

## Donaldson's Woods: Two Decades of Change

DAMIAN V. SCHMELZ, St. Meinrad College, JAMES D. BARTON, Alfred University (U. Y.), and ALTON A. LINDSEY, Purdue University

### Introduction

During the summer of 1974 the second 10-year study was made of the mature tree stratum of 19.6 acres of Donaldson's Woods, an 80-acre stand of original mixed woods forest (3) in Spring Mill State Park, Lawrence County, Indiana. As in the 1964 study (2), data were recorded directly on ozalid copy sections of the 1954 tree-by-tree scale map (1). Each surviving tree was measured with a diameter tape; trees growing across the 4-in. dbh threshold were added to the map, and trees that had died were deleted. This record provides the basis for a comparison between the two decades of population dynamics and for discerning the overall trend of species dominance.

### Replacement Size-Class

Stability in species composition and dominance or the change which will alter the forest type is indicated partly by the additions to and the survival within the lowest size-class, in which both stand density and mortality are highest in an undisturbed old-growth forest. Species tolerance to suppressing conditions and competitive success for openings made available by the death of larger trees as well as response to any variation in the physical environment all find sharpest expression in these data, indicating how easily modified or reversed is the potential impact of a species in a stand.

The total number of sugar maples<sup>1</sup> decreased during the second decade but increased for the whole 20 years (Table 1). More than half the new trees at each decade's end were sugar maples, accounting for more new basal area addition than the 24 other species combined. The number of entrants remained about the same, but mortality was much greater during the second decade. Nevertheless, there were net gains in both density and basal area during both decades. Very few areas within the tract are unsuited to sugar maple, the most widely distributed species.

Less successful but continuing to compete strongly for sites on the variable topography, beech clearly ranked second in importance and potential. Although the net losses in density and basal area were small comparing new trees to deaths, there was a significant decrease in total number of trees throughout the 20 years, many trees growing into the next larger size-class.

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<sup>1</sup> 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 *Frazinus americana*, Qv *Quercus velutina*, Lt *Liriodendron tulipifera*, Cl *Carya laciniosa*, Ov *Ostrya virginiana*, Ce *Carya cordiformis*, Cf *Cornus florida*, and others (less than 1 per cent density in tables) are *Frazinus pennsylvanica*, *Juglans nigra*, *Sassafras albidum*, *Ulmus rubra*, *U. americana*, *Carpinus caroliniana*, *Tilia americana*, *Celtis occidentalis*, *Ulmus thomasi* and *Morus rubra*.

TABLE 1. Total number, accessions and deaths of trees in the six-inch size-class, 1954-74.

