A TWENTY-YEAR ECOLOGICAL INVESTIGATION IN A RELATIVELY UNDISTURBED SUGAR MAPLE-BEECH STAND IN SOUTHERN MICHIGAN

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This is to certify that the

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ABSTRACT

A TWENTY-YEAR ECOLOGICAL INVESTIGATION IN A RELATIVELY UNDISTURBED SUGAR MAPLE-BEECH STAND IN SOUTHERN MICHIGAN

by Gerhardt Schneider

This study describes ecological changes occurring over 20-years in a 15-acre stand of sugar maple-beech in southern Michigan. These changes are in an area experiencing little man-made disturbances for over 100 years. Since few land areas presently exist in such condition, important comparisons can be made between managed and unmanaged woodlands for this forest type.

Vegetative data were collected between June and August in 1940, 1950, and 1960. Soil investigations were conducted in 1961 and 1962. Plant species with stems less than 1-inch in diameter at breast height were recorded in thirty one 24-inch x 34-inch quadrats. Ground cover maps and photographs were prepared of each quadrat. A 100 percent inventory was made of all woody stems in the stand over 1-inch, recording species by 1-inch diameter classes. The ages, rates of diameter and height growth, changes in crown classification, and bark thickness were recorded for sample trees. Changes in light intensity, and stand mortality for all tree species was also measured.

A detailed soil survey was made and a soil type map prepared. Predominant soils were examined for soil texture, structure, consistence, color, and reaction. Soil moisture depletion and recharge were estimated at 1-foot intervals in the 0- to 9-foot depth of the major soil over a period of 16 months by the neutron scattering method. Evapotranspiration losses during this time were calculated.

The numbers of species in the understory has nearly doubled over the 20-year period. Data on the sequence of species present on individual plots indicates that most herbaceous species have life spans less than 10 years within those quadrats examined. Fluctuations in ground cover occurred in many directions, and it appears that most changes were not directional, but represented non-cyclic replacement changes.

The overstory is composed of 22 tree species, with sugar maple the predominant species in all diameter classes throughout the study period. American beech, the second most abundant tree, is maintaining itself, and actually increased in several diameter classes. American basswood and American elm have shown a general decline, while black cherry and northern red oak have remained relatively constant. White ash and slippery elm have shown large increases.

Changes in light intensity have occurred on the 31 small quadrats over the period. However, it was difficult to evaluate the influence of the loss of an occasional tree or large branch, or the closing of the canopy on plots surrounding those being measured. These changes, not always apparent, are of utmost importance in influencing the amount of light entering the stand.

Stand mortality, expressed in both numbers of individuals and basal area per acre, has steadily increased for most species. Data from sample trees indicate that numerous individuals are from 200 to 300 years old. As the overstory population is composed of many overmature individuals, large losses in timber volume are expected to continue.

Six soil types were represented in the area; Hillsdale sandy loam and Spinks loamy fine sand are predominant. From soil moisture contents of the 0- to 9-foot depth, certain moisture accretion and depletion relationships are apparent. For example, soil moisture depletion occurred at all depths but not at equal rates, and while moisture depletion takes place in the upper depths, moisture accretion may possibly take place in the lower depths. The amount of evapotranspiration loss computed for 12 months was 28.56 inches.

The existing stand structure does not compare favorably with that recommended for a well-managed stand of this type. Growing stock present in the larger diameter classes exceeds that desired. It is recommended that such areas be managed for sawlogs, using a moderate group-selection cutting system. Creating small or medium openings, by removal of overmature and defective trees, will improve both stand composition and quality. On the other hand, it is also of value to forest sciences that relatively undisturbed examples, such as this stand, be retained as reference points for future studies, and steps should be taken to preserve similar stands in the other forest types in Michigan.

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INTRODUCTION

The forest resources of Michigan are indeed abundant, with more than half of the State in forest land. Nearly 20 million of Michigan's 36 million acres are forested, and approximately 97 percent of this is classified as commercial forest land. In the southern half of the lower peninsula of Michigan, where agricultural and industrial activities prevail, only 17 percent of the area is forested. Of this amount, the majority of the forest is in farm woodlots. However, this area contains the largest volume of sawtimber in Michigan, with hardwood forests of sugar maple, oak, hickory, beech, ash, and elm being the predominant species 1/. It is of interest to note that nearly two-thirds of the forest stands are owned by private landowners having less than 25 acres in woodlots 2/.

To manage our forests wisely, it is essential to understand the various ecological agents which operate in the forest, and to improve and/or maintain favorable conditions therein with a minimum of harmful effects. To accomplish these ends, it becomes necessary to apply sound silvicultural practices to these forests which, of course, depend upon certain ecological principles. Intelligent management of our forests cannot possibly be achieved without a thorough knowledge of the silvical characteristics of the tree species involved. Wherever land areas exist that have escaped man's activity, nature has produced a vegetation which

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1/ Findell, V. E. *et al*. 1960. Michigan's forest resources. U. S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 82, 46 pp.

2/ Schallau, Con H. 1961. An investigation of private forest landownership in the southernmost thirty-seven counties of the Lower Peninsula of Michigan. Ph. D. thesis, Michigan State University.

is in equilibrium with the environment presently surrounding it. Where favorable environmental conditions allow their existence, forests are produced. These forests, composed of the prevailing climax species, when placed under sound forest management practices, are easily kept in good condition. Although there may be times when the prevailing forest types are not the most desirable for commercial purposes, knowledge of their characteristics becomes increasingly important for furnishing information to be incorporated into guides that are useful in forest management.

This study was designed primarily to provide information on the ecological changes occurring over a period of time in a sugar maple-beech stand in southern Michigan. They are changes which have taken place in an area that has been little disturbed. Since few areas presently exist in such an undisturbed condition, they are valuable far beyond their timber value for many purposes, including comparisons between managed and unmanaged woodlands for the particular forest type. Data on mortality of the various species in the natural state have many important silvicultural implications.

The soil types of the area are examined and characterized by certain widely-used soil characteristics. From differences in tree growth and herbaceous cover on the different soils, inferences can be made concerning differences in growth of managed stands of this forest type to be expected on related soils in the region. The examination of the soil moisture regime at intervals throughout a growing season may indicate, and help to explain, the vegetative patterns observed in the stand.

REVIEW OF LITERATURE

Although plant succession and vegetative climax are concepts well-known to plant ecologists, wide discrepancies exist in the interpretations of the definition of climax. An important reason for the resulting confusion stems from the great number of climax terms found in the literature. Whittaker (1953) lists no less than 34 different terms containing the word climax as described by numerous investigators.

Without discussing the already numerous and well-known climax concepts contained in the literature, the author ascribes generally to the climax pattern hypothesis of Whittaker (1953). From this viewpoint, climax is treated as a population phenomenon with the climax pattern reflecting more-or-less continuous variation in composition as the populations respond differentially along environmental gradients. A frequent method of ordering prominent features of this pattern is to arrange the various compositional segments in terms of moisture, temperature, and elevation gradients. The continuum approach of Curtis and McIntosh (1951) and Curtis (1959) is an example of this method, in which vegetation is viewed as a continuous variable.

As all climaxes are actually physiographic, edaphic and biotic, as well as climatic, a substitute for the "climatic" climax, to characterize a whole climax pattern, is the concept of the "prevailing climax" proposed by Whittaker (1951). By determining what the most numerous dominant populations in the climax pattern are, or what type occupies the greatest percentage of sites in an area, the prevailing climax thus becomes a quantitatively definable term. Selleck (1960) criticizes this "prevailing climax" theory on the grounds that a comparatively minor constituent of a mature community can actually become an important dominant in later generations. However, if this is a common trend throughout the area, the prevailing climax will then also change to fit the situation. As a result, prevailing climax statements are at an advantage since they are made about average climax characteristics of an area, and thus make no assumptions as to the possible convergence to a monoclimax. In areas having a very diverse and complex environmental and vegetational pattern, however, no single prevailing climax-type may exist.

Three principal propositions of climax theory stated by Whittaker (1953) are presented below and are accepted by the writer as meaningful.

(1) The climax is a steady-state of community productivity, structure, and population, with the dynamic balance of its populations determined in relation to its site.

(2) The balance among populations shifts with change in environment, so that climax vegetation is a pattern of populations corresponding to the pattern of environmental gradients, and more or less diverse according to diversity of environments and kinds of populations in the pattern.

(3) Since whatever affects populations may affect climax composition, this is determined by, or in relation to, all "factors" of the mature ecosystem -- properties of each of the species involved, climate, soil, and other aspects of site, biotic interrelations, floristic and faunistic availability, chances of dispersal and interaction, etc. There is no absolute climax for any area, and climax composition has meaning only relative to position along environmental gradients and to other factors.

Forests on Mesic Sites in Southern Lower Michigan

Braun (1950), who adopts a mono-climax viewpoint, indicates that 3 of the 9 climax forest regions of the Deciduous Forest Formation of eastern North America are present in Michigan. The Hemlock-White Pine-Northern Hardwood climax forest region is located in the upper peninsula of Michigan. The Oak-Hickory climax forest region, and the Beech-Maple climax forest region, are found in the southern portion of the lower peninsula.

The Beech-Maple forest region in Michigan is characterized by the development on mesic sites of a climax in which sugar maple (Acer saccharum Marsh.) and beech (Fagus grandifolia Ehrh.) are the dominant trees of the canopy. 3/ Although referred to as the Beech-Maple Forest by Braun (1950), sugar maple is the more abundant of the two species where this forest occurs in Michigan. This forest type is not present as a single continuous area, as the climax forest region of the same name portrayed by Braun (1950), but rather is scattered throughout the southern half of the lower peninsula of Michigan, on the more mesic sites. The approximate location of this southern mesic forest type in presettlement times is illustrated in Figure 1, after Veatch (1959). It is of interest to note that this forest type is restricted to the southern podzolic soil region of Michigan.

The Beech-Maple forest region, as recognized by Braun (1950), occupies an extensive area. It occurs throughout much of the till plains of Ohio and Indiana, the western end of the glaciated Allegheny Plateau in northern Ohio and western Pennsylvanis, and southern portions of the Great Lakes Region. It almost surrounds Lakes Erie, and Ontario, and extends across the southern half of the lower peninsula of Michigan and into southeastern Wisconsin.

3/ Common and scientific names of all tree species are according to Little, E. L., 1953. Check list of native and naturalized trees of the United States. U.S. Dept. Agr. Handbook No. 41, 472 pp.

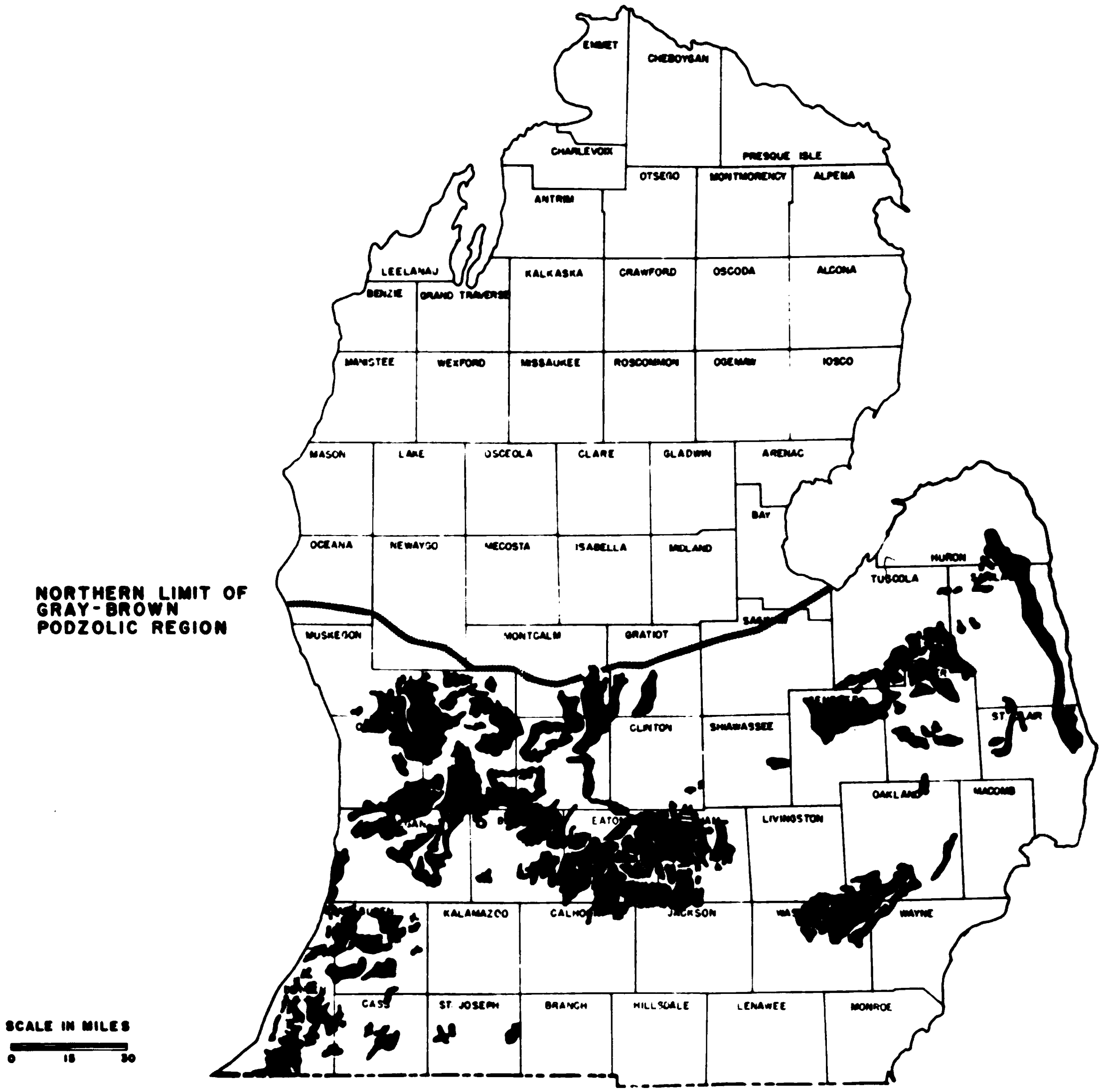

Figure 1. The distribution of the main bodies of naturally occurring sugar maple-beech stands in the presettlement forests of lower Michigan, (Veatch, 1959)

The local variations related to differences in soil, relief, and stages of plant succession, afford considerable variation in this forest type. Benninghoff and Geben (1960) comment on the great contrast in composition and reproduction of beech-maple stands in the northern and in the southeastern extremities of the lower peninsula of Michigan. The non-uniform composition indicates different successional characteristics. The authors, with a mono-climax orientation, suggest that in the lower peninsula of Michigan, beech-maple communities are in the nature of edaphically selected segregates within the oak-hickory region in the south and with the hemlock-white pine-northern hardwoods in the north.

An area of the beech-maple forest region north of Cleveland, Ohio, reported by Williams (1936), is interesting because of the transitional nature of some of its communities. The relatively level land has the beech-maple forest type on it, whereas the forest type of the ravine slopes is composed of mixed mesophytic species. The structure and distribution of the forest community is often determined by local edaphic factors. Potzger (1935), studying the forest types in central Indiana, observed that next to climate, topography with its influence on edaphic and atmospheric factors, probably plays the most important role in control of forest type on an area. In a further study, Potzger (1939) reported that in central Indiana, ridges had beech-maple forests on the northern slopes and oak-hickory on the southern slopes. Evaporation and surface soil moisture were consistently higher and lower, respectively, on the south slopes. The distribution of different forest types in relation to topography in this region is well shown by Shanks (1953). The beech-maple forest type in western Ohio occupies slopes having a good supply of moisture and adequate aeration. Livingston (1903; 1905) states that the distribution of the upland plants of Kent County, Michigan, depended greatly on soil factors, with particular relationship to the moisture retention capacity of the soil. Cain's (1935) work in Warren's Woods, Berrien County, Michigan, also indicates that soil moisture is a critical factor in determining the composition of beech-maple forests.

Braun (1950) characterizes the Beech-Maple forest region of today as mostly farm country. The forest communities which occupied the better soils have been reduced the most. Much of the flat-to-gently undulating country was once beech-maple forests, with predominantly beech in some areas and maple in others. The vernal flora has no species that may be thought of as characteristic to the region since all are common to this region as well as areas southward and northward.

The main characteristics of this region are the degrees of dominance of certain species and the number of species. The two species which give the name to the region occur throughout much of the deciduous forest formation. It is primarily in the Beech-Maple Region, however, that they alone are the dominant species of the climax. Braun (1950) determined the average dominance of beech and sugar maple in the main tree canopy to be approximately 80 percent. In 6 out of 7 beech-maple forest stands reported by Braun for the entire Beech-Maple Forest Region, beech and sugar maple are the two most abundant species in the tree canopy. The numbers of canopy species in the climax beech-maple communities are listed by Braun as ranging from 3 to 14, with an average of 9.5 species. In comparison, Curtis (1959) reports that the average tree composition of the southern mesic forest in Wisconsin contains 26 species, 6 of which occupy 86 percent of the stand: sugar maple - 43 percent; basswood (*Tilia americana* L.) - 12 percent; beech - 10 percent; slippery elm (*Ulmus rubra* Mühl) - 9 percent; red oak (*Quercus rubra* L.) -

7 percent; and eastern hophornbeam (Ostrya virginiana (Mill.) K. Koch) - 5 percent. Sugar maple and beech have an average dominance of approximately 53 percent. As can be observed, basswood is an important component in the mesic forests in Wisconsin, more so than found in southern Michigan. Braun considers much of southern Wisconsin to be in the Maple-Basswood forest region.

The conditions existing in the Western Mesophytic and Mixed Mesophytic forest regions, which lie to the south of the Beech-Maple forest region, are more variable. The average dominance of beech and sugar maple in the former region is about 50 percent, and the average number of tree canopy species is 14.5. For the latter mentioned region, beech-maple has an average dominance of 35 percent, and has an average number of tree canopy species of 15.7. These differences in dominance and in number of species often permit a distinction to be made between the different regions of the eastern deciduous forest formation.

Development of Beech-Maple Association

The Beech-Maple forest region has been well discussed by Braun (1947; 1950). It is a region entirely within the area covered by the last great ice sheet, the Wisconsin. In all of this recently glaciated area, the vegetation was destroyed by the ice. Much of the soil was also destroyed, either removed by glacial scouring or deeply buried beneath the glacial drift. After the recession of the ice, the weathering of parent material and soil development began. Invasion by plants moving in from unglaciated areas also began. The amount and nature of this invasion was primarily controlled by climate and secondarily influenced by edaphic factors. Soil development is influenced by climate and vegetation in the broad sense and by topography and parent material in the narrower sense, according to Lutz and Chandler (1946).

Revegetation involved the slow process of plant succession beginning on a primary bare area. The rapidity of the succession was also affected by the availability of suitable invaders. The climax associations of the glaciated area, as stated by Braun (1947), owe their origin to post-glacial migrations. It is believed that the beech-maple association is a climax of relatively recent origin, and derived from the more complex ancestral mixed mesophytic association of the southern Appalachians. However, Braun also states that some invasion probably came from the Ozarkian center. This interpretation is also supported by Curtis (1959). Of the two major floristic elements represented in this region, the Alleghenian predominates. This group of species actually centers in the Cumberland and Great Smoky Mountains of the southern Appalachians. It ranges through the area above the fall line from the Mississippi Embayment around through Georgia, up through the eastern states to New England, and westward to the vicinity of Lake Superior. This area contains the majority of the hardwoods and its species are largely members of that area.

In addition to sugar maple and beech, which are dominant species in this Alleghenian section, other important constituent species are basswood, white oak (Quercus alba L.), white ash (Fraxinis americana L.), and eastern hophornbeam. Familiar herbs are bloodroot Sanguinaria canadensis L.), spring-beauty (Claytonia virginica L.), trillium (Trillium grandiflorum (Michx.) Salisb.), may apple (Podophyllum peltatum L.), and blue cohosh (Caulophyllum thalictroides (L.)

Michx.)[4/] These and additional species are cited by Curtis (1959).

The Alleghenian floristic element is a very ancient one, extending back to Tertiary times. Curtis (1959) states that it is thought to have been part of a very widespread flora, the Arctotertiary temperate forest flora, which circled the globe in regions currently in mid-and-high latitudes.

The other floristic element of importance, the Ozarkian, is one that Curtis (1959) believes to be closely related to the Alleghenian, and is probably of Tertiary origin. It differs in that its center is in the Ozark Mountains of Arkansas and Missouri. Its range extends south and east to the fall line, west to the arid plains, and north to Minnesota, Wisconsin, and Michigan. Many of the genera found in this element are the same as those in the Alleghenian element, but the species have become differentiated through long isolation. The Ozark flora on the whole is better adapted to drought conditions than the species of the Alleghenian flora. The Ozark species are capable of establishing quite stable vegetational types on the more xeric sites such as sands, gravels, and south-facing slopes. Various oaks and hickories are typical tree species of this group. The oaks most common are bur oak (*Quercus macrocarpa* Michx.), black oak (*Q. velutina* Lam.) and chinquapin oak (*Q. muehlenbergii* Engelm.). Common ground cover species are redroot

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4/ Common and scientific names of all herbaceous species are according to *Gray's Manual of Botany*, 8th Ed. (Fernald, 1950), 1632 pp.

(*Ceanothus americanus* L.), rue anemone (*Anemonella thalictroides* (L.) Spach), and wild-indigo (*Baptisia leucophaea* Nutt). These and additional species are cited by Curtis (1959).

Pre-Settlement Vegetation

Prior to the period of intensive settlement, which began in the early half of the 19th century, Veatch (1953) estimates that forests covered probably no less than 95 percent of the area of the state. Veatch (1928; 1931) attempts to reconstruct the original forests, based on soil-vegetation correlations. His basic premises for this approach are: (1) that the distribution of vegetation is a function of climate; (2) that climate is a factor in determining the character and distribution of soil; (3) moisture and temperature are primary factors determining the nature of the vegetation and also are responsible for local differences in the soil; (4) investigations on soil genesis suggest that there is a simultaneous development of the soils and the vegetation; (5) it is known that plants obtain a great part of their nutrients from the soil, and a certain nutrient condition will favor some plants over others; and (6) that time, in general, has been sufficient for adequate adjustment to have taken place between the soil and the vegetation.

The soundness of this approach, as Veatch (1931) states, depends upon the degree of consistency with which a particular type of forest is restricted to a particular type or types of soil. The correlation appears to be closest where the separate soil types appear in relatively large and uniform bodies. Where one soil occurs as a small body included in a larger body of another type, the vegetation of the dominant soil is very likely to spread over the minor one. It is also doubtful whether any particular soil type is precisely the same in its chemical and physical characters throughout its range. Wilde (1933) points out that the dependence of forest growth upon the state of underground water, soil texture, internal drainage, and aeration represents one phase of the correlation of soil-vegetation which indeed often becomes complex. It may be further noted that fire and other disturbances may keep certain areas in some particular vegetative type.

Veatch (1928) is of the opinion that the original forest types of the northern two-thirds of Ingham County consisted of sugar maple and beech, as well as oaks, hickories, and other southern species. The lower one-third of the county is typed as oak-hickory. Kenoyer (1929; 1934; 1940; 1943) based his pre-settlement vegetation studies on field notes compiled during the original land survey made during 1820-1830. For Kalamazoo County, he found that beech-maple areas occupied about one-fourth of the county and were most dense. Kenoyer further suggests that, in relation to maple, beech was more numerous than it is in most places today. He reports that oak-hickory types were also well represented.

Disturbances to forest vegetation due to natural causes were present before even primitive man came on the scene. In a study of the northern hardwoods in Wisconsin, Stearns (1949) observed that fire, especially from lightning, as well as windthrow, were very important causes of disturbance. However, up until settlement by the white man, primitive man altered the vegetational composition and distribution greatly. That primitive man has existed for some time in North America has been well established. Curtis (1959) indicates that primitive Indian cultures have been found in the southwestern part of the United States with radiocarbon dating of 37,000 B.C. or well before the Wisconsin Stage of the Pleistocene. Indians have also lived in Michigan and surrounding areas for a great length of time. Fuller (1924) reported evidence of relics of the Mound Builders in Aurelius Township of Ingham County. Chase (1922) states that tribes of Algonquins, Chippewas, Ottawas, Menomines, and Potawatomies resided in Michigan.

There were several ways in which the Indians altered the vegetation in which they lived. Day (1953) indicates the clearance of areas for village sites and fuelwood had a pronounced affect on the vegetational types. Also, the practice of agriculture was widely dispersed over the Northeast. The first white men on the scene may have under-estimated the amount of land which had been cleared for gardens and fields, since once cultivation ceased, rapid succession to forest occurred. Curtis (1959) suggests that the hunting of game also affected plant communities indirectly through the influence on the control of animal populations. In addition, studies by Gilmore (1930) and Day (1953) indicate that the favoring of certain plants used for food and medicinal purposes influenced the existing vegetation.

It appears that fire, however, was probably by far the most important factor in the influence on the existing vegetation. This overshadowed the combined influence of all other factors previously mentioned. Day (1953) states that fire was used for driving game, improving visibility, facilitating travel, reducing unwanted fauna, increasing the supply of grass seeds and berries, for various reasons, during warfare, and in clearing of land for agriculture. Day maintains, however, that all of these factors are not helpful in evaluating the extent and intensity of Indian influence. Other factors which must be known are the duration of Indian occupancy, population density, population concentration and movement, and the location of village sites. Day feels that the tendency of the Indian population to congregate in villages and to migrate had a direct bearing upon their effectiveness in disrupting natural plant successions. Fuller (1924) claims that the Indian population of Michigan was not up to the numbers present elsewhere. As for Ingham County, Fuller believes that there were no more than 500 Indians here after the settlers began to know it. There is no evidence that there was ever more than that number here. The village of Okemos was the Indian metropolis of the county. However, even this was not always a year-around place of habitation.

Curtis (1959), however, believes that since the influence of a fire is expressed far beyond the point of original ignition, it becomes unimportant to estimate the Indian populations in order to account for widespread vegetative effects. A few widely scattered Indian tribes could start enough intentional or accidental fires to keep all but the most protected sites in a retrogressive state.

Post-Settlement Vegetation

Although the general effects of settlement during the past century, with the accompanying severe forest fires, are widely known, the precise vegetational history of any particular area is rarely well understood. Without this information, the investigator is often handicapped, both in understanding how present conditions came to be and in predicting what course future changes will take.

The rate of vegetation change was relatively slow in post-glacial times until the coming of European man. After his arrival the rate of vegetation change increased rapidly. Chase (1922) and Fuller (1924) relate that the first white farmers in Michigan were the French from Canada, located in the southeastern part of the state. After the completion of the Erie Canal in 1825, the population of Michigan increased rapidly. By 1835, there were 212,000 inhabitants in Michigan. Ingham was designated a county in 1829, and the first purchase of land in Okemos was in 1832. The big rush in inhabitants took place between 1835 and 1837, at which time Michigan changed from a territory to a state.

Curtis (1956; 1959) gives a good account of the activities of the white man upon settlement into a new area. In the early stages of settlement, the most important vegetational effects were caused by the elimination of fire, the major influencing agent of the Indian. However, while the white man removed the fire, he introduced new agents which influenced the vegetation that was present. As Clawson *et al.* (1960) points out, by bringing the axe, plow, and grazing animals into the picture, great biotic changes took place in the forest.

The harvesting of timber on a rapidly increasing scale began in Ingham County in the 1840's. A large amount of timber was clear-cut prior to the clearing of land for agricultural purposes, but forest woodlots which did remain were utilized for various needs on a selective basis. The majority of the uncleared forests were thus subjected to drastic changes in species composition, both qualitative and quantitative. Accompanying these changes in species composition have been changes in the micro-environment within the forest. Logging resulted in the opening of the forest canopy, thus creating a very different microclimate. The environmental changes induced are in the direction of a more xeric condition, with greater light and more variable temperature and moisture conditions. As Niering (1953) suggests, the present vegetational pattern found is a result of man's activities superimposed upon climatic, edaphic and physiographic conditions.

For northern Michigan, the interval between 1880 and 1920 is described by Kilburn (1960) as one of constant fires, with an average of one major conflagration taking place every four years. In southern Michigan, however, few catastrophic fires occurred during this same period of time because of the reduced amount and type of timber present. Far less forest land remained after the main timber harvest because much of the land was cleared for agriculture, a task nearly completed during the 1860's. Mitchell and Robson (1950) report, however, that many isolated farm woodlots and other tracts of wildlands were burned one or more times prior to the 1920's, when adequate state fire protection was first established.

Along with the increasing agricultural developments, European man has been much more effective than the Indian in the matter of plant introduction. A whole new set of weed species was brought in and allowed to attain high population levels on the croplands and farms. Some of the plants used as crops were able to escape and become established in a variety of situations.

From the preceding discussion, it becomes evident that the pre-settlement forests of Michigan had pronounced differences in species composition and areal distribution. The effects of former lumbering operations and subsequent fires have been enormous. These disturbances have done much to alter and retard the normal course of plant succession. Also, an increase in agricultural activities, with resulting clearance of forested land, and such tillage practices as drainage of swamplands, have influenced the normal plant successions. Man has also modified the vegetation through the pasturing of woodlots. It can be concluded that forest stands in Michigan represent all phases of development, ranging from those with little or no disturbance, to those with light cuttings,"selection" cuttings, clearcutting and/or burning, followed by areas farmed and later abandoned and presently once again going through various stages of succession.

When a comparison of the effects of Indians and Europeans is made for the vegetation, Curtis (1959) suggests that they appear similar. The actions of the Indian, however, tended to leave the soil covered with some type of living material, so that soil erosion and water depletion were not great problems. Europeans, however,

tended to destroy all soil covering and thus induced extensive amounts of erosion damage. This in turn affected water runoff, infiltration and percolation rates, and also water-storage capacities.

Soil Moisture Investigations

Variations in available soil moisture have an important influence on forest vegetation and the relative productivity of forest sites. Although the growth of trees is governed by a complex set of interrelated environmental factors, Black (1957) has emphasized that water is probably the most single important limiting factor in plant growth. Kozlowski (1958) states that soil moisture deficits occur widely, and frequently become the critical factor at seasons of the year when other environmental factors, such as temperature, and light, are at their optimum levels for plant growth.

Recent approaches to site evaluation concepts by Heiberg and White (1956), and Hills and Pierpoint (1960), have stressed the importance of considering all of the effective factors of site. Oftentimes, however, one or two factors appear to be responsible for limiting plant growth. For example, Zahner (1958) reported that two closely related soil factors, soil moisture and soil aeration, limited southern pine growth during each growing season. According to White (1958), the majority of successful forest site classification schemes attempt in some manner to estimate the existing soil moisture regime. Therefore, available soil moisture is an important site factor. However, the measurement of available soil moisture still remains a difficult and time-consuming one.

In addition to measurement difficulties, some controversy exists as to just how available this soil water actually is to

plants. The amount of water between the field capacity (maximum capillary moisture) and the permanent wilting point (minimum capillary moisture) is thought to represent the water available to plants. However, no complete agreement has occurred as to whether all of the water is equally available over the entire range represented by these two soil moisture constants. A recent publication by Hewlett (1961) suggests, for example, that soil moisture in the range of field capacity may perhaps be the primary storage aquifer and source of base flow. While the depletion of soil water within the range of field capacity occurs at a very slow rate, constant drainage from it over long periods of time may satisfactorily explain the existence of sustained base flow in areas where no ground water supplies could maintain the stream flows observed. As a result of this loss, less water would be available to plants within the two moisture constants. While the literature on this subject has been well-reviewed by Black (1957) and Kramer (1949), the pertinent information has been well summarized by White (1958) as follows:

> (1) Plants can use water readily between these two equilirium values, but at a decreasing rate with increasing tension, accompanied by a decrease in growth on finer textured materials as the soil moisture is depleted below the field capacity.
>
> (2) On coarse textured materials, the point of rapid increase in tension on the depletion curve is so close percentage-wise to the wilting point that moisture is considered to be uniformily available over the range for practical purposes.

Of the number of experiments conducted on the general influence of forest cover upon the soil moisture regime, only a small number have actually estimated the amounts of seasonal water used by forest cover.

Investigations have been conducted to determine the rate of available soil moisture depletion by forest vegetation. Rowe and Colman (1951) studied the disposal of rainfall in the woodland-chaparral and ponderosa pine in the San Gabriel Mountains of California. Soil moisture samples were taken to bedrock (3-6 feet). It was observed that the shallower soils dried by evaporation more completely than deeper soils. As evaporation losses were greatest in the surface layers, the moisture content of the soil was found to increase with depth.

McLintock (1959) recorded daily soil moisture measurements in the upper 12 inches of soil during the growing season in a mixed pine-fir-spruce stand in Maine. The soils were shallow, with an impervious layer present at 15 to 30 inches. While rainfall was evenly distributed during the growing season, the perched water table present resulted in unfavorable soil moisture and soil aeration conditions for tree growth. However, during a dry summer period, the perched water table soon dropped below the root zone, at which time the shallow soils rapidly reached the wilting point.

Veihmeyer and Hendrickson (1955) investigated the water consumption of pine and oak, as well as of various fruit trees. The rate of moisture depletion from the soil was not found to be influenced by the quantity of water in the soil, provided soil moisture was kept above the permanent wilting point.

Thames et al. (1955) examined soil moisture changes in forested (jack pine and some northern hardwoods) and nonforested (grass) areas in northern Wisconsin. They determined that the forest depleted

soil moisture more readily than did the nonforested area, especially in the upper 24 inches of the soil. In contrast, Axley and Thomas (1948) found more soil moisture in a woodlot (unclassified as to type) than in a pasture area. The authors reasoned that greater reduction of evaporation on the part of the forest vegetation was the critical factor in reducing water loss.

A study by Fletcher and McDermott (1957), on the moisture depletion of saturated soils in the Ozarks of Missouri indicates that once the soil surface has been dried by evaporation, further water losses occur at rather constant rates. Also, transpiration takes place until the soil moisture supply is reduced below the permanent wilting point.

Hoover et al. (1953) report that soil moisture in a loblolly pine plantation was withdrawn most rapidly from the zone in which it was most readily available regardless of depth. Rapid rates of water loss up to a depth of 5 feet were observed, despite the greater concentration of tree roots in the upper surface layers.

Gaiser's (1952) study on oak stands in Ohio revealed that from soils 3 and 4 feet deep, all horizons of the profile arrived at the permanent wilting point at approximately the same time. Similar results were reported by Boggess (1953) in a 15-year-old shortleaf pine and white oak stand. Here, soil moisture was depleted simultaneously at various depths throughout the upper 2 feet of soil. Lull and Axley (1958), investigating soil moisture variation under 4 kinds of cover in the New Jersey Pine Barrens, reported that within the upper 5 feet of soil, moisture depletion took place simultaneously within each foot-depth. Furthermore, this depletion occurred at about the same rate. It was observed that 30, 22, and 16 percent of the moisture removed came from the 1-, 2-, and 3- to 5-foot levels, respectively.

Reimer (1953) observed the percentage of available water present at the 1-foot and 3-foot level of sandy loam and loamy sand soils in a relatively undisturbed sugar maple-beech stand in Michigan. Within the woodlot at the 1-foot depth, the percentage range of available water from July to October was 70 to 90 percent. For the same period of time, the 3-foot level showed that from 65 to 95 percent available water was present. Ample water was thus available at all times for plant growth in the upper 3-foot layer of soil. Reimer noted, however, that plots located on the edge of the woodlot, for this same period of time, showed the percentage of available water to range between 95 to 12 percent, for both depths.

Fraser (1957) followed the seasonal and annual changes of soil moisture on four different sites of Canada. On all of the dry sites (water table several feet from the surface), the upper layers of the soil dried out first. Soils whose depths averaged 1 foot were found to exhibit frequent drought conditions. The deeper soils, having increased storage capacities, were subject to fewer drought conditions.

Coltharp (1958) conducted a soil moisture study on a well-stocked stand of second-growth oak-hickory in southern Michigan. The average monthly soil moisture for the upper 3 feet of a sandy loam soil, in inches of available water, during the growing seasons of

1946–1951 were: April = 7.05; May = 6.94; June = 6.69; July = 3.74; August = 1.58; and September = 2.20. Coltharp stated that at no time did the soil moisture content go below the permanent wilting point.

