# Twenty years of change in the Hutcheson Memorial Forest

Judy S. Sulser
Rutgers University

Sulser, Judy S. (Rutgers University, New Brunswick, N.J.) Twenty years of change in the Hutcheson Memorial Forest. Hutcheson Memorial Forest Bull. 2(4): 15-24. 1971. A measurement of the temporal changes in the vegetation of Hutcheson Memorial Forest over the past twenty years was attempted through a comparison of quadrat and transect data collected in 1950 and 1969. These data were accompanied by data on the light environment within the forest. Although the gap areas created by windthrows or death of trees are characterized by more intense sunlight, the forest floor beneath a continuous canopy and understory has become more intensely shaded. In 1950 the average percent light penetration during the summer months was 3.7 and 3.4 at 6 inches and 6 feet above the forest floor. In 1969 the average light penetration had dropped to 1.1 and 1.8 percent of full sunlight. The more intense shade which has developed beneath the canopy has favored the establishment of shade-tolerant species, such as the maples and beech, while inhibiting establishment of such less shade-tolerant species as the oaks. Therefore, succession within the forest appears to be progressing from an oak-hickory forest to one in which the northern hardwoods—the maples, beech, and ash — are becoming more important. This succession and its rate are strongly associated with the effects of fire, windstorm, and drought, and the relative tolerance of the component species.

The William L. Hutcheson Memorial Forest, an old oak forest (Buell, 1957) of approximately 65 acres, is situated adjacent to East Millstone, New Jersey. It is on the Triassic Piedmont and is underlain by the Brunswick formation from which its soil is largely developed (Ugolini, 1964). Recent change in this forest is the subject of this paper.

The present composition of Hutcheson Memorial Forest has been affected most strongly by conditions that existed at the time the present trees became established; but it is also affected by all that has happened since that time. The history of fire (Buell, Buell, and Small, 1954) presumably accounts for the dominance of oaks in the canopy; the elimination of fire has played a major role in the later development of the forest. More recently, windstorms and drought have had their influence.

The windstorm of November 1950 toppled and broke more than 300 trees. Most of these damaged trees were removed by loggers the following year (Monk, 1957, 1961a, 1961b). Since the 1950 storm, hurricanes in 1954 and 1955 caused extensive damage to the forest (Reiners and Reiners, 1965). An additional 186 trees were injured or killed by the severe summer drought of 1957 (Small, 1961). It is likely that these events have affected the development of the forest.

The objective of this study was to investigate the manner in which the forest vegetation has changed over the past twenty years. This investigation is based on quantitative comparisons of the forest vegetation and the light penetration beneath the canopy. Data which had been collected in 1950 by Drs. Murray Buell, Helen Buell, and John Small, and data which I collected in 1969, were utilized in these comparisons.

The William L. Hutcheson Memorial Forest has been preserved as a natural area for ecological research. As such, a record of the forest vegetation through time would be valuable to future investigations. Also, with a temporal record, past studies may be considered with a knowledge of the changes which have taken place within the forest since that time. Records of the vegetation are particularly valuable since the forest is in a successional stage of development (Monk, 1961b).

## Methods

To accomplish the objective of a quantitative comparison of the data collected in 1969 with those which had been collected in 1950, it was essential to use precisely the same methods as those which had been employed previously.

### Light measurement

A 100-meter light line has been permanently marked since the 1950 light studies. Light was measured using a Weston light meter (Model 756) at one-meter intervals along this line. Readings were taken at a level of 6 inches and 6 feet above the forest floor.

Light readings were recorded on a weekly or semimonthly basis as weather permitted. These readings were restricted to sunny days between the hours of 11:00 A.M. and 1:00 P.M. Ten readings were taken in the open fields adjacent to the forest before and after the completion of the forest readings. These readings were averaged to give the illuminance of full sunlight on each particular day. The 100 readings taken within the forest were also averaged and then divided by the illuminance of full sunlight. Thus the light penetrating through the canopy to the levels of 6 inches and 6 feet above the forest floor was expressed as the percentage of full sunlight for that day. An attempt was made to have the 1969 readings coincide as closely as possible with the dates of the 1950 light readings.



1971. William L. Hutcheson Memorial Forest Bulletin 2(4):15-24.

## Vegetation analysis

Transects and quadrats of varying sizes were used to sample the different vegetation layers within the forest (Figure 1). The exact location of the 1950 quadrats were duplicated with a good degree of accuracy (Figures 1 and 2). The information for the positioning of the transects was obtained from J. A. Small's field notebook. I drove metal pipes into the ground as permanent markers. These are at the ends of each of the transect lines and are painted blue. Their locations are indicated by solid circles in Figure 1. Thus the sampling area is permanently marked for future reference.

The arborescent layer was sampled using twenty-five 10 x 10-meter quadrats. These quadrats were arranged on alternating sides of four compass lines and spaced ten meters apart (Figure 1). The diameters of all trees within the quadrats over one inch in diameter at breast height (d.b.h.) were recorded. Those trees which occurred on the boundary lines of the quadrats were considered within the quadrat for sampling purposes. From these data the basal area, density, and frequency were calculated.