| Species  | Total |      |      |      | Number |      |      |      | B.A. Sum |      |      |      |      |      |
|----------|-------|------|------|------|--------|------|------|------|----------|------|------|------|------|------|
|          | 1954  |      | 1964 |      | 1974   |      | 1974 |      | 1964     |      | 1974 |      | 1974 |      |
|          | New   | Died | New  | Died | New    | Died | New  | Died | New      | Died | New  | Died | New  | Died |
| Qa       | 83    | 24   | 4    | 1    | 22     | 31   | 0.48 | 0.13 | 3.99     | 6.18 | 0.13 | 3.99 | 6.18 |      |
| Fg       | 371   | 264  | 24   | 26   | 35     | 44   | 2.91 | 3.27 | 5.13     | 7.51 | 3.27 | 5.13 | 7.51 |      |
| As       | 342   | 358  | 98   | 95   | 10     | 66   | 11.5 | 12.5 | 1.24     | 10.3 | 12.5 | 1.24 | 10.3 |      |
| Co       | 38    | 18   | 1    | 3    | 5      | 15   | 0.10 | 0.37 | 0.79     | 2.24 | 0.37 | 0.79 | 2.24 |      |
| Qr       | 5     | 3    | 1    | 1    | —      | 1    | 0.09 | 0.11 | —        | 0.09 | 0.11 | —    | 0.09 |      |
| Ns       | 37    | 28   | 3    | 6    | 8      | 10   | 0.36 | 0.82 | 1.19     | 1.73 | 0.82 | 1.19 | 1.73 |      |
| Ar       | 59    | 40   | 8    | 4    | 8      | 12   | 1.04 | 0.43 | 1.73     | 1.95 | 0.43 | 1.73 | 1.95 |      |
| Cg       | 40    | 23   | 3    | 2    | 15     | 10   | 0.37 | 0.18 | 2.40     | 1.84 | 0.37 | 2.40 | 1.84 |      |
| Fa       | 52    | 59   | 14   | 20   | 8      | 16   | 1.70 | 2.43 | 0.94     | 2.50 | 2.43 | 0.94 | 2.50 |      |
| Qv       | 1     | —    | —    | —    | —      | —    | —    | —    | —        | —    | —    | —    | —    |      |
| Lt       | 4     | —    | —    | —    | —      | 1    | —    | —    | —        | —    | —    | —    | 0.14 |      |
| Cl       | 7     | 3    | —    | —    | 2      | 2    | —    | —    | 0.21     | 0.41 | —    | 0.21 | 0.41 |      |
| Ov       | 29    | 27   | 6    | 6    | 4      | 12   | 0.59 | 0.61 | 0.42     | 1.43 | 0.61 | 0.42 | 1.43 |      |
| Cc       | 7     | 5    | —    | —    | 2      | 3    | —    | —    | 0.32     | 0.52 | —    | 0.32 | 0.52 |      |
| Cf       | 25    | 21   | 13   | 7    | 8      | 17   | 1.30 | 0.65 | 0.92     | 1.82 | 0.65 | 0.92 | 1.82 |      |
| Others   | 26    | 15   | 4    | 6    | 7      | 10   | 0.43 | 0.76 | 1.02     | 1.88 | 0.76 | 1.02 | 1.88 |      |
| Total    | 1126  | 885  | 179  | 177  | 134    | 250  | 20.9 | 22.3 | 20.3     | 40.5 | 22.3 | 20.3 | 40.5 |      |
| Per Acre | 57.5  | 45.2 | 9.15 | 9.04 | 6.85   | 12.8 | 1.07 | 1.14 | 1.04     | 2.07 | 1.14 | 1.04 | 2.07 |      |

The species of oak and hickory presented a sharp contrast, with little growth out of this size-class and few or no trees entering, mortality continuing to deplete representation.

American ash was the only mesophytic species successful enough during these 20 years to hold promise for becoming important in the canopy. Both red maple and black gum, more site-restricted, showed slight net losses. The future of tulip, like that of the xerophytic white oak, continued to appear bleak.

Stand density decreased by 4.9 trees per acre during the first decade even though there was a net gain of 2.30 trees per acre comparing entrants to deaths, growth out of the size-class accounting for the difference. During the second decade the mortality nearly doubled, stand density decreasing by 7.4; the net loss, comparing entrants to deaths, was 3.76 trees per acre. Although stand density decreased by 12.3 trees per acre over both decades, deaths exceeded entrants by only 1.4 trees per acre. The number of new trees was about the same during both decades, contributing about the same amount of new basal area. There was a small net gain of 0.03 in basal area during the first decade and a net loss of 0.93 during the second decade.

### Mortality

It was evident in the field that mortality had been high during the second decade throughout all size-classes. Many large trees had been windthrown or were standing dead; especially hard hit were the oaks and hickories in the 22-inch size-class. In addition to shading and suppression, high mortality among the smaller sizes resulted from windthrow damage, white oak bacterial bark disease, and the trampling along the bridle trail, now 50 ft. wide or more in many places. In all instances, as noted in 1964 (2), rate of decay was surprisingly rapid; frequently nothing could be found of small trees which had died.

In 1964 trees per acre lost by white oak represented 24% of the total stand loss (Table 2); all oaks and hickories combined lost 45%, and beech and maple lost 25%. The 1974 losses were 22% white oak, 38% oaks-hickories, and 36% beech-maple. The impact upon the stand is seen more clearly in the corresponding basal area losses. In 1964 white oak lost 56% of the total, oaks-hickories 80%, and beech-maple 8%; the 1974 losses were 52% white oak, 74% oaks-hickories, and 13% beech-maple.