In western North Carolina the seasonal and annual soil moisture trends in a 7-foot profile were examined over a 7-year period by Helvey and Hewlett (1962). The soils sampled were sandy loams originating from mica schists and gneisses. The area of the study is one in which rainfall generally exceeds evapo-transpiration. It was shown that the upper surface 12 inches of soil both stored and lost more water on a percent-by-volume basis than did the remainder of the profile. Moisture conditions were very uniform throughout the 2- to 7-foot layers. The authors observed that the soil moisture content, in any layer of the 7-foot profile, at no time approached the permanent wilting point during the period of study.

Several investigations have been made which indicate that pronounced differences exist in amounts of soil moisture used by different types of vegetation. Whereas some plants are characteristically deep-rooted, others are shallow-rooted. Croft (1950) studied the soil moisture depletion of aspen, herbaceous ground cover, and bare sites in Utah. The annual water loss due to evapo-transpiration was nearly four times greater on the aspen sites than on the bare sites. The herbaceous cover used twice the amount of water as did the bare area. Hoover (1952) found that loblolly pine removed moisture to depths greater than 5 feet. whereas surrounding herbaceous cover, having shallower roots, removed soil moisture to a depth of 3 feet.

Koshi (1959) conducted a study of the soil moisture trends under undisturbed, thinned, and cleared post oak stands in Texas. He observed that the moisture content of the upper 2 feet of soil was highest in the cleared area and lowest in the undisturbed oak stands. Most of the difference in moisture content occurred in the 12- to 24-inch horizon, where tree roots were well established. Metz and Douglass (1959) estimated soil moisture depletion under various Piedmont cover types. Forest types were observed to draw upon soil water to depths of at least 66 inches, and at relatively the same rates regardless of species. Under old-field herbaceous cover, as well as bare soil, the majority of soil moisture removed was that from the upper 30 inches. Moyle and Zahner (1954), working in Arkansas, found that nearly equal amounts of water were removed during the same interval of time from an all-aged pine stand, an all-aged hardwood stand, and a young even-aged hardwood stand.

Zahner (1955) has examined the influence of both loblolly pine and hardwoods on soil moisture depletion. He reported that little difference existed between the two types of vegetation with respect to water consumption for corresponding depths. Lull and Axley (1958) found that 15-year-old shortleaf pine utilized soil moisture to a depth of 8 feet. Older stands of both shortleaf pine and oak used about equal amounts of water, at the same rate, to a depth of 5 feet. Furthermore, the authors reported that both types of vegetation removed moisture to at least a depth of 12 feet.

The importance of aspect and topographic position on the soil moisture regime of an area has been reported by a few workers. Potzger

(1939) found better soil moisture conditions on north-facing slopes than on south-facing slopes in central Indiana. Stoeckeler and Curtis (1960) examined the interaction of these factors with different plant covers (hardwoods, Scotch pine, white pine) in the Driftless Area of Wisconsin. They found: (1) soil moisture was significantly higher in north-facing than in south-facing slopes; (2) soil moisture contents increased systematically from top to bottom on the north-facing slopes but only to a lesser extent on the south-facing slopes; (3) the moisture content under the hardwoods on the north-facing slope was almost twice that under white pine on the same aspect; and (4) moisture content was similar in hardwoods and Scotch pine stands located on south-facing slopes.

Soil Moisture Determinations

A number of methods have been employed for determining soil moisture. In fact, the literature has become voluminous with descriptions of different methods and techniques used in measuring this factor. Ideally, soil moisture measurements on a continuous basis are needed to fully understand the nature of soil water movement. To achieve these results, the method used must be reliable throughout the entire range of soil moisture conditions, a condition not satisfied by any one method.

The primary methods used in soil moisture determinations, as well as some of their advantages and disadvantages, are described by Olson and Hoover (1954), Lull and Reinhart (1955), and most recently by Johnson (1962). The most common and precise method of determining soil moisture is the gravimetric method. Water is reported as a percentage of the oven-dry (105° C.) weight of the soil. The disadvantages cited for this method are: (1) restrictions placed on the number of possible samples which can be taken per day; (2) length of time necessary to collect samples, especially from depths greater than a few feet; (3) destruction or disturbance of the sample plots, making continuous soil moisture studies at a particular point impossible unless special precautions are taken; and (4) the loss of time required before the results of sampling become available. One or two days may be required for the soil samples to be weighed, dried, reweighed, and perhaps sieved (for stony soils), before calculations can be made. Despite these disadvantages, however, the gravimetric method still remains as the one direct quantitative measure of soil water.

Methods using electrical and thermal conductivity, and moisture tension principles, are influenced by factors other than soil moisture alone. Some of these factors which may disturb calculations are soil texture, temperature, electrical contact resistance, salt concentrations, and the physical nature of the blocks themselves.

The most sophisticated method for measuring soil moisture is the neutron scattering method or radioactive method. It is considered by Sartz and Curtis (1961) to be the most reliable method available in the determination of soil water movement. Johnson (1962) states that radioactive methods are probably the best for obtaining repeated measurements of soil moisture.

The operational principle of the neutron method in moisture measurements is based on physical laws governing the scattering of neutrons. When a radioactive source of fast neutrons is placed in a material, the neutrons collide with nuclei of the surrounding atoms and are randomly scattered in all directions. Each collision by a neutron causes a loss of part of its kinetic energy, and this reduction of energy process continues until the kinetic energy of the neutron approaches the average kinetic energy of the surrounding medium. At this point the neutron is termed a slow neutron.

The average energy loss by fast neutrons is much greater in collisions with atoms of low atomic weight than in collisions with heavier atoms. As hydrogen is the only element of low atomic weight in most inorganic soils, and is largely contained in the molecules of free water, the slow neutron count recorded is related to the moisture content. The moisture probe used in this method is constructed with a special detector which is only affected by slow neutrons. Therefore, the number of slow neutrons detected per unit of time is directly related to the number of hydrogen atoms present. As a result, it is also related to the soil moisture content by volume in the mass of soil surrounding the point of measurement.

The slow neutron count is detected by means of a portable scaler. The moisture probe is connected to the scaler by means of a coaxial cable and the probe is lowered into the soil to the desired depth. After a prescribed period of time of operation, the total neutron count is registered visibly in dots of light upon the scaler's glow-tube decade counters and summed automatically. The count may then be located on a calibration chart, and the moisture content by volume determined. For further information on the theory and operation principles of the neutron method for determining soil moisture,

the reader is referred to the work of Van Bavel (1958) and the Nuclear-Chicago Corporation (1960).

The neutron scattering method has many advantages that other soil moisture measurement methods do not have. Olson and Hoover (1954) present a discussion of some of these which include: (1) inhomogenieties, such as rocks, present no serious problems; (2) salt concentrations and normal quantities of organic matter found in soils do not influence soil moisture values obtained; (3) the same calibration curve is used for many different types of soil; (4) large numbers of samples can be taken per day; and (5) as little disturbance of the sample plots occur, continuous soil moisture measurement at a particular point is made possible. In addition, the moisture determination that is made is for a volume of soil rather than for just any one given point in the soil profile. Therefore, the moisture values obtained represent an average for a larger volume of soil and thus require fewer replications to characterize a particular site or location.

Several investigators point out that the neutron method also possesses some inherent disadvantages. Since the neutron probe normally measures a spherical volume of material with an average diameter of 15 inches, it becomes difficult to measure the moisture contained in an individual soil horizon which might be thinner than 15 inches. In a similar manner, it is also hard to determine the precise location of a wetting front in the soil profile.

Merriam (1959) cites the cost of the original equipment, as well as the high cost of site preparation, as disadvantages. While the initial costs may be considered high, the information obtained over a long period of time certainly reduces the significance of this objection. Merriam also points out that a radiation hazard exists in the use of this equipment. While this is true, it is believed that if normal safety precautions are observed, no element of radiation danger need exist.

One additional disadvantage of the neutron method which is cited by Olson and Hoover (1954), Stone et al. (1955), Marston (1958), Hammond (1959), Sartz and Curtis (1961), and Johnson (1962), is its inaccuracy in the upper 6 inches of the soil surface. At this depth the neutrons, which are emitted upward from the radioactive source, escape to the atmosphere. As Sartz and Curtis (1961) point out, this loss varies with the moisture content of the soil in the upper surface layer. The loss increases as the moisture content decreases since there is less chance for the fast neutrons to collide with the hydrogen atoms of the water molecules.

Numerous investigators have reported excellent results with the neutron method and have compared it favorably with some of the other methods used in soil moisture determinations. Stone et al. (1955) reported that except for the surface 6-9 inches, the neutron method gave results within the range of the standard deviation of gravimetric determinations. Stewart and Sterling (1957), using both a fine sand and a loamy soil, found that between 30-125 cm. depths, the correlation coefficient was 0.95 for the neutron count and gravimetric method. The correlation coefficient for the two methods at the 15 cm. depth was 0.76. Marston (1958), using the neutron method in evapotranspiration studies on mountain soils, found correlation coefficients

of 0.045 to 0.715 between the neutron method and gravimetric method. The poor results obtained by the neutron method was probably the result of the shallow nature of the soils, causing neutron loss to the atmosphere.

Merriam (1959), comparing gravimetric, electric, and neutron methods on grass-covered lysimeters, reported close agreement between each method. On a bare lysimeter, gravimetric results were 18.02 inches of water in the profile, nuclear method yielded 17.42 inches of water, and the Colman moisture blocks gave readings which deviated 3 inches from the other two methods. Hammond (1959), comparing gravimetric and neutron methods of soil moisture determination on fine sands in Florida, reported that the two methods were about equal in precision for all depths except the upper 6-inch layer.

DESCRIPTION OF AREA

Acquisition and General Description

In May, 1939, 15 acres of woodland were acquired by Michigan State University from the Frank Bennett estate. The property is located in the NE 1/4 of the SE 1/4 of Sec. 30, T 4N, R IW of the Michigan Meridian, Ingham County, Michigan. The woodlot is approximately two miles south of the main campus of Michigan State University, East Lansing, Michigan. The property was named Toumey Woodlot in 1940, after the late Dr. James W. Toumey, professor in the School of Forestry at Yale University, and an alumnus of Michigan State University.

According to the past owner, the woodland was obtained by the Bennett family in 1852. Their aim was to maintain the land as undisturbed as possible. Consequently, only dead and down trees were ever removed from the area for fuelwood. The past owners also related that the area had been fenced off and no domestic livestock had been permitted to graze in it. There is no past record or present evidence of fires in the woodlot, and very likely the area has not been burned for a long period of time. It is reported not to have been burned during the past known ownership and this is corroborated by the present appearance of the area.

The woodlot was set aside and reserved as a check on corresponding managed woodlands in southern Michigan, as well as providing an outdoor laboratory for the study of forest ecology. All activities which would possibly interfere with the natural processes were

discontinued as reasonable precaution and the location of the area would permit.

Establishment of Windbreak and Buffer Zone

It was realized that a 15-acre tract of forested land could scarcely be thought of as representing a natural forest. Its small size allows the woodland environment to be influenced by the surrounding cleared farmland and roadways. The wind, sun, and other climatic elements penetrating from all four sides materially affect conditions within the forested area. To alleviate this condition somewhat, a 20-foot-wide evergreen windbreak was planted in 1941 and 1942 along the north side of the woodlot facing open fields. Along the west side of the woodlot, a 44-foot-wide strip, which contained brush and pole-sized hardwoods, was planted at the same time. In total, 802 trees, of 5 species, were planted, these being white pine, Norway spruce, white fir, black spruce, and white cedar.

Several spacing arrangements were used in these plantings, but for the most part, on the north side, the windbreak was 2 rows wide, with a distance of 6 to 8 feet between rows, and 12 feet between individual trees. Along the west side of the woodlot, the windbreak was 3 to 5 rows wide and spacing varied from 3 to 8 feet between rows, and 6 feet between trees. All rows were placed in a staggered position, to obtain the maximum benefit from the shelterbelt planting. At the present time (20 years after planting) a portion of the north strip is still in existence, but the west strip is essentially missing, mainly because of severe competition from the hardwood overstory. Figure 2 and 28 (Appendix) indicate these features from aerial photo-

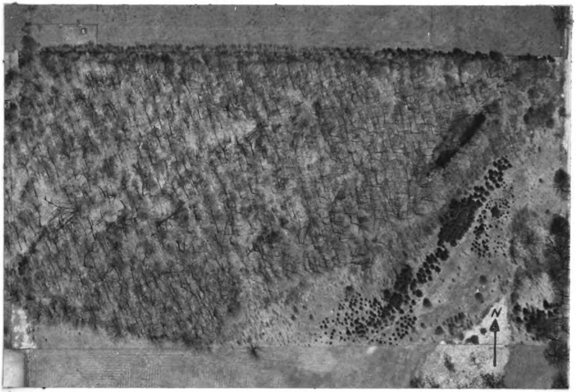

Figure 2. Aerial photograph of Toumey Woodlot, May 10, 1961 (Scale: 1 inch = 240 feet). (Courtesy of Abrams Aerial Survey Corporation)

graphs taken of the area. In addition to the establishment of the windbreak, in order to minimize the abnormal effect of climatic elements penetrating from the sides, all studies were initiated as far inside the woodlot boundaries as possible. Therefore, an additional buffer zone was created between the established windbreak and the study plots. As a result of this buffer zone, the present study is based on approximately 13 of the 15 acres in the woodlot. Figure 3 is a generalized map of the study area, indicating the buffer zone and topographic characteristics.

Climate

The climate of Ingham County is characterized as rather mild in the summer and fairly cold in the winter. The precipitation is fairly evenly distributed during most of the year, with normal precipitation being approximately 31 inches. However, the precipitation regime in the lower peninsula of Michigan, as reported by Brunnschweiler (1962), does show a pronounced midsummer decline of rainfall. He indicates that whereas the mean monthly precipitation for the county is approximately 3.8 inches and 3.5 inches for May and June, respectively, the values for July and August are 2.2 inches and 2.8 inches, respectively. More precise data of the annual precipitation for the immediate study area are presented in the section dealing with the Soil Moisture Regime. The decline in midsummer rainfall is evident. Veatch (1941), however, states: "Although the rainfall shows considerable annual and seasonal variation, and marked differences exist in the moisture-holding capacity of the soils receiving the same amount of precipitation, general crop failures due to a deficiency or an excess of water have never occurred."

The average frost-free season is about 160 days, from about May 3 to October 10. Frost has been recorded as early as September 8 in the fall and as late as May 8 in the spring. The mean annual temperature for the county is 46.9^{o} F., with a mean winter and mean summer temperature of 24.2^{o} F., and 68.6^{o} F., respectively.

Baten and Eichmeyer (1951) report that the prevailing winds are westerly and commonly are low in velocity. The average annual wind velocity is approximately 7 miles per hour, whereas the average annual maximum wind velocity is about 14 miles per hour. The climate for the county as a whole does not appear to have marked differences, and only small variations occur due to local depressions and slope.

Physiography

Leverett (1917) reported that the rock formations of the southern peninsula range in age from the upper part of the Silurian, through the Devonian, to the lower Carboniferous, and consist of a series of limestone, shale, and sandstone beds. For Ingham County, Martin (1955) estimates the age of the rock at or near the surface to be Pennsylvanian. Of the physiography of Ingham County, Veatch (1941) states:

> The relief as a whole is smooth or gently undulating, although some parts are choppy and comparatively hilly. The secondary topographic features are those common to the moraines, till plains, outwash plains, and old glacial drainage valleys of this section.... As streams are not numerous, stream dissection is comparatively slight. The extreme difference in elevation between the highest and lowest points in the county is less than 300 feet, and local differences between the levels of swamps, lakes or stream valleys, and the adjacent higher land generally do not exceed 100 feet. Most of the slopes are short, smooth and rounded, rather than angular. They are related to constructional features

of glacial origin rather than to subsequent stream dissection or geological erosion.

The region probably embraces the largest area of thick drift in North America. Leverett and Taylor (1915) estimate that parts of the southern peninsula have nearly 1,000 feet of drift present. However, the average thickness of the drift is approximately 300 feet. Leverett (1917), indicates that it is not the product of any one single ice advance, but rather of two or more advances. As a result of the variability of drift thickness. the topography of the land also varies. Leverett (1917) has estimated that 96 percent of the southern peninsula has a difference of from 580 to 1,200 feet in elevation, and that the average relief for this same area is about 835 feet. As indicated in Figure 3, the elevation of Toumey Woodlot is between 850–890 feet.

Drainage

There are numerous lakes in the lower peninsula of Michigan, and nearly all occupy depressions in the surface of glacial deposits. The drainage for the lower peninsula is almost equally divided between west-flowing streams that enter Lake Michigan, and east-flowing streams that enter Lakes Huron and Erie.

Most of the county drainage is controlled by the Grand River Drainage Basin which empties into Lake Michigan at Grand Haven, Michigan. The area surrounding Toumey Woodlot is drained by the Red Cedar River, a tributary of the Grand River. Both the physiography and the drainage of Ingham County represent features resulting primarily from glacial activity. During the Cary substage of the Wisconsin glaciation, the Saginaw Lobe, by readvances and retreats, formed numerous moraines. Martin (1955) calculated that approximately one-half of Ingham County lies in these ground moraines. Toumey Woodlot is situated on a portion of one of these moraines, the Lansing Moraine.

Soils

Veatch (1941) states that 85 percent of the soils in Ingham County are mineral soils, and that of that amount 43 percent are well-drained soils. These soils belong to the great group of Gray-Brown Podzolic soils which are representative of the central and east-central parts of the United States. These soils are all podzolic, with the leaching of calcium and magnesium carbonates, and the removal of sesquioxides from the surface layers being common. As the surface geologic formations were deposited during the last stages of the Wisconsin, the land surface is comparatively young. The glacial drift is characterized by a great variety of igneous, metamorphic, and sedimentary rocks.

Veatch (1941) recognizes 7 general groups of soils for Ingham County based on their natural drainage and the texture of the parent material. These are: (1) well-drained clayey soils: (2) imperfectly and poorly drained clayey soils; (3) well-drained loamy and sandy soils; (4) well-drained very sandy soils; (5) poorly drained sandy soils; (6) alluvial soils; and (7) organic soils. The soil group of greatest area in Toumey Woodlot is well-drained loamy and sandy soil group, with Hillsdale sandy loam being the predominant soil type.

Biotic Factors

Although this particular investigation does not include information pertaining to biotic influences in Toumey Woodlot, the author is aware that they do exist, and are an important part of the entire community.

No detailed study has been made of animal activities in this area, but a few observations have been made. Gysel[5/] conducted a live-trapping study in October of both 1958 and 1959, and for a total of 170 trap-nights in Toumey Woodlot found:

Species	1958	1959
Opossum	-	4
Eastern cottontail	1	1
Fox squirrel	14	15
White-footed mouse	4	2
Raccoon	4	1

Exclusive of actual trapping data, Gysel also observed red fox and woodchuck in this stand.

Wallace[6/] reports that numerous species of birds are permanent residents in this woodlot. Several of the more important of these are:

Mourning Dove	Cedar Waxwing
Hairy Woodpecker	Starling
Downy Woodpecker	English Sparrow
Flicker	Goldfinch
Tufted Titmouse	Blue Jay
White-breasted Nuthatch	Crow

Common summer residents observed were:

Crested Flycatcher	Grackle
Catbird	Cowbird
Robin	Rose-breasted Grosbeck
Baltimore Oriole	Field Sparrow

It can be quickly surmised that the above animal species may greatly influence the entire community structure of Toumey Woodlot. Numerous species of birds are seed eaters as well as insect eaters, and thus influence the potential reproduction of many plant species.

5/ Gysel, L. Personal communication, 1962.
6/ Wallace, G. Personal communication, 1962.

The fox, squirrel, and mouse populations also have their effect on plant seeds and germinated seedlings and saplings.

Although disease and insect influences undoubtedly exist in the woodlot, they were not considered important enough to be included at the initiation of this study, and no information on the role of these factors is available for the 20-year period.

FIELD PROCEDURES

Plot Location

In 1940, to facilitate the counting and measurement of the flora in the woodlot, the entire area was marked off into a grid of 60-foot squares, the corners of which were indicated with a permanent set of iron pipes. These 60-foot square plots, of which there are 163, are designated from west to east by letters, and from north to south by numbers. For example, the plot in the northwest corner of the tract is known as A-1. Metal tabs for identifying each plot are on each of the iron pipes, and thus it becomes easy to orient oneself during measurements. Figure 3 illustrates the manner in which the woodlot was subdivided into plots at the start of the investigation, and the numbering system used in plot identification. String was placed between the iron pipes of each plot to delineate the individual plots, and to facilitate collection of data.

Collection of Vegetative Data

All data were collected between June and August of 1940, 1950, and 1960. This was done using the following described criteria.

A. Woody species

All woody stems of 1-inch d.b.h. (diameter-breast-height) and over were recorded by species, and by 1-inch diameter classes. This procedure enables the determination of the growth and relative abundance for the surviving stems of each species during the 20-year period. A steel diameter tape was used for all d.b.h. measurements.

B. Remeasurement of sample trees

To determine the approximate ages of the trees and their rates of growth in diameter and total height, sample trees were tagged and measured in 1940. For each species, 5 trees for each crown class, in 10-inch d.b.h. classes, were chosen wherever possible. Following the Society of American Foresters (1958) classification of crowns for even-aged stands, the crowns were designated as: (1) dominant, (2) co-dominant, (3) intermediate, and (4) overtopped or suppressed. The 10-inch d.b.h. classes distinguished are from 1- to 10-inch d.b.h.; 11- to 20-inch d.b.h.; 21- to 30-inch d.b.h.; and 31- to 40-inch d.b.h. In several instances it was not possible to find 5 trees in certain d.b.h. classes or crown classes.

The selected sample trees were remeasured in the summers of 1950 and 1960. Diameter measurements were recorded to the nearest 1-inch class and bark thickness was measured with the Swedish increment borer. As the total heights of these trees are difficult to measure with any degree of accuracy in the summer owing to the dense foliage, heights to the nearest foot were determined in the winters of 1940, 1950, and 1960, using the Abney Level. All sample trees that were found dead or down were recorded as to the direction of fall wherever possible, and their final measurements were recorded as described under mortality-loss data collection.

C. Ground cover component species

For trees, shrubs, and herbaceous vegetative not having a d.b.h. of 1 inch or over, and thereby having been excluded from the complete plot tally, a separate ground cover tally was made. In 31 of the 163 large plots (60x60-foot), a smaller, nested quadrat (24x34-inches), was located in the northwest corner of the larger plot. The 34-inch axis paralleled the north and south side, and the 24-inch axis paralleled the east and west side. The actual ground cover plots sampled were located in every fourth large plot and on every other interior line on the tract in staggered arrangement. Figure 3 indicates the location of the ground cover plots.

Ground cover maps were prepared of each small plot at a scale of 1 inch on the map equalling 4 inches on the ground. In mapping the ground cover species, the location of tree and shrub stems was indicated with a small "x". The general extent of the foliage from these stems is shown by solid lines, although it was not deemed necessary to correlate the spread of the foliage with particular stems of the same species. The crowns were identified by species. With herbaceous vegetation, the location of the individual stems was not plotted. Rather, the extent of the vegetation coverage over the plot as a whole was mapped with a solid line. Where the vegetation interlaced with the foliage from other species, dotted lines were used to indicate the interlacing. The crowns of the herbaceous species were also designated by species or genera. An example of a prepared ground cover map is shown in Figure 9. Where there were distinctly two levels of ground cover, as occurs when herbs or seedlings are found under saplings or shrubs averaging 5 to 10 feet in height, a second map was prepared for the secondary story. This second map denoted the location of such stems, and their crown spread, above the primary story.

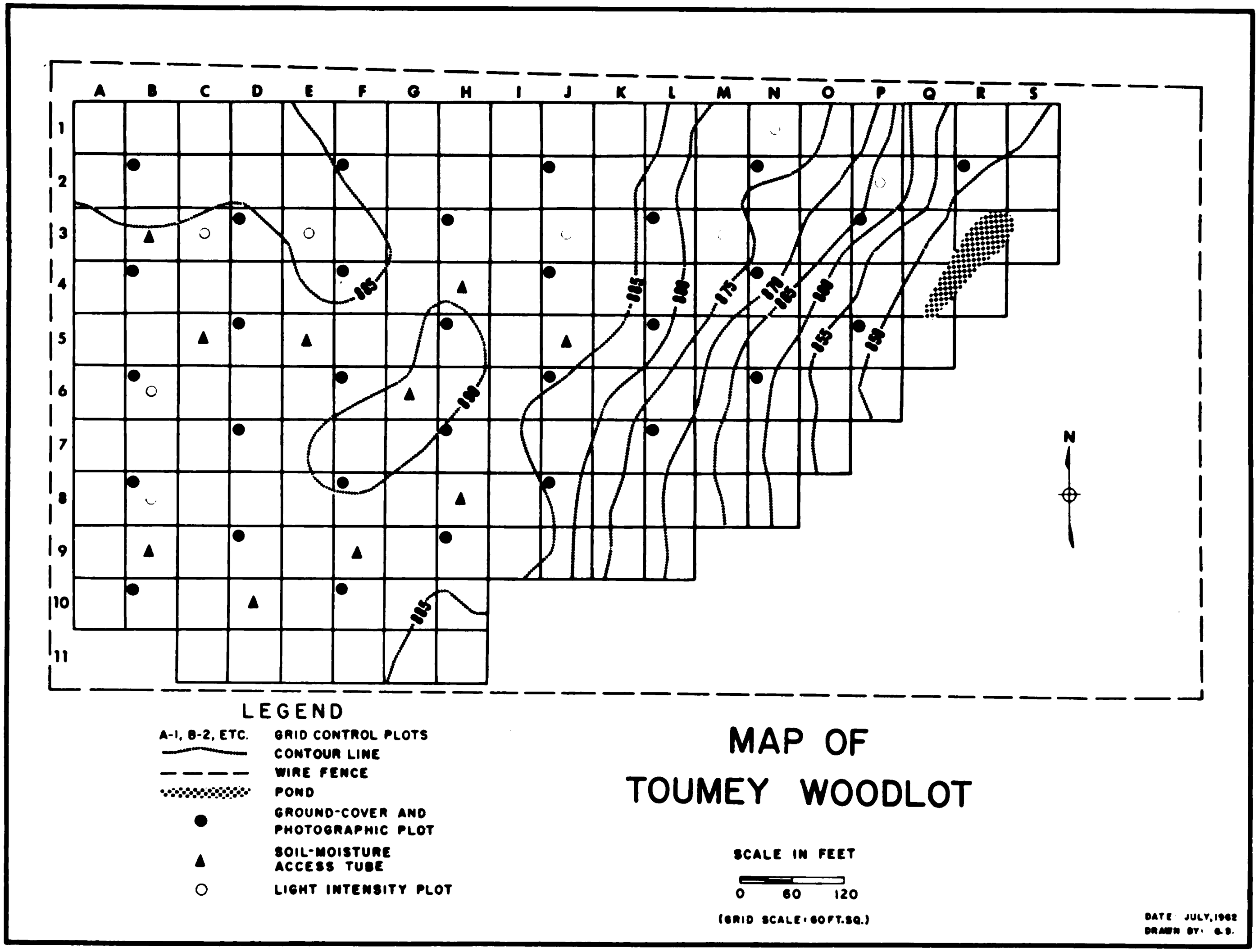

Figure 3. Generalized map of Toumey Woodlot, with locations of grid control plots, ground cover, soil moisture, and light measurement plots, and general topography.

D. Photographs

Photographs were taken at each subplot from which a ground cover map was made. The camera used in the 1960 photographs was a 4x5 Crown Graphic, whereas a 5x7 Linhof Standard View was used in preceding years. At each photographic station, 6 pictures were taken. One picture was taken of the 24x34-inch ground cover plot from a vertical position. To insure that this specific area was recorded, a white frame of those dimensions was placed on the ground with the northwest corner at the reference stake.

Without moving the tripod setting used in taking the subplot photograph, a second picture was taken directly upward of the crown canopy which covers the ground plot. For the remaining 4 pictures, the tripod was centered over the permanent iron pipes, and photographs taken in the 4 cardinal directions. In this manner, pictures of virtually the entire Toumey Woodlot were taken.

E. Mortality losses

All dead and down trees in all plots were recorded as to their direction of fall wherever possible, species, d.b.h., total height, volume, and growth rate.

Light Measurements

Light measurements taken in 1950 and 1960 were based upon reflected light rather than direct light falling upon the light meter from above, as was done in 1940. A newly calibrated Weston Foot-Candle Meter, Model 614, was used for all light intensity readings. The intensity of measured light in the woodlot was related to reflected full sunlight in the open by expressing it as a percentage of full sunlight.

For the actual readings, the light receptor was held 12 inches directly above the center of a 8 1/2 inch by 11-inch piece of white bond paper placed on the ground. Light measurements were made on 8 (5 percent) of the 163 (60x60-foot) plots. On each of these 8 plots, 25 readings were made, spaced 15 feet apart in all directions. A total of 200 individual measurements were thus taken within the stand (8 plots x 25 measurements per plot).

The 8 plots selected for the light study represented areas of average density, blowdown, slope, and depression. This type of stratification is arbitrary, but nevertheless serves to achieve average conditions in the stand. Figure 3 indicates the position of the plots where light measurements were made. Measurements were made on cloudless days with a minimum of wind. All of the readings were taken between the hours of 10:30 a.m. and 1:30 p.m. of the same day. At half-hour intervals, open-field measurements were taken to eliminate any discrepancy in light intensity, and to arrive at an open-field average.

Collection of Soil Data

All soil data were collected during the years 1961 and 1962 and the criteria measured were as follows.

A. Preparation of soil type map

During 1961-1962, a detailed examination of the soils of Toumey Woodlot was made. Previous to this, little soil information was available for the area other than that reported by Veatch *et al.* (1933), on the Ingham County Soil Survey Map. The Toumey Woodlot area falls within the Miami-Hillsdale-Conover Soil Association as mapped by Veatch (1953).

Soil borings were dug at random with a bucket auger in 32 of the 163 plots (60x60-foot). Based on 5-foot soil profile observations, the soils were mapped in the field at a scale of 1 inch to 140 feet, and a soil type map of the area was prepared (Figure 5). This large scale and high frequency of sampling are justifiable because the survey data can be used as a basis for future ecological studies, especially those concerned with changes in soil-site relationships.

B. Soil physical properties

A comprehensive examination of the soil profile was made at 8 locations, including the designation of each horizon, its range in depth from the surface, and its range in thickness. The physical analyses performed on these profiles were confined to separate soil horizons designated as follows: A_1 - infiltrated humic horizon; A_2 - eluvial or leached layers; B_2 - illuvial or accumulative layer; and C - parent material.

The texture of the soil indicates the relative proportion of sand, silt, and clay separates which make up the soil body. Soil texture was determined by the pipette mechanical analysis technique as described by Baver (1956). These separates were expressed as percentages of total separates less than 2 mm in size. The Soil Survey Manual, edited by the U. S. Soil Survey Staff (1951), was used as the standard reference for the determination of soil structure (the arrangement of soil particles), soil consistence (the degree of cohesion and adhesion of soil particles), and soil color. The Munsell notation for color was used for all soil color measurements, and refers to the moist condition of the soil. In addition, soil reaction was determined electrometrically by the use of a glass electrode in a 1:1 soil-water suspension.

C. Soil moisture regime

Soil moisture depletion and recharge were estimated during the 1961 growing season and in the winter, spring, and early summer of 1962 by the neutron method.7/ Measurements were made with this device since it is non-destructive and requires no physical or chemical processing of the material being tested. As the probe is usually inserted into a permanent access tube which is driven into the soil, the site is not seriously disturbed, and long-term studies of the same volume of material is possible. This is not possible with other soil moisture measurement techniques.

Before establishing permanent sampling points for soil moisture determinations in Toumey Woodlot, certain conflicts involving access tube placement, counting-time intervals, and moisture calculations had to be resolved. For easy insertion of the neutron source into the soil, access tubes are usually placed into the soil. The use of proper care in the placement of access tubes has proved to be very important in obtaining accurate soil moisture readings. This was well emphasized in a study conducted by Horonjeff and Javete (1956). One-inch access tubes, 3 feet in length, were placed into the soil in 4 different ways as follows: (1) A hole was made with a 3-inch soil auger. The hole was then filled loosely with the soil

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7/ Nuclear-Chicago Corp. (1960). The d/M Gauge for rapid field determination of moisture content and density. Nuclear-Chicago Corporation, Chicago, Illinois.

material, and the access tube was driven into the soil. (2) The same procedure was followed as above but a 1 1/2-inch soil auger was used. (3) Again, the same procedure as above but using a 1-inch soil auger. (4) The access tube was driven directly into the soil. When the soil moisture results obtained by the neutron method were compared with the gravimetric method, the lowest error observed was that where the access tube had been driven directly into the soil. The error was four times greater in the access tube from the 3-inch augered hole. The other two types of placement were intermediate in their results.

Marston (1958) also reported that the access tubes should be driven into the soil whenever possible, so that a firm contact is made between tube and soil. Furthermore, the diameter of the access tube should be just large enough to accommodate the neutron probe, thereby avoiding any great play between them. In addition, care must be taken to avoid unnecessary accumulations of excess water in the access tubes.

A great deal of confusion has resulted over the proper counting time interval when using the neutron probe. Until very recently, the common belief held was that longer counts were required at the lower soil moisture contents than at the higher soil moisture contents. Van Bavel (1958) was one of the first to show that this was not true if the error in terms of absolute soil moisture was considered to be the important factor, rather than the error in terms of the counting rate. What is important is the proper selection of a counting interval which will maintain a random error in the measurement of water at some allowable level. A formula for approximating the random counting error in terms of soil moisture has been fully discussed by Merriam and Knoerr (1961). A more recent publication by Merriam (1962) presents a coaxial graph which allows the approximate determination of the counting-time interval required to satisfy any level of statistical accuracy chosen.

Moisture contents may be determined in one of two ways. The total neutron count registered on the scaler may be located directly upon the calibration chart, thereby allowing for the immediate determination of the moisture content. A second and more accurate method is where the moisture contents are plotted against the count-ration. The count-ration is the ratio of the count obtained in the soil to the count obtained when the probe is in its shield (standard count). Horonjeff and Javete (1956) report that the advantage of the count-ratio is that any variation in counts due to either the decay of the radioactive source, or the performance of the scaler or probe, are automatically included. Therefore, a more accurate estimate of the soil moisture content is obtained by use of the count-ratio than obtained by use of the direct count.

In the present study, 10 access tubes were placed in such manner as to sample the entire predominant soil type of the area (Hillsdale sandy loam). The tubes were 10 feet long, 1 3/4 inch inside diameter, 2-inch outside diameter, and of rigid aluminum conduit. The actual sinking of the access tubes involved the use of the Veihmeyer tube, which was driven into the soil for the entire 10 feet to pre-probe the site for possible obstacles which might interfere with the movement of the access tubes into the holes. In this way, tubes were placed in holes having as tight a fit as possible. Care was also taken to lower the tubes vertically into the soil. Soil moisture determinations were to be made weekly during the growing season and monthly during the remaining seasons of the year. Unfortunately, mechanical malfunctions of the neutron equipment, especially in the initial stages of measurement, caused data to be collected irregularly. By extending the length of measurement to a 16-month period, however, sufficient data were collected which gave, upon analysis, reliable information of the seasonal soil moisture regime. The 10 established soil moisture plots were measured on 18 separate occasions over the 16-month period. The location of the soil moisture access tubes is shown in Figure 3.

Soil moisture readings commenced at 1 foot below the soil surface, and continued at 1-foot intervals to 9 feet. It is assumed that little error resulted from neutron losses to the atmosphere at these depths. Furthermore, as a precautionary measure to insure that excess moisture did not accumulate in the access tubes between measurements, a steel cap and metal cover were placed on top of each access tube.

A counting-time interval of 1 minute was used for the determination of soil moisture with the neutron probe. As the soil moisture contents observed throughout the study never exceeded 25 percent by volume, a random error equivalent to approximately 0.10-inch of water per foot of soil was obtained, as stated by Merriam (1962). In addition, all soil moisture calculations were made using the count-

ratio values. The component parts of the neutron moisture measuring equipment on site in Toumey Woodlot are illustrated in Figure 4.

