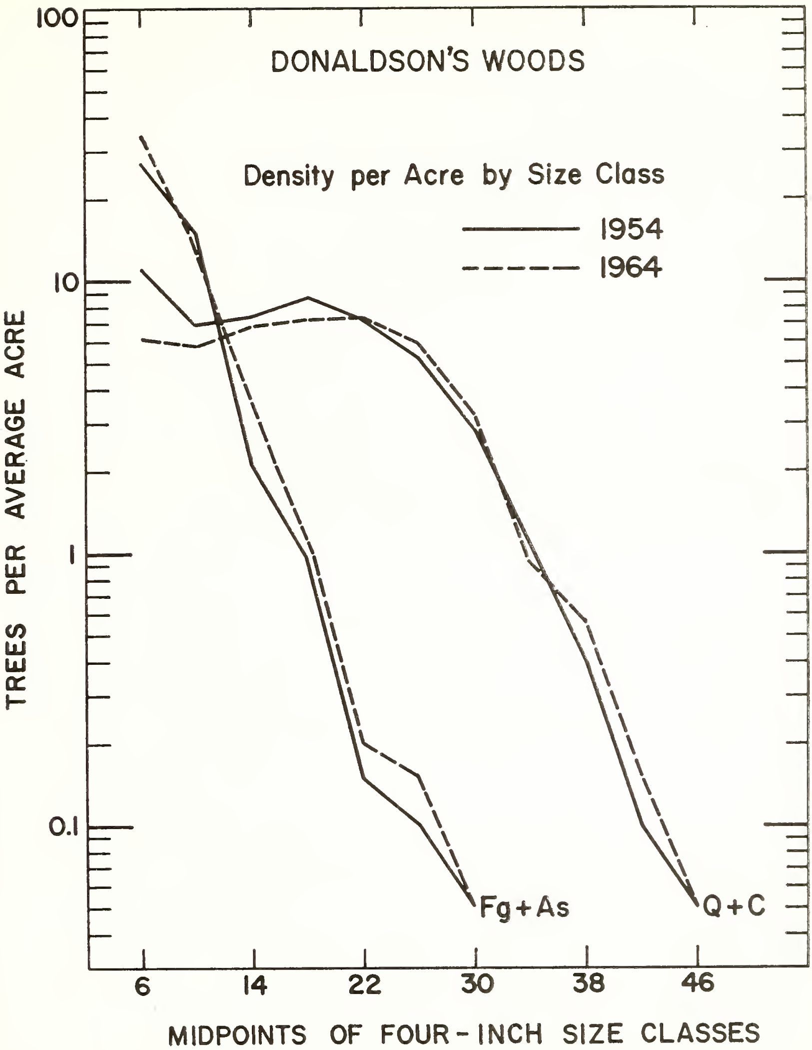

Fig. 2. Semilog plot of tree densities, by four-inch size classes of genera dominance groups in 1954 and 1964. Each line represents either beech and sugar maple combined or oaks and hickories combined, in order to reveal trend of change to a different forest type.

Projected Trend and Discussion

A trend toward a change in species dominance which, if continued, will alter the forest type, is clearly discernible in several ways. Figure 2 brings out this trend by combining the 2 or more dominants of each major forest type of Indiana into a single line, and segregating oak-hickory dominants from the 2 dominant species of the beech-maple type. The crossing of 2 pairs of curves shows that beech and sugar maple dominate in the 6 and 10 in. size-classes, while oaks and hickories dominate the higher size classes. Figure 2 also shows that, during the decade, the combined density of beech and sugar maple increased in nearly all size-classes, while oaks and hickories lost numbers in all classes below 22 in. d.b.h. This clearly suggests a future shift from mixed mesophytic composition to beech-maple.

Beech, and especially sugar maple, far exceed other species in the number of small trees crossing the lower threshold. The same species showed high gross and net growth. Only 4 small white oaks, one red oak, and no oaks of other species, crossed the 4-inch threshold. Three pignut hickories and one shagbark did so. A substantial number of white oak died, especially in the medium and large size-classes, and the net growth of oak-hickory species was lower than that of the beech-maple or the miscellaneous group.

It is evident, then, that the woods is changing from a white oak—beech—maple dominated mixed stand toward a beech—maple type in the distant future, if present trends continue. The latter type is now found (3) in Cox Woods, 14 miles to the south.

A map of presettlement Indiana vegetation (4) shows that Spring Mill State Park lies well within the western mesophytic (Fagus-Quercus-Acer-Carya) forest type of the Mitchell plain. The soil type in Donaldson's Wood is Frederick silt loam (5) a zonal soil of the IV drainage profile. Crankshaw (6) tallied 2,300 bearing trees from early land surveyors records throughout the Frederick silt loam area. He found that the importance value of beech in presettlement days on this soil type was 24.3, white oak 20.5, tulip tree 9.1, all hickories 8.8, sugar maple 8.0, and black oak 6.4. This places the soil type as definitely having supported western mesophytic, as it still does in Donaldson's Woods. Why should it be changing from this to beech-maple? Is the forest change consistent with the climatic situation during the decade?

Climatic data of the U. S. Weather Bureau (7, 8) were examined, both before and after 1954. Paoli, 13 miles away, is the nearest station having a record long enough to give accurate pre-1954 normals for temperature and precipitation. The 55 years of precipitation recorded there averaged 19.4 inches of precipitation for April 1-August 31, whereas this season for the years 1954-1963 averaged 21.2. The 54 years of temperature records averaged 68.3°F over the same 5-month period, but the 1954-1963 mean was 1.2°F, less. Thus, the decade which saw beech-maple increase and oak-hickory decline had climate consistent with this change, i.e., moister and cooler than normal. Records at Bedford (9 mi. from the woods) kept only since 1939 corroborate the difference. The occurrence of such a minor climatic change, even though it went in the direction suitable for beech-maple rather than oak-hickory, does not establish that this actually brought about the observed forest change. Earlier analysis (1) of the 1954 size-class table suggested a marked trend then toward beech-maple which the present study has established for the later period. Although it is tempting to speculate on the significance of the recent vegetation change, this should be more fruitful when data on the stand and the climate for 1964-1974 are at hand.

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