The number of trees lost throughout all size-classes by all species increased by 82% from 1964 to 1974; basal area loss increased by 74%. During the 20 years the loss was 29.0 trees per acre and 20.8 sq. ft. basal area.

### Growth and Change

The 118.6 trees per acre in 1954 (Table 3) had a basal area per acre of 121.8 sq. ft. and averaged 11.5 in. dbh. Of these 108.2 survived to 1964, and their basal area had increased by 13.1, from 114.2 to 127.3. In 1964 there were 9.1 new trees per acre, for a stand density of 117.3, a net loss of 1.3 trees per acre from 1954; these new trees had a basal area of 1.1, for a stand basal area of 128.4, a net gain of

TABLE 2. Number of trees and their actual basal area sums lost by attack for all size-classes of white oak, red and black oaks, all hickories, oaks, and maple, and all other species combined.

| Size-Class | Qa   |      |      |       |      |      | Or, Qv |      |      |      |      |      | Co, Cg, Cl, Cc |      |      |      |      |  |
|------------|------|------|------|-------|------|------|--------|------|------|------|------|------|----------------|------|------|------|------|--|
|            | No.  |      | B.A. |       | No.  |      | B.A.   |      | No.  |      | B.A. |      | No.            |      | B.A. |      |      |  |
|            | 1974 | 1964 | 1974 | 1964  | 1974 | 1964 | 1974   | 1964 | 1974 | 1964 | 1974 | 1964 | 1974           | 1964 | 1974 | 1964 | 1974 |  |
| 6          | 22   | 31   | 3.99 | 6.18  | —    | —    | 1      | —    | —    | —    | —    | —    | —              | —    | —    | —    | —    |  |
| 10         | 8    | 10   | 3.73 | 4.55  | 1    | 1    | 2      | 0.66 | 0.91 | 4    | 4    | 8    | 2.06           | 4.12 | 8    | 2.06 | 4.12 |  |
| 14         | 6    | 11   | 7.16 | 10.9  | 3    | 3    | 2      | 2.79 | 2.02 | 2    | 2    | 3    | 1.76           | 3.43 | 3    | 1.76 | 3.43 |  |
| 18         | 2    | 5    | 3.08 | 9.14  | 2    | 2    | 3      | 3.74 | 5.16 | —    | —    | 1    | —              | 1.71 | —    | —    | 1.71 |  |
| 22         | 1    | 8    | 3.08 | 22.1  | —    | —    | 4      | —    | 10.7 | —    | —    | 3    | 5.37           | 8.48 | —    | —    | 8.48 |  |
| 26         | —    | 4    | —    | 15.0  | 3    | 3    | 2      | 11.8 | 6.68 | —    | —    | 2    | 3.19           | 8.19 | —    | —    | 8.19 |  |
| 30         | 4    | 4    | 19.3 | 20.1  | —    | —    | —      | —    | —    | —    | —    | —    | —              | —    | —    | —    | —    |  |
| 34         | 34   | 5    | 23.9 | 31.5  | —    | —    | —      | —    | —    | —    | —    | —    | —              | —    | —    | —    | —    |  |
| 38         | 1    | 2    | 7.75 | 15.3  | —    | —    | —      | —    | —    | —    | —    | —    | —              | —    | —    | —    | —    |  |
| 46         | 1    | —    | 12.2 | —     | —    | —    | —      | —    | —    | —    | —    | —    | —              | —    | —    | —    | —    |  |
| Total      | 49   | 80   | 84.2 | 134.7 | 9    | 9    | 14     | 19.0 | 25.6 | 33   | 33   | 47   | 16.1           | 30.9 | 47   | 16.1 | 30.9 |  |
| Per Acre   | 2.50 | 4.09 | 4.30 | 6.88  | 0.46 | 0.46 | 0.72   | 0.97 | 1.31 | 1.69 | 1.69 | 2.40 | 0.82           | 1.58 | 2.40 | 0.82 | 1.58 |  |