D. Precipitation

No collection of the precipitation falling on Toumey Woodlot was made. Instead, full use was made of the precipitation data measured at the Michigan Hydrologic Research Station, located on the campus of Michigan State University, and approximately 300 yards to the west of Toumey Woodlot. In a very few instances, where no precipitation data were available elsewhere, the precipitation measured at the Michigan State University Horticulture Farm was used. This is located on the university campus, approximately 1/2 mile north of Toumey Woodlot.

E. Evapo-transpiration

Evapo-transpiration values were calculated by one of two methods, depending on whether measurements showed soil-moisture depletion or accretion. When soil moisture was depleted, evapo-transpiration was considered to equal the difference between any two consecutive soil moisture values plus precipitation received during the period. If accretion rather than depletion occurred, evapo-transpiration equalled the difference between precipitation received, and the amount of soil moisture increase. Evapo-transpiration losses were computed for the entire 9-foot profile, and values expressed are those estimated to have occurred between successive soil moisture measurements from April, through July, 1962.

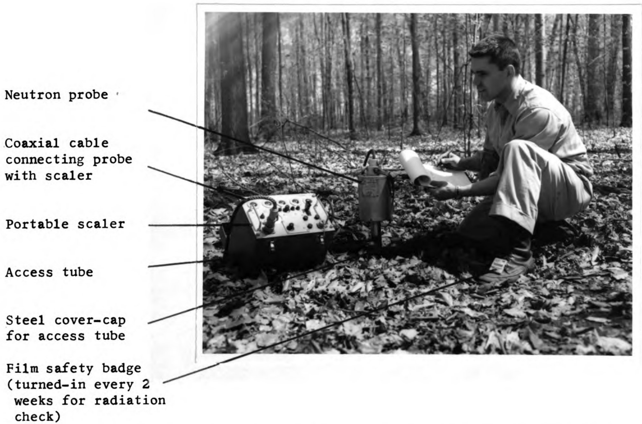


Figure 4. Component parts of the neutron moisture measuring equipment on site, Toumey Woodlot, Spring, 1962.

RESULTS AND DISCUSSION

Description of Soils

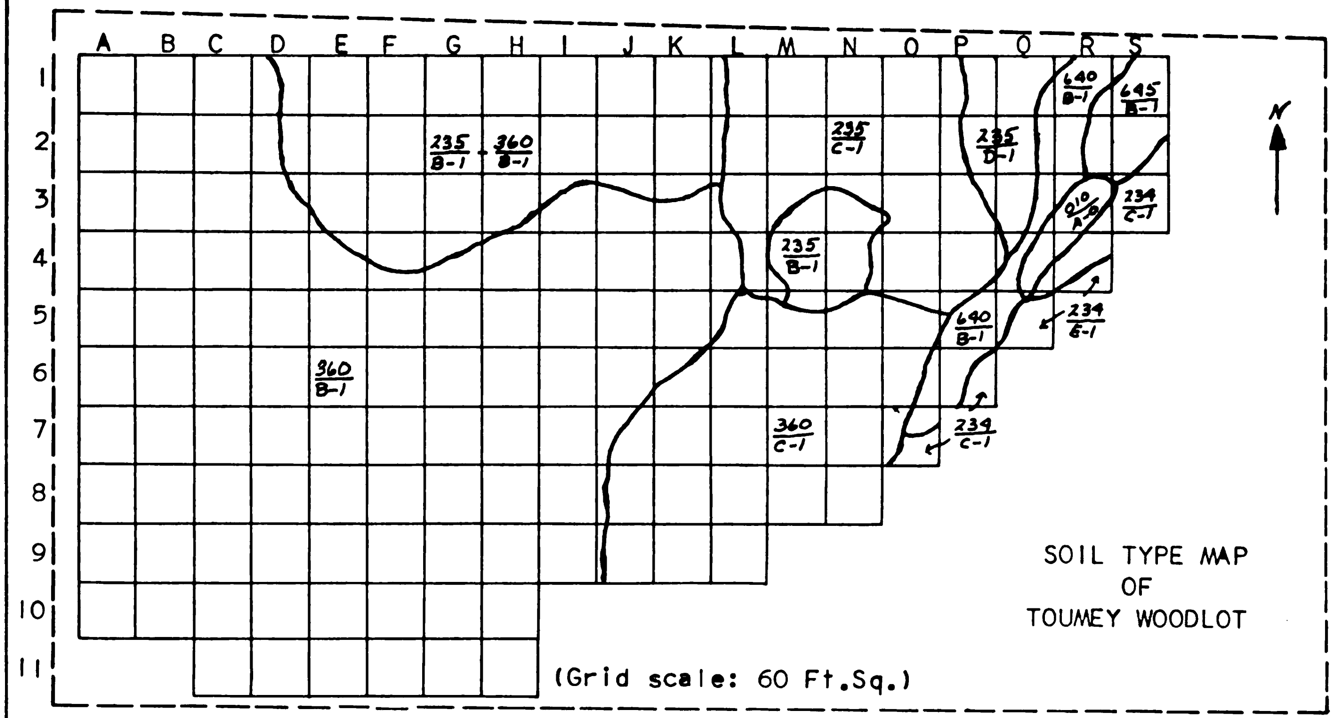
In a detailed soil survey of Toumey Woodlot made in 1961, 6 soil types were represented, and these are shown in Figure 5. Hillsdale sandy loam, which represents approximately 2/3 of the area, is the dominant soil type. Spinks loamy fine sand occupies about 1/4 of the area. The remaining soil types, Spinks loamy sand, Conover silt loam, Conover loam, and Carlisle muck are of minor importance.

Hillsdale sandy loam is the principal well-drained soil in Toumey Woodlot. The Hillsdale soils consist of well-drained Gray-Brown Podzolic soils which developed in sandy loam till that is calcareous at a depth of 42 to 66 inches. The texture of the various soil horizons is given in Table 1.

Table 1. Percentage of soil separates present in an average Hillsdale sandy loam profile in Toumey Woodlot

Horizon	Depth (inches)	Sand	Silt	Clay	Textural Class
A_1	0 - 4	63.4	25.2	11.4	Sandy loam
A_2	4 - 16	62.1	25.8	12.1	Sandy loam
B_1	16 - 22	63.1	16.2	20.7	Sandy clay loam
B_2	22 - 48	65.3	10.5	24.2	Sandy clay loam
B_3	48 - 52	60.3	25.2	14.5	Sandy loam
C	52+	62.1	26.4	11.5	Sandy loam

A composite profile description of the Hillsdale sandy loam in Toumey Woodlot follows.



LEGEND

Soil Type	Slope	Erosion
010 = Carlisle muck	A = 0– 2 percent	0 = None or an accumulation
234 = Spinks loamy sand	B = 2– 6 percent	1 = Little or none
235 = Spinks loamy fine sand	C = 6–12 percent	
360 = Hillsdale sandy loam	D = 12–18 percent	A-1, B-1, etc. = Grid control plots
640 = Conover silt loam	E = 18–25 percent	----- = Wire fence
645 = Conover loam		

Figure 5. Soil map of Toumey Woodlot.

A_0	½ - 1"	Loose, thin layer of primarily sugar maple-beech leaves, as well as other twigs and forest litter.
A_1	0 - 4"	Dark grayish brown (10YR 3/2)[8/]; deep, medium mull[9/]; sandy loam; weak, fine granular structure; friable; slightly acid (pH 6.0-6.5). Penetrated by a network of roots from trees and ground cover vegetation; considerable evidence of earthworm activity.
A_2	4 -16"	Yellowish brown (10YR 5/4); sandy loam; weak, fine to medium, subangular blocky structure; friable; medium acid (pH 5.5-6.0). Roots are numerous throughout the horizon and evidence of earthworm activity is common.
B_1	16-22"	Dark yellowish brown (10YR 4/4); sandy loam to sandy clay loam; weak, fine, subangular blocky structure; medium acid (pH 5.5-6.0). The horizon is friable and penetrated extensively by tree roots.
B_2	22-48"	Dark brown (7.5YR 4/4); sandy clay loam; weak to moderate, medium, subangular blocky structure; friable; medium acid above (pH 5.5-6.0), with gradual change to slightly acid (pH60-6.5). Sub-rounded stones of various sizes are common in places; horizon is penetrated by tree roots.
B_3	48-52"	Yellowish brown (10YR 6/4); sandy loam; weak, fine, subangular blocky structure; slightly acid (pH 6.0-6.5) to neutral (pH 6.6-7.3). The horizon is friable and contains numerous fine roots.
C	52+".	Brown (10YR 5/3) to yellowish brown (10YR 5/4); sandy loam; massive to weak, fine or medium, subangular blocky structure; friable and calcareous.

All of the major vegetative components found throughout the forest stand also occur on the Hillsdale sandy loam soil type. Sugar

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8/ Munsell color notations refer to the moist condition.

9/ Designation of humus type based on that from Hoover, M.D., and Lunt, H.A., 1952. A key for the classification of forest humus types. Soil Sci. Soc. Amer. Proc. 16:368-370.

maple and beech are the dominant overstory vegetation. Veatch (1941) indicates that Hillsdale soils were originally predominantly oak-hickory stands. The Hillsdale sandy loam in Toumey Woodlot, however, appears to have a higher moisture-holding capacity than the Hillsdale soil described by Veatch (1941). Consequently, the site is perhaps more favorable for the growth of sugar maple and beech.

Spinks loamy fine sand, which occupies well-drained areas on the sloping topography, is the other important soil type in Toumey Woodlot. Some Spinks loamy sand areas were also recognized. This type differs from Spinks loamy fine sand only in the texture of the surface horizons. Therefore, the two soil types are considered together. The Spinks soils include well-drained Gray-Brown Podzolic soils developed in calcareous or neutral loamy sands, sands, or fine sands. The texture of the various soil horizons is given in Table 2.

Table 2. Percentage of soil separates in an average Spinks loamy fine sand profile in Toumey Woodlot.

Horizon	Depth (inches)	Sand	Silt	Clay	Textural Class
A_1	0 - 7	75.0	20.6	4.4	Loamy sand
A_2	7 - 20	76.1	19.4	4.5	Loamy sand
B_t	20 - 27	63.4	20.6	16.0	Sandy loam
series of A_2 - B_t	27 - 50	57.3	33.0	8.4	Sandy loam
C_{21}	50 - 54	60.3	28.1	11.6	Sandy loam
C_{22}	54 - 60	83.6	11.5	4.9	Loamy sand
C_{23}	60+	87.4	8.3	4.3	Loamy sand

A detailed description of the Spinks loamy fine sand profile follows:

A_0	½-1".	Loose, thin layer of sugar maple and beech leaves, along with other forest litter.
A_1	0-7"	Dark grayish brown (10YR 3/2); deep, medium mull; loamy fine sand to loamy sand; weak, fine, granular structure; very friable; neutral reaction (pH 6.6-7.3); penetrated by roots of both trees and ground cover species; earthworms are common.
A_2	7-20"	Yellowish brown (10YR 5/4); loamy sand; weak, medium platy to weak, fine subangular blocky structure; very friable; neutral reaction (pH 6.6-7.3); penetrated by roots of both trees and ground cover species; earthworms are common.
B_t	20-27"	Dark yellowish brown (10YR 4/4); sandy loam; weak, fine to medium, subangular blocky structure; friable; slightly acid (pH 6.0-6.5) to neutral (pH 6.6-7.3); roots are numerous in the horizon.
series of A_2-B_t	27-50"	Light yellowish brown (10YR 6/4) sand (A_2) and strong brown (7.5YR 5/6) sandy loam (B_t); alternate A_2 and B_t horizons where B_t horizons occur as thin and oftentimes wavy bands. The B_t bands are separated by A_2 horizons which are single grain structure and loose; B_t lenses have weak, fine, subangular blocky structure; slightly acid (pH 6.0-6.5) to neutral (pH 6.6-7.3). Tree roots penetrate this series of horizons.
C	50+"	Pale brown (10YR 6/3); increasing sand content with depth (sandy loam to loamy sand to sand); loose; calcareous.

The tree species and ground cover species on this soil type are similar to those on the Hillsdale sandy loam soil type. The Hillsdale soils, however, are finer textured throughout the profile than the Spinks soils. Because of the coarser texture in the Spinks soils, oak-hickory is usually the predominant native vegetative type on them. It appears that the moisture-holding capacity of the Spinks soils in Toumey Woodlot, however, is sufficiently great enough to allow for the growth of sugar maple and beech.

Conover loam and silt loam represent two of the other soil types which occur in the northeast part of the woodlot. These two soil types differ only in the texture of the surface horizons. Conover soils are imperfectly-drained Gray-Brown Podzolic soils which developed on loam to silt loam calcareous till, with the natural water table at 18 to 54 inches. Mottling occurs throughout the profile. The soil reaction is slightly acid to mildly alkaline. The topography is level and the soil permeability is moderate. The natural vegetation consists of sugar maple and beech, as well as elm, ash, oaks, hickory, and walnut (Veatch, 1941).

Carlisle muck is the other soil type recognized in Toumey Woodlot. This soil consists of mixed woody and vegetative organic materials over 42-inches in depth. The organic materials are dark brown to black, and are slightly to moderately decomposed in the upper 12 to 24 inches of the profile. The Carlisle muck is found in the relatively small depression in the northeast part of the woodlot. This very poorly drained soil is frequently ponded. The water table is at or near the surface for much of the year, and contains water for at least 6 months of the year. The natural vegetation consists chiefly of elm, ash, and an occasional willow and sycamore, all of which occur along the edge of the pond.

Of the 6 soil types present in Toumey Woodlot, the Hillsdale and Spinks soils are the most productive for tree growth. Their infiltration and permeability rates are high. They are naturally well-drained, but their moisture level remains fairly good for most of the year. In contrast, the Conover and Carlisle series are imprefectly and poorly drained, respectively. In these soils the soil moisture is often extremely high and may actually become detrimental to tree growth. Root systems become superficial and often shallow, thereby increasing the possibility of windthrow. As the shallow root systems are restricted to a shallow soil mass, a decrease in available soil nutrients may also occur.

It is essential to point out, however, that variations in some of the soil horizons within a particular soil type do exist. As a result, they may be responsible for an increase or decrease in site quality. Hebb (1961), studying the relation of site factors to forest composition and productivity in west Tennessee, also points to this fact and states that soil series may at times become approximations of forest productivity.

Soil Moisture Regime

A knowledge of soil moisture changes during the various seasons of the year is fundamental to the determination of the moisture requirements of vegetation. Certain silvicultural implications also become apparent from an investigation of the soil moisture regime of an area. The amount of moisture in a soil at any given time depends on a large number of factors. Some of the more important of these are: quantity, duration, and distribution of precipitation; season of year; type and condition of the vegetative cover; and the water-holding capacity of the soil. The complexity of correlating these factors emphasizes the importance of soil moisture as a dynamic property of the soil body. Where the vegetative cover is represented by the prevailing climax species, i.e. where a similar vegetative cover remains on the area for a number of years, soil moisture tends to exhibit annual and seasonal fluctuations as the result of variations in both climate and phenology.

The trend of seasonal soil moisture in the relatively undisturbed sugar maple-beech stand of this study is graphically presented in Figure 6. Soil moisture was measured at 1-foot intervals from 12 to 108 inches. This estimates the soil moisture in a 9-foot profile extending from approximately 6 inches below the surface to a depth of 112 inches (9 ½ feet). To distinguish differences in soil moisture change at various depths, the 9-foot profile was divided into 3 different zones, these being: the upper zone indicating the A_1, A_2 and upper B horizon (1- and 2-foot depth); the lower solum (3- and 4-foot depth); and the parent material (5-to 9-foot depths). The

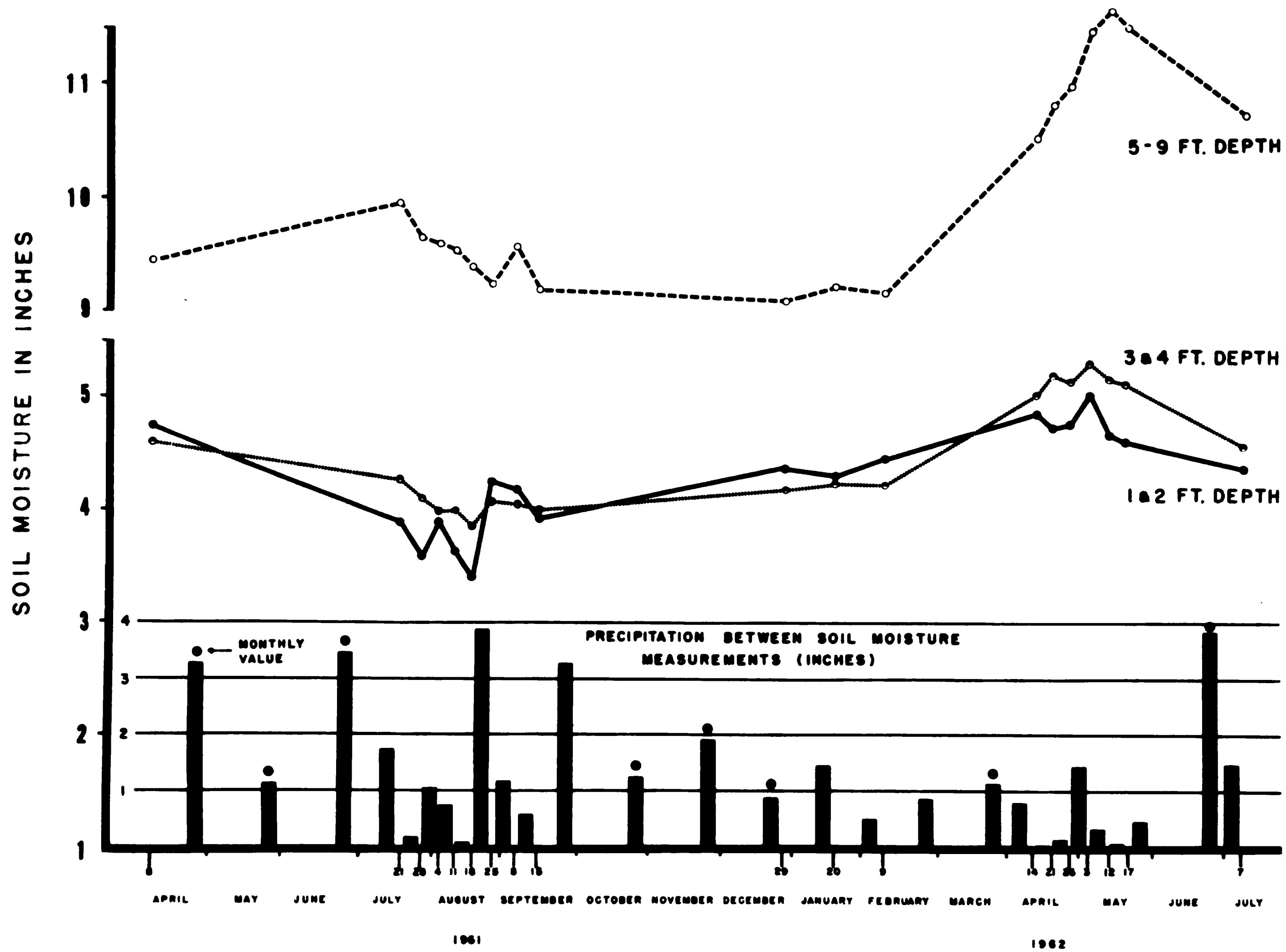


Figure 6. Soil moisture content for 1- to 2-foot depth, 3- and 4-foot depth, and 5- to 9-foot depth, Toumey Woodlot, 1961-1962; corresponding precipitation between soil moisture measurements.

values plotted are averages obtained from 9 of the 10 stations sampled. Station B-3, the location of which is indicated in Figure 3, gave results differing greatly from those obtained at the other sites. Examination of the moisture contents for this particular station (Table 22, Appendix), revealed exceptionally low values in the 6-to 9-foot depths. The divergence of this station from all others justified rejection of these values from the calculation of total averages. Individual values of soil moisture contents from all stations are found in Tables 22-31 of the Appendix. The average periodic soil moisture in inches, by 1-foot depths for all station in Toumey Woodlot, is shown in Table 3 for the 1961 measurements, and in Table 4 for the 1962 measurements.

Total profile. The general soil moisture pattern is shown in Figure 6. The period of April through August is one of soil moisture depletion, and results from continuous evapo-transpiration losses. Late fall, winter, and early spring are characterized as periods of soil moisture recharge, the result of reduced transpirational demands from the vegetative cover and lower evaporation losses.

It is interesting to note that the over-all soil moisture content was considerably greater during the 1962 period of measurement than during the 1961 period of record. An examination of the monthly precipitation during the 12 months preceding the initial start of the soil moisture study helps to explain this difference. Monthly precipitation for the study and pre-study periods is shown in Table 5. Average monthly precipitation for the past 19 years of record is also

Table 3. Average periodic soil moisture in inches for 9-foot profile at 9 stations in Toumey Woodlot (April-December, 1961)

Depth (ft.)	4/8	7/21	7/28	8/4	8/11	8/18	8/25	9/8	9/15	12/29
1	2.32	1.87	1.68	1.85	1.69	1.52	2.20	2.09	1.92	2.15
2	2.43	2.02	1.91	2.04	1.94	1.88	2.05	2.09	2.00	2.23
1+2	4.75	3.89	3.59	3.89	3.63	3.40	4.25	4.18	3.92	4.38
3	2.42	2.16	2.02	1.93	2.01	1.93	2.04	2.02	2.01	2.17
4	2.18	2.11	2.08	2.04	1.98	1.92	2.04	2.03	1.96	2.02
3+4	4.60	4.27	4.10	3.97	3.99	3.85	4.08	4.05	3.97	4.19
5	2.03	1.98	1.90	1.91	1.86	1.79	1.83	1.87	1.82	1.85
6	2.07	2.14	2.08	2.04	2.05	2.07	1.98	2.02	1.99	1.98
7	1.81	1.96	1.90	1.90	1.89	1.84	1.81	1.88	1.81	1.80
8	1.92	2.05	2.02	1.99	1.98	1.98	1.93	2.07	1.91	1.81
9	1.63	1.84	1.77	1.77	1.77	1.73	1.70	1.74	1.69	1.66
5-9	9.46	9.97	9.67	9.61	9.55	9.41	9.25	9.58	9.22	9.10
Sum 1-9	18.81	18.13	17.36	17.47	17.17	16.66	17.58	17.81	17.11	17.67

Table 4. Average periodic soil moisture in inches for 9-foot profile at 9 stations in Toumey Woodlot (January-July, 1962)

Depth (ft.)	1/20	2/9	4/14	4/21	4/26	5/3	5/12	5/17	7/7
1	2.10	2.24	2.45	2.34	2.32	2.48	2.25	2.20	2.11
2	2.20	2.21	2.41	2.40	2.44	2.54	2.43	2.42	2.28
1+2	4.30	4.45	4.86	4.74	4.76	5.02	4.68	4.62	4.39
3	2.22	2.18	2.47	2.56	2.54	2.62	2.56	2.54	2.31
4	2.03	2.04	2.56	2.64	2.60	2.68	2.60	2.57	2.27
3+4	4.25	4.22	5.03	5.20	5.14	5.30	5.16	5.11	4.58
5	1.89	1.91	2.37	2.35	2.40	2.48	2.40	2.37	2.16
6	1.89	1.98	2.25	2.28	2.30	2.36	2.32	2.33	2.27
7	1.83	1.74	2.16	2.22	2.32	2.32	2.39	2.33	2.08
8	1.93	1.88	2.08	2.18	2.22	2.30	2.45	2.36	2.24
9	1.70	1.67	1.69	1.81	1.76	2.02	2.12	2.13	2.00
5-9	9.24	9.18	10.55	10.84	11.00	11.48	11.68	11.52	10.75
Sum 1-9	17.79	17.85	20.44	20.78	20.90	21.80	21.52	21.25	19.72

shown. The precipitation data were collected at the Michigan Hydrologic Research Station, with the exception of a few winter values which were collected at the Michigan State University Horticulture Farm, located one-half mile away from Toumey Woodlot.

The monthly precipitation for the 12 months prior to the study was definitely below the 19-year average. Taking the difference between the average monthly precipitation over the past 19 years from the monthly precipitation recorded during this 12-month period, indicates that an antecedent moisture deficit of 7.58 inches existed over this interval of time. Of this amount, 6.39 inches occurred between September, 1960, and March, 1961, when maximum moisture recharge of the soil ordinarily takes place. The soil moisture measurements taken in 1961 definitely reflect this deficit of water recharge. In contrast, the greater moisture contents found throughout the 1962 measurements can be attributed to a more normal pattern of precipitation. On the other hand, starting in the spring of 1962, the monthly precipitation for the 12-month period of April, 1961 to March, 1962 shows that the antecedent moisture deficit for this period was only 1.33 inches. Of this amount, 1.28 inches occurred between September, 1961, and March, 1962. In addition, late summer rainfall in 1961 was considerably above normal. Consequently, soil moisture recharge was greater at the beginning of the water year, 1961-1962, than for the preceding water year starting in October, 1960, thereby resulting in a greater over-all soil moisture content.

Table 5. Average monthly precipitation during 1941-1959, and the monthly precipitation recorded for portions of 1960-1962

Month	Normal (1941-1959)	Recorded 1960	Deviation from normal	Recorded 1961	Deviation from normal	Recorded 1962	Deviation from normal
				-inches-			
January	1.60			0.16	-1.44	1.86	+0.26
February	1.37			1.14	-0.23	0.90	-0.47
March	2.11			2.07	-0.04	1.13	-0.98
April	2.71	2.39	-0.32	3.54	+0.83	1.23	-1.48
May	3.93	3.02	-0.91	1.14	-2.79	1.95	-1.98
June	3.53	3.66	+0.13	3.48	-0.05	3.83	+0.30
July	2.97	2.23	-0.74	2.85	-0.12	1.49	
August	3.02	3.67	+0.65	5.10	+2.08		
September	2.52	1.21	-1.31	4.72	+2.20		
October	2.59	1.29	-1.30	1.22	-1.37		
November	2.07	1.53	-0.54	1.91	-0.16		
December	1.64	0.11	-1.53	0.88	-0.76		

It appears from the data collected that at no time during the 16-month period of record did soil moisture contents drop below levels required by plants to maintain growth. The study by Reimer (1953) in this same woodlot reported similar results. The available water present in the upper 3 feet of soil was found to vary between 65 and 95 percent throughout the growing season. Growing season soil moisture depletion from 1946 to 1951, in an oak-hickory woodlot located some 10 miles distant from Toumey Woodlot, and on similar soil, was reported by Coltharp (1958) to have shown soil moisture values continuously above the wilting point in the upper 3 feet of soil profile.

Upper soil zone (1-and 2-foot depth). At the start of the soil moisture study, April 8, 1961, the soil moisture recorded at this portion of the profile was 4.75 inches. Although 9.59 inches of precipitation fell on the area between this date and July 21, a steady decrease in soil moisture occurred, as shown in Figure 6. Soil moisture storage depleted 0.86 inches during this period. Since only two measurements were possible during this 3-month period [10], fluctuations which undoubtedly occurred in this upper zone, as the result of the more-than 9 ½ inches of precipitation between measurements, went unobserved. Nevertheless, the over-all soil moisture content did become depleted during this interval. This period of time coincides with the resumption of vegetative growth, resulting in increased water needs.

During the remaining portion of the 1961 growing season, alternate periods of soil moisture accretion and depletion took place.

10/ Inopportune instrument breakdown resulted in undesirable omission of data.

A 1.05-inch rainfall during July 29 and August 3, recharged the soil moisture content, as indicated by the August 4 measurement. Heavy rainfall between August 19 and August 24, totaling 3.87 inches, again recharged the soil moisture. Soil moisture depletion continued during September, but at a reduced rate. Following leaf-fall, soil moisture accretion began.

Lower solum (3- and 4-foot depth). This portion of the profile reacted in much the same manner as did the upper 2-foot depth. Following the initial observation on April 8, 1961, a gradual decline in soil moisture occurred until August 25, when the moisture content of the soil was recharged by the 3.87-inch rainfall of August 19 to August 24, Soil moisture depletion during September was greatly reduced. During the fall, winter, and early spring months, moisture recharge was observed. The peak moisture content reached in 1962 was on May 3, the same time that it was observed in the upper zone.

The primary distinction between this layer of soil and the upper surface layers is the smaller fluctuations which occur in the soil moisture content. A steady depletion of the soil moisture was observed in this zone, with many of the intermittent rains not large enough to interrupt this general depletion trend.

Parent material (5- to 9-foot depths). Moisture losses from this depth differed from those of the upper 4 feet of soil. From a high of 9.97 inches of water in this zone on July 7, 1961, depletion continued without interruption until August 25, and then only a recharge of approximately 1/4-inch was recorded on September 8. With a probable experimental error of 0.10 inch of water per foot of soil, this recharge is negligible. However, as the result of the almost 5 inches of rainfall occurring between August 19 and September 7, some soil moisture recharge may have actually occurred. One may note also that soil moisture recharge reached its peak on August 25, in the upper 4-foot depth. On September 8, when the 5- to 9-foot depth indicated moisture recharge, the upper 4-foot depth was observed to have had a moisture decrease. This represents a 2-week lag in soil moisture recharge at the lower depths from that of the upper 4-foot depths.

One additional relationship observed during the first year of measurement was the moisture accretion of the lower depths while moisture depletion occurred in the upper 4-foot depth. Between April 8, and July 21, 1961, moisture accretion of 0.51 inches was found in the 5- to 9-foot depth, while more than 1 inch of water was lost in the upper 4 feet of profile. This observation is of interest since it may be partially explained by Hewlett's (1961) work on the Coweeta Hydrologic Laboratory in western North Carolina. Hewlett has postulated that the movement of water held at tensions below field capacity (capillary water) may move out of the upper soil layers and into the ground-water supplies. In the present study some of the soil moisture depletion observed in the upper 4-foot depths may have been due to water movement into the lower depths.

Evapo-transpiration

Evapo-transpiration is the loss of soil water by evaporation from the soil surface layers and by transpiration of the vegetation. Evapo-transpiration is the primary means of depleting available soil moisture. However, Black (1957) points out that evapo-transpiration is limited by the supply of water in the soil in many regions. Several examples are cited where the yield of crops increased, along with an increase in evapo-transpiration rates, with a corresponding increase in the supply of water in the soil. When the evapo-transpirational processes can occur at their maximum rate, with ample soil moisture present at all times, the maximum water loss resulting is termed potential evapo-transpiration. A water deficiency results when the forest soil is unable to supply the full amount of water required by the existing potential evapo-transpiration conditions.

Computed evapo-transpiration losses occurring throughout the 9-foot profile depth, during 1961-1962, are presented in Table 6. As soil moisture determinations were curtailed at various times of the year due to mechanical failure of the neutron equipment, values are presented as those estimated to have occurred during the time between successive soil moisture measurements. Calculations are presented for the entire depth sampled since it was not possible to accurately determine the water movement occurring within any specific level of the profile. By considering the entire depth sampled, an over-all estimate of evapo-transpiration loss becomes possible.

From the values in Table 6, it is observed that the evapo-transpiration loss during the first growing season studied (April 8-

Table 6. Periodic and cumulative evapo-transpiration losses in inches, recorded in Toumey Woodlot on Hillsdale sandy loam, in 1961-1962, 0- to 9-foot depth

Period from 1961	Periodic	Cumulative	Period from 1962	Periodic	Cumulative
Apr. 8-Jul. 21	10.27		Dec. 29-Jan. 20	1.31	27.97
Jul. 21-Jul. 28	1.94	12.21	Jan. 20-Feb. 9	0.44	28.41
Jul. 28- Aug. 4	0.94	13.15	Feb. 9-Apr. 14	0.15	28.56
Aug. 4-Aug. 11	1.01	14.16	Apr. 14-Apr. 21	0.32	28.88
Aug. 11-Aug. 18	0.59	14.75	Apr. 21-Apr. 26	0.01	28.89
Aug. 18-Aug. 25	2.95	17.70	Apr. 26-May 3	0.53	29.42
Aug. 25-Sept. 8	0.96	18.66	May 3-May 12	0.60	30.02
Sept. 8-Sept. 15	1.29	19.95	May 12-May 17	0.32	30.34
Sept. 15-Dec. 29	6.71	26.66	May 17-Jul. 7	7.31	37.65

September 15) was 19.15 inches. The largest portion of this loss, nearly 52 percent, occurred during April 8 and July 21. Measurements in 1962 indicate that of the 8.77 inches of water lost during April 14 and July 7, 83 percent was lost between May 17 and July 7. These high losses of soil moisture in the early part of the growing season correspond to the resumption of growth by the vegetative cover, growth which requires large amounts of water. During the remaining portions of the year, greatly reduced evapo-transpiration losses occur.

The total amount of evapo-transpiration loss computed for the approximate 12-month period of April 8, 1961 to April 14, 1962, was 28.56 inches. This estimate compares favorably with Kittredge's (1938) estimate of 20 to 30 inches of annual water loss for this region.

Kittredge, by subtracting the amount of runoff from precipitation, obtained the total possible water losses which occurred in an area. Coltharp (1958) estimated evapo-transpiration losses of nearly 17 inches to have occurred in the upper 3 feet of soil in an oak-hickory stand in southern Michigan during June to September, 1946 to 1951, Lull and Axley (1958) reported annual evapo-transpiration losses exceeding 30 inches for a 10-foot depth in New Jersey oak stands.

Although the evapo-transpiration losses estimated in this study generally agree with those reported by other workers, the values obtained may perhaps be somewhat high. One reason for this is internal drainage losses which may occur to depths below the sampling zone. However, perhaps more important is the lateral drainage within the soil profile which may have resulted in further water losses. As these water losses were unknown in quantity, they were not deducted in calculations of evapo-transpiration losses in this study.

Understory Composition

All ground cover species observed in this investigation were recorded during the summer months of July and August in 1940, 1950, and 1960. Consequently, several of the spring ephemerals are not recorded in this study since the above-ground parts of these ephemerals are no longer visible at this season. Some indication of plants that bloom in the spring was possible for species retaining identifiable leaves or other parts. Some of these species are: bloodroot (*Sanguinaria canadensis* L.), Jack-in-the-pulpit (*Arisaema triphyllum* (L.) Schott), woods phlox (*Phlox divaricata* L.), and mayapple (*Podophyllum peltatum* L.).

As the same rectangular 31 ground cover plots (24 inches x 34 inches) were remeasured each time, a comparison can be made for each particular plot over the entire 20-year span of observations. Table 7 indicates the various plant species which were present in the woodlot over the time period involved. It is recognized that in long-time vegetative studies involving numerous individuals, problems may arise as to the correct identification of plant materials. This is especially true in the seedling and immature stages of many herbaceous species. Although some discrepancies were encountered with earlier collected data, every effort was made to correct this source of error, and to present information considered reliable. Careful examination of the plot photographs was helpful in this matter.

In the first measurement of ground cover undertaken in 1940, and following through the second and third remeasurements of 1950 and

1960, respectively, there were present:

	1940	1950	1960
HERBACEOUS			
Families	9	15	13
Genera	9	17	15
SHRUBS			
Families	3	3	5
Genera	3	3	6
TREES			
Families	4	8	9
Genera	4	8	9
TOTAL			
Families	16	26	27
Genera	16	28	30

A sizeable increase in floristic richness has occurred over the 20-year period. In 1940, only 9 herbaceous genera, representing a like number of families, were present in the plots measured. Together with 3 shrub and 4 tree genera, representing 3 and 4 separate families, respectively, a total of 16 genera, representing 16 different families, were present in 1940.

The increase in flora in 1950 was quite noticeable. At this time, 17 herbs, 3 shrubs, and 8 tree genera were recorded, for a total of 28 genera and 26 families. The third measurement of the ground cover plots in 1960 indicated additional changes in the flora. The total number of herbaceous genera decreased from that in 1950, with 15 genera and 13 families present. An increase in shrubs was noted, with 6 genera from 6 families present. The number of tree species for 1960 increased from that found in 1950, that being 9 species in 9 separate families.

When looking at the total number of species present at the three measurements, a general increase in numbers is evident.

The total number of species has almost doubled from that observed in the initial measurement in the 20-year period, and the number of families represented has nearly kept pace with this increase of species. However, more information becomes available when the individual plots themselves are examined as to their floristic content. All of the observations have been tabulated and are presented in Table 7. From this, 21 herbaceous species, 6 shrub species, and 10 tree species are observed to have been present at one or more of the measurements over the 20-year period.