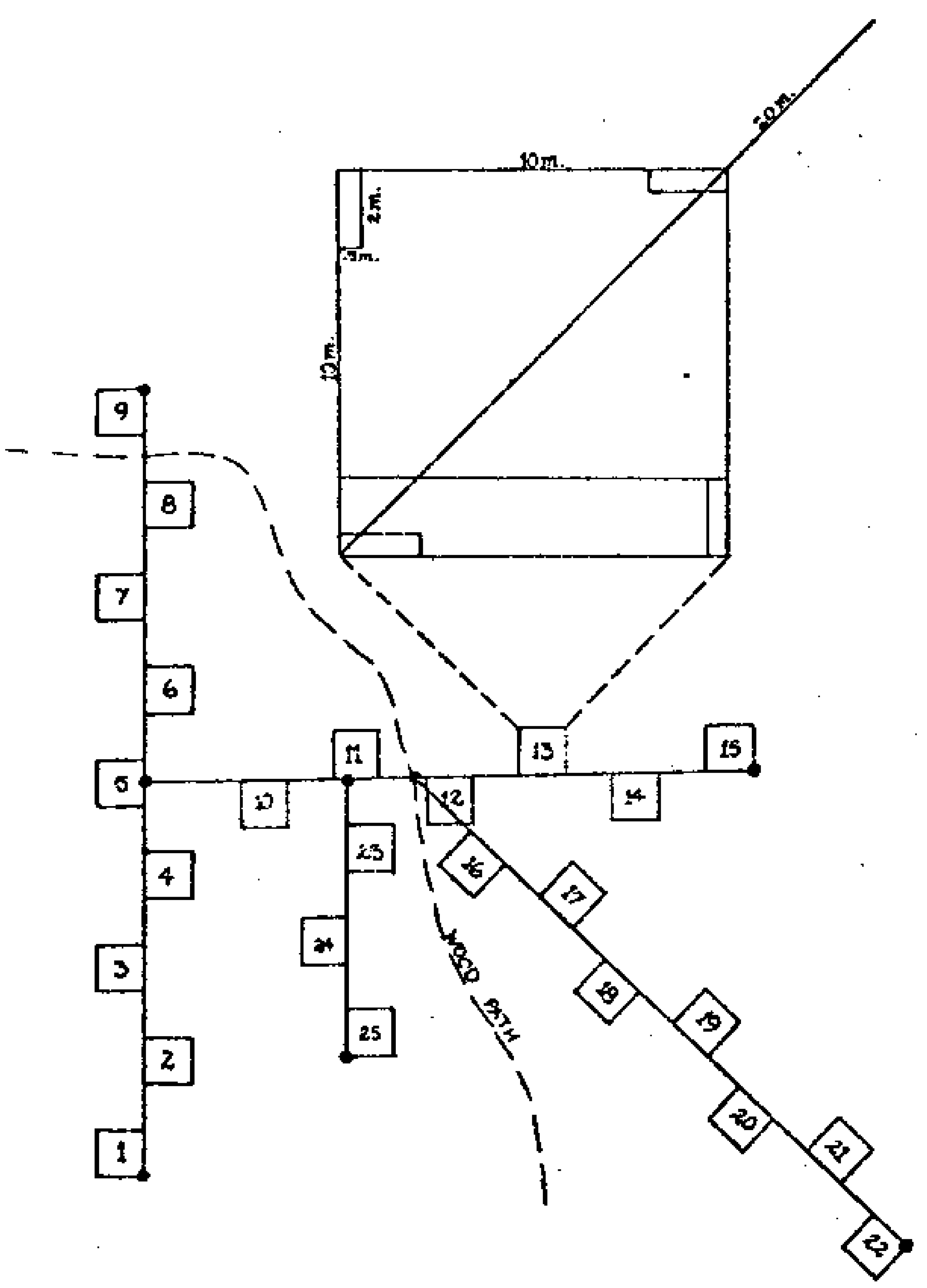


Figure 1. The arrangement of the quadrats on alternate sides of four transects. The information for the positioning of these transects was obtained from J.A. Small's field notebook. Also shown is an enlargement of one of the quadrats depicting subsample units. The circles at the ends of the transect lines indicate the location of the steel pipes.

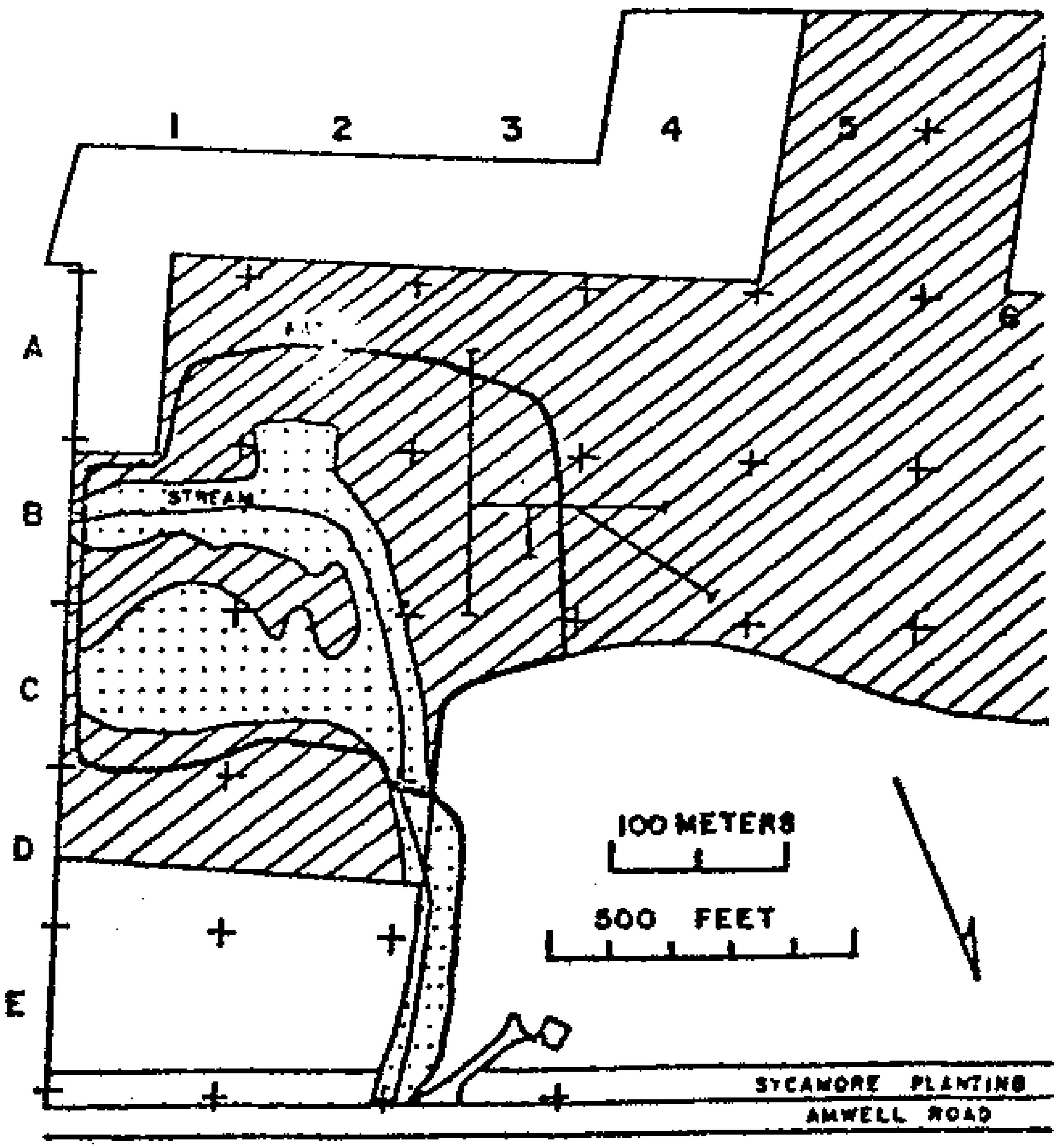


Figure 2. The position of the transects within the forest. The sampling area was located on the upland site at Hutcheson Memorial Forest, designated by Monk (1957) as the *Viburnum acerifolium* shrub type.

Tree coverage data were obtained along a 100-meter transect by the line-intercept method, that is, by projecting the crown of the tree onto the ground and measuring in decimeters the spread of the crown over the transect line (Bauer, 1943). A cover sight was used to determine the limits of the tree crowns along the transect (Buell and Cantlon, 1950). Coverage of the individual tree species was expressed as the total decimeters of cover and as the percentage of the total cover of all species, including space, along the transect. This transect was located along the 100-meter light line, and is known to be precisely the same transect as that used in 1950 and 1953.

Saplings were defined as those individuals of tree species under one inch d.b.h. and over one foot in height. The number of saplings was recorded which occurred within the twenty-five 2 x 10-meter quadrats located within each of the larger quadrats and along the main transect line. Density and frequency for each of the sapling species were calculated from these data.