| Size-Class | Fig. As |      |      |      |      |      | Others |      |      |      |      |      | Total |       |      |       |
|------------|---------|------|------|------|------|------|--------|------|------|------|------|------|-------|-------|------|-------|
|            | No.     |      | B.A. |      | No.  |      | B.A.   |      | No.  |      | B.A. |      | No.   |       | B.A. |       |
|            | 1974    | 1964 | 1974 | 1964 | 1974 | 1964 | 1974   | 1964 | 1974 | 1974 | 1964 | 1974 | 1964  | 1974  | 1964 | 1974  |
| 6          | 45      | 110  | 6.37 | 17.8 | 43   | 43   | 78     | 6.35 | 11.4 | 134  | 134  | 250  | 20.3  | 40.5  | 20.3 | 40.5  |
| 10         | 3       | 16   | 1.66 | 8.34 | 13   | 13   | 6      | 7.26 | 3.42 | 29   | 29   | 42   | 15.4  | 21.4  | 42   | 15.4  |
| 14         | 1       | 3    | 0.86 | 3.08 | 4    | 4    | 6      | 3.58 | 6.38 | 16   | 16   | 25   | 16.2  | 25.6  | 16.2 | 25.6  |
| 18         | 2       | 2    | 3.34 | 3.72 | —    | —    | 1      | —    | 1.77 | 6    | 6    | 12   | 10.2  | 21.5  | 12   | 10.2  |
| 22         | —       | —    | —    | —    | —    | —    | 2      | —    | 5.80 | 3    | 3    | 17   | 8.45  | 47.1  | 3    | 8.45  |
| 26         | —       | —    | —    | —    | —    | —    | —      | —    | —    | 4    | 4    | 8    | 15.0  | 29.8  | 4    | 15.0  |
| 30         | —       | —    | —    | —    | —    | —    | 1      | —    | 4.81 | 4    | 4    | 5    | 19.3  | 24.9  | 5    | 19.3  |
| 34         | —       | —    | —    | —    | —    | —    | —      | —    | —    | —    | —    | —    | —     | —     | —    | —     |
| 38         | —       | —    | —    | —    | —    | —    | —      | —    | —    | —    | —    | —    | —     | —     | —    | —     |
| 46         | —       | —    | —    | —    | —    | —    | —      | —    | —    | —    | —    | —    | —     | —     | —    | —     |
| Total      | 51      | 131  | 12.2 | 32.8 | 60   | 60   | 94     | 17.2 | 33.6 | 202  | 202  | 366  | 148.7 | 257.6 | 366  | 148.7 |
| Per Acre   | 2.61    | 6.69 | 0.62 | 1.68 | 3.06 | 3.06 | 4.80   | 0.88 | 1.72 | 10.3 | 10.3 | 18.7 | 7.60  | 13.2  | 18.7 | 7.60  |

6.6 from 1954. Average stem diameter had increased to 11.9 in. dbh. In 1974 there were 103.2 survivors; their basal area increased by 15.9, from 115.2 to 131.1. There were 9.0 new trees per acre, giving a stand density of 112.2, a decrease of 5.0 from 1964; their basal area contribution was 1.1, giving a stand basal area of 132.2, a net increase of 3.8. Average stem diameter had increased to 12.4 in. dbh.

Density data by size-classes has been used to recognize past disturbance and stages of recovery in a stand (4). Such data, when plotted on semi-log paper, theoretically yield a straight line for the undisturbed stand; severe disturbance shows as one or more breaks in the slope of the line; recovery by increased reproduction and accelerated growth by survivors in the newly available space smooth out the line again.

Information on Donaldson's Woods reveals little natural or human disturbance. Currently only the bridle trail still in use along the east edge of the study area continues to affect the stand adversely, the trail widening, erosion increasing, soil trampling not only killing small trees and preventing reproduction but probably impeding growth of larger trees.