Using the available information on the sequence of species present on individual plots, some inferences can be made as to the possible longevity of certain species over this period of time. The interval between measurements is 10 years; hence, the short-time changes in ground cover vegetation have been missed completely. In many circumstances involving herbaceous species, it is not possible to follow the development of a particular individual over a period of years. Therefore, the longevity of certain species must be considered for a local population rather than for any specific individual.

In Table 7, the presence of a species in a plot is designated by the letter "P", and a blank space indicates the complete absence of that species. It immediately becomes obvious that certain species appear more often than others and also appear sequentially within the same plot. Several species appear at each of the 3 measurements in a particular plot. Others are more sporadic and appear but once over the 20 years or appear, disappear, and then

Table 7. Summer ground cover species observed at each of three measurement periods, 1940, 1950, and 1960, in Toumey Woodlot (Data based on 31 quadrats, 24 x 34 inches)

Ground Cover Species	B-2			B-4			B-6			B-8			B-10		
	40	50	60	40	50	60	40	50	60	40	50	60	40	50	60
HERBS															
Actaea pachypoda															
Arisaema triphyllum															
Carex spp.															
Circaea quadrisulcata var. canadensis													P	P	P
Cirsium vulgare							-	-	P						
Cryptotaenia canadensis															
Hydrophyllum appendiculatum															
Hystrix patula															
Impatiens capensis															
Osmorhiza claytoni															
Phlox divaricata													-	P	-
Phryma leptostachya															
Pilea pumila															
Podophyllum peltatum													-	P	-
Polygonatum pubescens															
Sanguinaria canadensis															
Sanicula trifoliata															
Smilacina racemosa	-	P	-												
Solidago caesia															
Viola spp.							-	-	P						
SHRUBS															
Euonymus obovatus	-	-	P												
Parthenocissus quinquefolia				P	-	-									
Rubus spp.							-	-	P						
Sambucus canadensis							-	-	P						
Toxicodendron radicans															
Vitis spp.															
TREES															
Acer saccharum	-	-	P	P	-	-	-	-	P	P	P	P	P	-	P
Carya cordiformis															
Fagus grandifolia															
Fraxinus americana													-	P	P
Ostrya virginiana													-	-	P
Prunus serotina										-	-	P	P	P	P
Quercus rubra															
Tilia americana															
Ulmus rubra							-	-	P	-	-	P			
Zanthoxylum americanum							-	-	P	-	-	P			

Table 7. (continued)

Ground Cover Species	D-3			D-5			D-7			D-9			F-2		
	40	50	60	40	50	60	40	50	60	40	50	60	40	50	60
HERBS															
Actaea pachypoda															
Arisaema triphyllum															
Carex spp.															
Circaea quadrisulcata var. canadensis										-	-	P			
Cirsium vulgare															
Cryptotaenia canadensis															
Hydrophyllum appendiculatum															
Hystrix patula															
Impatiens capensis															
Osmorhiza claytoni															
Phlox divaricata															
Phryma leptostachya							-	P	P						
Pilea pumila															
Podophyllum peltatum															
Polygonatum pubescens															
Sanguinaria canadensis															
Sanicula trifoliata															
Smilacina racemosa													-	-	P
Solidago caesia															
Viola spp.							P	P	P						
SHRUBS															
Euonymus obovatus													P	P	P
Parthenocissus quinquefolia	P	P	P										-	P	P
Rubus spp.															
Sambucus canadensis	-	-	P				P	-	-						
Toxicodendron radicans															
Vitis spp.										-	-	P			
TREES															
Acer saccharum	P	P	P	-	P	P	P	P	P	P	P	P	-	P	P
Carya cordiformis															
Fagus grandifolia															
Fraxinus americana															
Ostrya virginiana															
Prunus serotina															
Quercus rubra															
Tilia americana															
Ulmus rubra															
Zanthoxylum americanum															

Table 7. (continued)

Ground Cover Species	F-4			F-6			F-8			F-10			H-3		
	40	50	60	40	50	60	40	50	60	40	50	60	40	50	60
HERBS															
Actaea pachypoda															
Arisaema triphyllum	P	P	P												
Carex spp.										P	-	-			
Circaea quadrisulcata var. canadensis													-	-	P
Cirsium vulgare															
Cryptotaenia canadensis															
Hydrophyllum appendiculatum															
Hystrix patula															
Impatiens capensis															
Osmorhiza claytoni	-	-	P												
Phlox divaricata															
Phryma leptostachya															
Pilea pumila															
Podophyllum peltatum															
Polygonatum pubescens															
Sanguinaria canadensis													-	-	P
Sanicula trifoliata															
Smilacina racemosa															
Solidago caesia															
Viola spp.															
SHRUBS															
Euonymus obovatus															
Parthenocissus quinquefolia															
Rubus spp.															
Sambucus canadensis															
Toxicodendron radicans															
Vitis spp.															
TREES															
Acer saccharum	P	P	P	-	-	P	P	-	-	P	-	-	P	-	P
Carya cordiformis															
Fagus grandifolia													-	-	P
Fraxinus americana										-	-	P			
Ostrya virginiana															
Prunus serotina										-	-	P	-	-	P
Quercus rubra															
Tilia americana										P	-	-			
Ulmus rubra				-	-	P							-	-	P
Zanthoxylum americanum															

Table 7. (continued)

Ground Cover Speices	H-5			H-7			H-9			J-2			J-4		
	40	50	60	40	50	60	40	50	60	40	50	60	40	50	60
HERBS															
Actaea pachypoda	-	-	P												
Arisaema triphyllum	-	-	P												
Carex spp.							P	P	P						
Circaea quadrisulcata															
var. canadensis							-	P	-						
Cirsium vulgare															
Cryptotaenia canadensis							-	P	-						
Hydrophyllum appendiculatum															
Hystrix patula															
Impatiens capensis							-	P	-						
Osmorhiza claytoni															
Phlox divaricata															
Phryma leptostachya							-	P	-						
Pilea pumila							P	P	-						
Podophyllum peltatum															
Polygonatum pubescens										-	-	P			
Sanguinaria canadensis															
Sanicula trifoliata							-	P	P						
Smilacina racemosa															
Solidago caesia							-	-	P						
Viola spp.							-	P	P	P	-	-			
SHRUBS															
Euonymus obovatus															
Parthenocissus quinquefolia	P	-	-												
Rubus spp.															
Sambucus canadensis															
Toxicodendron radicans															
Vitis spp.															
TREES															
Acer saccharum	-	P	P	P	-	P	-	-	P	P	P	P	-	P	P
Carya cordiformis															
Fagus grandifolia															
Fraxinus americana															
Ostrya virginiana															
Prunus serotina															
Quercus rubra				-	P	P									
Tilia americana															
Ulmus rubra													-	-	P
Zanthoxylum americanum															

Table 7. (continued)

Ground Cover Species	J-6			J-8			L-3			L-5			L-7		
	40	50	60	40	50	60	40	50	60	40	50	60	40	50	60
HERBS															
Actaea pachypoda															
Arisaema triphyllum							-	P	P	-	P	P			
Carex spp.				-	-	P				P	-	-			
Circaea quadrisulcata var. canadensis										-	-	P	-	-	P
Cirsium vulgare															
Cryptotaenia canadensis										-	P	-			
Hydrophyllum appendiculatum				-	P	P	-	-	P				P	P	P
Hystrix patula													-	P	-
Impatiens capensis															
Osmorhiza claytoni										-	-	P	-	P	P
Phlox divaricata															
Phryma leptostachya										-	P	P			
Pilea pumila										P	-	-			
Podophyllum peltatum															
Polygonatum pubescens															
Sanguinaria canadensis				-	-	P									
Sanicula trifoliata										-	P	P	P	-	P
Smilacina racemosa															
Solidago caesia															
Viola spp.				-	P	P									
SHRUBS															
Euonymus obovatus															
Parthenocissus quinquefolia				P	-	-									
Rubus spp.															
Sambucus canadensis															
Toxicodendron radicans															
Vitis spp.															
TREES															
Acer saccharum	P	-	P	P	P	-	P	P	P	P	P	P	P	P	-
Carya cordiformis										-	P	-			
Fagus grandifolia															
Fraxinus americana															
Ostrya virginiana															
Prunus serotina	-	-	P												
Quercus rubra															
Tilia americana							P	P	P						
Ulmus rubra				P	-	-							-	-	P
Zanthoxylum americanum															

Table 7. (continued)

Ground Cover Species	N-2			N-4			N-6			P-3			P-5		
	40	50	60	40	50	60	40	50	60	40	50	60	40	50	60
HERBS															
Actaea pachypoda							-	-	P						
Arisaema triphyllum										-	P	P			
Carex spp.				P	-	-									
Circaea quadrisulcata var. canadensis															
Cirsium vulgare															
Cryptotaenia canadensis															
Hydrophyllum appendiculatum							P	P	P				-	P	P
Hystrix patula															
Impatiens capensis	P	-	-										-	-	P
Osmorhiza claytoni	-	P	P	-	P	P				-	P	P			
Phlox divaricata										-	P	-			
Phryma leptostachya													-	P	P
Pilea pumila															
Podophyllum peltatum															
Polygonatum pubescens															
Sanguinaria canadensis													-	P	P
Sanicula trifoliata				-	P	P									
Smilacina racemosa										P	P	P			
Solidago caesia															
Viola spp.	P	P	P	P	P	P	-	P	P	-	-	P			
SHRUBS															
Euonymus obovatus															
Parthenocissus quinquefolia										P	P	-			
Rubus spp.															
Sambucus canadensis															
Toxicodendron radicans															
Vitis spp.															
TREES															
Acer saccharum	P	-	P	P	P	P	P	P	P	P	-	P	-	P	P
Carya cordiformis															
Fagus grandifolia															
Fraxinus americana															
Ostrya virginiana															
Prunus serotina							-	-	P						
Quercus rubra															
Tilia americana							P	-	-						
Ulmus rubra				P	P	-				P	P	-			
Zanthoxylum americanum															

Table 7. (continued)

Ground Cover Species	R-2 40	R-2 50	R-2 60	Actual Frequency 40	Actual Frequency 50	Actual Frequency 60	Percentage Frequency 40	Percentage Frequency 50	Percentage Frequency 60
HERBS									
Actaea pachypoda				0	0	2	0	0	6.5
Arisaema triphyllum				1	4	5	3.2	12.9	16.1
Carex spp.	P	P	-	6	3	4	19.4	9.7	12.9
Circaea quadrisulcata var. canadensis				0	1	3	0	3.2	9.7
Cirsium vulgare				0	0	1	0	0	3.2
Cryptotaenia canadensis	-	P	-	0	3	0	0	9.7	0
Hydrophyllum appendiculatum				2	4	5	6.5	12.9	16.1
Hystrix patula				0	1	0	0	3.2	0
Impatiens capensis				1	1	1	3.2	3.2	3.2
Osmorhiza claytoni				0	4	6	0	12.9	19.4
Phlox divaricata	-	P	-	0	3	0	0	9.7	0
Phryma leptostachya	-	P	-	0	5	3	0	16.1	9.7
Pilea pumila				2	1	0	6.5	3.2	0
Podophyllum peltatum				0	1	0	0	3.2	0
Polygonatum pubescens				0	0	1	0	0	3.2
Sanguinaria canadensis				0	1	3	0	3.2	9.7
Sanicula trifoliata	P	P	-	2	4	4	6.5	12.9	12.9
Smilacina racemosa				1	2	1	3.2	6.5	3.2
Solidago caesia	-	P	-	0	1	1	0	3.2	3.2
Viola spp.	P	P	P	5	7	9	16.1	22.5	29.0
SHRUBS									
Euonymus obovatus				1	1	2	3.2	3.2	6.5
Parthenocissus quinquefolia	P	-	-	6	3	2	19.4	9.7	6.5
Rubus spp.				0	0	1	0	0	3.2
Sambucus canadensis				1	1	2	3.2	3.2	6.5
Toxicodendron radicans				0	0	1	0	0	3.2
Vitis spp.				0	0	1	0	0	3.2
TREES									
Acer saccharum	P	P	P	22	18	26	70.9	58.1	83.9
Carya cordiformis				0	1	0	0	3.2	0
Fagus grandifolia				0	0	1	0	0	3.2
Fraxinus americana				0	1	2	0	3.2	6.5
Ostrya virginiana	-	P	-	0	1	1	0	3.2	3.2
Prunus serotina				1	1	6	3.2	3.2	19.4
Quercus rubra				0	1	1	0	3.2	3.2
Tilia americana				3	1	1	9.7	3.2	3.2
Ulmus rubra				3	2	6	9.7	6.5	19.4
Zanthoxylum americanum				0	0	2	0	0	6.5

reappear over this period of time. There are 8 possible sequences of occurrence or absence which can take place for a particular species over the 20-year period of observation, and these are:

PPP - present at each of the 3 measurements
PPA - present at the first 2 measurements only
PAA - present at but the first measurement
APP - present at the last 2 measurements only
APA - present at but the second measurement
AAP - present at but the last measurement
PAP - present at the first and last measurement only
AAA - present at no measurement

From these various categories, certain inferences can be made about the possible longevity of a particular individual or local population of a species. For example, a species that was present at each of the 3 measurements (PPP) suggests that it may have continued on that site for at least 20 years. This is based on the two-fold assumption that the same individual, clone, or local population was observed at each recording and that it was not absent from the quadrat anytime during the 20 years. There may be times when both of these assumptions become difficult to defend. At times there is no way of knowing whether the same individual or clone encountered at an earlier date is the same one recorded at a later date. Also, the species may have been absent for up to 9 years between readings and thus show the individuals to be far younger than the data indicate.

From Table 7, it is apparent that 5 herbaceous, 2 shrubby, and 2 arboreal species have indeed been present at all 3 measurements for any one plot. These are: Parthenocissus quinquefolia (L.) Planch - D-3; Viola spp. - D-7, N-2, N-4, R-2; Carex spp. - B-10, H-9; Arisaema triphyllum - F-4; Euonymus obovatus Nutt. - F-2; Smilacina racemosa (L.) Desf. - P-3; Hydrophyllum appendiculatum Michx. - L-7, N-6; Acer saccharum - B-8, D-3, D-7, D-9, F-4, J-2, L-3, L-5, N-4, N-6, R-2; and Tilia americana - L-3. Of these it seems safe to assume that at least some of the Acer seedlings concern different individuals.

From the above data it can be inferred that for the majority of the herbaceous species encountered, either a longevity range of 20 years is not common or the rate of growth of the rhizome carried the plants beyond the confines of the plot. Probably both are correct for particular cases. In 4 of the 31 plots, Viola was present at all 3 measurements. However, in this study, Viola is actually several species considered as a unit because of identification problems. For this group, some small repetition does occur. On the other hand, Acer occurs at 3 sequential measurements on over one-third of the plots, This is probably indicative of the abundance of the generally short-lived sugar maple seedlings in the woodlot, although some individuals have actually maintained a continuous presence as indicated by the photographs. The only other tree species that appeared sequentially in a particular plot over the 20-year period was Tilia americana. In this instance, the same sprouts persisted in the plot over that period of time.

A sequence of occurrences that implies a longevity of not less than 10 years is where a species was present in the 1940 and 1950 recordings but absent in 1960 (PPA) or absent in 1940 but present in 1950 and 1960 (APP). Once again the assumption must be made that the individuals recorded are the same. That this assumption is unwarranted can be seen in quadrat H-9 where Pilea pumila (L.) Gray, an annual, appears sequentially in 1940 and 1950. However, with this assumption

in mind, the sequence of occurrence PPA was observed in 4 non-arboreal species, those being: Parthenocissus - P-3; Carex - R-2; Pilea - H-9; and Sanicula trifoliata Bickn. - R-2. Two tree species represented in this category are: Acer - J-8, L-7; and Ulmus rubra - N-4, P-3 In the sequence of occurrence category APP, 8 non-arboreal species were recorded as follows: Parthenocissus - F-2; Viola - H-9, J-8, N-7; Arisaema - L-3, L-5, P-3; Phryma leptostachya L. - D-7, L-5, P-5; Hydrophyllum - J-8, P-5; Osmorhiza claytoni (Michx) C. B. Clarke - L-7, N-2, N-4, P-3; Sanicula - H-9, L-5, N-4; and Sanguinaria canadensis - P-5. There were also 3 tree species found in this group and they were: Acer - D-5, F-2, H-5, J-4, P-5; Fraxinus americana L. - B-10; and Quercus rubra - H-7.

A comparison between species found in the sequence PPP and those in the sequences PPA and APP reveals that only 2 species are common to all of them, those being the woody species Parthenocissus and Acer. The only species common to both the sequences PPP and PPA was Carex. The species common to both sequences PPP and APP were: Viola, Arisaema, and Hydrophyllum. These data suggest that most herbaceous species have life spans less than 10 years or grow rapidly enough in 10 years to escape the confines of the small study plot.

The three sequences of occurrence which relate little useful information as to longevity of species are those of PAA, AAP, and PAP. In the first instance the species became established an unknown period before 1940, and could have left the plot the year following the initial measurement, or could have remained until the year preceding the second remeasurement. In the second case, the species

became established since 1950 but how long after 1950, and for how long it will continue to live, is unknown. In the third situation, the species became established an unknown period before 1940, and then left some unknown time thereafter, not to appear again until 1960. Other than indicating that a species can re-invade a site (PAP), these categories relate little information on species behavior.

The APA category unequivocally indicates that the individuals of these species had a longevity less than 10 years, or grew fast enough to leave the quadrat in that period. In this group are found 9 herbaceous species, these being: Cryptotaenia canadensis (L.) DC. -H-9, L-5, R-2; Impatiens capensis Meerb. - H-9; Smilacina - B-2; Podophyllum peltatum L.- B-10; Phryma - H-9, R-2; Phlox divaricata L. - B-10, P-3, R-2; Circaea quadrisulcata (Maxim.) Franch & Sav., var. canadensis (L.) Hara - H-9; Hystrix patula Moench - L-7; and Solidago caesia L. - R-2. The 2 tree species observed in this category were Carya cordiformis (Wangenh.) K. Koch - L-5; and Ostrya virginiana - R-2. When comparing the species of this group with those of the first three groups discussed, PPP, PPA, and APP, only two species are common, and those to the APP category. These species are Smilacina and Phryma. These data again suggest that many species probably have life spans less than 10 years within small, local sites. Other aspects of these vegetative fluctuations are illustrated in Table 7. Thus, trends in the differences in frequencies of occurrence between successive years for the various species suggests that certain genera appear to be decreasing in abundance, e.g., Parthenocissus and Pilea.

On the other hand, genera like Viola, Arisaema, and Sanquinaria appear to be increasing. Still other species appear to be maintaining themselves, with little indication of either increase or decrease. The data do not lend themselves to rigorous statistical treatment, and the confidence limits cannot be provided for these statements.

It is also interesting to note that 7 species were recorded in the ground layer composition quadrats for the first time in 1960. These were: Toxicodendron radicans, (L.) Kuntze, Cirsium vulgare (Savi.) Tenore, Vitis spp., Polygonatum pubescens (Willd.) Pursh, Actaea pachypoda (Ell.), Rubus spp., and Fagus grandifolia. Since there is little question that these species were most probably in the woodlot more-or-less continuously since before 1940, the first appearance in 1960 can be attributed to three possible causes. It could be the result of: (a) normal sampling error, (b) improved inventory and identification in 1960, or (c) an actual increase in the abundance of these species. Most likely a combination of these factors, rather than any single cause, is responsible for the appearance of these species.

To better illustrate some of the changes which have taken place on various ground cover plots over the 20-year period, a representative series of photographs are presented which characterize the range of conditions common to the 31 ground cover plots, and thus for the entire woodlot. Figure 8, offers a comparison of ground cover conditions existing in 1940, 1950, and 1960, at Plot N-4. In this particular plot, the 1940 photograph shows a fairly rich flora consisting of 4 species, Acer saccharum, Ulmus rubra, Viola spp., and

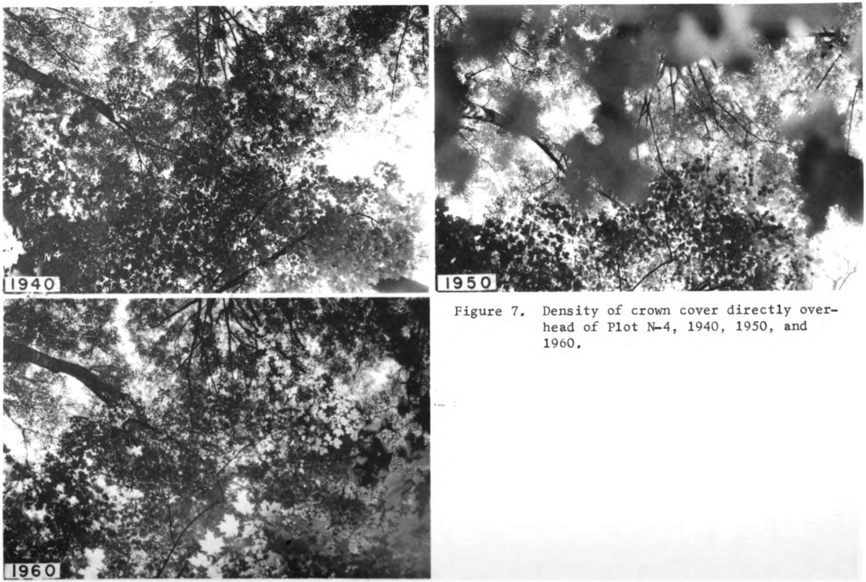


Figure 7. Density of crown cover directly overhead of Plot N-4, 1940, 1950, and 1960.

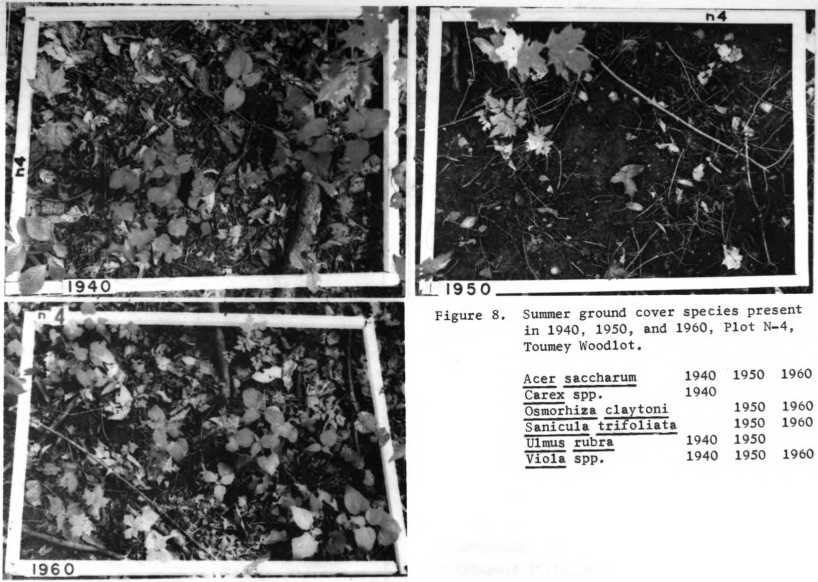
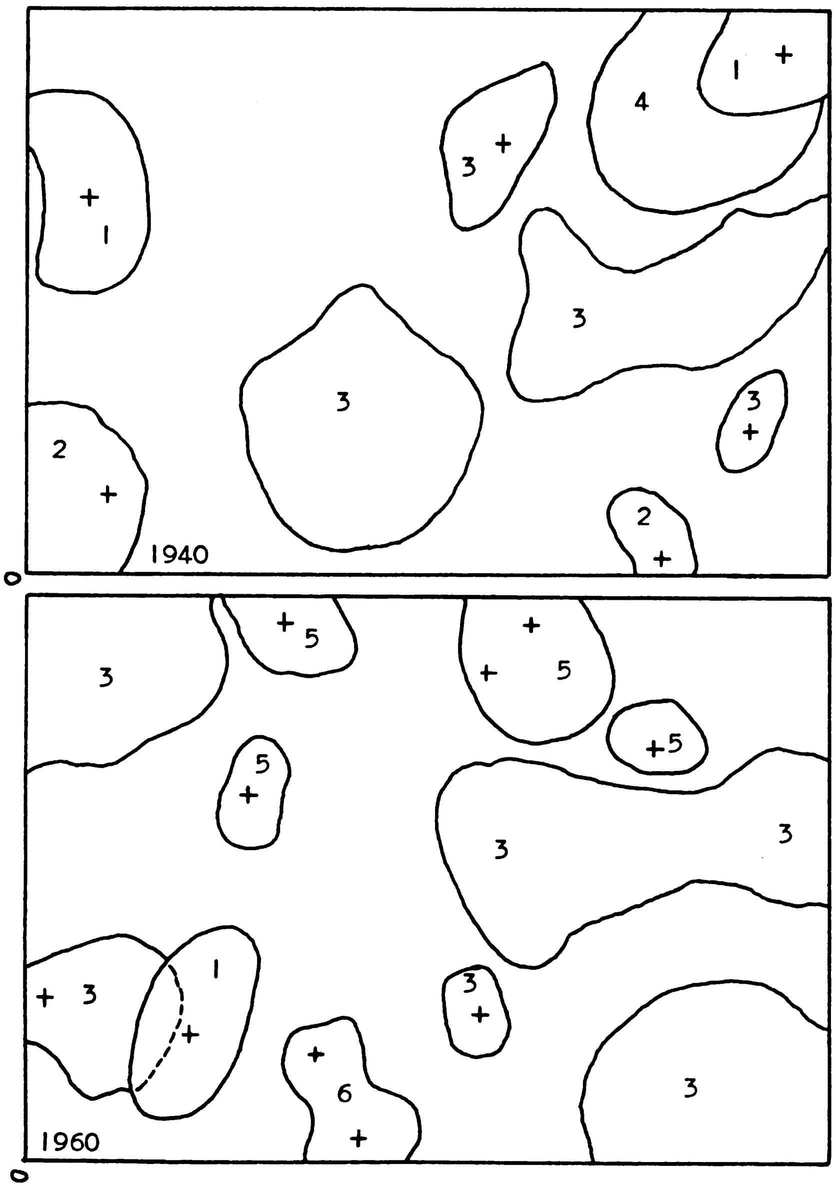


Figure 8. Summer ground cover species present in 1940, 1950, and 1960, Plot N-4, Toumey Woodlot.

Acer saccharum	1940	1950	1960
Carex spp.	1940		
Osmorhiza claytoni		1950	1960
Sanicula trifoliata		1950	1960
Ulmus rubra	1940	1950	
Viola spp.	1940	1950	1960



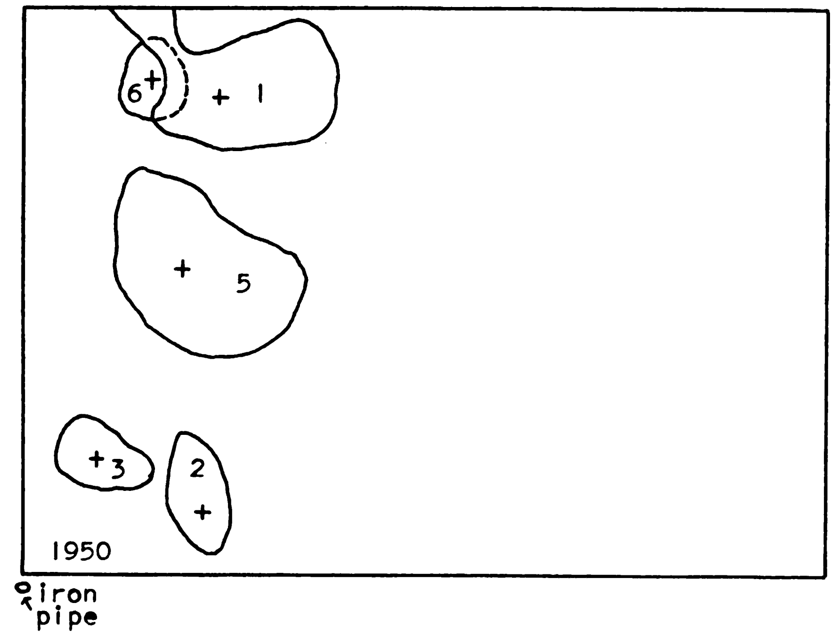


Figure 9. Ground cover maps of Plot N-4, with summer flora and their area of occupancy, 1940, 1950, and 1960.

LEGEND

1 = Acer saccharum
2 = Ulmus rubra
3 = Viola spp.
4 = Carex spp.
5 = Osmorhiza claytoni
6 = Sanicula trifoliata

x = location of stem
(solid outline) = extent of foliage
(dashed outline) = interlaced foliage

Scale: 1 in. = 8 in.

Carex spp. The 1950 photo shows that although there are now 5 species present, Acer saccharum, Ulmus rubra, Osmorhiza claytoni, Sanicula trifoliata, and Viola spp., the total ground cover is less than in 1940. In 1960, although once again only 4 species were present, Acer saccharum, Osmorhiza claytoni, Sanicula trifoliata, and Viola spp., these individuals appear more vigorous and cover more of the plot than in 1950. In this plot, the trend of changes has gone from moderate ground cover to sparse cover and again back to a moderate cover. The crown cover photographs for this plot (Figure 7) as well as the ground cover map (Figure 9), indicate that the 1950 sparse cover is associated with sugar maple cover a short distance above the ground surface. The loss of several large trees in neighboring plots between 1950 and 1960 has also played a role in these ground cover changes.

Another type of ground cover change is illustrated in Figure 11, Plot B-6, showing marked increases in species abundance. In this example, no vegetation was present in either 1940 or 1950, but no less than 7 species of plants were recorded for 1960. Here is a change going from no vascular vegetation in the first 10 years to abundant and diverse plant cover in the second 10 years.

To understand this change more fully, it is helpful to look at the corresponding crown canopy photographs taken at the same time as the ground cover photographs (Figure 10). It can readily be observed that the dense overhead cover present in both 1940 and 1950 has been greatly reduced in the 1960 photograph. In actuality, several trees in the plots bordering immediately to the south and east

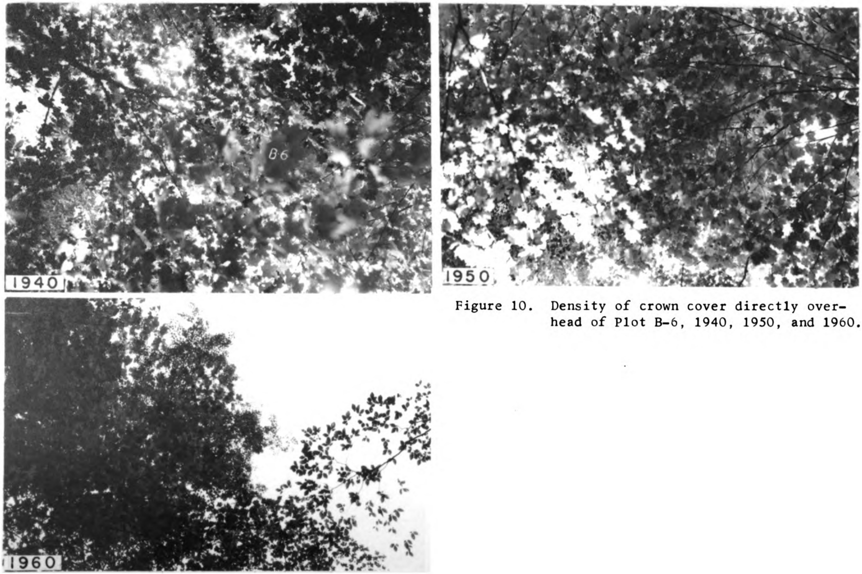


Figure 10. Density of crown cover directly overhead of Plot B-6, 1940, 1950, and 1960.

Figure 11. Summer ground cover species present in 1940, 1950, and 1960, Plot B-6, Toumey Woodlot.

(No species present in 1940, 1950)

<u>Acer</u> <u>saccharum</u>	1960
<u>Cirsium</u> <u>vulgare</u>	1960
<u>Rubus</u> spp.	1960
<u>Sambucus</u> <u>canadensis</u>	1960
<u>Ulmus</u> <u>rubra</u>	1960
<u>Viola</u> spp.	1960
<u>Zanthoxylum</u> <u>americanum</u>	1960

have been windthrown. The increase in light intensity between 1950 and 1960 permitted light-demanding species to enter, e.g. Cirsium vulgare and Rubus spp. Gysel (1951), found similar species-groupings in borders and openings of beech-maple stands of southern Michigan. In openings which had been extant for a few growing seasons, Gysel observed a frequently occurring group of species composed of common thistle (Cirsium vulgare), pokeweed (Phytolacca americana (L.), and common elder (Sambucus canadensis L.). Although no pokeweed was observed in ground cover plot B-6, this species is abundant immediately outside the plot boundaries. It is interesting to note that as many of the trees in the area were windthrown in the fall of 1959, a good estimate of how rapidly species can enter a newly created open area is obtained. From the aerial photographs (Figure 2 and 28) taken May, 1961, this opening in Plot B-6, as well as others in the woodlot, is shown.

In the photographs of Figure 13, a different condition exists. Here is an example where the ground vegetation is less in 1950 and 1960 than in 1940. The 1940 observation of Plot F-8 shows an abundance of young sugar maple, while the 1950 and 1960 photographs indicate the complete absence of vegetation for the same area. The crown cover present over this particular plot, as observed in Figure 12, shows an increasing canopy height over the past 20 years, and this may account for the decline of sugar maple for this plot.

Figure 12. Density of crown cover directly overhead of Plot F-8, 1940, 1950, and 1960.

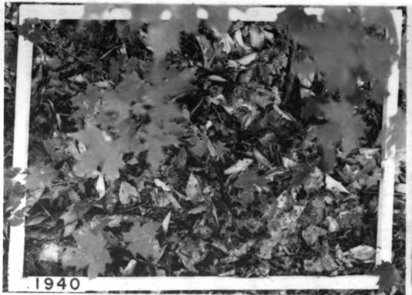


Figure 13. Summer ground cover species present in 1940, 1950, and 1960, Plot F-8, Toumey Woodlot.

(No species present in 1950, 1960)

Acer saccharum 1940

In Figure 15, which represents the changes in Plot F-10, still another type of fluctuation of the ground cover is shown. The 1940 photograph shows 3 species present: Carex spp., the only herbaceous plant of the group; Acer saccharum; and Tilia americana. The 1950 photograph shows no vegetation whatsoever. In the 1960 photograph, 2 new species, Prunus serotina and Fraxinus americana, are present for the first time. The corresponding crown cover of this plot (Figure 14) shows an increasing height, as well as density, of the crown canopy.

One final set of conditions in vegetative fluctuation is illustrated in Figure 17. In this plot, P-5, no vegetation was present in 1940, but an increase in vegetation occurred, with a moderate amount shown in 1950 and still more in 1960. The corresponding crown cover illustrations (Figure 16) show little clear-cut change over the 20-year period.

This series of 5 plots represents 5 different cases of vegetative change in Toumey Woodlot, but illustrate conditions encountered in the 31 ground cover plots examined, and also common throughout the woodlot. It seems evident that most of these changes are not illustrative of directional change but are probably nearer to what Hanson and Churchill (1961) call non-cyclic replacement change. The precise species sequence involved in this type of change is, as the name implies, probably unpredictable. The changes in species are due simply to the death of one ground cover species, followed by the germination of another on the site, with no clearly established causal relationship between the two events. The important point to be emphasized is

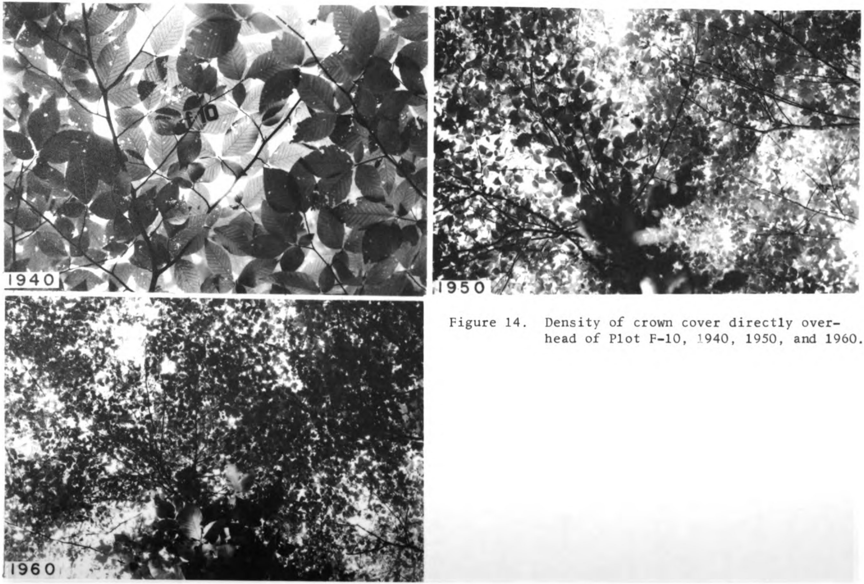


Figure 14. Density of crown cover directly overhead of Plot F-10, 1940, 1950, and 1960.