Woody species comprising the shrub layer were sampled using the line-intercept method as described above. Cover was taken along transects running diagonally across each of the tree quadrats and extending a total of 20 meters. Cover was recorded in decimeters for each shrub species and expressed as the percentage of 5000 decimeters, the total length of the 25 transects. Frequency data were also obtained for all shrub species.

Woody vines, such as honeysuckle *(Lonicera japonica)*, poison ivy *(Rhus radicans)*, and Virginia creeper *(Parthenocissus quinquefolia)*, which were trailing along the ground, were recorded with the herbs. Those found climbing on shrubs and saplings were recorded with the shrubs.

The herbaceous layer was sampled using one hundred 2 x 0.5-meter plots located within each of the corners of the tree quadrats. Percent cover was estimated for each of the non-woody herbaceous species, as well as small woody species which occupy space in this layer. The percent of ground unoccupied by herbs was also estimated. Frequency data were obtained for all herb species. Within these quadrats the number of seedlings of tree species were also recorded.

All vegetation sampling was initiated and completed in June of 1950 and 1969, with the exception of the tree cover data which were obtained in October.

Voucher specimens were deposited in the Chrysler Herbarium at Rutgers — The State University. Nomenclature follows the New Britton and Brown Illustrated Flora (Gleason, 1968). Lists of the species which have been found within the Hutcheson Memorial Forest have been compiled by Monk (1959) and Frei and Fairbrothers (1963).

## Results

A comparison of the data collected for the years 1950 and 1969 shows significant changes in all the vegetation layers within the forest. Fluctuations of the light environment within the forest have accompanied these vegetation changes.

### THE FOREST VEGETATION

#### Trees

From an examination of Table 1, it can be seen that the oaks still dominate the canopy. *Quercus alba* has

Table 1. Density, frequency, and basal area of trees over one inch d.b.h. for 1950 and 1969. Density, frequency, and basal area are on the basis of twenty-five 10 x 10-meter quadrats, a total of 2500 square meters. Density is presented for three tree size classes and the total.

| | | Trees one inch d.b.h. and over | | | | | |
|---|---|---|---|---|---|---|---|
| Species | Year | 1-3.9 in. | 4-9.9 in. | 10 in. or over | Total density | Frequency | Basal area (sq. ft.) |
| *Cornus florida* | 1950 | 224 | 103 | – | 327 | 25 | 13.5 |
| | 1969 | 213 | 106 | – | 319 | 25 | 16.3 |
| *Quercus alba* | 1950 | – | 2 | 16 | 18 | 13 | 30.5 |
| | 1969 | – | – | 18 | 18 | 15 | 38.5 |
| *Fagus grandifolia* | 1950 | 6 | 1 | 3 | 10 | 3 | 4.4 |
| | 1969 | 8 | 2 | 3 | 13 | 3 | 6.2 |
| *Quercus velutina* | 1950 | – | – | 4 | 4 | 4 | 5.7 |
| | 1969 | – | – | 4 | 4 | 4 | 4.1 |
| *Quercus borealis* | 1950 | – | – | 4 | 4 | 4 | 7.9 |
| | 1969 | – | – | 2 | 2 | 2 | 3.0 |
| *Carya ovalis* | 1950 | – | – | 4 | 4 | 4 | 8.0 |
| | 1969 | 1 | – | 2 | 3 | 3 | 3.0 |
| *Acer rubrum* | 1950 | – | 2 | – | 2 | 2 | 0.4 |
| | 1969 | 5 | 2 | – | 7 | 4 | 0.5 |
| *Fraxinus americana* | 1950 | 1 | – | – | 1 | 1 | < 0.1 |
| | 1969 | 14 | – | – | 14 | 6 | 0.2 |
| *Acer saccharum* | 1950 | 1 | – | – | 1 | 1 | < 0.1 |
| | 1969 | 2 | 1 | – | 3 | 3 | 0.2 |
| *Ulmus americana* | 1950 | 1 | – | – | 1 | 1 | < 0.1 |
| | 1969 | 1 | – | – | 1 | 1 | < 0.1 |
| *Acer platanoides* | 1950 | – | – | – | – | – | – |
| | 1969 | – | 1 | – | 1 | 1 | 0.2 |
| *Amelanchier arborea* | 1950 | – | – | – | – | – | – |
| | 1969 | 1 | – | – | 1 | 1 | < 0.1 |
| Total | 1950 | 233 | 108 | 31 | 372 | 25 | 70.4 |
| | 1969 | 245 | 112 | 29 | 386 | 25 | 72.3 |

Table 2. Coverage data for trees over one inch d.b.h. for 1950, 1953, and 1969. Coverage is expressed as total decimeters of cover for each species and also as the percent of the total cover of all species, including open space, along the 1000 decimeter transect.

| Species | Total dm. cover | | | Percent cover | | |
|---|---|---|---|---|---|---|
| | 1950 | 1953 | 1969 | 1950 | 1953 | 1969 |
| *Cornus florida* | 939 | 643 | 832 | 52.25 | 45.00 | 44.58 |
| *Quercus alba* | 387 | 171 | 333 | 21.53 | 11.97 | 17.84 |
| *Quercus borealis* | 173 | 183 | 267 | 9.62 | 12.81 | 14.30 |
| *Quercus velutina* | 130 | 142 | 172 | 7.23 | 9.94 | 9.21 |
| *Carya ovalis* | 109 | 100 | 100 | 6.06 | 7.00 | 5.35 |
| *Acer rubrum* | 59 | 62 | 105 | 3.28 | 4.34 | 5.62 |
| *Acer saccharum* | – | – | 44 | – | – | 2.35 |
| Open space | – | 128 | 13 | – | 8.96 | 0.69 |
| Total cover (excluding space) | 1797 | 1301 | 1853 | 100.00 | 91.04 | 99.30 |

the greatest density of any single tree species, and in 1969 all individuals were larger than 10 inches in diameter. *Quercus velutina*, *Q. borealis*, *Fagus grandifolia*, and *Carya ovalis* are the only other tree species in this size class. *Fagus grandifolia* is also represented by a number of smaller trees, but the frequency of this species is low. These smaller individuals are root sprouts grouped around the larger parent trees (Haines, 1965).

The density of *Fraxinus americana* has increased from one individual in 1950 to 14 individuals found in 1969. These trees were all less than 4 inches in diameter, and 10 of the 14 were clumped within two quadrats in gap areas.

Three species of maple were found in the 1969 sample, *Acer rubrum*, *A. saccharum*, and *A. platanoides*, the latter being absent from the 1950 sample. Both *A. rubrum* and *A. saccharum* showed an increase in density and frequency since 1950.

The understory of *Cornus florida* had suffered greatly during the windstorms and droughts (Small, 1961), but can be seen to have recovered in number almost completely. The 1969 density for *Cornus florida* is only six individuals below the density recorded in the 1950 sample.

The total density (one inch d.b.h. and over) in 1950 was 372 trees as compared to 386 trees in 1969. This increase was largely due to the increase in the number of trees less than 4 inches in diameter.