Table 3 and Figure 1A show which size-classes gained or lost during the 20 years. Losses were consistent during both decades for

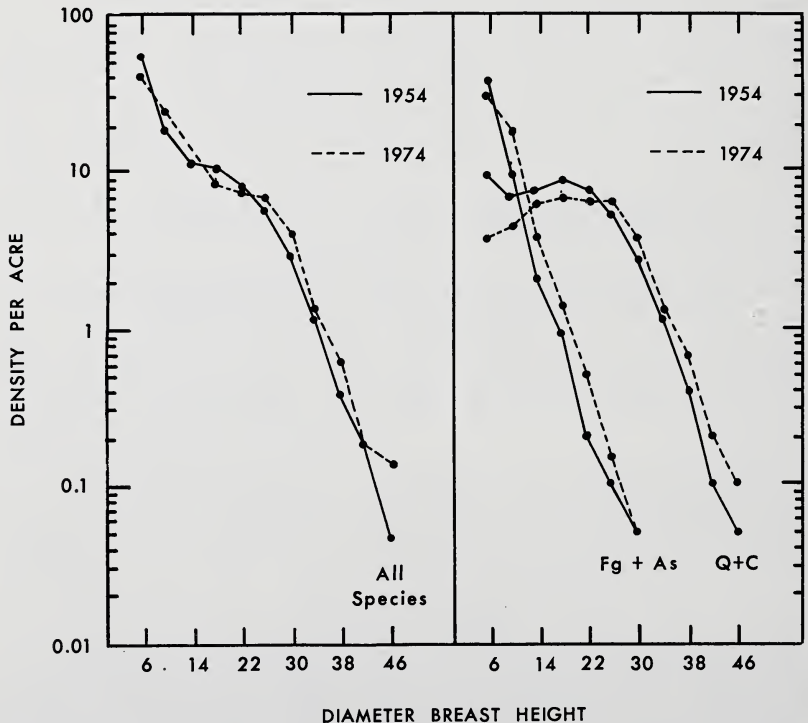


FIGURE 1. Semi-log plots of tree densities by 4-inch size-classes for 1954 and 1974: A) all species combined; B) beech-sugar maple and oaks-hickories.

TABLE 3. Net changes by size-classes in density per acre and basal area per acre for all species combined.

| Size-Class | Density/Acre |       |       |       | Basal Area/Acre |       |       |       | % Change |       |
|------------|--------------|-------|-------|-------|-----------------|-------|-------|-------|----------|-------|
|            | % Change     |       |       |       | % Change        |       |       |       |          |       |
|            | 1954         | 1964  | 1974  | 54-64 | 64-74           | 1954  | 1964  | 1974  |          | 54-64 |
| 6          | 57.5         | 52.6  | 45.2  | - 8.5 | -14.1           | 10.3  | 9.80  | 8.66  | - 4.9    | -11.6 |
| 10         | 19.9         | 22.8  | 25.6  | +14.6 | +12.3           | 10.1  | 11.6  | 13.4  | +14.9    | +15.5 |
| 14         | 11.4         | 11.9  | 11.4  | + 4.4 | - 4.2           | 11.8  | 12.5  | 12.0  | + 5.9    | - 4.0 |
| 18         | 10.9         | 9.44  | 9.14  | -13.4 | - 3.2           | 19.0  | 16.7  | 16.1  | -12.1    | - 3.6 |
| 22         | 7.92         | 8.33  | 7.51  | + 5.4 | - 9.8           | 21.0  | 22.0  | 19.6  | + 4.8    | + 6.9 |
| 26         | 5.82         | 6.44  | 6.84  | +11.0 | + 6.2           | 21.1  | 23.5  | 24.9  | +10.4    | + 6.9 |
| 30         | 3.16         | 3.83  | 4.14  | +21.2 | + 8.1           | 15.1  | 18.4  | 19.9  | +21.8    | + 8.2 |
| 34         | 1.23         | 1.07  | 1.43  | -13.0 | +33.6           | 7.56  | 6.79  | 8.71  | -10.2    | +23.3 |
| 38         | 0.40         | 0.56  | 0.67  | ---   | ---             | 3.13  | 4.27  | 5.16  | ---      | ---   |
| 42         | 0.20         | 0.20  | 0.20  | ---   | ---             | 2.02  | 1.93  | 1.94  | ---      | ---   |
| 46         | 0.05         | 0.10  | 0.15  | ---   | ---             | 0.63  | 1.09  | 1.68  | ---      | ---   |
| Total      | 118.6        | 117.3 | 112.2 | - 1.0 | - 4.4           | 121.8 | 128.4 | 132.2 | + 5.4    | + 2.9 |