Figure 15. Summer ground cover species present in 1940, 1950, and 1960, Plot F-10, Toumey Woodlot.

(No species present in 1950)

Acer saccharum	1940
Carex spp.	1940
Fraxinus americana	1960
Prunus serotina	1960
Tilia americana	1940

the ever-changing characteristic of the ground cover in a relatively stable forest community.

Another characteristic type of change is involved with a sequence of events prompted by the death of an overstory tree. This latter sequence of changes has been called "gap-phase replacement" by both Bray (1956) and Curtis (1959), after the concept was introduced by Watt (1947). Stearns (1949), Cooper (1961), Hanson and Churchill (1961), have also referred to this phenomenon. The gap-phase replacement concept recognizes that, given enough time, openings in the crown canopy will occur as the results of disease, insects, fire, and wind, in any closed stand. The gaps or openings created have a different microclimate than that of the rest of the stand, with light, moisture, and possibly soil conditions altered. The seedlings of many species can become established in these openings. In fact, the seedlings of many intolerant species may only be able to enter under these conditions. This is well illustrated in Plot B-6 (Figure 11) where, following the large opening created in 1959, light-demanding genera such as Cirsium, Rubus, and Zanthoxylum entered the plot. Certain intolerant tree seedlings are also probably more abundant under these openings, e.g., Prunus. It can easily be seen that the phenomena involved in gap-phase replacement are complex, and play an important role in determining the species composition in a stand.

There is one important aspect which must be kept in mind, however, about the differences between the three successive observations for each plot over the 20-year period. Since the intervals between observations is 10 years, the short-time changes in ground cover are missed completely. Whereas the recordings at 10-year intervals

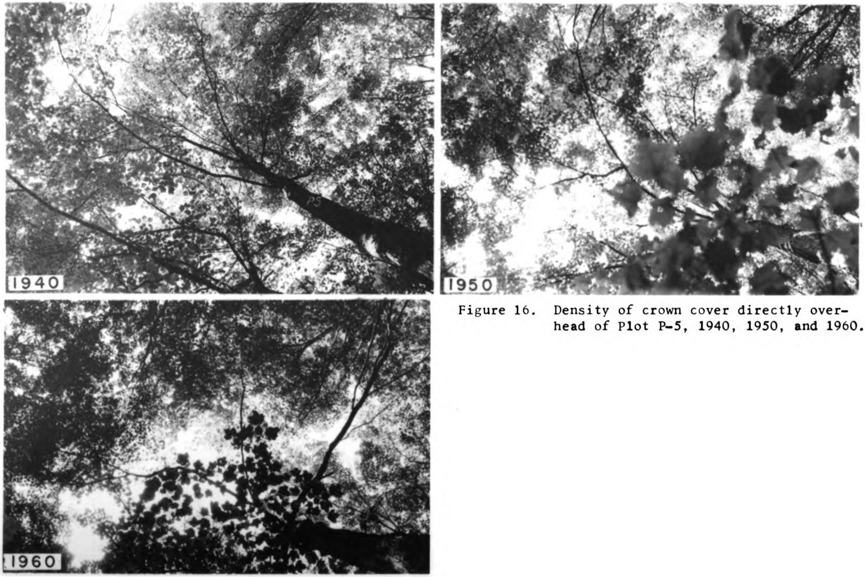


Figure 16. Density of crown cover directly overhead of Plot P-5, 1940, 1950, and 1960.

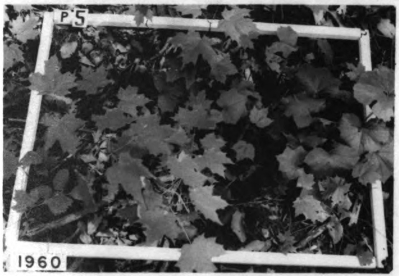


Figure 17. Summer ground cover species present in 1940, 1950, and 1960, Plot P-5, Toumey Woodlot.

(No species present in 1940)

<u>Acer saccharum</u>	1950, 1960
<u>Hydrophyllum appendiculatum</u>	1950, 1960
<u>Phryma leptostachya</u>	1950, 1960
<u>Impatiens capensis</u>	1960
<u>Sanquinaria canadensis</u>	1950, 1960

catch certain major changes in vegetation, they miss many generations of annual, biennial, and other short-lived herbs. They also cannot portray differences in mortality rates of woody seedlings. These summaries, therefore, convey an idea of suddenness for events that occur more gradually. For example, the decomposition of large woody debris in the plots appears to be complete in 10 years for material less than 4 inches in diameter. At shorter remeasurement intervals, for example every 2 or 3 years, a more detailed and smoother pattern of change would be evident.

Overstory Composition

A portion of this investigation deals with the changes in composition and structure of the tree layer(s). For this purpose, all woody stems of 1-inch d.b.h. and larger were recorded by species and by 1-inch diameter classes, at each of the three measurements. By this procedure, the total number of trees, by species, was accurately determined in each diameter class for the entire woodlot. This information is tabulated in Table 8 as number of trees per acre for the major species, and in Table 9 for the species of relatively minor importance. There are 22 tree species recorded in these two tables. Sugar maple is by far the most abundant and important species in the stand, followed by beech which is the second most abundant tree species. Other abundant species are slippery elm, basswood, American elm, white ash, red oak, and black cherry. The remaining 14 species are are relatively less abundant.

Sugar Maple. Sugar maple is one of the largest and most important hardwoods occurring in the eastern half of the United States and Canada. Optimum growth is achieved on fertile, moist but well-drained soils.

The high level of dominance often observed for sugar maple is based upon three main factors, that of high seed production rates, great tolerance of shade, and long life. Curtis (1959) states that high levels of reproduction are found in many mesic stands, but are subject to quite wide fluctuations from year to year, depending on the size of the seed crop and weather conditions. Eyre and Zillgitt (1953) reported that some seed is produced every year and good seed crops

Table 8. Number of trees per acre, by 1-inch diameter classes, for the more abundant tree species in Toumey Woodlot, in 1940, 1950, and 1960 (Values based on 100 percent inventory)

D.B.H. (inches)	SUGAR MAPLE			BEECH		
	1940	1950	1960	1940	1950	1950
1	104.60	161.54	208.17	12.40	17.59	16.26
2	47.96	42.17	80.48	9.50	5.94	8.91
3	18.63	16.11	31.40	5.20	4.83	3.93
4	11.66	12.03	13.44	4.45	3.34	3.27
5	9.73	7.35	9.43	2.60	2.23	2.38
6	6.38	6.31	7.57	0.97	1.34	1.34
7	5.12	4.53	4.83	1.63	1.11	1.34
8	4.08	4.45	4.08	1.41	1.41	0.82
9	3.64	2.67	3.56	1.19	1.34	0.97
10	4.60	3.79	2.38	0.82	0.89	1.04
11	3.71	3.71	3.56	1.04	0.52	0.82
12	3.41	3.12	3.04	0.52	0.74	0.74
13	3.41	3.27	2.67	0.74	0.67	0.74
14	3.71	2.90	2.75	1.04	0.59	1.26
15	2.75	3.50	2.67	0.82	0.74	1.26
16	2.75	2.97	3.12	0.89	0.82	1.34
17	2.52	2.38	3.12	1.19	1.19	0.97
18	1.19	2.23	2.38	1.11	0.59	0.74
19	1.56	1.48	1.63	0.97	1.11	1.11
20	0.89	1.11	2.08	0.97	0.82	0.67
21	0.67	0.97	1.48	0.52	0.89	0.89
22	1.19	0.82	1.11	0.59	0.59	1.11
23	0.74	0.89	1.04	0.30	0.30	0.52
24	0.74	0.97	0.59	0.15	0.37	0.59
25	0.52	0.45	0.82	0.15	0.07	0.07
26	0.22	0.37	0.45	0.22	0.22	0.30
27	0.45	0.45	0.59	0.07	0.07	0.07
28	0.22	0.37	0.52	0.07	0.07	0.22
29	0.22	0.07	0.37	0.07	0.07	0.07
30	0.67	0.22	0.07	0.07	0.07	0.07
31	0.15	0.15	0.22	-	0.15	0.07
32	0.15	0.22	0.30	-	0.07	0.07
33	0.15	0.15	0.15	-	-	0.07
34	0.07	0.15	0.07	-	-	0.07
35	0.07	-	-	0.07	-	-
36	-	0.07	0.07	-	-	-
37	-	-	0.07	-	0.07	-
38				-	-	-
39				-	-	-
40				-	-	0.07
45						
TOTAL	248.53	293.94	400.28	51.74	50.82	54.17

Table 8. (continued)

D.B.H. (inches)	BASSWOOD			AMERICAN ELM			BLACK CHERRY		
	1940	1950	1960	1940	1950	1960	1940	1950	1960
1	3.79	3.12	3.34	1.78	2.30	0.89	1.11	0.59	0.89
2	4.16	2.23	1.19	1.71	1.63	0.74	0.52	0.22	0.37
3	0.74	0.97	0.97	1.19	0.59	1.26	0.22	0.15	-
4	0.22	0.45	0.45	0.59	0.30	0.97	-	-	0.37
5	0.30	0.07	0.22	0.22	0.30	0.22	-	0.07	-
6	0.22	0.07	0.52	0.67	0.30	0.30	-	-	-
7	-	0.07	0.07	0.15	0.15	0.15	-	-	0.07
8	0.30	0.07	0.07	0.30	0.22	0.15	-	-	-
9	0.30	0.30	-	0.15	0.15	0.30	0.07	0.07	-
10	0.22	0.07	-	0.15	0.07	-	0.07	-	-
11	0.15	0.22	0.15	0.37	0.15	0.07	-	-	-
12	0.30	0.22	0.22	0.07	0.30	0.07	0.07	-	-
13	0.15	0.07	0.15	0.22	-	0.15	0.07	-	-
14	0.07	0.07	-	-	0.07	0.15	-	0.07	-
15	0.37	0.30	0.07	0.22	-	-	-	-	0.07
16	0.37	0.30	0.15	0.22	0.30	0.15	-	-	-
17	0.30	0.22	0.22	0.30	0.30	0.07	-	-	-
18	0.37	0.22	0.07	0.22	0.15	0.15	0.07	-	-
19	0.30	0.37	0.22	0.22	0.07	0.37	-	0.07	-
20	-	0.30	0.37	0.07	0.22	0.07	0.07	-	-
21	0.07	0.15	0.22	0.22	0.07	0.07	-	0.15	-
22	0.37	-	0.15	0.07	0.22	0.22	-	-	-
23	0.07	0.15	0.07	0.07	0.15	-	-	-	0.07
24	-	0.07	0.07	0.37	0.15	0.15	-	-	0.07
25	0.30	0.07	0.15	0.22	0.37	0.30	0.07	-	-
26	0.07	0.07	0.07	0.07	0.22	0.07	0.07	-	-
27	0.07	0.07	0.15	0.07	0.07	0.15	-	0.07	-
28	0.07	0.15	0.07	-	-	0.22	-	-	0.07
29	-	0.07	0.07	-	0.07	0.15			
30	-	-	-	-	-	-			
31	0.07	-	-	0.07	-	-			
32	-	0.07	-	-	0.07	-			
33	-	-	-	0.07	-	-			
34	-	-	0.07	0.07	0.07	-			
35	0.07	0.07	-	-	-	0.07			
36	-	-	-	-	0.07	-			
37	-	-	0.07						
38	-	0.07	-						
39									
40									
45									
TOTAL	13.79	10.72	9.61	10.12	9.10	7.63	2.41	1.46	1.98

Table 8. (continued)

D.B.H. (inches)	WHITE ASH			RED OAK			SLIPPERY ELM		
	1940	1950	1960	1940	1950	1960	1940	1950	1960
1	0.67	0.89	15.07	-	0.22	0.82	9.58	25.69	16.85
2	0.45	0.45	3.27	-	-	0.37	3.27	6.01	8.61
3	0.07	0.15	1.48	0.07	-	0.07	0.45	1.93	4.75
4	-	-	0.22	-	0.15	-	0.15	1.11	3.04
5	0.07	0.22	0.22	-	-	0.07	0.07	0.15	1.26
6	0.07	0.07	0.07	0.22	0.07	0.07	0.07	0.22	0.97
7	0.07	0.07	0.22	0.07	-	0.07	0.15	0.15	0.59
8	0.07	-	-	-	0.15	-	0.22	0.07	0.30
9	0.22	0.07	-	0.07	-	0.15	0.22	0.15	-
10	0.07	0.07	-	-	0.07	-	0.07	0.15	0.30
11	0.07	0.15	0.07	0.07	-	0.07	0.15	0.07	0.07
12	0.22	0.15	0.15	0.07	0.07	-	-	0.15	0.15
13	0.30	0.07	0.15	0.07	0.07	-	0.07	-	0.15
14	0.07	0.22	-	-	0.07	0.07	0.22	0.07	0.07
15	0.15	0.15	0.07	-	0.07	-	0.15	0.22	-
16	-	0.07	0.15	0.22	0.15	0.15	0.07	0.15	0.07
17	0.07	-	0.07	0.07	-	-	0.07	-	0.07
18	0.07	0.22	0.22	0.15	0.37	0.15	0.37	0.15	0.07
19	0.07	0.07	-	0.07	-	0.07	0.22	0.30	-
20	0.15	-	0.07	-	-	0.15	0.15	0.22	0.07
21	-	0.07	0.07	0.07	0.15	0.15	0.07	0.07	0.30
22	0.15	0.15	-	0.15	0.07	-	-	0.07	0.15
23	-	-	0.07	-	-	0.07	0.07	0.22	0.15
24	-	0.07	-	0.07	0.22	-	-	-	-
25	0.07	-	-	-	0.07	0.22	-	-	0.22
26	-	0.07	0.07	-	-	0.15	-	-	0.07
27	0.07	-	0.07	-	-	-	-	-	-
28	-	-	0.07	-	-	0.15	-	-	-
29				0.07	0.07	-	-	-	-
30				-	0.07	-	-	-	-
31				-	-	-	-	-	-
32				-	-	0.07	0.07	-	-
33				-	-	0.07			
34									
35									
36									
37									
38									
39									
40									
45				0.07	0.07	0.07			
TOTAL	3.22	3.45	21.85	1.58	2.18	3.23	15.93	37.32	38.28

occur at intervals of 2 to 5 years depending on climatic conditions.

Although sugar maple reproduction is easily obtained, mortality is very high in unreleased, virgin stands. Curtis (1959) reports that an initial crop of 15,000 seedlings in a single opening may be reduced to about 150 during the first 3 years. These are further reduced to no more than 1 or 2 individuals by the time the trees mature. Gleason (1923) made similar observations for the sugar maple forests of northern Michigan. However, as Stoeckler and Arbogast (1947) observed, sugar maple is an extremely tolerant species, and is able to withstand suppression for several years and still show a strong response to release. Once established in the canopy, sugar maple is able to remain for long periods of time because of its great longevity. Godman (1957) and Curtis (1959) report that mature trees reaching ages of 300 to 400 years, and diameters over 40 inches are not uncommon.

Figure 18 shows graphically the population size-structure for sugar maple in Toumey Woodlot, based on 100 percent inventories taken in 1940, 1950, and 1960. An increasing abundance of trees in the 4 lowest diameter classes is obvious over this period. Reproduction of this species is very common throughout the area, and appears to have been so for the entire 20-year period. This is evident from the data on ground cover plots recorded in Table 7. This abundance of reproduction is also illustrated in Figure 19.

The increase in the first 4 diameter classes does not continue for the pole-size and medium timber-size classes. For the 6-

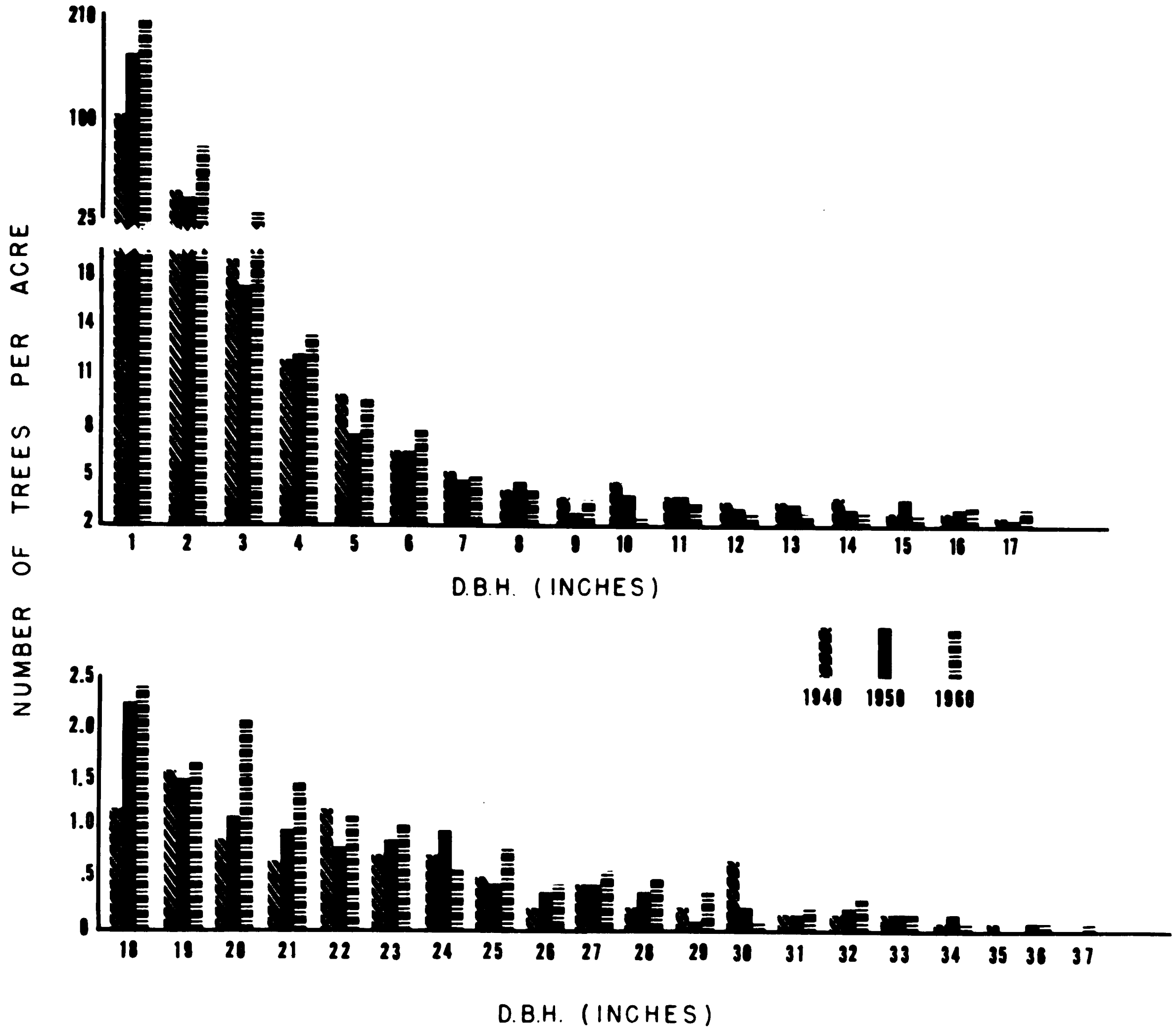


Figure 18. Sugar maple per acre, by 1-inch diameter classes, in 1940, 1950, and 1960, Toumey Woodlot.

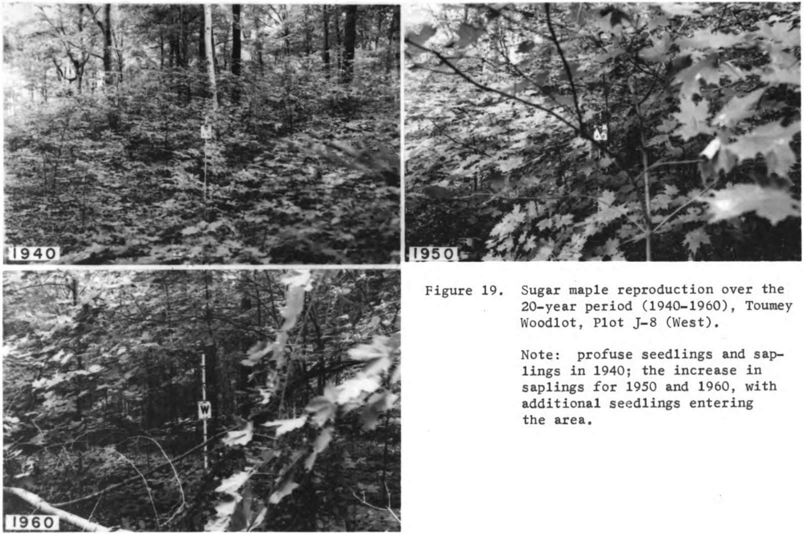


Figure 19. Sugar maple reproduction over the 20-year period (1940-1960), Toumey Woodlot, Plot J-8 (West).

Note: profuse seedlings and saplings in 1940; the increase in saplings for 1950 and 1960, with additional seedlings entering the area.

to 15-inch diameter classes, for example, a small decrease in number of trees per acre has occurred. Some of this decrease represents growth which moved this group into larger size classes. That this actually took place can be noted from the increase in number of trees per acre in the 16-inch to 25-inch diameter classes (12.77 in 1940, 14.27 in 1950, and 17.37 in 1960). In addition, some of the observed decrease in the 6- to 15-inch diameter classes is also due to mortality.

For the diameter classes above 26 inches, very slight fluctuations have occurred over this 20-year period. The total number of trees per acre for all diameter classes above 26 inches was 2.37 in 1940, 2.22 in 1950, and 2.88 in 1960. Of all these diameter classes, only the 30-inch class showed a decrease in numbers over the period of record. This could represent a movement forward to still larger diameter classes, a measurement error, or mortality which was observed in some instances, primarily due to windfall.

From the above data, which indicates the large quantity of reproduction present, and the general increase in the medium and large diameter classes, the over-all abundance of sugar maple in the woodlot is well illustrated.

Beech. American beech is one of the most common trees of the eastern hardwood forest, and is the only native species of this genus in the United States. It is found on a great variety of soil, but the species does best on moist soils. The ordinarily shallow but extensive root system extends deeper where less favorable moisture conditions exist. There is a tendency for the species to produce

sprouts as a result of root suckering. Harlow and Harrar (1958) indicate that the prevailing opinion is that these root suckers seldom develop into desirable forest trees. Curtis (1959) does point out, however, that this sprouting characteristic does allow the species to remain in an area. It also enables the species to advance into unoccupied sites, even under conditions unfavorable to seed or seedling production.

It appears that large seed crops are produced at irregular intervals. The United States Forest Service (1948) states that good seed crops occur every 2 or 3 years. However, Smith (1952) reports good seed crops come but once every 3 or 4 years, and Cheyney (1942) relates that intervals of 4 or 5 years are necessary to produce good seed crops.

American beech is very shade tolerant, and is closely associated with sugar maple in this respect. Curtis (1959) points out that upon occasion, beech saplings can tolerate periods of suppression even better than sugar maple. However, this is often due to the sustaining nourishment of the parent tree when these saplings are root suckers.

Camp (1950) has apparently made the only study of genetic variation in this species, and reports that beech has a complex genetic history. By means of population samples, Camp distinguishes 3 races in the United States. The white beech is found on moist sites in the southeast United States. The red beech occurs on well-drained slopes of the southern Appalachians. The gray beech is found in the cool moist regions of both the southern Appalachians and the

southern edge of the northern coniferous forest. Camp emphasizes that the beech of the Beech-Maple climax forest does not consist of a uniform population but rather contains genetic elements derived from all 3 of the basic populations.

In Table 8, the number of beech stems per acre, for Toumey Woodlot, by 1-inch diameter classes are indicated. The 1-inch diameter class is shown to have increased in number from that observed in 1940 (12.40 trees per acre), and that found in 1950 (17.59) and 1960 (16.26). The small decrease in number between 1950 and 1960 is of no consequence. However, a greater decrease in number of trees per acre is observed in the 2- to 5-inch diameter classes, where 21.75, 16.34, and 18.49 trees per acre were found in 1940, 1950 and 1960, respectively. This decrease, although not great, indicates that seedling and sapling mortality occurred in this group, and also that some advancement occurred to the larger diameter classes. However, for the 1- to 5-inch diameter classes as a whole, the number of stems per acre has maintained itself over the period of record (34.15 in 1940; 33.93 in 1950; and 34.75 in 1960). This suggests that reproduction is taking place at a rate nearly equal to the sum of mortality in this group, and the advancement from this group to larger diameter classes.

Whereas the numbers of trees per acre in the remaining diameter classes have maintained themselves in approximately the same proportions over the past 20 years, some decreases can be observed. The 6- to 10-inch diameter classes, for example, showed a slight drop in number of trees per acre, with 6.02, 6.09, and 5.51 being recorded in 1940, 1950, and 1960, respectively. This small decline could not be the result of measurement error, but may also be due to the movement of these classes to the larger diameter classes, where increases were observed. In the 10- to 25-inch diameter classes, 10.10 trees per acre were recorded in 1940, 10.01 in 1950, and 12.83 in 1960. The pronounced increase in number of stems in 1960 corresponds to the decrease in number of stems recorded in the 6- to 10-inch diameter classes for the same period of time.

Another increase is observed in the diameter classes above 26 inches. There were 0.57 trees per acre in 1940, 0.79 in 1950, and 1.08 in 1960. These data indicate that beech in the largest diameter classes is almost twice as abundant in 1960 as in 1940. In comparison, for the same size classes, sugar maple increased only about 18 percent (2.37 in 1940, 2.22 in 1950, and 2.88 trees per acre in 1960).

To further illustrate the stand structure of beech, Figure 20 is presented, based on a 100 percent inventory for each of the three measurements, by one-inch diameter classes. It is apparent that beech is maintaining itself in the stand, and is actually increasing in numbers in many of the diameter classes.

It is of interest to point out that several investigations have yielded results which indicate definite decreases of beech in sugar maple-beech stands since the mid-1800's. Shanks (1953), working in the beech-maple region of Ohio, found a striking change in forest composition when comparing the present stand structure with that reported in survey records of the early 1800's. Beech is

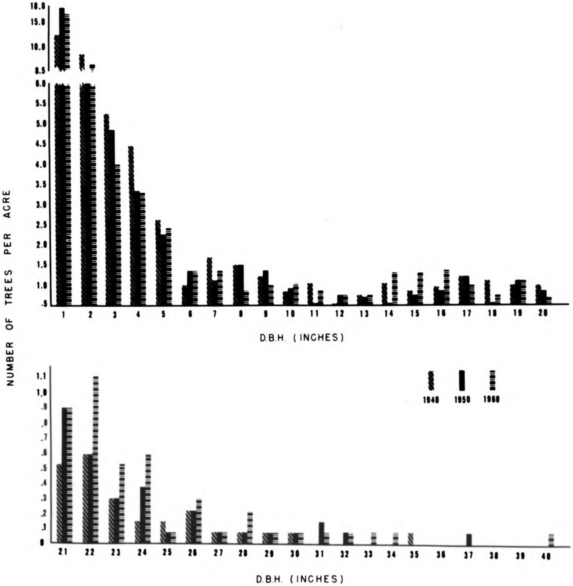


Figure 20. American beech per acre, by 1-inch diameter classes, in 1940, 1950, and 1960, Toumey Woodlot.

presently holding a much less important position than formerly. Williams (1936) reported similar results for a beech-maple climax community in Ohio, where a ratio of 250 sugar maple to 1 beech sapling was the average existing condition. Illick and Frontz (1928) reported some 230 maple seedlings per acre to 1 beech in the beech-birch-maple forests of Pennsylvania. Ward (1953) reports this change in forest composition for the beech forests of Wisconsin as a common one.

Similar findings have been reported extensively for the state of Indiana. Esten (1932) reported on a beech-maple association, indicating that for both seedlings and saplings, there were 20 times more sugar maple than beech. Other workers in Indiana, such as Potzger and Friesner (1943), Keller (1945), Jones (1952) and Trotter (1952) have noted this same trend of increase in sugar maple and a decrease in beech.

This change in composition of the sugar maple-beech forests has also been reported by many investigators in Michigan. Frothingham (1915) observed that in northern hardwood stands, sugar maple was becoming more abundant than beech. Clayberg (1920), in a study of upland societies near Petosky, reported that sugar maple composed from 70 to 90 percent of the stands, whereas beech accounted for 5 to 30 percent. Wollett and Sigler (1928) noted that for areas in the Douglas Lake region, there were 10 times more sugar maple entering the stands than beech. Kenoyer (1930) studied early land survey data from the southwestern part of the state, and concluded that beech was much more numerous in the early 1800's than it is now. An estimate that beech was 5 times more abundant than sugar maple at one time is given. Cain (1935) recorded declining abundance of beech reproduction in comparison to sugar maple for a beech-maple climax forest in Berrien County. Elliott (1953) examined early surveyor's records for Missaukee County, and found that at the time of survey beech was much more abundant than is the case at present.

There appears to be no agreement as to reasons for this decrease of beech. Several opinions have been offered but no concrete evidence has been presented. Ward (1956) offers the hypothesis of an increase in self-sterility among beech. If through abundant root sprouting and extensive timber cutting in surrounding areas, abundant isolated populations result, each of which are genetically similar, then the amount of viable seed which can be produced is greatly decreased. The numerous amounts of empty nuts which are common tend to support this theory. Still other possibilities are that a climatic change has occurred which is less favorable to beech than to any other species, or that through long-term succession, sugar maple has attained predominance over beech.

As mentioned above, no evidence is given to support any of these opinions given by Ward (1956). However, it would seem that one further possibility in the explanation of the decrease in beech has been overlooked. It should be remembered that many of the investigations reporting a reduction in beech abundance were based on information recorded in early land survey notes. The mere fact that beech was often mentioned and used as witness trees actually offers little proof that a decrease in this species has occurred. Surveyors probably much preferred beech as witness trees since they were easily recognized, very conspicuous, and easily marked. It is possible that the early surveyors made an effort to use beech whenever possible, and thus the supposed early abundance of beech would have been greatly exaggerated.

Confusion also results when comparing the abundance of sugar maple with that of beech. The issue is not whether sugar maple exceeds beech in abundance, which it does, but whether beech is declining in number. From the present study there appears to be no sound evidence which indicates that beech has decreased in abundance over the past 20-year period. In fact, it may be debated that the abundance of this species is, and has been, increasing in numbers over this period of time.

Basswood. American basswood is a tree indigenous to the northern half of the eastern United States and adjacent Canada. It attains its best development on rich, moist but well-drained soils. Several studies have indicated that the species is somewhat specific in its site requirements. Westveld (1933) reported that basswood in Michigan was found more commonly on loamy soils or on fine-textured soils than on coarse-textured soils. Eggler (1938) observed that soils containing high amounts of colloidal material and possessing a moisture equivalent of 12 percent, at a depth of 24 to 36 inches, supported good basswood trees in Wisconsin. According to Wilde, Wilson, and White (1949), the species site requirement should be on soils having a minimum silt and clay content of 35 percent.

Most authorities, United States Forest Service (1948), and Scholz (1958a), conclude that good yields of seed are produced at almost yearly intervals. However, Harlow and Harrar (1958) indicate that seeds are produced at rather irregular intervals, and that they require 2 years for germination. Basswood does possess a characteristic, however, which allows it to compete quite successfully in a forested stand. This species can reproduce itself prolifically by means of basal sprouts. Curtis (1959) points out that this type of vegetative reproduction enables basswood to maintain itself in very dense stands, even though its seedlings often do not become established. This was well illustrated when the survey of ground cover plots was completed in 1960, and tabulated in Table 7. For the 31 plots examined, the percentage frequency of basswood reproduction was 9.7, 3.2, and 3.2 for the 1940, 1950, and 1960 measurements, respectively. Two of the three seedlings reported in 1940, were no longer present in the following measurements. The other individuals, of sprout origin, are still present. Scholz (1958a) also reported high seedling mortality during the first 3 growing seasons. Although this high seedling mortality in closed stands would indicate a species having a low tolerance, the older trees are quite tolerant, and basswood ranks next to sugar maple and beech in tolerance according to Graham (1954) and Curtis (1959).

The abundance of basswood in Toumey Woodlot is shown in Table 8, and illustrated in Figure 21. The 1-inch diameter class indicates that about the same number of new sprouts has been in the woodlot at all 3 periods (3.79 in 1940, 3.12 in 1950, and 3.34 trees

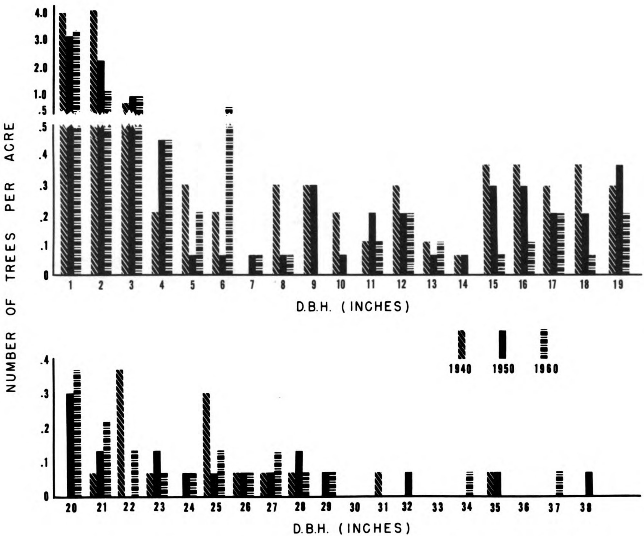


Figure 21. American basswood per acre, by 1-inch diameter classes, in 1940, 1950, and 1960, Toumey Woodlot.

per acre in 1960). However, the total number of trees per acre has declined nearly 33 percent in the 1- to 10-inch diameter classes, with 10.25 in 1940, 7.42 in 1950, and 6.83 recorded in 1960. A similar decline can also be observed in the 11- to 25-inch diameter classes. However, in the 26-inch class and above, a small increase in number of trees per acre occurred, with 0.35 in 1940, 0.57 in 1950, and 0.49 in 1960.

Therefore, for basswood in general, a decline in all but the largest diameter classes has taken place. This could possibly mean that the increase in both sugar maple and beech is progressing at the expense of basswood. However, in the light of the highly clumped distribution of basswood stems, this trend could also mean that more single-stemmed basswoods are in the main canopy and fewer multiple-stemmed ones. This is actually the case in Toumey Woodlot.

Many of the observed individuals, both of sprout origin and possible seed origin, were quite defective and decay was common. Scholz (1958a) states that most present-day basswoods are 20 to 30 inches in d.b.h., although occassional 36- to 38-inch d.b.h. trees do exist. With two exceptions, no individual basswood tree observed had a greater d.b.h. than 29 inches in 1960.

American Elm. American elm is the largest and most important of the native elms in eastern North America. Although common on wet sites, it is found on nearly all great soil groups which occur within the species range. American elm is able to maintain itself on practically all soil textures, but attains optimum development on fertile, well-drained loams. Guilkey (1957) states that elm does poorly on droughty sands, and on soils having a high summer water table.

Westveld (1933) reported, however, that soil texture alone may not be the main controlling growth factor, but rather the entire soil moisture regime, or a compromise between these two properties.

Good seed production is reported to be common most every year. There is evidence, however, that although abundant yearly seed crops are produced, high loss of both seed and seedling occurs. Smith (1952) indicates that the falling seeds, being very light and thin, dry out quickly and few have an opportunity to germinate successfully except those on a relatively moist ground. In addition, Guilkey (1957) states that spring frosts can do great harm in reducing the numbers of both flowers and fruits. Numerous mammals also take a high percentage of seed.