Tree coverage over a 100-meter transect is available for 1950, 1953, and 1969 (Table 2). These data were all collected in October along the same transect, that is, along the permanent light line within the forest. The significance of the 1953 data is that these data were taken just three years after the severe 1950 windstorm, whereas the 1950 data were taken the month before the storm. A continuous tree canopy had existed along the light line before the 1950 windstorm. As a consequence of windthrow and windbreak, gaps in the canopy were created covering 128 decimeters of the transect in 1953. This gap space was reduced to 13 decimeters by 1969, largely due to the crowns of bordering trees expanding into the openings (Trimble and Tryon, 1966). Total tree cover was highest in 1969, indicating greater overlapping of tree canopies.

*Cornus florida* has shown a remarkable recovery with 832 decimeters of cover in 1969. The 1953 coverage value of 643 decimeters was a considerable decrease from the 939 decimeters of cover in 1950. This same recovery was true of *Quercus alba*, *Q. borealis*, and *Q. velutina*, which have increased in cover since 1953. The increase in *Q. borealis* was conspicously due to the growth of one large individual occurring on the transect. *Carya ovalis* has decreased slightly, while *Acer rubrum* and *A. saccharum* have increased.

Table 3 contains the density and frequency data of saplings for 1950 and 1969. It is necessary to point out that the density of saplings may vary with the quality of previous seed years, as well as the intensity of light penetrating the canopy and the drought tolerance of the species. The number of *Cornus florida* saplings has decreased appreciably. *Fraxinus americana* saplings have increased since 1950. It is probable that of the 22 saplings present in 1950 some must have grown to be numbered among the 14 small trees of *F. americana* in the 1969 tree sample (Table 1).

Of the maples, *Acer rubrum* saplings have decreased in number. *Acer platanoides* and *A. saccharum*, both absent from the 1950 sample, were represented by three saplings and one sapling, respectively, in 1969. *Carya ovalis* likewise had only one sapling present in the 1969 sampling. *Fagus grandifolia* sap-

Table 3. Density and frequency of tree saplings for 1950 and 1969. Saplings are defined as those individuals of tree species less than one inch d.b.h. and greater than one foot in height. Density and frequency of saplings are on the basis of twenty-five 10 x 2-meter plots.

| Species | Density | | Frequency | |
|---|---|---|---|---|
| | 1950 | 1969 | 1950 | 1969 |
| *Cornus florida* | 125 | 67 | 23 | 20 |
| *Fraxinus americana* | 22 | 30 | 8 | 8 |
| *Acer rubrum* | 8 | 3 | 5 | 3 |
| *Fagus grandifolia* | 3 | 1 | 3 | 1 |
| *Ulmus americana* | 2 | — | 1 | — |
| *Prunus serotina* | 1 | — | 1 | — |
| *Crataegus* sp. | 1 | — | 1 | — |
| *Carya ovalis* | — | 1 | — | 1 |
| *Acer platanoides* | — | 3 | — | 2 |
| *Acer saccharum* | — | 1 | — | 1 |

lings had decreased since 1950. The most significant feature of these data is the total absence of oak saplings of any species.

The density of seedlings, as well as saplings, is important for the propagation of the species. The quality of the seed year is likely to be an important factor in the establishment of seedlings, but seedling mortality is generally high (Kramer and Kozlowski, 1960). Table 4 contains the 1950 and 1969 seedling data.

Table 4. Density and frequency of seedlings for 1950 and 1969. Seedlings include individuals of tree species less than one foot in height. Density and frequency are on the basis of one hundred 2 x 0.5-meter plots.

| Species | Density | | Frequency | |
|---|---|---|---|---|
| | 1950 | 1969 | 1950 | 1969 |
| *Cornus florida* | 168 | 2288 | 61 | 93 |
| *Carya* sp. | 10 | 2 | 9 | 2 |
| *Acer rubrum* | 5 | 3 | 4 | 2 |
| *Quercus alba* | 4 | — | 4 | — |
| *Fraxinus americana* | 3 | 17 | 3 | 13 |
| *Quercus velutina* | 2 | — | 2 | — |
| *Prunus serotina* | 2 | 3 | 2 | 3 |
| *Juniperus virginiana* | 2 | 3 | 2 | 2 |
| *Celtis occidentalis* | 2 | — | 2 | — |
| *Prunus virginiana* | — | 1 | — | 1 |
| *Betula* sp. | — | 1 | — | 1 |

In 1969 *Cornus florida* had an overwhelming number of seedlings, suggesting a previous year of good seed production. These seedlings were all about one inch tall, in dense patches.

*Quercus alba* and *Q. velutina* seedlings, while having low densities in 1950, were entirely absent in the 1969 sample. *Acer rubrum*, the only maple present in either sample, showed a decrease in the number of seedlings since 1950. Other than *Cornus florida*, *Fraxinus americana* was the only tree species with an appreciable increase in the density of seedlings.

## Shrubs

*Viburnum acerifolium* is the dominant shrub in the forest, but it shows a decrease in cover since 1950, having suffered during the drought years (Small, 1961). *Viburnum prunifolium* and *V. dentatum* have increased in cover since 1950, *V. dentatum* having been absent from the 1950 sample (Table 5).

Table 5. Shrub coverage and frequency for 1950 and 1969. Coverage is expressed in decimeters of cover and percent cover of a total of 5000 dm. Frequency is on the basis of twenty-five 20-meter transects.

| Species | Year | Dm. cover | Percent cover | Frequency |
|---|---|---|---|---|
| *Viburnum acerifolium* | 1950 | 2171 | 43.42 | 25 |
| | 1969 | 1359 | 27.18 | 24 |
| *Viburnum prunifolium* | 1950 | 28 | 0.56 | 4 |
| | 1969 | 56 | 1.12 | 5 |
| *Lonicera japonica* | 1950 | 13 | 0.26 | 1 |
| | 1969 | 890 | 17.80 | 17 |
| *Parthenocissus quinquefolia* | 1950 | 5 | 0.10 | 1 |
| | 1969 | 55 | 1.10 | 12 |
| *Rubus* sp. | 1950 | 4 | 0.08 | 1 |
| | 1969 | 3 | 0.06 | 1 |
| *Rhus radicans* | 1950 | 2 | 0.04 | 1 |
| | 1969 | 30 | 0.60 | 5 |
| *Rosa multiflora* | 1950 | 2 | 0.04 | 1 |
| | 1969 | 23 | 0.46 | 1 |
| *Celastrus scandens* | 1950 | 1 | 0.02 | 1 |
| | 1969 | — | — | — |
| *Lindera benzoin* | 1950 | — | — | — |
| | 1969 | 102 | 2.04 | 7 |
| *Viburnum dentatum* | 1950 | — | — | — |
| | 1969 | 28 | 0.56 | 3 |
| *Sambucus canadensis* | 1950 | — | — | — |
| | 1969 | 9 | 0.18 | 2 |
| *Vitis aestivalis* | 1950 | — | — | — |
| | 1969 | 3 | 0.06 | 1 |
| Unoccupied space* | 1950 | 2282 | 45.64 | 25 |
| | 1969 | 2368 | 47.36 | 25 |

* Some discrepancy exists between the method of measuring the cover of the shrub layer in 1950 and 1969 such that the unoccupied space in the shrub layer for 1950 would be greater in terms of the 1969 data.