size-classes 6 and 18 and in size-classes 14 and 22 represented reversals from gain during the previous decade. The pattern of plotted points changed in several significant ways. The line tended to straighten overall and its slope to flatten, an indication of some recovery. However, the unexpected heavy natural losses, especially by white oak (Table 2), further depressed the portion of the slope (size-classes 18 and 22) where disturbance had been evident in 1954 (2), not enough time having elapsed for growth into these sizes especially by beech and maple with their high rates of growth and survival.

The decrease in stand density was accompanied by increased stand basal area (Table 3) as expected when density losses are not excessively high especially among the larger trees. Gains and losses within most size-classes corresponded with density changes both in direction and percentage change. High variability is to be expected among the largest size-classes where there are few trees contributing low basal area sums.

Although white oak (Table 4 and Figure 2) continued to be the single most dominant species, its importance declined through both decades, as measured by all absolute and relative attributes. The other oaks and the hickories all showed losses in density through each decade, yet for most the growth of survivors more than offset the basal area lost by deaths, and the importance values of red and black oaks and shellbark hickory increased during the 20 years.

While the impact of sugar maple within the stand was still among the size-classes below 20 inches, this species clearly showed the greatest net gains in all attributes, ranking second in importance value, slightly above beech. Density losses by beech were small each decade; it reproduced, survived, and grew well enough that it became relatively more important. Among the other mesophytic species, only white ash

TABLE 4. *Comparison of species attributes 1954-74 and net gain (+) or loss (-) of density and basal area.*

| Species      | Density per Acre (D <sub>2</sub> ) |       |       | Relative Density (D <sub>3</sub> ) |      |      |
|--------------|------------------------------------|-------|-------|------------------------------------|------|------|
|              | 1954                               | 1964  | 1974  | 1954                               | 1964 | 1974 |
| Qa -----     | 27.1                               | 24.5  | 20.9  | 22.8                               | 20.8 | 18.6 |
| Fg -----     | 26.9                               | 26.5  | 25.9  | 22.7                               | 22.6 | 23.1 |
| As -----     | 22.5                               | 26.9  | 29.2  | 18.9                               | 22.9 | 26.0 |
| Co -----     | 6.59                               | 6.08  | 5.31  | 5.56                               | 5.18 | 4.73 |
| Qr -----     | 4.75                               | 4.49  | 4.04  | 4.00                               | 3.83 | 3.60 |
| Ns -----     | 4.70                               | 4.19  | 3.98  | 3.96                               | 3.57 | 3.54 |
| Ar -----     | 4.65                               | 4.29  | 4.09  | 3.92                               | 3.66 | 3.64 |
| Cg -----     | 4.55                               | 3.78  | 3.58  | 3.84                               | 3.22 | 3.19 |
| Fa -----     | 3.58                               | 3.78  | 4.14  | 3.02                               | 3.22 | 3.69 |
| Qv -----     | 3.42                               | 3.27  | 3.17  | 2.88                               | 2.79 | 2.82 |
| Lt -----     | 1.94                               | 1.89  | 1.69  | 1.64                               | 1.61 | 1.50 |
| Cl -----     | 1.58                               | 1.48  | 1.23  | 1.33                               | 1.26 | 1.10 |
| Ov -----     | 1.53                               | 1.64  | 1.38  | 1.29                               | 1.40 | 1.23 |
| Cc -----     | 1.33                               | 1.18  | 0.87  | 1.12                               | 1.00 | 0.77 |
| Cf -----     | 1.28                               | 1.53  | 1.07  | 1.08                               | 1.30 | 0.95 |
| Others ----- | 2.15                               | 1.84  | 1.63  | 1.80                               | 1.55 | 1.43 |
| Totals ----- | 118.6                              | 117.3 | 112.2 |                                    |      |      |