From Table 8, it is evident that a fairly constant rate of decrease in elm has taken place over the past 20-year period. This is true for all but the very largest diameter classes present. Little reproduction of this species is found in the study area, and none was recorded over the study period in the ground cover plots, as indicated in Table 7. This decline probably results from a combination of the factors which cause high losses in seeds and seedlings. Since elm is an intermediate in tolerance, it will be suppressed by more tolerant species, such as sugar maple and beech, and ultimately be greatly reduced in number.

A decrease occurred in the 1- to 10-inch diameter classes, with 6.91 in 1940, 6.01 in 1950, and 4.98 trees per acre in 1960. A similar decrease was observed in the 11- to 25-inch diameter classes. One explanation for the decline noted in these size classes is the

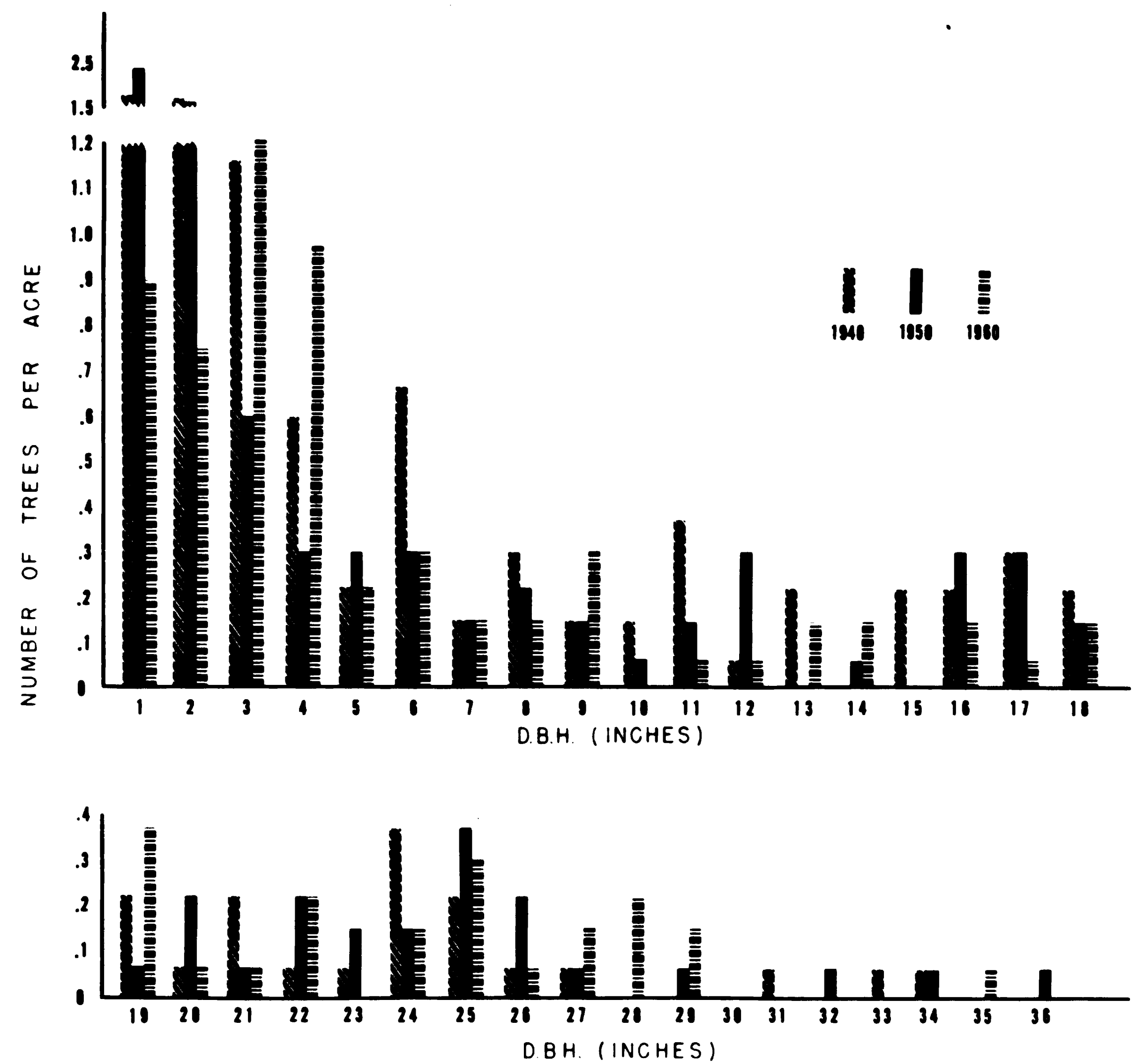


Figure 22. American elm per acre, by 1-inch diameter classes, in 1940, 1950, and 1960, Toumey Woodlot.

presence of Dutch elm disease, which has recently been found in Toumey Woodlot.[11/] For another woodlot within one mile of the study area, over 70 individuals were dead, or suspected to have this disease in 1961.[12/] However, for those individuals above 26 inches d.b.h. a sizeable increase was observed, with 0.35, 0.57, and 0.66 trees per acre in 1940, 1950, and 1960, respectively, Figure 22 graphically illustrates the general decline of this species in the area.

Black Cherry. Black cherry has a very wide range in distribution, extending throughout the easter half of the United States. This species, and its numerous varieties, grows under diverse climatic conditions, and does well on podzol and gray-brown podzolic soils which are moist, but well-drained.

Some investigators believe that good seed crops are produced almost yearly, as does the United States Forest Service (1948). Others, as Hough (1960), state that good seed years occur every 3 to 4 years. Since ample seed supplies for forest regeneration are usually present and black cherry seedlings are quite vigorous, reproduction is normally easily obtained. However, the species is intolerant to shade, and seedlings are not able to withstand root and light competition for very long. Commonly, therefore, black cherry germinates in large numbers, becomes temporarily established, and then begins to suffer high mortality in the second and third year. It appears that this may

11/ Strong, F. Personal communication, 1962. Laboratory examination of samples taken in Toumey Woodlot in 1962 verified the presence of Dutch elm disease. Analyses courtesy of James Stewart, Botany & Plant Pathology Department, Michigan State University.

12/ Cantlon, J. Personal communication, 1962.

have happened in Toumey Woodlot as well. As is indicated in Table 8, little sapling reproduction is present. In the ground cover plots, however, rather abundant reproduction was present in 1960, with nearly 20 percent of the area sampled containing the species (Table 7, page 77). Heavy mortality is occuring during the early years, whereby few individuals can survive the light and root competition of surrounding vegetation. Only in openings of substantial size, such as are caused by death or windthrow of canopy trees, does the species become established as a canopy tree. Upon occupying a dominant position, black cherry grows well under favorable soil conditions.

Figure 23 portrays the population size-structure of black cherry in the woodlot. The sparse distribution of stems in the smaller diameter classes is evident. Also, larger diameter classes are not very prevalent and, in general, the species composes a minor part of the stand. There appear to be no clear-cut trends in the population. Although the 1950 inventory showed the lowest number of individuals in the 1- to 10-inch group, and 1960 showed the lowest count in the 10- to 25-inch diameter classes, the differences are small and of little consequence.

White Ash. White ash, the commonest of the American ashes, occupies a natural range which extends over most of the eastern United States. It is found frequently on brown and gray-brown podzolic soils. Two important factors which are required by the species for optimum growth are fertile soils, and adequate soil moisture, as pointed out by Wright (1959). High nitrogen and calcium contents are required for best development. That soil moisture is a critical factor in white

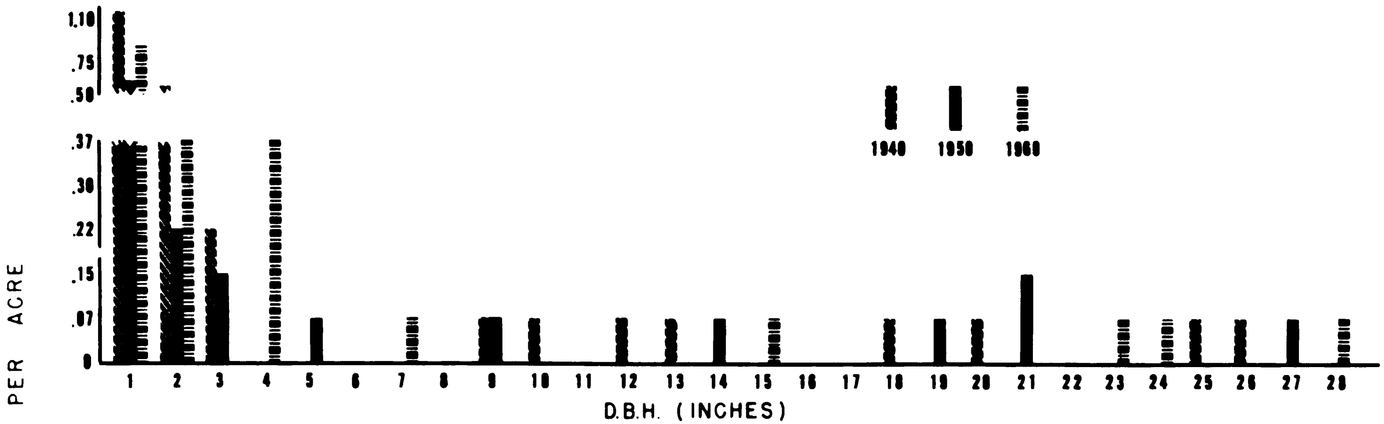


Figure 23. Black cherry per acre, by 1-inch diameter classes, in 1940, 1950, and 1960, Toumey Woodlot.

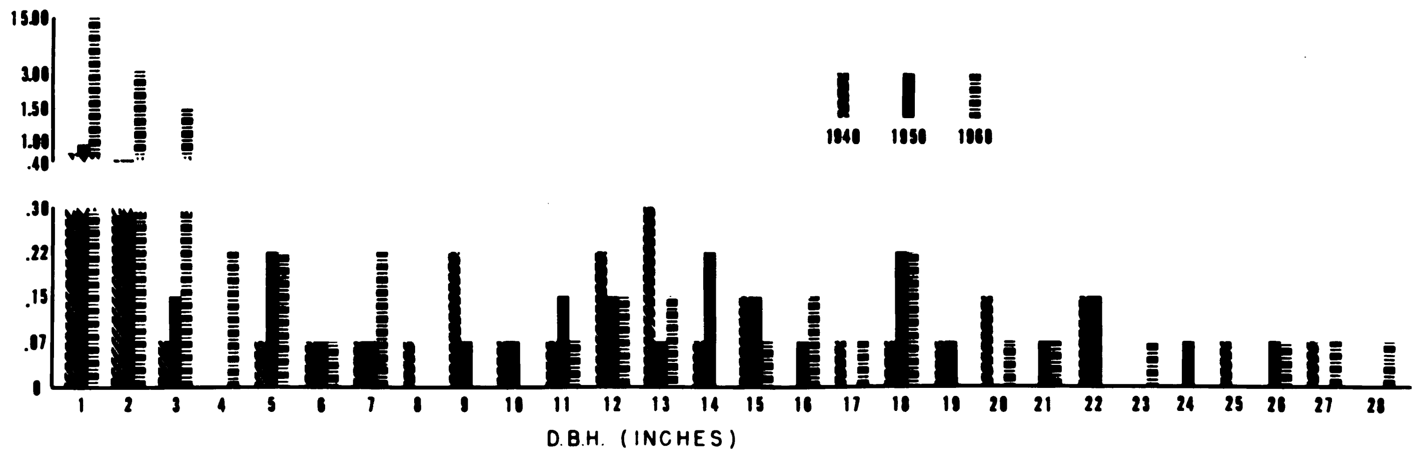


Figure 24. White ash per acre, by 1-inch diameter classes, in 1940, 1950, and 1960, Toumey Woodlot.

ash development is shown by Elliott's (1953) results for the lower peninsula of Michigan. Here the species was abundant on soils high in moisture, but rare on light-textured, well-drained soils.

While white ash is a minor component of the sugar maple-beech forest, it is a relatively constant one. The United States Forest Service (1948) states that heavy seed crops occur but every 3 to 5 years. Wright (1959) reported that only half of the flowering trees bear good seed crops while the remainder bear none. Optimum growing conditions for seedlings appear to be those of high soil moisture, high soil fertility, and abundant sunlight. These conditions are not usually met under old-growth maple-beech forests.

Harlow and Harrar (1958) mention that white ash in the seedling stage can withstand a great deal of shade. Consequently, with an adequate seed source nearby, white ash seedlings are able to establish themselves. With increasing age, the species becomes more tolerant. This is evidenced by the fact that more individuals are found in the understory than the overstory in most old-growth mesic hardwood forests. However, since the species can persist in rather dense shade for several years in its youth, and can grow rapidly when released, it is able to obtain an occasional position in the main tree canopy when an opening in the stand occurs.

The stand composition of white ash in Toumey Woodlot is tabulated in Table 8, and is illustrated in Figure 24. There appears to have been little change between 1940 and 1950 in the size structure of this population. The very low numbers in the first 3 diameter classes, and of seedlings noted in the ground cover plots (Table 7), suggests that during the first 10-year period of measurement either a poor seed source existed or that conditions for seedling germination and early survival were poor. However, a very remarkable increase in this size group has taken place in the last decade, with 19.82 trees per acre recorded in 1960, as compared to 1.49 in 1950, and 1.19 in 1940. This large increase suggests that either a very much heavier than usual seed crop occurred sometime between 1950 and 1960 and/or a sequence of conditions came about which produced greater survival. It is very possible that both factors contributed to this population increase. The precipitation records for 1950 through 1955 reveal that for the most part, moisture conditions were above normal, and were thus adequate for seedling germination and early survival. It is also of interest to note where the reproduction occurred in the woodlot. Over 77 percent of the stems in the 1- to 3-inch diameter classes in 1960 were recorded in the 17 sample plots (10.4 percent of the 163 plots) on the southern border of the woodlot. This abundant reproduction has thus occurred in areas having considerable light as the result of the south exposure.

The remaining size classes do not indicate any probable significant changes. A slight increase is noted in the 4- to 10-inch diameter classes and a slight decrease occurred in the 11- to 25-inch diameter classes. The small increase observed in the 26-inch and larger classes (0.07 in 1940, 0.07 in 1950, and 0.22 trees per

acre in 1960) is also not a significant one.

Northern Red Oak. Northern red oak is one of the most important and far-ranging species of the eastern red oak group. It occurs on a variety of soils, but grows best on deep, moist, and well-drained soils of medium texture, as reported by Westveld (1949). That depth of soil and soil moisture are two important factors was indicated by the study of Gysel and Arend (1953). They found that where moist substrata layers were present within 4 to 10 feet of the ground surface, the site quality was notably improved.

The United States Forest Service (1948) reports that good seed crops are produced every 3 to 5 years, but are very variable. Gysel (1957), on a study of acorn production on good, medium, and poor oak sites in southern Michigan, reported that on a weight per seed basis, red oak was much more productive on the good sites. During the 5-year period of his study, most of the acorns were eaten by various animals and insects. Gysel also states that during but 1 year out of 5 did enough sound red oak acorns remain on the good sites to develop a partial stocking. Consequently, because of such a high loss of seed, adequate regeneration of this species depends on years of heavy seed production.

Available moisture is a critical factor in the early survival and establishment of red oak. Germination occurs in the spring and is followed by a rapid growth of a taproot. Once this taproot is firmly positioned in the soil, survival is much enhanced. Northern red oak is rated as being an intermediate to intolerant species. It is indeed less tolerant than sugar maple, American beech and American

basswood, but Sanders (1957) indicates that it is more tolerant than the ashes and black cherry. Schölz's (1955) study in Wisconsin revealed that red oak seedlings were able to survive under rather dense shade conditions for short periods of time. This species also responds well to release, and it is thus able to occupy a dominant position in the crown canopy when given an opportunity to do so.

In Table 8, the population size-structure of northern red oak is shown. It is apparent that this species is not a major component of the stand. It is a species which contributes more to the forest composition on drier sites. However, the species is reproducing itself in this stand, as evident from the increase in number of individuals in the various diameter classes. In the 1- to 10-inch diameter classes, the species rose from 0.43 trees per acre in 1940, to 0.66 in 1950, and 1.62 in 1960. In the 11- to 25-inch diameter classes, a smaller rise is shown, with 1.01 in 1940, 1.31 in 1950, and 1.10 trees per acre in 1960. An increase is also noted for the 26-inch and over classes, but it is a small one. These data indicate that the species is certainly maintaining itself in the woodlot. Figure 25 graphically illustrates the population size-structure for this species. It is of interest to point out that the majority of the increase in reproduction of this species is occurring on the southern border of the woodlot. For example, over 90 percent of the 1-inch diameter class in 1960 was recorded in only 6 of the 17 sample plots located on the southern border of the woodlot (3.1 percent of the 163 plots). The greatest reproduction has therefore occurred in an area having less shade on it, and considerable quantities of light.

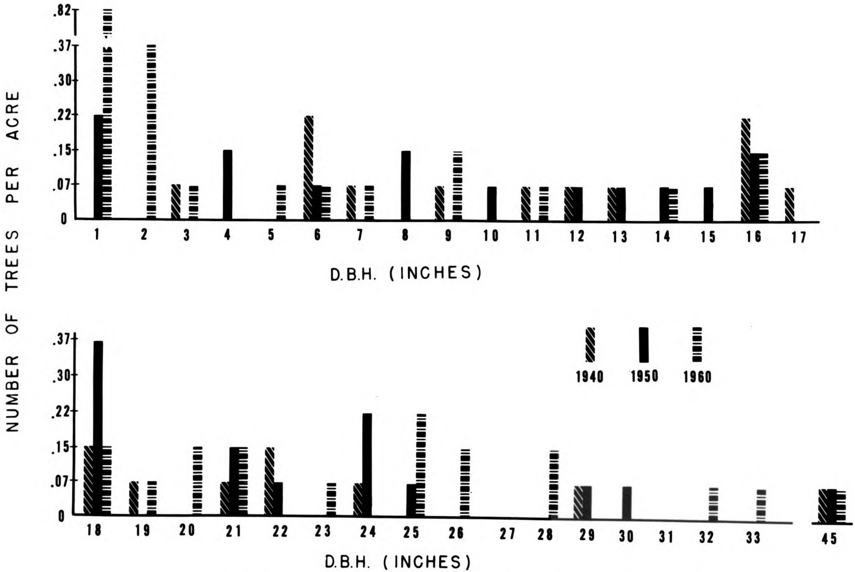


Figure 25. Northern red oak per acre, by 1-inch diameter classes, in 1940, 1950, and 1960, Toumey Woodlot.

Slippery Elm. Although slippery elm has a botanical range in distribution which extends over most of the eastern United States, it is most abundant in the southern half of the Lake States, and throughout the midwestern States, as reported by Scholz (1958b). The species appears on numerous soil types, but is more closely associated with high soil moisture conditions than with particular soil types. Wilde, Wilson, and White (1949) found that in Wisconsin, slippery elm, when a component of climax or subclimax forests, was predominantly found on soils possessing a gley horizon at 1- to 2-foot depths from the surface. Such gley layers indicate periodic high water tables, and resulting high soil moisture conditions.

The United States Forest Service (1948) states that good seed years occur at 2- to 4-year intervals. Scholz (1958b) reported that this species also reproduces vegetatively by means of interconnecting rhizomes during its seedling stage.

Deters (1943) listed slippery elm as third among many species for reproducing and establishing itself in farm woodlands of southeastern Minnesota under diverse site conditions. Once established, the species is able to withstand prolonged periods of suppression, and is classified as being relatively tolerant, although not to the extent of sugar maple and beech.

As indicated in Table 8, and illustrated in Figure 26, slippery elm has increased greatly over the past 20 years. In fact, its abundance for the 1- to 10-inch diameter classes has more than doubled during that period of time. The largest increases have occurred in the 5 smallest diameter classes, and especially so for the 1-inch class. Although this class was represented to a lesser degree in

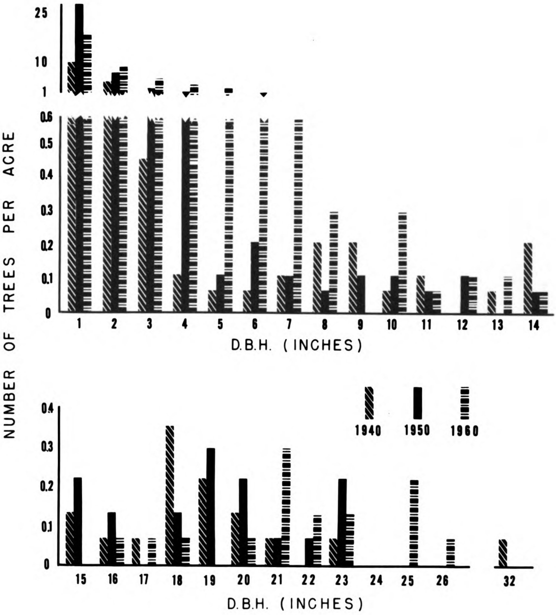


Figure 26. Slippery elm per acre, 1-inch diameter classes, in 1940, 1950, and 1960, Toumey Woodlot.

1960 than in 1950, the numbers of stems have remained at a high level. Also, many of the individuals in the first 5 diameter classes have advanced into the next 5 diameter classes, as evidenced by their number in the 1960 remeasurement values. The 11- to 25-inch, and the larger than 25-inch diameter classes are slightly smaller to essentially unchanged over the 20-year period.

Generally speaking, this species is doing well in the stand, and abundant reproduction is continuing. This increase is also evident from the ground cover data collected, where Table 7 shows that approximately 20 percent of the plots had slippery elm on them. It was noted that this reproduction and abundant survival of the first 5 diameter classes was somewhat localized. Although this species is well distributed throughout most of the woodlot, more than 50 percent of the increase observed in 1960 was located in the southernmost plots of the woodlot. In addition, many of the remaining stems observed were near openings within the woodlot. It remains to be seen whether this increase in numbers of slippery elm will continue as more openings are created in the woodlot.

Remaining Species. The remaining 14 tree species found in Toumey Woodlot are indicated in Table 9. It is obvious that these species are of minor importance in the woodlot. As a general rule, they do not appear to be increasing in numbers, in fact several are represented but by a few individuals, such as willow (Salix spp.), black ash (Fraxinus nigra March.), blue ash (Fraxinus quadrangulata Michx.). Three other species which were recorded in previous measurements are no longer in the area. They are: silver maple (Acer saccharinum L.), hackberry (Celtis occidentallis L.), and serviceberry

Table 9. **Number of trees per acre, 1-inch diameter classes, for the less abundant tree species in Toumey Woodlot, in 1940, 1950, and 1960 (Values based on 100 percent inventory)**

D.B.H. (inches)	HOPHORNBEAM			BITTERNUT HICKORY			BLACK MAPLE		
	1940	1950	1960	1940	1950	1960	1940	1950	1960
1	4.97	11.43	11.66	0.15	0.67	0.59	-	-	-
2	1.93	1.48	4.83	0.15	0.22	0.30	0.07	0.07	-
3	1.71	1.41	1.26	0.67	0.15	-	0.22	0.07	-
4	0.89	0.82	0.52	-	0.07	0.07	-	-	-
5	0.67	0.52	0.37	-	-	0.30	0.07	0.07	-
6	0.67	0.45	0.22	0.07	-	-	0.15	0.07	-
7	0.07	0.15	0.15	-	0.07	-	0.15	0.22	0.07
8	0.30	0.37	0.30	-	-	0.07	0.22	0.15	0.30
9	0.30	0.22	0.15	-	-	-	0.15	0.15	0.22
10	-	0.15	-	0.15	0.07	-	0.30	0.22	0.07
11	0.07	-	0.07	0.07	-	-	0.22	0.15	0.15
12				-	-	0.07	0.15	0.22	0.15
13				-	0.07	-	0.15	0.15	0.22
14				-	-	-	-	0.15	0.07
15				-	-	-	0.07	0.07	0.22
16				-	-	0.07	-	-	0.15
17									
18									
19									
TOTAL	11.58	17.00	19.53	1.26	1.32	1.47	1.92	1.76	1.62

Table 9. (continued)

D.B.H. (inches)	WHITE OAK			RED MAPLE			MISCELLANEOUS 1/		
	1940	1950	1960	1940	1950	1960	1940	1950	1960
1	-	-	0.15	-	-	-	2.42	3.70	4.69
2	-	-	0.07	0.07	-	-	0.74	0.74	0.82
3	-	-	-	-	-	-	0.37	0.07	0.37
4	-	-	-	-	-	-	-	0.07	0.30
5	0.07	-	-	0.07	-	-	0.29	-	-
6	-	0.07	-	-	-	-	0.07	-	0.07
7	-	-	0.07	-	-	-	0.22	-	-
8	-	-	-	-	-	-	-	0.15	-
9	-	-	-	-	-	-	-	0.07	0.15
10	-	0.07	-	-	-	-	0.07	0.07	-
11	0.07	-	0.07	-	-	-	-	-	-
12	-	-	-	-	0.07	-	-	0.07	-
13	0.15	0.07	-	0.07	-	-	0.07	-	-
14	-	0.15	-	-	-	-	-	-	-
15	-	-	0.07	-	-	-	-	-	-
16	-	-	0.15	0.07	-	-	0.15	-	-
17	-	-	0.07	-	0.07	-	-	0.07	-
18				-	-	-	-	-	-
19				-	-	0.07	-	-	0.07
TOTAL	0.29	0.36	0.65	0.28	0.14	0.07	4.40	5.01	6.47

1/ Miscellaneous species: black ash, blue ash, blue beech, hackberry, prickly ash, serviceberry, silver maple, sycamore, and willow.

(*Amelanchier arborea* (Mich.f.) Fern.).

Regeneration of these species is quite low, and hophornbeam and prickly ash (*Zanthoxylum americanum* Mill.) are the only two species which have increased in abundance over the past 20 years. In the case of prickly ash, this increase has occurred almost entirely in the openings along the southern stand boundary. The species in this miscellaneous category are not reaching very large diameters. For the entire woodlot, there are but 3 stems over 5 inches in d.b.h.; a sycamore (*Platanus occidentalis* L.), a black ash, and a red maple.

Light Measurements

The main source of energy for all green plants is solar radiation. This is absorbed by the plants directly as heat, and is also transformed by them, once absorbed, into chemical energy. While light is necessary for the synthesis of food, light also regulates and modifies other factors of the environment such as temperature and moisture. Therefore, light becomes an essential element in the growth and development of vegetation.

As Toumey and Korstian (1947) have pointed out, foresters have based many of their silvicultural practices upon the relative light requirements of various forest tree species, or in part upon their relative tolerance to shade. The common assumption is made that forest vegetation is arranged from the ground cover species to the overstory species, based on the intensity, quality, and duration of the light reaching each level of the vegetation. Therefore, the presence or absence of particular plant species in a forest stand depends in part upon the minimum light requirements of the species.

It is important to remember that the light intensity and quality which reaches the earth's surface varies with latitude, altitude, season of the year, and the time of day. Furthermore, topographic features, cloud formations, and amount of water vapor in the atmosphere tend to influence the quantity of light reaching the earth's surface. Consequently, the total light received on the earth's surface is a very variable quantity affected by many factors.

Although the importance of light is well known, its measurement has been a problem of much concern to many investigators. The desired objective is to measure the sum total of visible light falling on an area during any given interval of time. Many devices have been tried, such as photographic methods, actinometers, and various chemically-coated substances, and have been described by Connor (1958), and Fairbairn (1958). All have proved to be costly, time-consuming, or inaccurate. A chemical light meter described by Marquis and Yelenosky (1962), for example, requires an expensive spectrophotometer in its operational procedure. Connor (1958) reports that the barrier-layer cell, much used in British forestry, appears to yield reliable results on the total light energy falling on an area over a period of of time. Another instrument, the integrating light meter described by Atkins (1957), produces good results but is a very expensive device. Minckler (1961), measuring light in uneven-aged hardwood stands with a Brockway exposure meter, obtained results that were comparable to those with an integrating light meter. Minckler stressed that repeated instantaneous light measurements, which properly sample the day and season, yield results comparable to the devices which measure cumulative light.

In the present study, light measurements were made in August of 1940, 1950, and 1960. The measurements taken in 1940 were based on incident light, and used a Weston Meter which was found later to be calibrated improperly for full-light readings. As a result, it was decided to eliminate the 1940 measurements and set up a new light-measuring system. The new system, based on reflected light rather than direct light, was utilized in the 1950 and 1960 measurements. Measurements in 1950 were taken on August 12, 13, and 26, and on

August 4, 21, and 23, in 1960. It is assumed that these intervals of time are close enough for comparative purposes.

The Weston Foot-Candle Meter, Model 614, was used in all measurements for both the 1950 and 1960 seasons. This instrument indicates the illumination in foot-candles and is standardized on tungsten light at a color temperature of 2,700°K. This meter, which operates by a photoelectric cell, is equipped with a 3-way switch which permits measuring effective light ranges up to 10,000 foot-candles. This meter measures reflected light, whereas the Brockway meter used by Minckler (1961) measures incident light.

Table 10 presents the light measurements taken for both the 1950 and 1960 seasons. The average conditions for each plot are outlined fully. Of the 8 plots used, only 2 have changed in appearance to a marked degree. Plot E-3, a blowdown area in 1950, had a fairly closed crown canopy in 1960. This blowdown condition actually existed prior to 1940, and at the time of the 1950 recordings, the canopy was already beginning to close, although much light was still entering through the opening. By 1960, the canopy was closed, and the light readings reflected this condition. Whereas the percent of full sunlight was 6.4 in 1950, it was reduced to 1.4 percent in 1960.

Another plot showing marked changes in light intensity is B-6. In 1950, this plot had what was considered to be an average crown canopy, under which 2.0 percent of full sunlight was recorded. Between 1950 and 1960, a large blowdown occurred in this plot, almost eliminating the entire overstory. The percent of full sunlight at the 1960 measurements rose to 21.7 percent. This is a large increase

Table 10. Changes in reflected light measured at 1 foot above the ground in Toumey Woodlot, from 1950 to 1960

Plot Number	Plot conditions in 1950 and 1960	Average light intensity per plot[3/] 1950	1960	Percent of full sunlight per plot[4/] 1950	1960
		-foot candles-			
C-3	Average crown density	10	18	0.46	0.87
E-3	Blowdown area[1/]	138	29	6.40	1.40
B-6	Average crown density[2/]	44	448	2.04	21.69
B-8	Average crown density	46	70	2.13	3.39
N-1	North border plot	47	46	2.18	2.23
M-3	Average crown density; depression to southeast	47	35	2.19	1.69
J-3	Average crown density	11	23	0.52	1.11
P-2	Average crown density; slope to southeast	27	37	1.25	1.79

1/ Blowdown condition at time of 1950 readings had changed to average crown density by 1960.
2/ Average crown density condition of 1950 readings had changed to a large blowdown area by 1960.
3/ Based on 25 light measurement readings per plot.
4/ Average foot-candles in open field: 1950 = 2,155; 1960 = 2,065.

in the amount of light reaching the forest floot and, as expected, the ground cover species were influenced to a great extent. Some of these changes were described fully in the ground cover plot data, and the ground cover changes shown in Figure 10 for plot B-6.

Data for the remaining plots indicate only slight changes in light intensity. No mortality of tree speaies occurred in any of these particular plots which would result in a larger amount of light entering them. It is difficult to evaluate the influence of the loss of an occasional tree in plots surrounding the sampled plots. However, the loss of overstory trees is not the only way that more light can enter the area. Frequently, the loss of large and small branches, causing a variety of gaps in the crown canopy, are responsible for changes in the light reaching the ground floor. Again, these changes in the crown canopy structure may not be apparent to the investigator, especially if the changes are small. However, these gaps or openings do influence the amount of entering light. The changes in light readings recorded in Table 10 for plots other than B-6, are quite possibly due to these phenomena.

The influence of sunflecks on woodland vegetation has been studied by several British workers, including Evans (1956), Evans and Coombe (1959), and Evans, Whitmore, and Wong (1960). These sunflecks on the ground surface are the result of gaps or openings in the crown canopy. They vary in intensity from full sunlight to low light and also as to their location over a period of time. Until recently, any influence that these sunflecks might have on increasing the total light, or affecting the light quality, and thereby affecting photosynthesis, has been ignored.

In this study, the percentage of full sunlight on each plot, with few exceptions, was above one percent. For all plots in 1950, the average percent of full sunlight falling on the plots was 2.1. Excluding the high reading recorded for B-6 in 1960, the average percent of full sunlight for the remaining 7 plots was approximately 1.6 in 1960. From these data, it appears that for the forest stand as

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a whole, the amount of light reaching the forest floor has decreased during the past 10 years. Although the crown canopy may become more dense over a period of time, openings or gaps in the canopy are constantly being created as stems either fall or their branches break off. Therefore, a varying degree of light intensity exists throughout the forest stand.

Toumey and Korstian (1947) cite numerous authorities who agree that many plant species are able to reproduce themselves at very low light intensities, provided other site factors are favorable. It is also generally agreed that the proportion of energy used in photosynthesis averages about 1 percent of full sunlight, and perhaps even less. Toumey and Korstian state that light intensity as low as 2 percent or less is common in many hardwood stands. Although the light intensity reaching the forest floor is rarely so low as to exclude the possibility of obtaining adequate reproduction, it may become a critical factor in the growth of the vegetation. Seedlings and saplings of various tree species may often persist for many years in low light intensities. However, if they do not grow at a reasonable rate, they often perish.

Stand Mortality

An investigation was begun in 1940 to obtain information on stand mortality occurring in various species growing in Toumey Woodlot over a period of time. At each of the 3 measurement periods, 1940, 1950, and 1960, the number of dead individuals for each species, by 1-inch diameter classes, was recorded. In this way a comparison could be made of mortality between species, as well as observing differences within a particular species.

Although the measurement of mortality at 10-year intervals of time may allow for errors in the inventory of some individuals, especially those in the small diameter classes, a large majority of these errors can be resolved. While the individuals in the smaller diameter classes may die and deteriorate between 10-year observations, their absence would be noted and mortality would be thus indicated. In addition, this error would not affect those individuals in the larger diameter classes, for example those 10 inches in d.b.h, and above. Their death, decomposition, and complete disappearance would not take place within this short period of 10 years. One further point to be made is that in the mortality count, care was taken to count the death of a species but once. This was made possible by recording all mortality on a plot basis rather than for the whole stand. By this means, a more accurate accounting of each species was maintained, and tended to prevent the counting of a dead stem more than once. Of course, the condition of dead individuals would oftentimes indicate approximately how long they had been dead. Therefore, the recorded data present a reliable estimate of the mortality which has occurred in the stand.

In Tables 11-18, the major component species are listed separately, showing the total growing stock for that species in 1940, 1950, and 1960, and the corresponding mortality for that same period of time. The total mortality for the 20-year period is listed, as well as an estimate of the average annual mortality for each species. All values are given in both number of individuals per acre, and total basal area per acre for each 1-inch diameter class. All of the above information is also presented in Table 19, where the remaining miscellaneous species are grouped.

The mortality for sugar maple, as well as the total growing stock for the 3 measurements, is shown in Table 11. A comparison of these quantities for the 3 periods shows that definite changes have occurred. The changes in the total growing stock have already been discussed for sugar maple in the section pertaining to the overstory composition. A slight drop in the growing stock occurred in the 1950 inventory as compared to that in 1940, for basal area per acre values. However, it increased to a new high in the 1960 count. The mortality observed in 1940, which probably covered the period between 1930-1940, or at least for 5 years prior to 1940, was 0.342 sq. ft. of basal area per acre, and 3.97 trees per acre. This is a rather small amount of mortality, most of which occurred in the small diameter classes. There was little recorded mortality in the saw-timber size classes, 10-inch d.b.h. and over.