Many changes in the cover of shrubs are significant of the gap areas within the forest. For example, *Lonicera japonica* has increased greatly since 1950 and has become very extensive in the gaps. *Lindera benzoin*, absent from the 1950 sample, now occupies gap areas. *Rosa multiflora* and *Sambucus canadensis* are field species which have become established in the gap areas. Likewise *Parathenocissus quinquefolia* and *Rhus radicans* have also increased in cover since 1950.

## Herbs

As indicated by the data, certain species occupying the herbaceous layer have increased in cover since 1950. While others have decreased; some were absent in 1969 (Table 6). Outstanding among those which have increased in cover are *Lonicera japonica** and *Pilea pumila* which are associated with the gap areas. *Parthenocissus quinquefolia**, *Podophyllum peltatum*, and *Arisaema triphyllum* have likewise increased in cover, while *Galium circaezans* and *Impatiens biflora* have become more sparse since 1950.

A number of herb species found in 1950 were absent from the 1969 sample. Many of these were present in the forest but did not appear in any of the plots where herbaceous plants were sampled. It commonly happens that the more infrequent members of the plant community do not occur within the sample plots.

### THE LIGHT ENVIRONMENT WITHIN THE FOREST

Measurements of the light penetration beneath the forest canopy show consistently lower percentages in 1969 at both 6 feet and 6 inches above the forest floor (Table 7). Relating this change to the change in vegetation, the reasons for the decrease become apparent (Table 8). The tree cover over the light line has increased from 1797 decimeters of cover in 1950 to 1853 decimeters of cover in 1969. Total tree density and basal area have also increased, and there has been an increase in shrub cover.

Taking the average percent light penetration for the months June through August, the light penetrating the canopy for the summer season was greater in 1950 than 1969 (Table 8). These percentages were obtained by averaging the values of the percent light penetration given in Table 7. In 1969 an average of only 1.1 percent of full sunlight reached the 6-inch level, and only 1.8 percent reached the 6-foot level, as compared to values in 1950 of 3.7 and 3.4 percent, respectively. However, the light penetration in gap areas may reach as high as the value for full sunlight during certain hours of the day. Light penetration in the spring season is also higher than in the summer season.

These averages alone do not describe the fluctuations which have taken place between the years 1950 and 1969. However, J.A. Small had recorded light readings taken along the permanent light line on several occasions between the years 1950 and 1969. These data were available. A graph of the light data, along with a histogram of the total tree cover for 1950, 1953, and 1969, clearly shows the kind of fluctuations of light penetration and canopy density

* While these plants are shrubs, those parts that sprawl about over the herb layer have greater significance in that layer than in the shrub layer.

Table 6. Cover and frequency of the species occupying the herbaceous layer on the basis of one hundred 2 x 0.5-meter plots (a total of 10,000 sq. dm.) for 1950 and 1969.

| Species | Sq. dm. cover | | Frequency | |
|---|---|---|---|---|
| | 1950 | 1969 | 1950 | 1969 |
| *Anemonella thalictroides* | 3 | 5 | 3 | 1 |
| *Ariaema triphyllum* | 28 | 80 | 15 | 8 |
| *Botrychium* sp. | 2 | 1 | 2 | 1 |
| *Carex* sp. | 2 | 1 | 1 | 1 |
| *Circaea lutetiana* | 113 | 120 | 19 | 25 |
| *Galium circaezans* | 20 | 1 | 12 | 1 |
| *Galium triflorum* | 1 | 1 | 1 | 1 |
| *Geranium maculatum* | 16 | 3 | 7 | 1 |
| *Impatiens biflora* | 49 | 3 | 7 | 1 |
| *Lonicera japonica* | 175 | 1298 | 8 | 44 |
| *Mitchella repens* | 2 | 1 | 2 | 1 |
| *Oxalis* sp. | 2 | 2 | 2 | 3 |
| *Parthenocissus quinquefolia* | 17 | 102 | 13 | 28 |
| *Phytolacca americana* | 34 | 15 | 27 | 6 |
| *Pilea pumila* | 1 | 132 | 1 | 6 |
| *Podophyllum peltatum* | 250 | 855 | 39 | 73 |
| *Polygonatum biflorum* | 34 | 35 | 9 | 11 |
| *Rhus radicans* | 32 | 19 | 27 | 6 |
| *Smilacina racemosa* | 58 | 79 | 17 | 16 |
| *Smilax rotundifolia* | 5 | 1 | 5 | 1 |
| *Viola sagittata* | 3 | 6 | 2 | 4 |
| *Vitis aestivalis* | 1 | 3 | 1 | 1 |
| **Species Found in 1950 Only** | | | | |
| *Amphicarpa bracteata* | 5 | | 1 | |
| *Asclepias quadrifolia* | 1 | | 1 | |
| *Berberis thunbergii* | 1 | | 1 | |
| *Galium aparine* | 1 | | 1 | |
| *Geum canadense* | 2 | | 1 | |
| *Maianthemum canadense* | 3 | | 3 | |
| *Oakesia sessilifolia* | 5 | | 5 | |
| *Ranunculus* sp. | 7 | | 2 | |
| *Sanicula trifoliata* | 5 | | 4 | |
| *Symplocarpus foetidus* | 2 | | 2 | |
| *Uvularia perfoliata* | 3 | | 1 | |
| **Species Found in 1969 Only** | | | | |
| *Boehmeria cylindrica* | | 4 | | 1 |
| *Fragaria virginiana* | | 1 | | 1 |

which must have occurred over the past twenty years (Figure 3).

After the 1950 windstorm, more light penetrated the forest canopy triggering an immediate response in the growth of the vegetation. So immediate was this response that by 1953 the shade at 6 inches above the forest floor was nearly as dense as it had been in 1950. By 1959 the percent light penetration at 6 feet above the forest floor had dropped sharply. The percent light penetration in 1964 was nearly equal to the 1969 values. These data are consistent with the tree cover data for the years 1950, 1953, and 1969 (Figure 4).

## Discussion

Analysis of the data collected for the years 1950 and 1969 documents the changes which have taken place within the forest during the past two decades.