| Species      | Basal Area per Acre (B <sub>2</sub> ) |       |       | Relative Basal Area (B <sub>3</sub> ) |      |      |
|--------------|---------------------------------------|-------|-------|---------------------------------------|------|------|
|              | 1954                                  | 1964  | 1974  | 1954                                  | 1964 | 1974 |
| Qa -----     | 62.0                                  | 62.3  | 60.4  | 50.9                                  | 48.5 | 45.7 |
| Fg -----     | 9.99                                  | 11.9  | 13.4  | 8.20                                  | 9.28 | 10.1 |
| As -----     | 5.95                                  | 8.29  | 10.2  | 4.88                                  | 6.46 | 7.72 |
| Co -----     | 7.44                                  | 7.69  | 7.93  | 6.11                                  | 5.99 | 6.00 |
| Qr -----     | 8.04                                  | 8.74  | 9.37  | 6.60                                  | 6.81 | 7.09 |
| Ns -----     | 2.85                                  | 2.79  | 2.73  | 2.34                                  | 2.17 | 2.06 |
| Ar -----     | 1.67                                  | 1.57  | 1.80  | 1.37                                  | 1.22 | 1.36 |
| Cg -----     | 3.24                                  | 3.11  | 3.30  | 2.66                                  | 2.42 | 2.50 |
| Fa -----     | 1.68                                  | 1.90  | 2.23  | 1.38                                  | 1.48 | 1.69 |
| Qv -----     | 7.95                                  | 8.51  | 10.1  | 6.53                                  | 6.63 | 7.67 |
| Lt -----     | 5.87                                  | 6.33  | 5.78  | 4.82                                  | 4.93 | 4.37 |
| Cl -----     | 1.78                                  | 1.91  | 1.86  | 1.46                                  | 1.48 | 1.41 |
| Ov -----     | 0.21                                  | 0.23  | 0.19  | 0.17                                  | 0.18 | 0.14 |
| Cc -----     | 1.60                                  | 1.54  | 1.38  | 1.31                                  | 1.20 | 1.04 |
| Cf -----     | 0.13                                  | 0.16  | 0.11  | 0.11                                  | 0.12 | 0.08 |
| Others ----- | 1.35                                  | 1.40  | 1.35  | 1.12                                  | 1.10 | 1.02 |
| Totals ----- | 121.8                                 | 128.4 | 132.2 |                                       |      |      |

| Species      | Importance (V <sub>3</sub> ) |      |      | % Change 1954-74 |                |
|--------------|------------------------------|------|------|------------------|----------------|
|              | 1954                         | 1964 | 1974 | D <sub>2</sub>   | B <sub>2</sub> |
| Qa -----     | 36.9                         | 34.7 | 32.2 | -22.9            | - 2.6          |
| Fg -----     | 15.4                         | 15.9 | 16.6 | - 3.7            | +34.1          |
| As -----     | 11.9                         | 14.7 | 16.9 | +29.8            | +71.4          |
| Co -----     | 5.84                         | 5.58 | 5.36 | -19.4            | + 6.6          |
| Qr -----     | 5.30                         | 5.32 | 5.34 | -15.0            | +16.5          |
| Ns -----     | 3.15                         | 2.87 | 2.80 | -15.3            | - 4.2          |
| Ar -----     | 2.64                         | 2.44 | 2.50 | -12.0            | + 7.8          |
| Cg -----     | 3.25                         | 2.82 | 2.84 | -21.3            | + 1.8          |
| Fa -----     | 2.20                         | 2.35 | 2.69 | +15.6            | +32.7          |
| Qv -----     | 4.70                         | 4.71 | 5.24 | - 7.3            | +27.0          |
| Lt -----     | 3.23                         | 3.27 | 2.94 | -12.9            | - 1.5          |
| Cl -----     | 1.39                         | 1.37 | 1.76 | -22.2            | + 4.5          |
| Ov -----     | 0.73                         | 0.79 | 0.68 | - 9.8            | - 9.5          |
| Cc -----     | 1.22                         | 1.10 | 0.90 | -34.6            | -13.8          |
| Cf -----     | 0.59                         | 0.71 | 0.52 | -16.4            | -15.4          |
| Others ----- | 1.46                         | 1.32 | 1.21 | -24.2            | 0.0            |
| Totals ----- |                              |      |      | - 5.4            | + 8.5          |