As previously mentioned, some harvesting of down trees occurred prior to the acquisition of the woodlot by the university of 1939. To what extent this harvesting of dead trees took place is unknown. It

Table 11. Sugar maple growing stock and mortality, Toumey Woodlot, for 1940, 1950, and 1960

D.B.H.	1940			1950			1960			1940-1960	
	Total Growing Stock	Observed Mortality		Total Growing Stock	Observed Mortality		Total Growing Stock	Observed Mortality		Total Observed Mortality	
inches	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.
1	0.631	1.83	0.011	0.974	10.00	0.060	1.256	23.92	0.145	35.75	0.216
2	1.061	0.52	0.011	0.932	2.95	0.065	1.780	6.15	0.136	9.62	0.212
3	0.918	0.52	0.025	0.757	1.26	0.062	1.547	2.30	0.113	4.08	0.200
4	1.019	0.15	0.013	1.052	0.59	0.051	1.175	2.00	0.175	2.74	0.239
5	1.330	0.37	0.050	1.005	0.74	0.101	1.289	0.67	0.091	1.78	0.242
6	1.258	0.15	0.029	1.243	0.22	0.043	1.492	0.67	0.131	1.04	0.203
7	1.375	0.07	0.019	1.215	0.22	0.059	1.295	0.37	0.099	0.66	0.177
8	1.432	0.15	0.052	1.563	0.15	0.052	1.432	0.45	0.157	0.75	0.261
9	1.616	0.07	0.031	1.187	-	-	1.583	0.45	0.199	0.52	0.230
10	2.522	-	-	2.074	0.37	0.202	1.301	0.30	0.164	0.67	0.366
11	2.463	0.07	0.046	2.463	0.07	0.046	2.364	0.07	0.046	0.21	0.138
12	2.695	0.07	0.055	2.460	0.07	0.055	2.402	0.15	0.118	0.29	0.228
13	3.405	-	-	3.257	0.15	0.138	2.477	0.22	0.203	0.37	0.341
14	3.989	-	-	3.111	0.15	0.160	2.952	0.15	0.160	0.30	0.320
15	3.388	-	-	4.300	0.22	0.270	3.296	0.22	0.270	0.44	0.540
16	3.855	-	-	4.167	0.07	0.098	4.376	0.15	0.209	0.22	0.307
17	3.999	-	-	3.764	-	-	4.940	0.22	0.347	0.22	0.347
18	2.110	-	-	3.956	0.07	0.124	4.220	0.37	0.654	0.44	0.778
19	3.086	-	-	2.939	0.15	0.295	3.233	0.15	0.295	0.30	0.590
20	1.953	-	-	2.441	-	-	4.557	-	-	-	-
21	3.410	-	-	2.333	0.07	0.168	3.590	0.15	0.361	0.22	0.529
22	3.152	-	-	2.167	0.07	0.185	2.955	0.07	0.185	0.14	0.370
23	2.153	-	-	2.584	0.07	0.202	3.014	0.15	0.433	0.22	0.635
24	2.345	-	-	3.048	0.15	0.471	1.876	0.15	0.471	0.30	0.942
25	1.781	-	-	1.527	-	-	2.799	0.07	0.239	0.07	0.239

Table 11. (continued)

D.B.H. inches	1940 Total Growing Stock B.A. /acre sq.ft.	1940 Observed Mortality No. trees /acre	1940 Observed Mortality B.A. /acre sq.ft.	1950 Total Growing Stock B.A. /acre sq.ft.	1950 Observed Mortality No. trees /acre	1950 Observed Mortality B.A. /acre sq.ft.	1960 Total Growing Stock B.A. /acre sq.ft.	1960 Observed Mortality No. trees /acre	1960 Observed Mortality B.A. /acre sq.ft.	1940-1960 Total Observed Mortality No. trees /acre	1940-1960 Total Observed Mortality B.A. /acre sq.ft.
26	0.826	-	-	1.377	-	-	1.652	0.07	0.258	0.07	0.258
27	1.782	-	-	1.782	-	-	2.376	0.07	0.279	0.07	0.279
28	0.958	-	-	1.597	0.07	0.300	2.236	-	-	0.07	0.300
29	1.028	-	-	0.337	0.07	0.321	1.713	-	-	0.07	0.321
30	3.298	-	-	1.099	0.07	0.344	0.366	-	-	0.07	0.344
31	0.782	-	-	0.782	-	-	1.173	-	-	-	-
32	0.834	-	-	1.251	0.07	0.391	1.669	0.15	0.839	0.22	1.230
33	0.887	-	-	0.887	-	-	0.887	0.07	0.416	0.07	0.416
34	0.470	-	-	0.940	0.07	0.441	0.470	0.07	0.441	0.14	0.882
35	0.499	-	-	-	-	-	-	-	-	-	-
36	-	-	-	0.528	0.07	0.495	0.528	0.07	0.495	0.14	0.990
37	-	-	-	-	-	-	0.557	-	-	-	-
TOTAL	68.310	3.97	0.342	67.099	18.23	5.199	76.828	40.07	8.129	62.27	13.670

Average Annual Mortality (1940-1960) = 0.684

Average Annual Mortality (1950-1960) = 1.333

would be logical to assume, however, that tree stumps would remain on the area for some time after the tree's removal, at least for sawtimber size classes. However, from a visual examination made of the area in 1960, no evidence was observed which might indicate that large quantities of dead trees had ever been removed. Therefore, in the present analysis of stand mortality, it will be assumed that the harvesting of down trees for fuelwood prior to 1939, had little appreciable influence on the mortality recorded in 1940, especially for those above 10 inches in diameter.

In contrast to the 1940 data, which showed little mortality, 1950 and 1960 data showed an increase in mortality. In 1950, over 18 trees per acre, and 5.199 sq. ft. basal area per acre were recorded as mortality. Of this amount, 85 percent of the trees came from the 5 smallest diameter classes, but this in turn only constituted 6 percent of the basal area. In 1960, over 40 trees per acre, having 13.670 sq. ft. basal area per acre, were added to the mortality count. Again, the greatest percentage of the loss came from trees in the 1- to 5-inch diameter classes (87 percent), but this accounted for only 8 percent of the basal area loss.

It is readily apparent that mortality increases, expressed in basal area, have occurred primarily in the sawtimber size classes. Many trees in these size classes were observed to have rot on various portions of the stem, as well as crowns, thereby becoming quite prone to mortality. As pointed out earlier, the lack of this mortality in 1940 was perhaps due to some of the earlier harvesting of down trees. However, it is believed that not enough was removed to account for such large differences in mortality between the measurement periods.

The total mortality recorded between 1940 and 1960 was 13.670 sq. ft. basal area per acre, with an average annual mortality of 0.684. For the period between 1950 and 1960, total mortality was 13.333 sq. ft. of basal area per acre, with an average annual mortality of 1.33.

The mortality of American beech between 1940 and 1960 is shown in Table 12. The mortality recorded in 1940 was small, and perhaps reflects some of the harvesting of dead trees prior to 1940. However, the amounts removed are considered to be of minor importance. The 1950 and 1960 data show an increasing amount of mortality. As was the case for sugar maple, much of the basal area of beech mortality occurred in the large diameter classes. In 1950, 90 percent of the mortality, in sq. ft. of basal area, took place in the 10-inch diameter class and above. In 1960, 80 percent of the mortality, in sq. ft. of basal area, took place in these same size classes. On the other hand, based on number of trees per acre, 75 percent of the mortality in 1950, and 84 percent in 1960, occurred in the 5 smallest diameter classes.

From the above data, one can observe that mortality increase has occurred in the saw-timber size classes. The large diameter classes of beech in Toumey Woodlot do contain considerable amounts of decay, both on the main stem, and in the crown layers where broken tops are quite common. This condition naturally increases susceptibility to mortality in the beech.

The total mortality recorded between 1940 and 1960 was 16.10 trees per acre, and 4.821 sq. ft. of basal area per acre. During this 20-year period, the average annual mortality was 0.241 sq. ft. basal

Table 12. American beech growing stock and mortality, Toumey Woodlot, for 1940, 1950, and 1960

D.B.H.	1940			1950			1960			1940-1960	
	Total Growing Stock	Observed Mortality		Total Growing Stock	Observed Mortality		Total Growing Stock	Observed Mortality		Total Observed Mortality	
inches	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.
1	0.074	0.22	0.001	0.106	2.00	0.012	0.098	3.50	0.021	5.72	0.034
2	0.209	0.37	0.008	0.131	1.11	0.024	0.196	1.56	0.034	3.04	0.066
3	0.255	0.07	0.003	0.237	0.52	0.025	0.192	1.26	0.062	1.85	0.090
4	0.387	0.15	0.013	0.291	0.37	0.032	0.284	0.82	0.071	1.34	0.116
5	0.354	0.15	0.020	0.303	0.22	0.030	0.324	0.37	0.050	0.74	0.100
6	0.190	0.07	0.014	0.263	0.07	0.014	0.263	0.30	0.059	0.44	0.087
7	0.435	0.15	0.040	0.296	0.15	0.040	0.358	0.15	0.040	0.45	0.120
8	0.492	-	-	0.492	0.07	0.024	0.286	0.07	0.024	0.14	0.048
9	0.526	0.07	0.031	0.592	0.07	0.031	0.429	-	-	0.14	0.062
10	0.447	0.07	0.038	0.485	-	-	0.567	0.15	0.082	0.22	0.120
11	0.686	0.07	0.046	0.343	-	-	0.541	-	-	0.07	0.046
12	0.173	0.07	0.055	0.581	-	-	0.581	0.07	0.055	0.14	0.110
13	0.682	0.07	0.065	0.618	0.07	0.065	0.682	0.07	0.065	0.21	0.195
14	1.432	-	-	0.631	0.15	0.160	1.347	0.07	0.075	0.22	0.235
15	1.006	-	-	0.908	0.07	0.086	1.546	-	-	0.07	0.086
16	1.242	-	-	1.145	-	-	1.871	-	-	-	-
17	1.875	-	-	1.875	0.15	0.236	1.529	-	-	0.15	0.236
18	1.961	-	-	1.042	0.15	0.265	1.308	0.15	0.265	0.30	0.530
19	1.910	-	-	2.186	0.15	0.295	2.186	-	-	0.15	0.295
20	2.116	-	-	1.788	-	-	1.461	0.07	0.153	0.07	0.153
21	1.251	-	-	2.140	-	-	2.140	0.07	0.168	0.07	0.168
22	1.558	-	-	1.558	0.07	0.185	2.930	0.15	0.396	0.22	0.581
23	0.866	-	-	0.866	0.07	0.202	1.500	-	-	0.07	0.202
24	0.471	-	-	1.162	-	-	1.854	0.07	0.220	0.07	0.220
25	0.512	-	-	0.239	-	-	0.239	-	-	-	-

Table 12. (continued)

D.B.H. inches	1940 Total Growing Stock B.A. /acre sq.ft.	1940 Observed Mortality No. trees /acre	1940 Observed Mortality B.A. /acre sq.ft.	1950 Total Growing Stock B.A. /acre sq.ft.	1950 Observed Mortality No. trees /acre	1950 Observed Mortality B.A. /acre sq.ft.	1960 Total Growing Stock B.A. /acre sq.ft.	1960 Observed Mortality No. trees /acre	1960 Observed Mortality B.A. /acre sq.ft.	1940-1960 Total Observed Mortality No. trees /acre	1940-1960 Total Observed Mortality B.A. /acre sq.ft.
26	0.812	-	-	0.812	-	-	1.107	-	-	-	-
27	0.279	-	-	0.279	0.07	0.279	0.279	-	-	0.07	0.279
28	0.300	-	-	0.300	-	-	0.942	-	-	-	-
29	0.321	-	-	0.321	0.07	0.321	0.321	0.07	0.321	0.14	0.642
30	0.344	-	-	0.344	-	-	0.344	-	-	-	-
31	-	-	-	0.786	-	-	0.367	-	-	-	-
32	-	-	-	0.391	-	-	0.391	-	-	-	-
33	-	-	-	-	-	-	0.416	-	-	-	-
34	-	-	-	-	-	-	0.441	-	-	-	-
35	0.468	-	-	-	-	-	-	-	-	-	-
36	-	-	-	-	-	-	-	-	-	-	-
37	-	-	-	0.523	-	-	-	-	-	-	-
TOTAL	23.634	1.53	0.334	24.034	5.60	2.326	29.320	8.97	2.161	16.10	4.821

Average Annual Mortality (1940-1960) = 0.241

Average Annual Mortality (1950-1960) = 0.449

area per acre. The average annual mortality was 0.449 sq. ft. basal area per acre during the 10-year period of 1950 to 1960.

Basswood, although a smaller component species in Toumey Woodlot, has experienced greater mortality than sugar maple and beech. Based on the 1960 basal area data, 24 percent of the total growing stock for basswood was recorded as mortality, as compared to 10 percent in sugar maple, and 7 percent for beech during this same period of time. In Table 13, the total growing stock and mortality indicate an ever-increasing amount of loss through the past 20 years, and also more loss involving larger diameter classes. For example, in 1950, 95 percent of the mortality in basal area was in trees larger than 10 inches in diameter. For 1960, this percentage rose to 98. In the 1960 measurement, 3 trees, 29-inch in diameter, had succumbed, thus increasing the mortality percentage.

The mortality recorded for the period 1940 to 1960 was 4.25 trees per acre, and 2.824 sq. ft. basal area per acre. The average annual mortality for this period was 0.141 sq. ft. basal area per acre. For the period 1950 to 1960, 2.607 sq. ft. basal area per acre was recorded, for an average annual mortality of 0.261 sq. ft. of basal area per acre. Since much of the present basswood growing stock is defective with rot and broken crowns, a loss of the larger diameter classes will probably continue.

In Table 14, the mortality of American elm is indicated. Again, the 1940 figures show very little loss, but mortality in basal area has increased between 1940 and 1960. Losses have greatly increased in the larger diameter classes in comparison to the smaller ones. In 1950,

Table 13. Basswood growing stock and mortality, Toumey Woodlot, for 1940, 1950, and 1960

D.B.H. inches	1940 Total Growing Stock B.A. /acre sq.ft.	1940 Observed Mortality No. trees /acre	1940 Observed Mortality B.A. /acre sq.ft.	1950 Total Growing Stock B.A. /acre sq.ft.	1950 Observed Mortality No. trees /acre	1950 Observed Mortality B.A. /acre sq.ft.	1960 Total Growing Stock B.A. /acre sq.ft.	1960 Observed Mortality No. trees /acre	1960 Observed Mortality B.A. /acre sq.ft.	1940-1960 Total Observed Mortality No. trees /acre	1940-1960 Total Observed Mortality B.A. /acre sq.ft.
1	0.023	0.30	0.002	0.019	1.04	0.006	0.020	-	-	1.34	0.008
2	0.092	0.30	0.007	0.049	0.59	0.013	0.026	0.37	0.008	1.26	0.028
3	0.036	-	-	0.048	0.22	0.011	0.048	0.22	0.011	0.44	0.022
4	0.019	-	-	0.039	0.07	0.006	0.039	-	-	0.07	0.006
5	0.041	0.07	0.010	0.010	-	-	0.030	-	-	0.07	0.010
6	0.043	0.07	0.014	0.014	-	-	0.102	-	-	0.07	0.014
7	-	-	-	0.019	-	-	0.019	-	-	-	-
8	0.105	-	-	0.024	-	-	0.024	-	-	-	-
9	0.133	-	-	0.133	-	-	-	0.07	0.031	0.07	0.031
10	0.120	-	-	0.038	0.07	0.010	-	-	-	0.07	0.010
11	0.100	0.07	0.046	0.145	-	-	0.100	-	-	0.07	0.046
12	0.236	-	-	0.173	0.15	0.118	0.173	-	-	0.15	0.118
13	0.138	-	-	0.065	-	-	0.138	-	-	-	-
14	0.075	-	-	0.075	-	-	-	-	-	-	-
15	0.454	-	-	0.368	-	-	0.086	-	-	-	-
16	0.517	-	-	0.419	-	-	0.209	-	-	-	-
17	0.473	-	-	0.347	-	-	0.347	-	-	-	-
18	0.654	-	-	0.389	-	-	0.124	-	-	-	-
19	0.591	0.07	0.138	0.729	0.07	0.138	0.433	0.07	0.138	0.21	0.414
20	-	-	-	0.654	-	-	0.807	-	-	-	-
21	0.168	-	-	0.361	0.07	0.168	0.529	-	-	0.07	0.168
22	0.977	-	-	-	0.07	0.185	0.396	-	-	0.07	0.185
23	0.202	-	-	0.433	0.07	0.202	0.202	-	-	0.07	0.202
24	-	-	-	0.220	-	-	0.220	-	-	-	-
25	1.023	-	-	0.239	-	-	0.512	-	-	-	-

Table 13. (continued)

D.B.H. inches	1940 Total Growing Stock B.A. /acre sq.ft.	1940 Observed Mortality No. trees /acre	1940 Observed Mortality B.A. /acre sq.ft.	1950 Total Growing Stock B.A. /acre sq.ft.	1950 Observed Mortality No. trees /acre	1950 Observed Mortality B.A. /acre sq.ft.	1960 Total Growing Stock B.A. /acre sq.ft.	1960 Observed Mortality No. trees /acre	1960 Observed Mortality B.A. /acre sq.ft.	1940-1960 Total Observed Mortality No. trees /acre	1940-1960 Total Observed Mortality B.A. /acre sq.ft.
26	0.258	-	-	0.258	-	-	0.258	-	-	-	-
27	0.279	-	-	0.279	-	-	0.597	-	-	-	-
28	0.300	-	-	0.642	-	-	0.300	-	-	-	-
29	-	-	-	0.321	-	-	0.321	0.22	1.010	0.22	1.010
30	-	-	-	-	-	-	-	-	-	-	-
31	0.367	-	-	-	-	-	-	-	-	-	-
32	-	-	-	0.391	-	-	-	-	-	-	-
33	-	-	-	-	-	-	-	-	-	-	-
34	-	-	-	-	-	-	0.441	-	-	-	-
35	0.468	-	-	0.468	-	-	-	-	-	-	-
36	-	-	-	-	-	-	-	-	-	-	-
37	-	-	-	-	-	-	0.523	-	-	-	-
38	0.582	-	-	0.552	-	-	-	0.07	0.552	0.07	0.552
TOTAL	8.444	0.88	0.217	7.921	2.42	0.857	7.024	1.02	1.750	4.32	2.824

Average Annual Mortality (1940-1960) = 0.141

Average Annual Mortality (1950-1960) = 0.261

Table 14. American elm growing stock and mortality, Toumey Woodlot, for 1940, 1950, and 1960

D.B.H.	1940			1950			1960			1940-1960	
	Total Growing Stock	Observed Mortality		Total Growing Stock	Observed Mortality		Total Growing Stock	Observed Mortality		Total Observed Mortality	
inches	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.
1	0.011	-	-	0.014	0.45	0.003	0.005	0.22	0.001	0.67	0.004
2	0.038	0.07	0.002	0.036	0.52	0.011	0.016	0.30	0.007	0.89	0.020
3	0.058	-	-	0.029	0.15	0.007	0.062	0.15	0.007	0.30	0.014
4	0.051	-	-	0.026	0.07	0.006	0.084	-	-	0.07	0.006
5	0.030	-	-	0.041	0.07	0.010	0.030	0.07	0.010	0.14	0.020
6	0.131	0.07	0.014	0.059	0.07	0.014	0.059	-	-	0.14	0.028
7	0.040	-	-	0.040	0.07	0.019	0.040	-	-	0.07	0.019
8	0.105	-	-	0.077	-	-	0.052	-	-	-	-
9	0.066	-	-	0.066	-	-	0.133	-	-	-	-
10	0.082	-	-	0.038	-	-	-	-	-	-	-
11	0.244	0.07	0.046	0.099	0.07	0.046	0.046	-	-	0.14	0.092
12	0.055	-	-	0.236	-	-	0.055	0.07	0.055	0.07	0.055
13	0.203	-	-	-	-	-	0.138	0.07	0.064	0.07	0.064
14	-	-	-	0.075	-	-	0.160	-	-	-	-
15	0.270	-	-	-	-	-	-	-	-	-	-
16	0.307	-	-	0.419	-	-	0.209	-	-	-	-
17	0.473	-	-	0.473	-	-	0.110	-	-	-	-
18	0.389	-	-	0.265	-	-	0.265	0.07	0.124	0.07	0.124
19	0.433	-	-	0.138	-	-	0.729	-	-	-	-
20	0.153	-	-	0.480	-	-	0.153	-	-	-	-
21	0.529	-	-	0.168	0.07	0.168	0.168	-	-	0.07	0.168
22	0.185	-	-	0.581	-	-	0.581	-	-	-	-
23	0.202	-	-	0.433	-	-	-	0.07	0.202	0.07	0.202
24	1.163	-	-	0.471	-	-	0.471	-	-	-	-
25	0.750	-	-	1.262	-	-	1.023	0.07	0.239	0.07	0.239

Table 14. (continued)

D.B.H. inches	1940 Total Growing Stock B.A. /acre sq.ft.	1940 Observed Mortality No. trees /acre	1940 Observed Mortality B.A. /acre sq.ft.	1950 Total Growing Stock B.A. /acre sq.ft.	1950 Observed Mortality No. trees /acre	1950 Observed Mortality B.A. /acre sq.ft.	1960 Total Growing Stock B.A. /acre sq.ft.	1960 Observed Mortality No. trees /acre	1960 Observed Mortality B.A. /acre sq.ft.	1940-1960 Total Observed Mortality No. trees /acre	1940-1960 Total Observed Mortality B.A. /acre sq.ft.
26	0.258	-	-	0.812	-	-	0.258	0.07	0.258	0.07	0.258
27	0.279	-	-	0.279	-	-	0.597	-	-	-	-
28	-	-	-	-	-	-	0.942	-	-	-	-
29	-	-	-	0.321	-	-	0.689	-	-	-	-
30	-	-	-	-	-	-	-	-	-	-	-
31	0.367	-	-	-	-	-	-	-	-	-	-
32	-	-	-	0.391	-	-	-	-	-	-	-
33	0.416	-	-	-	-	-	-	-	-	-	-
34	0.441	-	-	0.441	-	-	-	0.07	0.441	0.07	0.441
35	-	-	-	-	-	-	0.468	-	-	-	-
36	-	-	-	0.495	-	-	-	-	-	-	-
TOTAL	7.729	0.21	0.062	8.265	1.54	0.284	7.543	1.23	1.408	2.98	1.754

Average Annual Mortality (1940-1960) = 0.088

Average Annual Mortality (1950-1960) = 0.169

90 percent of the mortality came from trees in diameter classes lower than 10 inches, but on a basal area basis, this group contributed only 13 percent to the total loss observed. In 1960, an even greater increase in mortality was observed, with over 97 percent of the basal area losses occurring in the diameter classes above 10 inches. The rapid increase in mortality for this species has probably been greatly influenced by the presence of Dutch elm disease, which has recently been found in Toumey Woodlot. As a consequence, the mortality of American elm will undoubtedly continue at much the same level as at present, perhaps even higher.

The total mortality for 1940 to 1960 was 2.98 trees per acre, and 1.754 sq. ft. basal area per acre. In turn, the loss observed between 1950 and 1960 was 2.77 trees per acre, and 1.692 sq. ft. basal area per acre.

Slippery elm, a species increasing in total growing stock, was observed to have the greatest mortality in the pole-size timber classes, as shown in Table 15. For example, 98 percent of the trees lost per acre, constituting 71 percent of the basal area loss, were present in the 5 smallest diameter classes in 1960. This is in contrast to losses in sugar maple, beech, basswood, and American elm, where the large diameter classes have contributed most to mortality. An explanation for this is that the growth of slippery elm is greatly reduced by suppression. Since the majority of the pole-size stems are usually overtopped or intermediate in crown position, they suffer competition for light and moisture. The large loss in this species was most probably due to severe competition. While mortality occurs in suppressed and intermediate stems, numerous individuals occupying dominant and codominant

Table 15. Slippery elm growing stock and mortality, Toumey Woodlot, for 1940, 1950, and 1960

D.B.H.	1940			1950			1960			1940-1960	
	Total Growing Stock	Observed Mortality		Total Growing Stock	Observed Mortality		Total Growing Stock	Observed Mortality		Total Observed Mortality	
inches	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.
1	0.057	0.07	-	0.154	1.93	0.012	0.101	7.70	0.047	9.70	0.059
2	0.072	-	-	0.132	0.22	0.005	0.189	4.22	0.094	4.44	0.099
3	0.022	-	-	0.095	0.07	0.003	0.233	1.19	0.058	1.26	0.061
4	0.013	-	-	0.097	-	-	0.264	0.15	0.013	0.15	0.013
5	0.010	-	-	0.020	0.07	0.010	0.171	0.07	0.010	0.14	0.020
6	0.014	-	-	0.043	-	-	0.190	-	-	-	-
7	0.040	-	-	0.040	0.07	-	0.158	0.07	-	0.14	-
8	0.077	-	-	0.024	-	0.024	0.105	-	0.024	-	0.048
9	0.098	-	-	0.066	-	-	-	-	-	-	-
10	0.038	0.07	0.038	0.082	-	-	0.164	-	-	0.07	0.038
11	0.099	-	-	0.046	-	-	0.046	-	-	-	-
12	-	-	-	0.118	-	-	0.118	-	-	-	-
13	0.065	-	-	-	-	-	0.138	0.07	0.065	0.07	0.065
14	0.235	-	-	0.075	0.07	0.075	0.075	-	-	0.07	0.075
15	0.184	-	-	0.270	-	-	-	-	-	-	-
16	0.098	-	-	0.209	-	-	0.098	-	-	-	-
17	0.110	-	-	-	-	-	0.110	-	-	-	-
18	0.654	-	-	0.265	-	-	0.124	-	-	-	-
19	0.433	-	-	0.591	-	-	-	-	-	-	-
20	0.327	-	-	0.480	-	-	0.153	-	-	-	-
21	0.168	-	-	0.168	-	-	0.722	-	-	-	-
22	-	-	-	0.185	-	-	0.396	-	-	-	-
23	0.202	-	-	0.635	-	-	0.433	-	-	-	-
24	-	-	-	-	-	-	-	-	-	-	-
25	-	-	-	-	-	-	0.750	-	-	-	-

Table 15. (continued)

D.B.H.	1940			1950			1960			1940-1960	
	Total Growing Stock	Observed Mortality		Total Growing Stock	Observed Mortality		Total Growing Stock	Observed Mortality		Total Observed Mortality	
inches	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.
26	-	-	-	-	-	-	0.258	-	-	-	-
32	0.391	-	-	-	0.07	0.391	-	-	-	0.07	0.391
TOTAL	3.407	0.14	0.038	3.795	2.50	0.520	4.996	13.47	0.311	16.11	0.869

Average Annual Mortality (1940-1960) = 0.043

Average Annual Mortality (1950-1960) = 0.083

positions compete successfully with other species. The data show that in the large diameter classes, many stems of this species are maintaining themselves in the stand.

Red oak. white ash, and black cherry have total growing stock values and mortality figures as indicated in Tables 16, 17, and 18, respectively. Red oak is a striking example of a species which has shown practically no mortality over the 20-year period. In fact, no mortality was recorded at the 1950 and 1960 measurements. The sample tree data for this species (Table 38, Appendix) show that this may be due to its individuals being younger than those of some of the other species. White ash and black cherry have experienced increases in mortality from 1940 to 1960. However, white ash had a slight reduction in mortality from 1950 to 1960, with 24 percent of the growing stock as mortality in 1950, and only 18 percent in 1960. The reverse was true for black cherry, which showed an increase in mortality between 1950 and 1960. In 1950, only 4 percent of the growing stock was recorded as mortality, while the inventory in 1960 revealed this to be 24 percent. However, nearly all of this increase came in the smaller diameter classes, with 75 percent in the 1- to 5-inch diameter classes, and 93 percent in the 1- to 10-inch diameter classes.

The miscellaneous species described in Table 19, include hophornbeam, white oak, black ash, red maple, silver maple, blue beech, bitternut hickory, black maple, blue ash, willow, prickly ash, and hawthorn. These 12 species do not contribute greatly to the total growing stock or mortality in the woodlot. As previously discussed in the section on overstory composition, most of these species are decreasing

Table 16. Red oak growing stock and mortality, Toumey Woodlot, for 1940, 1950, and 1960

D.B.H.	1940			1950			1960			1940-1960	
	Total Growing Stock	Observed Mortality		Total Growing Stock	Observed Mortality		Total Growing Stock	Observed Mortality		Total Observed Mortality	
inches	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.
1	-	-	-	0.001	-	-	0.005	-	-	-	-
2	-	-	-	-	-	-	0.008	-	-	-	-
3	0.003	0.07	0.003	-	-	-	0.003	-	-	0.07	0.003
4	-	-	-	0.013	-	-	-	-	-	-	-
5	-	-	-	-	-	-	0.010	-	-	-	-
6	0.043	-	-	0.014	-	-	0.014	-	-	-	-
7	0.019	0.07	0.019	-	-	-	0.019	-	-	0.07	0.019
8	-	-	-	0.052	-	-	-	-	-	-	-
9	0.031	-	-	-	-	-	0.066	-	-	-	-
10	-	-	-	0.038	-	-	-	-	-	-	-
11	0.046	-	-	-	-	-	0.046	-	-	-	-
12	0.055	-	-	0.055	-	-	-	-	-	-	-
13	0.064	-	-	0.064	-	-	-	-	-	-	-
14	-	-	-	0.075	-	-	0.075	-	-	-	-
15	-	-	-	0.086	-	-	-	-	-	-	-
16	0.307	-	-	0.209	-	-	0.209	-	-	-	-
17	0.110	-	-	-	-	-	-	-	-	-	-
18	0.265	-	-	0.654	-	-	0.265	-	-	-	-
19	0.138	-	-	-	-	-	0.138	-	-	-	-
20	-	-	-	-	-	-	0.327	-	-	-	-
21	0.168	-	-	0.361	-	-	0.361	-	-	-	-
22	0.396	-	-	0.185	-	-	-	-	-	-	-
23	-	-	-	-	-	-	0.202	-	-	-	-
24	0.220	-	-	0.691	-	-	-	-	-	-	-
25	-	-	-	0.239	-	-	0.750	-	-	-	-

Table 16. (continued)

D.B.H. inches	1940 Total Growing Stock B.A. /acre sq.ft.	1940 Observed Mortality No. trees /acre	1940 Observed Mortality B.A. /acre sq.ft.	1950 Total Growing Stock B.A. /acre sq.ft.	1950 Observed Mortality No. trees /acre	1950 Observed Mortality B.A. /acre sq.ft.	1960 Total Growing Stock B.A. /acre sq.ft.	1960 Observed Mortality No. trees /acre	1960 Observed Mortality B.A. /acre sq.ft.	1940-1960 Total Observed Mortality No. trees /acre	1940-1960 Total Observed Mortality B.A. /acre sq.ft.
26	-	-	-	-	-	-	0.554	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-
28	-	-	-	-	-	-	0.642	-	-	-	-
29	0.321	-	-	0.321	-	-	-	-	-	-	-
30	-	-	-	0.344	-	-	-	-	-	-	-
31	-	-	-	-	-	-	-	-	-	-	-
32	-	-	-	-	-	-	0.391	-	-	-	-
33	-	-	-	-	-	-	0.416	-	-	-	-
42	0.673	-	-	-	-	-	-	-	-	-	-
45	-	-	-	0.773	-	-	0.773	-	-	-	-
TOTAL	2.859	0.14	0.022	4.175	-	-	5.274	-	-	0.14	0.022

Average Annual Mortality (1940-1960) = 0.001

Average Annual Mortality (1950-1960) = 0

Table 17. White ash growing stock and mortality, Toumey Woodlot, for 1940, 1950, and 1960

D.B.H.	1940			1950			1960			1940-1960	
	Total Growing Stock	Observed Mortality		Total Growing Stock	Observed Mortality		Total Growing Stock	Observed Mortality		Total Observed Mortality	
inches	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.
1	0.004	-	-	0.005	-	-	0.090	0.37	0.002	0.37	0.002
2	0.010	-	-	0.010	-	-	0.072	-	-	-	-
3	0.003	-	-	0.007	-	-	0.072	-	-	-	-
4	-	-	-	-	-	-	0.019	-	-	-	-
5	0.010	-	-	0.030	-	-	0.030	-	-	-	-
6	0.014	0.07	0.014	0.014	-	-	0.014	-	-	0.07	0.014
7	0.019	-	-	0.019	-	-	0.059	-	-	-	-
8	0.024	-	-	-	0.07	0.024	-	-	-	0.07	0.024
9	0.097	-	-	0.031	0.07	0.031	-	-	-	0.07	0.031
10	0.038	-	-	0.038	-	-	-	-	-	-	-
11	0.046	-	-	0.100	-	-	0.046	-	-	-	-
12	0.173	-	-	0.118	0.07	0.055	0.118	-	-	0.07	0.055
13	0.277	-	-	0.064	0.07	0.065	0.138	-	-	0.07	0.065
14	0.075	-	-	0.235	-	-	-	-	-	-	-
15	0.184	-	-	0.184	0.07	0.086	0.086	-	-	0.07	0.086
16	-	-	-	0.098	-	-	0.209	0.07	0.098	0.07	0.098
17	0.110	-	-	-	-	-	0.110	-	-	-	-
18	0.124	-	-	0.389	-	-	0.389	-	-	-	-
19	0.138	-	-	0.138	-	-	-	0.07	0.138	0.07	0.138
20	0.327	-	-	-	-	-	0.153	-	-	-	-
21	-	-	-	0.168	-	-	0.168	-	-	-	-
22	0.400	-	-	0.396	0.07	0.185	-	-	-	0.07	0.185
23	-	-	-	-	-	-	0.202	-	-	-	-
24	-	-	-	0.220	-	-	-	-	-	-	-
25	0.239	-	-	-	-	-	-	-	-	-	-

Table 17. (continued)

D.B.H. inches	1940 Total Growing Stock B.A. /acre sq.ft.	1940 Observed Mortality No. trees /acre	1940 Observed Mortality B.A. /acre sq.ft.	1950 Total Growing Stock B.A. /acre sq.ft.	1950 Observed Mortality No. trees /acre	1950 Observed Mortality B.A. /acre sq.ft.	1960 Total Growing Stock B.A. /acre sq.ft.	1960 Observed Mortality No. trees /acre	1960 Observed Mortality B.A. /acre sq.ft.	1940-1960 Total Observed Mortality No. trees /acre	1940-1960 Total Observed Mortality B.A. /acre sq.ft.
26	-	-	-	0.258	-	-	0.258	-	-	-	-
27	0.279	-	-	-	0.07	0.279	0.279	-	-	0.07	0.279
28	-	-	-	-	-	-	0.300	0.07	0.300	0.07	0.300
TOTAL	2.591	0.07	0.014	2.522	0.49	0.725	2.812	0.58	0.528	1.14	1.277

Average Annual Mortality (1940-1960) = 0.064

Average Annual Mortality (1950-1960) = 0.125

Table 18. Black cherry growing stock and mortality, Toumey Woodlot, for 1940, 1950, and 1960

D.B.H.	1940			1950			1960			1940-1960	
	Total Growing Stock	Observed Mortality		Total Growing Stock	Observed Mortality		Total Growing Stock	Observed Mortality		Total Observed Mortality	
inches	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.
1	0.007	0.15	0.001	0.004	0.22	0.001	0.005	0.30	0.002	0.67	0.004
2	0.011	0.07	0.002	0.005	0.07	0.002	0.008	-	-	0.14	0.004
3	0.011	-	-	0.007	-	-	-	-	-	-	-
4	-	0.07	0.006	-	-	-	0.032	-	-	0.07	0.006
5	-	-	-	0.009	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-
7	-	0.07	0.019	-	-	-	0.019	-	-	0.07	0.019
8	-	-	-	-	-	-	-	-	-	-	-
9	0.031	-	-	0.031	-	-	-	-	-	-	-
10	0.038	-	-	-	0.07	0.038	-	0.07	0.038	0.14	0.076
11	-	-	-	-	-	-	-	-	-	-	-
12	0.055	-	-	-	-	-	-	-	-	-	-
13	0.064	-	-	-	-	-	-	-	-	-	-
14	-	-	-	0.075	-	-	0.075	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-
16	-	-	-	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	-	-	-	-
18	0.124	-	-	-	-	-	-	-	-	-	-
19	-	-	-	0.138	-	-	-	-	-	-	-
20	0.153	-	-	-	-	-	-	-	-	-	-
21	-	-	-	0.361	-	-	-	0.07	0.168	0.07	0.168
22	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	0.202	-	-	-	-
24	-	-	-	-	-	-	0.220	-	-	-	-
25	0.239	-	-	-	-	-	-	-	-	-	-

Table 18. (continued)

D.B.H.	1940			1950			1960			1940-1960	
	Total Growing Stock	Observed Mortality		Total Growing Stock	Observed Mortality		Total Growing Stock	Observed Mortality		Total Observed Mortality	
inches	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.
26	0.258	-	-	-	-	-	-	-	-	-	-
27	-	-	-	0.279	-	-	-	-	-	-	-
28	-	-	-	-	-	-	0.300	-	-	-	-
TOTAL	0.991	0.36	0.028	0.909	0.36	0.041	0.861	0.44	0.208	1.16	0.277

Average Annual Mortality (1940-1960) = 0.014

Average Annual Mortality (1950-1960) = 0.025

in number and are not reproducing themselves satisfactorily. They are primarily intolerant species which utilize open areas for their establishment, and following suppression, drop out of the stand. The two exceptions to this trend are hophornbeam and prickly ash, which appear to have increased in abundance during the 20-year period. In terms of wood volume, however, these species have little economic value, and are thus considered to be minor components in the woodlot.