Table 7. Percent average light penetration at 6 feet and 6 inches above the forest floor. Measurements were taken along the light line for comparable days in 1950 and 1969. Percent is given in terms of full sunlight as measured in the adjacent field.

| Date | Percent 6 feet | Percent 6 inches |
|---|---|---|
| April 22, 1950 | 56.30 | 49.00 |
| April 25, 1969 | 52.20 | 32.70 |
| May 6, 1950 | 57.08 | 46.42 |
| May 3, 1969 | 31.50 | 21.70 |
| May 13, 1950 | 42.39 | 36.90 |
| May 12, 1969 | 9.13 | 6.48 |
| May 21, 1950 | 24.00 | 18.00 |
| May 21, 1969 | 2.71 | 2.00 |
| May 27, 1950 | 6.79 | 6.60 |
| May 27, 1969 | 2.82 | 1.18 |
| June 2, 1950 | 6.50 | 7.10 |
| June 4, 1969 | 2.93 | 1.09 |
| June 7, 1950 | 2.70 | 4.00 |
| June 10, 1969 | 1.82 | 0.95 |
| June 18, 1950 | 4.04 | 4.10 |
| June 19, 1969 | 1.80 | 1.41 |
| July 7, 1950 | 2.61 | 2.80 |
| July 2, 1969 | 1.04 | 0.61 |
| July 28, 1950 | 2.43 | 1.41 |
| July 31, 1969 | 1.89 | 1.40 |
| August 9, 1950 | 2.27 | 2.87 |
| August 6, 1969 | 1.48 | 1.26 |
| October 1, 1950 | 2.50 | 2.10 |
| October 1, 1969 | 3.73 | 2.46 |
| October 16, 1950 | 11.60 | 13.20 |
| October 15, 1969 | 4.81 | 2.94 |
| October 26, 1950 | 16.20 | 12.30 |
| October 28, 1969 | 8.73 | 5.88 |
| November 14, 1950 | 50.30 | 37.60 |
| November 16, 1969 | 31.37 | 35.40 |

These changes are in considerable part a consequence of the windstorms and droughts which have occurred over the past twenty years, although all past events have undoubtedly played an important role in the development of the forest. It is probable that many of these changes would have taken place in the absence of these catastrophes, but perhaps the changes would have proceeded at a different rate. Several investigators have shown that drought and windthrow have the potential of accelerating succession in plant communities (McIntyre and Schnur, 1936; Stearns, 1949; Spurr, 1956).

Table 8. The average percent light penetration for the summer season June through August for 1950 and 1969 as related to the cover, basal area, and density of trees and shrubs.

| Value | | 1950 | 1969 |
|---|---|---|---|
| Total tree cover in dm. over the 100-meter transect | | 1797 | 1853 |
| Total basal area in sq. ft. per 2,500 sq. m. | | 70.39 | 72.27 |
| Total tree density per 2,500 sq. m. | | 373 | 386 |
| Total shrub cover in dm. over 500 meters of transects | | 2226 | 2558 |
| Percent light penetration as an average of the readings June through August | (6 in.) | 3.7 | 1.1 |
| | (6 ft.) | 3.4 | 1.8 |

That the hurricanes, windstorm, and drought inflicted severe damage on the more mature and less tolerant individuals in the forest community at Hutcheson Memorial Forest is well known. The 1950 windstorm harvested a great many of the oaks (Reiners and Reiners, 1965). Dogwood and red maple were severely damaged during the 1957 drought, and the oaks suffered from the combined forces of drought and disease (Small, 1961). Small (1961) reported that the root rot fungus, *Armillaria melea*, was particularly widespread in the forest during the drought years.

With the formation of gaps in the canopy, resulting from windfall and drought injury, the light environment within the forest is affected. A natural sequence of events follows the destruction of a canopy tree. When a canopy tree topples, it destroys much of the understory vegetation in its path. A gap is formed in the canopy which allows more light to penetrate to the forest floor. The herbs, shrubs, and suppressed seedlings and saplings respond immediately to the more favorable light conditions with vigorous growth. Shade-intolerant species are able to become established in the gap areas. The lush vegetation thus produced often has a more complete shading effect than that of the mature canopy (Bray, 1956). The

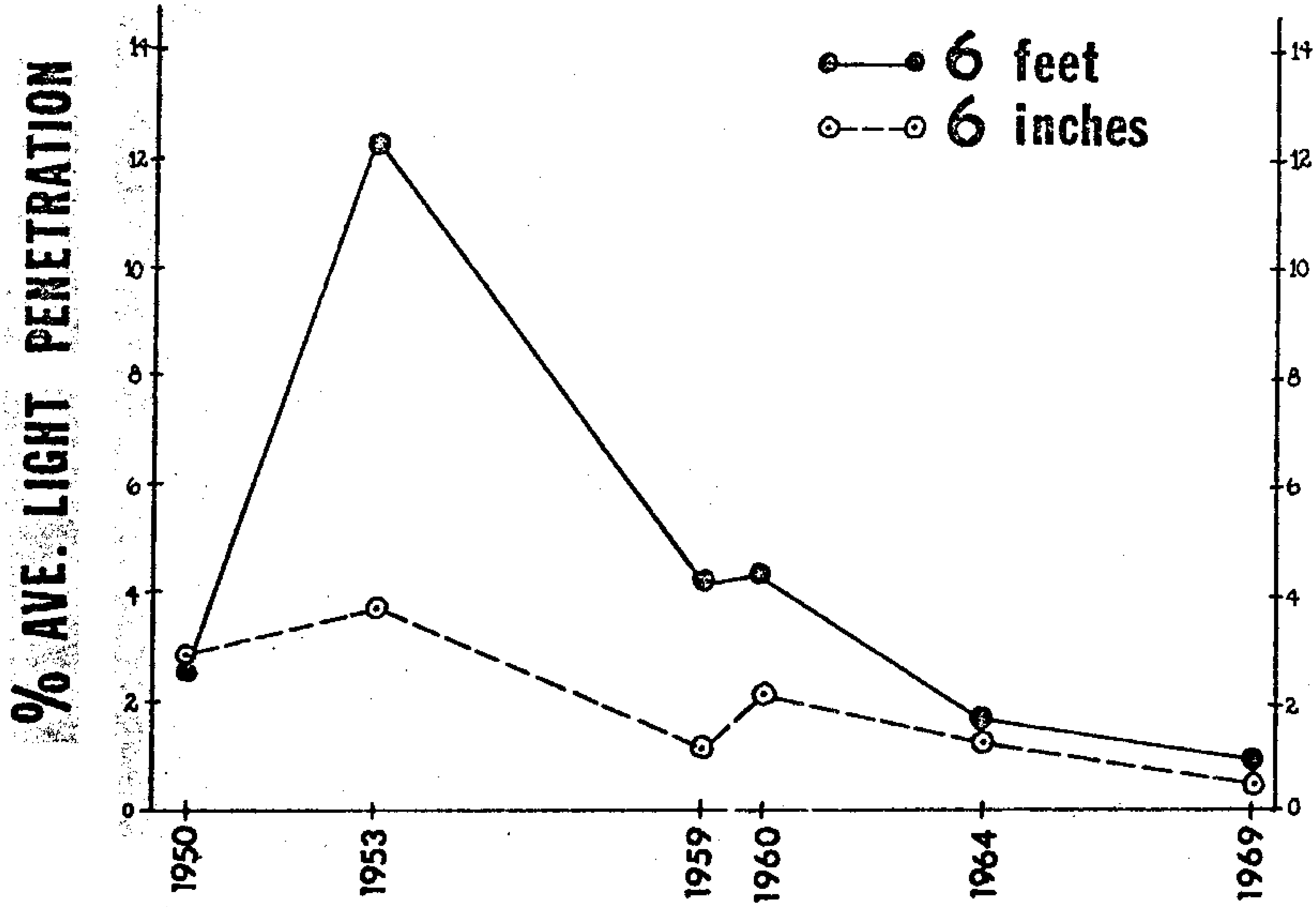


Figure 3. Fluctuation of the light penetration within the forest as related to the change in the total tree cover along the light line over the past twenty years. The light readings were taken on 7 July 1950, 7 July 1953, 5 July 1959, 9 July 1960, 27 June 1964, and 2 July 1966, at 6 feet and 6 inches above the ground.

expansion of tree crowns into the gap openings also contributes to this increased shade (Trimble and Tryon, 1966).