gained in all attributes. With fewer than 2 trees per acre, the impressive tulips became more restricted in their influence upon the stand.

The semi-log density plot (Figure 1B) of combined dominants in the beech-maple and oak-hickory forest types of Indiana clearly shows the shift from mixed-mesophytic to beech-maple dominance. Not only did beech and maple continue to dominate in size-classes 6 and 10 and to increase in all size-classes but one, but also with oaks and hickories declining in all size-classes below 24 inches the curves crossed at a higher diameter.



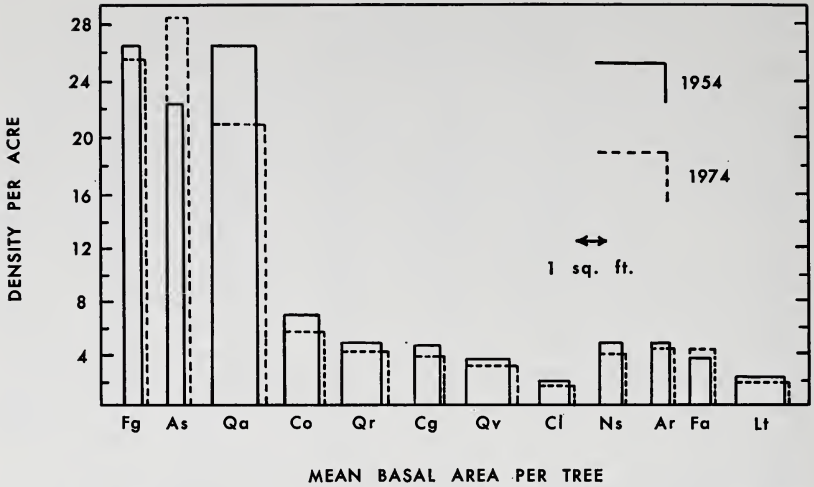


FIGURE 2. Comparison of the most important species for 1954-74 regarding basal area per acre (the area of the bar), the product of density per acre and mean basal area per tree.

### Trend

A change in species dominance continued during the second decade, indicating a slow altering of forest type from mixed woods to beech-maple. Beech and sugar maple reproduced and survived in all size-classes at much higher rates than the oaks and hickories; only 5 white oak grew across the 4-in. threshold during the 20 years. Although mortality increased for all species during the second decade and stand density decreased, the losses in the medium and large size-classes affected mainly the oaks and hickories. Survivors of all species grew well; stand basal area and average stem diameter increased. Overall, some degree of recovery from disturbance took place.

Climatic data from Paoli (5, 6), the nearest weather station with long records, showed a mean annual temperature of 54.8°F during the 54 years preceding 1953, 52.9°F for the period 1954-63, and 52.7°F for 1964-73. The corresponding annual precipitation means for the same periods were 42.2, 44.2, and 44.5 inches. For the April 1-August 31 season, the mean temperature was 68.3°F prior to 1953, 67.1°F for 1954-63, and 66.7°F for 1964-73; the corresponding precipitation means were 19.4, 21.2, and 21.4 inches. These minor climatic changes to cooler and moister are consistent with beech-maple increase and oak-hickory decrease. However, another nearby weather station recorded change to warmer and drier. Both a weather station in the woods and analysis of regional weather patterns are needed to assess climatic influence on observed forest changes.

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