The light data collected over the same 100-meter line during the past twenty years confirm that this sequence of events has taken place within the forest (Figure 3). The light penetration was greatest following the windstorm. It was also relatively high during the drought years 1957 to 1960, presumably due to drought kill, early defoliation, and wilting of leaves. However, by the middle and late 1960's the ground vegetation was more densely shaded than the previous years.

Oak reproduction is not successful under conditions of dense shade (Korstian, 1927), while the more shade-tolerant species are able to become established and survive. This partially accounts for the increase and persistence of the maples and beech.

Within the Hutcheson Memorial Forest the gaps which exist at present are occupied predominantly by herbaceous and shrubby vegetation. *Lonicera japonica* is by far the most extensive gap species, and is able to shade out seedlings and destroy young saplings (Ambler, 1965). Where it is very abundant, it excludes all other herb and shrub species. *Pilea pumila, Parthenocissus quinquefolia, Rhus radicans, Rosa multiflora, Sambucus canadensis, Lindera benzoin,* and all three *Viburnum* species also thrive in the gaps. These species were more abundant in 1969 than they had been in 1950. *Prunus serotina, Cornus florida, Acer rubrum,* and *Fraxinus americana* are the tree species most commonly found in the gaps (Wales, 1969).

The majority of these gap species can be divided into two categories: those which are heliophilic and those which are hydrophilic. In the first category, *Lonicera japonica, Parthenocissus quinquefolia, Rhus radicans, Sambucus canadensis,* and *Prunus serotina* are species which are common in the old fields and along the forest edge where sunlight is not limiting. *Viburnum prunifolium,* also found within the gaps, is a species which fails to flower beneath a dense canopy. The presence of these species in the gaps is to be expected.

*Pilea pumila* usually inhabits the moist areas along the stream traversing the lowland forest at Hutcheson. Likewise *Lindera benzoin* and *Viburnum dentatum* are characteristic shrubs of the poorly drained lowland site. The presence of these species

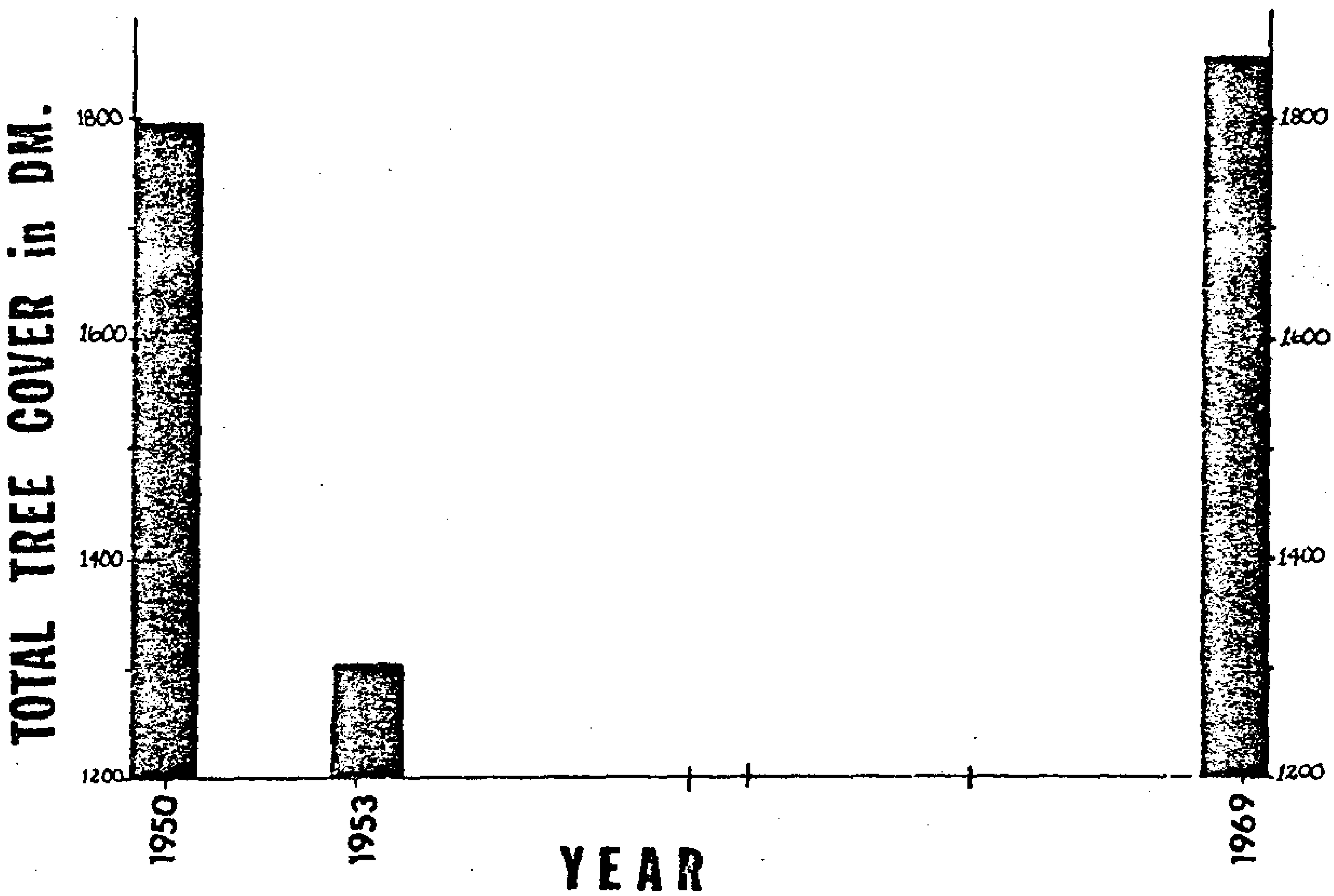


Figure 4. Total tree cover in decimeters as measured along transect lines in 1950, 1953, and 1969.

suggests that the gaps also have a more favorable moisture regime than the surrounding area beneath a dense canopy.

The forest canopy functions as an effective barrier to precipitation as well as sunlight. A considerable amount of rainfall never reaches the forest floor but is intercepted by the crowns of canopy trees (Kittredge, 1948). In areas where the canopy has been removed, there is no longer such a large surface area of foliage to intercept rainfall and, therefore, more moisture reaches the forest floor.

Plants growing in the gap areas are also relieved from considerable root competition for soil moisture. Forest trees greatly reduce the water content of the soil through transpiration loss. In a series of trenching experiments, Toumey (1929) found a significant contrast in soil moisture between trenched and untrenched plots beneath a canopy of white pine. Cutting the roots of the surrounding trees eliminated root competition on these trenched plots and produced higher moisture levels in the soil throughout the growing season. In a similar manner, the death of forest trees reduces root competition in the gaps which are formed. Thus gap areas have a more favorable moisture regime as a combined result of the reduction of rainfall interception and root competition for the available soil moisture.

Although conditions favorable to the establishment of seedlings exist in gap areas, oak reproduction has not increased relative to the increase in maples and ash. Bard (1952) considered Hutcheson Memorial Forest as climax on the grounds that "... replacement of these slowly expiring monarchs (oaks) requires but a few seedlings...." However, in a survey of the harvested trees in the forest the Reiners (1965) reported that 74.6 percent of the total number of harvested trees were oak. Many of these oaks were claimed by a single windstorm in 1950. In 1969 oak reproduction was absent from the quadrats sampled. It becomes apparent that oak reproduction is not keeping pace with the destruction of the oaks. Monk's interpretation (1959) that the oak reproduction is inadequate to maintain the present high dominance of oaks in the canopy is more compatible with the vegetation changes which have occurred over the past twenty years.

Considering its past history, Hutcheson Memorial Forest in precolonial times was a forest maintained by fire (Buell et al., 1954). That certain species are more fire resistant than other species is well known, and among the more resistant species are the oaks (Christianson, 1969, 1971). Fire also favors oaks by reducing shrub cover, thus allowing more light to reach the forest floor, and thereby favoring increased oak germination.

As long as fires prevailed in the area, the natural succession of the forest was halted. Since fires have been excluded, this succession has resumed. The understory layers have become denser and the light more limiting. The conditions under a mature oak canopy in which fire has been eliminated appear to be unfavorable to oak reproduction. It is under these conditions that the maples and beech become established in the understory, since they are shade tolerant (Baker, 1949). Ohmann and Buell (1968), in a study of the forest vegetation of northern New Jersey, observed that the longer oak forests are left undisturbed the more important such species as the maples and beech will become.

Besides the effects of the exclusion of fire, windstorms and droughts appear to be accelerating this succession, the mature oak trees being the most seriously affected by windstorms and by the combined forces of drought and disease. Due to the paucity of their reproduction, the oaks which are killed are not being replaced by oaks.

Therefore, succession within the Hutcheson Memorial Forest appears to be progressing from an oak-hickory forest to a forest in which the northern hardwoods — the maples, beech, and ash — are becoming more important. This succession and its rate are strongly associated with the effects of fire, windstorm, and drought, and the relative tolerance of the component species.

### Literature cited


Ambler, M.A. 1965. Seven alien plant species. William L. Hutcheson Memorial Forest Bull. 2:1-8.

Baker, F.S. 1949. A revised tolerance table. J. Forestry 47:179-181.

Bard, G.E. 1952. Secondary succession on the Piedmont of New Jersey. Ecol. Monogr. 22:195-215.

Bauer, H.L. 1943. The statistical analysis of chaparral and other plant communities by means of transect samples. Ecology 24:45-60.

Bray, J.R. 1956. Gap phase replacement in a maple-basswood forest. Ecology 37:598-600.

Buell, M.F. 1957. The mature oak forest of Mettler's Woods. William L. Hutcheson Memorial Forest Bull. 1:16-19

Buell, M.F., H. F. Buell, and J.A. Small. 1954. Fire in the history of Mettler's Woods. Bull. Torrey Bot. Club 81:253-255.

Buell, M.F., and J.E. Cantlon, 1950. A study of two communities of the New Jersey pine barrens and a comparison of methods. Ecology 31:567-586.

Christianson, J.D. 1969. The effects of fire on hardwood tree species in New Jersey. Ph.D. Thesis, Rutgers — The State University.

Christianson, J.D. 1971. The effect of surface fires on three species of hardwood tree seedlings. William L. Hutcheson Memorial Forest Bull. 2(4): 1-5.

Frei, K.R., and D.E. Fairbrothers. 1963. Floristic study of the William L. Hutcheson Memorial Forest (New Jersey). Bull. Torrey Bot. Club 90:338-355.

Gleason, H.A. 1968. The New Britton and Brown Illustrated Flora of the Northeastern United States and Adjacent Canada. Hafner Publishing Co., Inc., New York and London. Vols. 1-3.

Haines, E.M. 1965. The distribution of *Fagus grandifolia* in Hutcheson Memorial Forest, New Jersey. Bull. N.J. Acad. Sci. 10:12-21.

Kittredge, J. 1948. Forest influences. McGraw-Hill Book Co., Inc., New York. 394 pp.

Korstian, C.F. 1927. Factors controlling germination and early survival in oaks. Yale Univ. School of Forestry Bull. 19:7-115.

Kramer, P.J., and T.T. Kozlowski. 1960. Physiology of trees. McGraw-Hill Book Co., Inc., New York. 642 pp.

McIntyre, A.C., and G.L. Schnur. 1936. Effect of drought on oak forests. Bull. Pa. Agr. Exp. Sta. 325: 1-43.

Monk, C.D. 1957. Plant communities of Hutcheson Memorial Forest based on shrub distribution. Bull. Torrey Bot. Club 84:198-206.

Monk, C.D. 1959. The vegetation of the William L. Hutcheson Memorial Forest, New Jersey. Ph.D. Thesis, Rutgers — The State University.

Monk, C.D. 1961a. The vegetation of the William L. Hutcheson Memorial Forest, New Jersey. Bull. Torrey Bot. Club 88:156-166.

Monk, C.D. 1961b. Past and present influences on reproduction in the William L. Hutcheson Memorial Forest, New Jersey. Bull. Torrey Bot. Club 86:167-175.

Ohmann, L.F., and M.F. Buell. 1968. Forest vegetation of the New Jersey Highlands. Bull. Torrey Bot. Club 95:287-298.

Reiners, N.M., and W.A. Reiners. 1965. Natural harvesting of trees. William L. Hutcheson Memorial Forest Bull. 2:9-17.

Small, J.A. 1961. Drought response in William L. Hutcheson Memorial Forest, 1957. Bull. Torrey Bot. Club 88:180-183.

Spurr, S.H. 1956. Natural restocking of forests following the 1938 hurricane in central New England. Ecology 37:443-451.

Stearns, F.W. 1949. Ninety years of change in a northern hardwood forest in Wisconsin. Ecology 30:350-358.

Toumey, J.W. 1929. The vegetation of the forest floor: light versus soil moisture. Proceedings of the International Congress of Plant Science, Ithaca, New York. Vol. I:575-590.

Trimble, G.E., Jr., and E.H. Tryon. 1966. Crown encroachment into openings cut in Appalachian stands. J. Forestry 64:104-108.

Ugolini, F.C. 1964. Soil development on the red beds of New Jersey. William L. Hutcheson Memorial Forest Bull. 2:1-34.

Wales, B.A. 1969. Edge characteristics of a mature oak-hickory forest. Ph.D. Thesis. Rutgers — The State University.