It is readily apparent that losses in basal area due to mortality are steadily increasing for the major tree species in Toumey Woodlot. The mortality represents a considerable loss of timber volume. The losses observed in 1940 are not as great as those recorded in the latter two periodic measurements, probably due in part to the harvesting of down trees prior to 1939 when the university acquired this property . However, since it appears that only small amounts were removed in such a manner, the increase observed in mortality during the last decade is undoubtedly a noteworthy one. The series of photographs in Figure 27 illustrates these developments very well.

The mortality observed, with few exceptions, is distributed fairly uniformly over the woodlot, rather than being concentrated in any one area. In an aerial photograph taken in May, 1961, some of the openings made by fallen trees are visible (Figure 28, Appendix). The largest opening, about one-fifth acre in size, and several others, occurred during a windstorm in September, 1959.

Mortality during the past 20 years, and especially over the past 10 years, seems to have increased, and losses have occurred quite frequently in the large diameter classes. Some of the observed mortality which was recorded during 1950 and 1960 resulted from a windstorm

Table 19. Miscellaneous species [1/] growing stock and mortality, Toumey Woodlot, for 1940, 1950, and 1960

D.B.H.	1940			1950			1960			1940-1960	
	Total Growing Stock	Observed Mortality		Total Growing Stock	Observed Mortality		Total Growing Stock	Observed Mortality		Total Observed Mortality	
inches	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.	No. trees /acre	B.A. /acre sq.ft.
1	0.091	0.15	0.001	0.094	0.82	0.005	0.118	1.93	0.011	2.90	0.017
2	0.055	0.22	0.005	0.048	1.34	0.030	0.138	1.63	0.036	3.19	0.071
3	0.138	0.37	0.018	0.084	0.82	0.040	0.076	0.37	0.018	1.56	0.076
4	0.077	0.07	0.006	0.084	-	0.019	0.051	-	-	0.07	0.025
5	0.279	-	-	0.091	-	-	0.061	0.22	0.030	0.22	0.030
6	0.219	-	-	0.117	0.22	0.043	0.057	-	-	0.22	0.043
7	0.099	-	-	0.120	0.07	0.019	0.080	-	-	0.07	0.019
8	0.182	-	-	0.206	-	-	0.206	-	-	-	-
9	0.199	-	-	0.194	-	-	0.230	0.15	0.066	0.15	0.066
10	0.283	-	-	0.284	0.07	0.038	0.038	0.07	0.038	0.14	0.076
11	0.290	-	-	0.099	-	-	0.297	0.07	0.046	0.07	0.046
12	0.173	-	-	0.236	-	-	0.118	0.07	0.055	0.07	0.055
13	0.341	-	-	0.277	0.07	0.065	0.203	-	-	0.07	0.065
14	-	0.07	0.075	0.321	-	-	0.075	-	-	0.07	0.075
15	0.086	-	-	0.086	-	-	0.368	0.07	0.086	0.07	0.086
16	0.209	-	-	-	0.07	0.098	0.307	-	-	0.07	0.098
17	-	-	-	0.110	-	-	0.110	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	0.138	-	-	-	-
20	-	-	0.153	-	-	-	-	-	-	-	0.153
TOTAL	2.671	0.88	0.258	2.451	3.48	0.357	2.671	4.58	0.386	8.94	1.001

Average Annual Mortality (1940-1960) = 0.050

Average Annual Mortality (1950-1960) = 0.074

1/ Miscellaneous species: black ash, blue ash, blue beech, bitternut hickory, black maple, red maple, silver maple, hophornbeam, hawthorn, white oak, prickly ash, and willow.

in 1959. This natural chance event, considered by itself, gives little basis for assuming that mortality has actually increased during this time. However, an examination of the tree population reveals that many of the trees in this old-growth stand are overmature, and that the amount of defect in them is increasing. Consequently, large losses in timber volume from disease, natural deterioration, and windthrow will continue.

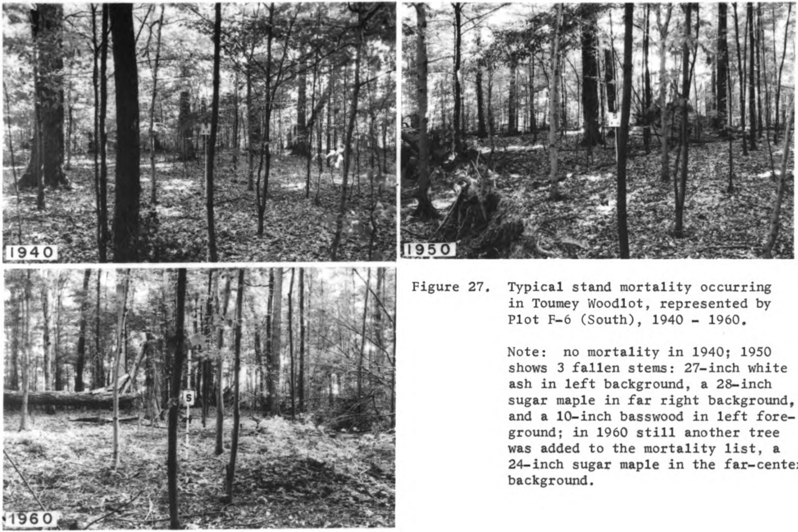

Figure 27. Typical stand mortality occurring in Toumey Woodlot, represented by Plot F-6 (South), 1940 - 1960.

Note: no mortality in 1940; 1950 shows 3 fallen stems: 27-inch white ash in left background, a 28-inch sugar maple in far right background, and a 10-inch basswood in left foreground; in 1960 still another tree was added to the mortality list, a 24-inch sugar maple in the far-center background.

Data from Sample Trees

To determine the approximate ages of the major component trees in Toumey Woodlot, as well as their rates of growth in diameter and total height, sample trees were tagged and measured in 1940, and remeasured in 1950 and 1960. The crown classification and bark thickness for each tree were also recorded. The techniques used for these measurements have been described in the field procedures.

Eight species were included in this sample and the number of trees for each species was: sugar maple (29); beech (24), American elm (26); American basswood (15); white ash (10); red oak (16); black cherry (3); and hophornbeam (4), for a total of 127 sample trees. As the result of mortality since the initial selection of these sample trees, only 110 living trees remained at the time of the 1950 inventory, and 95 in the 1960 tally.

The data collected on these trees are found in Tables 34-41 of the Appendix. Data for each species are listed separately, and comparisons for individual trees between subsequent measurements can be made easily. The crown classification reflects corresponding changes in d.b.h. increment rather well. In general, the suppressed trees are increasing in diameter at a slow rate. In like manner, their height increment is also low, but not as low as diameter increment.

Many changes in the crown class of trees were observed, even during as short a period as 20 years. Some trees recorded as suppressed in 1940 were classed as intermediate in 1960. In a few cases the trend was reversed, whereby trees recorded as intermediate in 1940 were classed as suppressed in 1960. In several instances codominant trees advanced to dominant positions in the crown canopy.

These conditions can be expected in a very old stand, such as Toumey Woodlot, where openings in the crown canopy are constantly changing. However, some of these fluctuations may be due to variations in classification of crown positions. Personal variation in crown classification by several investigators over a period of years tends to confuse alleged and actual changes. In general, however, the changes recorded are indicative of those actually occurring in the stand.

Changes during the 20-year period were not great enough to present the data graphically. For example, differences in height and diameter are not great enough to permit any specific distinction between these two parameters. Consequently, to show changes between and within the species in the stand for these parameters, a longer period of measurement is necessary.

These data also present information on tree longevity, as calculated from increment core data collected in 1940. Many trees in the stand have existed for a long period of time. Although it is difficult to ascertain ages of some sample trees due to either butt rot, as is common in American basswood, or to very large diameters and also hardness of wood, as in red oak and American elm, an approximation of the age was obtained for the majority of them. Some of the trees are quite old, as for example the 237-year-old sugar maple, the 235-year-old American elm, and the 290-year-old American beech. There are other trees probably much older than these in the stand. These individuals existed in the 16th century, long before the settlement of the white man in this area. In Tables 34-41 of the Appendix, the ages of all sample trees that could be determined are indicated.

It is unfortunate that the data collected on the established sample trees do not lend themselves to more detailed analyses. Had the same information been collected on a randomized plot basis, measuring each tree on the selected plots at each measurement period, the data could have been analyzed to yeild more meaningful results.

Silvicultural Implications

From a comparison of the 20-year results obtained in Toumey Woodlot with data for a managed forest, certain silvicultural implications become evident. These implications are of value since they give some indication of the potential productivity possible under prevailing site conditions. In addition, information is also obtained which is useful in evaluating stand and stock levels that provide for continuous good growth and desirable reproduction.

The overall stand density in number of trees and basal area per acre in 1940, 1950, and 1960, for the 13 sawtimber-sized species in Toumey Woodlot, is shown in Table 20. These data reveal that for the period of measurement, increases have taken place in both number of trees and basal area per acre. Of these two, the largest increases are noted in number of trees, with 362 in 1940, 430 in 1950, and 560 in 1960. Most of this increase has taken place in the 1-, 2-, and 3-inch diameter classes. The rise is not nearly as great in basal area, 117.19 in 1940, 120.51 in 1950 and 137.44 sq. ft./acre in 1960, which is not as greatly influenced by the large increases in sapling-sized diameter classes. This moderate increase in basal area over the past 20 years undoubtedly indicates that the maximum stocking potential for this area has not been reached, and that continued increases are quite possible, barring unforeseen catastrophes.

For the purpose of more fully understanding the overall stand structure in Toumey Woodlot, the data of Table 20 are regrouped and presented in Table 21. For comparison , the desirable stocking recommended for the management of this forest type by Eyre and Zillgitt, (1950 and Arbogast (1957), is also listed.

Table 20. Stand and stock table of 13 tree species[1/] in Toumey Woodlot, 1940, 1950, and 1960

D.B.H. (inches)	1940		1950		1960	
	Trees /acre	B.A. /acre	Trees /acre	B.A. /acre	Trees /acre	B.A. /acre
	number	sq.ft.	number	sq.ft.	number	sq.ft.
1	139.05	0.83	224.04	1.34	274.69	1.65
2	69.79	1.54	60.42	1.33	109.14	2.40
3	29.17	1.43	26.36	1.29	45.12	2.21
4	17.96	1.56	18.27	1.59	22.35	1.94
5	13.87	1.88	10.98	1.49	14.47	1.97
6	9.49	1.86	8.97	1.76	11.06	2.17
7	7.41	1.98	6.52	1.74	7.63	2.04
8	6.90	2.41	6.89	2.40	6.02	2.10
9	6.31	2.79	5.12	2.26	5.35	2.36
10	6.45	3.52	5.62	3.06	3.79	2.07
11	5.99	3.96	4.97	3.28	5.10	3.37
12	4.81	3.78	5.04	3.96	4.59	3.60
13	5.40	4.98	4.44	4.09	4.23	3.90
14	5.11	5.46	4.36	4.66	4.37	4.67
15	4.53	5.56	5.05	6.20	4.43	5.44
16	4.59	6.41	4.76	6.64	5.50	7.68
17	4.52	7.12	4.16	6.56	4.59	7.23
18	3.55	6.27	3.93	6.94	3.78	6.68
19	3.41	6.71	3.47	6.83	3.47	6.83
20	2.30	5.02	2.67	5.82	3.48	7.59
21	1.62	3.90	2.52	6.06	3.18	7.65
22	2.52	6.65	1.92	5.07	2.74	7.23
23	1.25	3.61	1.71	4.93	1.99	5.74
24	1.33	4.18	1.85	5.81	1.47	4.62
25	1.33	4.54	1.03	3.51	1.78	6.07
26	0.65	2.40	0.95	3.51	1.18	4.35
27	0.73	2.91	0.73	2.91	1.03	4.10
28	0.36	1.54	0.59	2.53	1.32	5.65
29	0.36	1.65	0.35	1.61	0.66	3.03
30	0.74	3.63	0.36	1.77	0.14	0.69
31	0.29	1.52	0.30	1.57	0.29	1.52
32	0.22	1.23	0.43	2.40	0.44	2.46
33	0.22	1.31	0.15	0.89	0.29	1.72
34	0.14	0.88	0.22	1.39	0.21	1.32
35	0.21	1.40	0.07	0.47	0.07	0.47
36			0.14	0.99	0.07	0.49
37			0.07	0.53	0.14	1.05
38			0.07	0.55		
39						
40					0.07	0.61
45	0.07	0.77	0.07	0.77	0.07	0.77
Total	362.65	117.19	429.57	120.51	560.30	137.44

1/ Sawtimber sized species include: sugar maple, beech, basswood, American elm, black cherry, white and red oak, bitternut hickory, slippery elm, white ash, red maple, black maple.

Table 21. Summarized stand and stock table of 13 tree species in Toumey Woodlot, 1940-1960, and the recommended growing stock per acre

D.B.H. (inches)	1940		1950		1960		Desirable Growing stock 1/	
	No. trees	B.A. sq. ft.	No. trees	B.A. sq. ft.	No. trees	B.A. sq. ft.	No. trees	B.A. sq. ft.
2 - 4	117	5	105	4	177	7	202	8
5 - 9	44	11	38	10	45	11	65	16
10 - 14	28	22	24	19	22	18	28	22
15 - 19	21	32	21	33	22	34	17	26
20 - 24	9	23	11	28	13	33	8	20
25+	5	24	6	26	8	29	-	-
TOTAL	224	117	205	120	287	132	320	92

1/ Obtained from Arbogast (1957), and Eyre and Zillgitt (1950).

The stand structure of a well-managed forest stand should contain from 65 to 75 square feet of basal area per acre in trees 10 inches to 24 inches d.b.h. This stocking allows for good growth within the sawtimber sizes, and also provides sufficient light to pass through the main crown canopy to the understory vegetation. From 10 to 20 square feet of basal area per acre are found in the 5- to 9-inch diameter classes. This is a sufficient amount to insure continuous movement of trees into the sawtimber classes. Again, this amount of pole-sized trees provides the ample quantities of light to reach the saplings. The sapling-sized trees contain from 5 to 10 square feet of basal area per acre. Maintaining a total basal area of 95 sq. ft. per acre is thus recommended for a northern hardwood forest which is managed on a sustained yeild basis.

Upon examination of the data in Table 21, important differences in stand structure are observed in the unmanaged stand of Toumey Woodlot compared to a managed stand. The number of trees per acre for the sapling and pole-sized trees in Toumey Woodlot is less than for the managed stand. Basal area for these diameter classes, however, is approximately equivalent to that of the managed stand. The most marked difference between the unmanaged stand of Toumey Woodlot and the managed stand, however, appears in the upper sawtimber size classes. While the 15- to 19-inch d.b.h. classes are similar in the two stands, they are not so for the larger diameter classes. The stocking in the 20- to 24-inch d.b.h. classes in Toumey Woodlot exceeds that recommended for the well-managed forest. That this difference has increased over the past 20 years is shown by the basal area values, which indicate that 23, 28, and 33 sq. ft. of basal area per acre were present in 1940, 1950, and 1960, respectively, for the 20- to 24-inch diameter classes. The recommended growing stock for these size classes is 20 sq. ft. of basal are per acre.

As Arbogast (1957) has stated, it is generally considered that many tree species within this forest type become economically mature when they reach 20- to 24-inch diameter classes. Trees that have grown beyond this economic maturity are usually removed before mortality and quality losses occur. In the managed stand, trees which have grown into these sizes are removed in periodic cuttings. Large amounts of basal area are contained in diameters larger than 24 inches Toumey Woodlot. That large amounts of defect and increased mortality have occurred in these diameter classes has already been emphasized.

As a result of the large amounts of basal area present in diameter classes above 24 inches, Toumey Woodlot has more stocking in these diameter classes than that considered desirable. As of 1960, for example, 29 sq. ft. of basal area per acre were present in these upper diameter classes. As pointed out, the total basal area for the woodlot has continuously increased since 1940, and was 132 sq. ft. in 1960. Of this amount, 62 sq. ft. occurred in the 20-inch and larger d.b.h. classes, whereas only 20 sq. ft. are recommended. Since the recommended total basal area is only 95 sq. ft. per acre, overstocking, primarily in the upper diameter classes, exists in Toumey Woodlot. Also, it is these large diameter classes which are becoming highly defective and subject to mortality.

While size-class distribution is an important silvicultural aspect to be considered, species composition of the stand is also important. While low-quality timber has about the same value regardless of species, large differences in value between species exist when tree quality is high. Consequently, in a managed forest stand, consideration is usually given to those species which are most economically desirable. From the data collected in this study, information was obtained not only as to the species present in the stand, but also as to their relative abundance and location within the stand.

As discussed in the section on overstory composition, sugar maple is the most abundant species, in all diameter classes, in Toumey Woodlot. Its numbers have increased rapidly, especially in the 1-, 2-, and 3-inch diameter classes. The high degree of tolerance

accorded this species is supported by the fact that, although its reproduction has occurred throughout the stand, it is very prevalent in areas having a rather dense overstory. Beech, the second most abundant species in Toumey Woodlot, has shown a slight increase in abundance in the 1-inch diameter class since 1940. In general, beech has maintained its position in the stand for the period of study. This species, being very tolerant, has also reproduced itself under dense shade conditions. This has not been the case for basswood and American elm, both of which have shown decreases in abundance for all but the largest diameter classes. Black cherry, red and white oak, and bitternut hickory are species which are not increasing in abundance, but are maintaining themselves in the woodlot. However, white ash, slippery elm, and hophornbeam have increased greatly over the past 20 years. Most of this increase occurred as reproduction in large openings caused by windfalls or along forest borders.

From these observations, it is readily apparent that the species composition in a stand often fluctuates with corresponding changes in the crown canopy. Where large openings are created, more light-demanding species are able to enter the area. Where smaller openings occur, e.g., as the result of the loss of an occasional dominant tree, more tolerant species are apt to enter. The point to be emphasized is that the size of the opening is very important in determining what the possible species composition may become.

The counterpart of naturally occurring openings are those created by timber harvesting. For northern hardwoods, Arbogast (1957) recommends the selection method of cutting. Under this all-aged system of

sustained yield forest management, poor quality trees are removed over the entire range of size classes, and mature and over-mature trees are removed through periodic partial cuts. The species composition desired in a stand often dictates the amount of timber which is removed in these partial cuts. Light partial cuttings will tend to favor tolerant species to the exclusion of light-demanding species. Heavy partial cuttings will tend to increase reproduction, but this may often consist of less desirable species, as well as result in a narrower size-class distribution. However, moderate selection cuttings have a tendency to perpetuate the intolerant tree species. Small openings, particularly near potential seed trees, increase the chances of obtaining reproduction for such species as American elm, basswood, black cherry, and white and red oak. Again, it is important to note that the size of the opening made may often influence the species composition that will result.

It is generally observed that in addition to the natural openings occurring in a forest stand, exposure of the mineral soil greatly enhances the possibility of obtaining tree reproduction. Based on these naturally occurring events, silvicultural practices involving various site preparation techniques, such as scarification, scalping, furrowing, prescribed burning, are often used to obtain maximum reproduction possible.

Cutting Recommendation

With respect to the species size-class distribution and composition found in Toumey Woodlot, as well as the quality and quantity of the growing stock, it is recommended that such an area, or equivalent commercial area, be managed for sawtimber production. For this purpose, a moderate group-selection cutting program is proposed.

That the seclection system is suited to this hardwood type has been well documented by Eyre and Zillgitt (1950), Zillgitt (1948; 1951), and Arbogast (1957). Zillgitt (1951) has reported that the success of the selection cutting system in this hardwood type has been due to several factors, among which are: (1) the tolerance of sugar maple, the predominant species in most stands; (2) sugar maple's capability, following partial cuttings, of growth response; and (3) the abundant natural reproduction which usually develops following a reproduction cutting.

As pointed out previously, many of the trees in Toumey Woodlot are overmature, and thus are frequently heavily defective. As a result, they have both high mortality rates, and slow growth rates. The data presented in Table 21 certainly show the economically unhealthy condition of the growing stock which exists, as compared to the more desirable growing stock recommended by Eyre and Zillgitt (1950), and Arbogast (1957). The growing stock for the small- and medium-sized diameter classes, in 1960, was approximately equivalent to that of the typical managed stand. It is in the upper sawtimber size classes, however, that the most noticeable differences occur between the growing stock in Toumey Woodlot and that considered desirable.

More than 62 sq. ft. of basal area per acre was concentrated in 1960 in the 20-inch and larger diameter classes. Almost one-half of this amount occurred in the 25-inch and larger d.b.h. classes. As shown in Table 21, only 20 sq. ft. of basal area in these larger diameter classes is recommended to be retained as growing stock in a managed stand, none of which appears in the 25-inch and larger diameter classes.

Consequently, it is recommended that the overmature and defective trees in a forest of this type and condition be removed, as well as distributing the total cut among all the sizes where necessary. The creation of large openings should be avoided wherever possible, since the entering reproduction might very well consist of undesirable tree species. However, moderate group selection cuttings, resulting in small or medium openings, are to be favored. These smaller openings, especially those near potential seed trees, increase the chances of obtaining desirable tree reproduction such as American basswood, black cherry, and both red and white oak. The tolerant sugar maple and American beech will also become established with little difficulty. Zillgitt (1948) has reported that reducing the growing stock to about 60 sq. ft. of basal area achieves the best volume growth, following cutting, in this forest type. This cutting plan improved the stand structure by bringing in diameter classes not previously well represented, in addition to greatly reducing mortality.

This study has revealed the large predominance of sugar maple over all other species in Toumey Woodlot. That this species is reproducing itself in sufficient numbers has been determined. The very tolerant nature of sugar maple also favors its continued reproduction and establishment within the forest stand. Based on the investigation of the soil of the area, sugar maple appears well able to utilize most efficiently the prevailing site conditions, and will continue to do so. However, since numerous large tree stems, not only of sugar maple but also of other species, are badly decayed, further losses of merchantable timber volume will result. As the result of subsequent changes in forest openings, continued fluctuations in both species composition and species abundance. will take place. The magnitude of these changes will be largely determined by the size of the created openings.

SUMMARY AND CONCLUSIONS

This study investigated certain ecological changes which have have occurred over a 20-year period in a relatively undisturbed sugar maple-beech stand in south-central Michigan. The area of about 15 acres, named Toumey Woodlot, is located approximately two miles south of the main campus of Michigan State University, East Lansing, Ingham County, Michigan.

In this investigation, the soil types of the area were examined and evaluated. The soil moisture regime for the major upland portion of the woodlot was also studied. Changes taking place in both the understory and overstory vegetation were recorded, and information pertaining to the amount of light entering the stand, species-growth data, as well as stand-mortality data, were also collected.

Soils

In 1961, a detailed soil survey was made of the Toumey Woodlot. Based on 5-foot soil profile observations taken at random throughout the forest stand, 6 soil types were represented. A soil-type map was prepared for the area, showing the approximate locations for each soil type. Hillsdale sandy loam, which comprises about two-thirds of the area, is the dominant soil type. Spinks loamy fine sand occupies about one-fourth of the area. A more comprehensive examination of the soil profile at several locations within these two soil types was made later. This included a determination of soil texture, structure, consistence, color, and reaction for each separate horizon in the soil profile. The remaining soil types, Spinks loamy sand, Conover silt loam, Conover loam, and Carlisle muck, are of minor importance in this woodlot.

Of the 6 soil types present, the Hillsdale and Spinks soils are the most productive for tree growth. Their infiltration and percolation rates are high. Although well-drained, their moisture level remains fairly high for most of the year. In sharp contrast, the Conover soils are imperfectly drained and the Carlisle soils are poorly drained. In these soils, the soil moisture is often too high, and a result may become detrimental to tree growth.

Soil Moisture Regime

Soil moisture depletion and recharge were estimated during portions of 1961 and 1962, by use of the neutron-scattering method. For this purpose, 10 access tubes, each 10 feet long, were place in the predominant soil type of the area, Hillsdale sandy loam. Soil moisture was measured at 1-foot intervals in a 9-foot profile. The 10 established soil moisture plots were measured on 18 separate occasions over a 16-month period.

From the soil moisture contents of the 0- to 9-foot depth observed during 1961 and 1962, certain moisture accretion and depletion relationships which were apparent are: (1) The general soil moisture pattern showed a depletion during the period of April through August as a result of continuous evapo-transpiration losses. Late fall, winter, and early spring are periods of soil moisture recharge, the result of reduced transpirational demands from the vegetation, and also lower evaporational losses. (2) Soil moisture depletion occurred at all depths but not at equal rates. The lower 5 feet of soil did not dry after the upper 4 feet of soil. (3) The most pronounced fluctuations in soil moisture occurred in the upper 2-foot depth. This was the depth most influenced by intermittent rains during spring and summer. (4) The surface 2 feet of soil tended to dry more rapidly than either of the lower depths. (5) Except for short periods of time following high summer rainfalls, the surface 2 feet of soil contained less moisture than lower depths during the growing season. However, this was not true in the winter and early spring, when snow accumulation and soil-surface freezing contribute soil moisture to this layer. (6) The moisture content of the 3- and 4-foot depths fluctuated much less than those of the upper 2 feet. In turn, the soil moisture contents of the 5- to 9-foot depth fluctuated less than either of the above levels. The primary reason for this disparity is probably due to these layers being less influenced by summer rainfall than those of the upper 4-foot depths. (7) While moisture depletion takes place in the upper 4-foot depth, moisture accretion may take place in the lower depths. Although insufficient data were available to warrant a more concrete conclustion, some evidence exists that this may have occurred. It is believed that soil moisture in the capillary pore spaces moves out of the upper soil layers and into the ground-water supplies. (8) The depth of moisture extraction indicates that although the largest amounts of moisture were removed from the upper 4 feet of soil, tree roots were using soil moisture from the 5- to 9-foot zone. However, soil moisture from these lower depths appears to function primarily as a moisture reserve. The moisture is used only to a small extent until definite moisture deficits exist in the upper soil layers. At such time, soil moisture may be readily withdrawn from the lower depths.

(9) It appeared from the data collected that at no time during the 16-month period of record did soil moisture contents drop below levels required by plants to maintain growth.

Evapo-Transpiration

Evapo-transpiration losses occurring throughout the 9-foot profile during 1961-1962 were computed. Greatest losses occurred during the early part of the growing season, a period of time corresponding to the resumption of growth by the vegetative cover. During the remaining portions of the year, greatly reduced evapo-transpirational losses occurred.

The total amount of evapo-transpiration loss computed for the 12-month period of April 8, 1961, to April 14, 1962, was 28.56 inches. This value, although comparing favorably with several other investigations, may be an over-estimate, since it included any water losses to both internal and lateral drainage, quantities undetermined in this study.

Understory Composition

All ground cover species were recorded during the summer months of June and August in 1940, 1950, and 1960. A complete inventory was made of all vegetation 1 inch d.b.h. and larger. For trees, shrubs, and herbaceous vegetation not having a d.b.h. of 1 inch and larger, data were collected in 31 quadrats, 24-inch x 34-inch in size, and well-distributed throughout the woodlot. As the same quadrats were remeasured each time, a comparison could be made for each particular quadrat over the 20-year span of observation.

A large increase in floristic richness has occurred over the 20-year period. In 1940, only 9 herbaceous genera, representing the same number of families, were present in the plots measured . Together with 3 shrubs and 4 tree genera, representing 3 and 4 separate families, respectively, 16 genera and 16 different families were present in 1940.

The increase in flora in 1950 was very pronounced. At this time 17 herbs, 3 shrubs, and 8 tree genera were recorded, for a total of 28 genera and 26 families.

The third measurement of the ground cover plots in 1960 indicated additional changes in the flora. The total number of herbaceous genera decreased from that in 1950, with 15 genera and 13 families present. An increase in shrubs was noted, with 6 genera from 5 families present. The number of tree species was 9, represented by 9 families. Using the available information on the sequence of species present on individual plots, inferences were made as to the possible longevity of certain species over the period of study. From the data collected, it was observed that a longevity range of 20 years was not common for the ground cover species in Toumey Woodlot. The data indicate that most herbaceous species have life spans less than 10 years within small, local sites, as those measured in this study.

Various instances of vegetative change were also observed in Toumey Woodlot over the 20-year period. It was apparent that fluctuations took place in many directions, with increases, decreases, or no changes occurring in some of the quadrats within the period of study. It seems evident that most of these changes are not illustrative of directional change, but probably represent non-cyclic replacement changes. The changes in species are due simply to the death of one ground cover species, followed by the germination of another on the site, with no clearly established causal relationship between the two events. The important point to be emphasized is the ever-changing characteristic of the ground cover in a relatively stable forest community.

The sequence of events following the death of an overstory tree, or gap-phase replacement, were also observed. The gaps or openings created have a different microclimate than that of the remaining portions of the stand, with light, moisture, and soil conditions altered. The seedlings of many species can, and do, become established in these openings. The seedlings of many intolerant species may only be able to enter under these conditions. These openings certainly play an important role in determining the species composition in a stand.

Overstory Composition

All woody stems of 1 inch d.b.h. and larger were recorded by species and by 1-inch diameter classes in 1940, 1950, and 1960. A total of 22 tree species was observed in Toumey Woodlot.

Sugar maple is by far the most abundant and important tree species in the stand. Large quantities of reproduction are present throughout the woodlot, and general increases in the medium and large diameter classes were observed. American beech was the second most abundant tree species in Toumey Woodlot. The data revealed that beech, rather than decreasing in numbers, is maintaining itself within the stand, and has actually increased in numbers in several of the diameter classes over the past 20 years.

Other important tree species are American basswood, American elm, black cherry, white ash, red oak, and slippery elm. For both basswood and American elm, a general decline in all but the largest diameter

classes has taken place over the past 20 years. The presence of Dutch elm disease has undoubtedly been, and will continue to be, a significant factor in the reduction of American elm. Black cherry is a minor component within the stand, and has exhibited little change over the past period of measurement. A slight reduction in the small diameter classes has occurred.

White ash has shown a large increase in the 1- to 3-inch diameter classes, but this is largely concentrated on the southern-most border of the stand. However, little change has occurred in the remaining diameter classes. While red oak is reproducing and maintaining itself in the stand, slippery elm has shown a tremendous increase in the 1- to 10-inch diameter classes over the past 20-year period of record. The majority of this occurs on the southern border of Toumey Woodlot. What effect the Dutch elm disease will have on this species remains to be seen.

The remaining 14 tree species found in Toumey Woodlot are of minor commercial importance. As a general rule, they do not appear to be increasing in numbers, and some in fact have decreased in abundance or have been eliminated from the stand. Hophornbeam and prickly ash are the only two species which have actually increased in abundance over the 20-year period.

Light Measurements

In the present study, light measurements were made in August of 1940, 1950, and 1960. The 1940 data were eliminated as the result of faculty instrumentation and procedure. The 1950 and 1960 readings measured reflected light and revealed the amount of light entering 8 plots within Toumey Woodlot, these representing areas of average crown density, blowdown, slope, and depression.

Changes in light intensity have taken place over the period of study within the stand. For example, a former area of average stand density, having 2.0 percent of full sunlight recorded in 1950, represented a blowdown area in 1960 where the percent of full sunlight was 21.7. As a result of such drastic light changes ground cover species were greatly influenced. In contrast, some areas decreased in the amount of light received over the past 10 years, while others remained relatively the same.

In this study, the percentage of full sunlight on each plot was, with two exceptions, above 1 percent. For all plots, the average percent of full sunlight was 2.1 in 1950, and 1.6 in 1960. It proved difficult to evaluate the influence of the loss of an occasional tree or large branch, however, in plots surrounding the light-sampled plots. These changes in the crown canopy structure are not always apparent to the investigator. However, these gaps or openings do influence the amount of light entering the stand, and cause constant fluctuations in light conditions within a stand.

Stand Mortality

At each of the 3 measurement periods, 1940, 1950, and 1960, the numbers of dead individuals for each species, by 1-inch diameter classes, were recorded.

It is readily apparent that mortality in basal area is steadily increasing for the major tree species in Toumey Woodlot. Sugar maple, American beech, American basswood, American elm, and white ash all have incurred mortality primarily in the sawtimber size classes. In contrast, slippery elm and black cherry have suffered their greatest losses in the 1- to 10-inch diameter classes. Red oak was the only species which exhibited virtually no mortality over the past 20 years. The remaining species, which do not contribute greatly to the total growing stock of the woodlot, are, in general, decreasing in number, and are not reproducing themselves satisfactorily. They are primarily intolerant species which utilize open areas for their establishment, and following suppression, drop out of the stand. The two exceptions to this trend, as already noted, are hophornbeam and prickly ash, which have increased in abundance during the 20-year period. In terms of wood volume, however, these species have little economic value.

The mortality which has occurred in Toumey Woodlot represents a considerable loss of timber volume. The mortality during the past 20 years has increased, and losses have occurred quite frequently in the large diameter classes. An examination of the tree population revealed that many of the trees in this old-growth stand are overmature, and that the amount of defect in them is increasing. Large losses in timber volume are thus expected to continue.

Sample Trees

To determine the approximate ages, rates of growth in diameter and total height, crown classification, and bark thickness of the major tree species in Toumey Woodlot, sample trees were tagged and measured in 1940, and remeasured in 1950 and 1960.

Large numbers of trees have existed in the stand for long periods of time, and several individuals are from 200 to 300 years old.

The crown classifications recorded reflect corresponding changes in both diameter and height increment. In general, suppressed trees increased in diameter at a slow rate, but not as slowly as they did in height increment.

Fluctuations over the 20-year period are inconclusive in furnishing useful data about the parameters measured. To show definite changes between and within the various species in the stand, a much longer period of measurement is necessary.

Silvicultural Implications

The overall stand density in numbers of trees and basal area per acre in 1940-1960, for the 13 sawtimber-sized species in Toumey Woodlot, has shown a steady increase. This probably indicates that the maximum stocking potential for the area has not as yet been reached, and will undoubtedly continue to rise.

The stand structure which exists in the study area, however, does not compare favorable with recommended for a well-managed stand of this type. While the growing stock in the 19-inch and lower diameter classes are somewhat similar between Toumey Woodlot and that recommended in managed stands, it greatly exceeds that considered desirable in the 20-inch and larger diameter classes. In 1960, for example, 21 trees per acre, representing 62 sq. ft. basal area per acre, were present in Toumey Woodlot in the 20-inch and larger diameter classes. The recommended amount is 8 trees per acre, and 20 sq. ft. of basal area per acre. This excessive overstocking in the larger diameter classes is primarily where the majority of the mortality is taking place in Toumey Woodlot. In addition, this condition does not allow

for proper stocking, species composition, and stand quality in the remaining size classes.

Cutting Recommendation

Based on the species size-class distribution and composition, as well as the quality and quantity of the growing stock in Toumey Woodlot, it is recommended that such an area, or similar commercial area, be managed for sawtimber production, using a moderate group-selection cutting system.

It is proposed that the overmature and defective trees be removed, as well as cutting inferior stock among all tree sizes. Small or medium stand openings are to be favored, as they will create conditions more favorable to the establishment of desirable timber tree species that normally have greater difficulty in doing so. American elm and basswood, as well as black cherry, and red oak and white oak, are to be considered in this category. Sugar maple and beech will have no great difficulty in also becoming established under this cutting system.

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APPENDIX

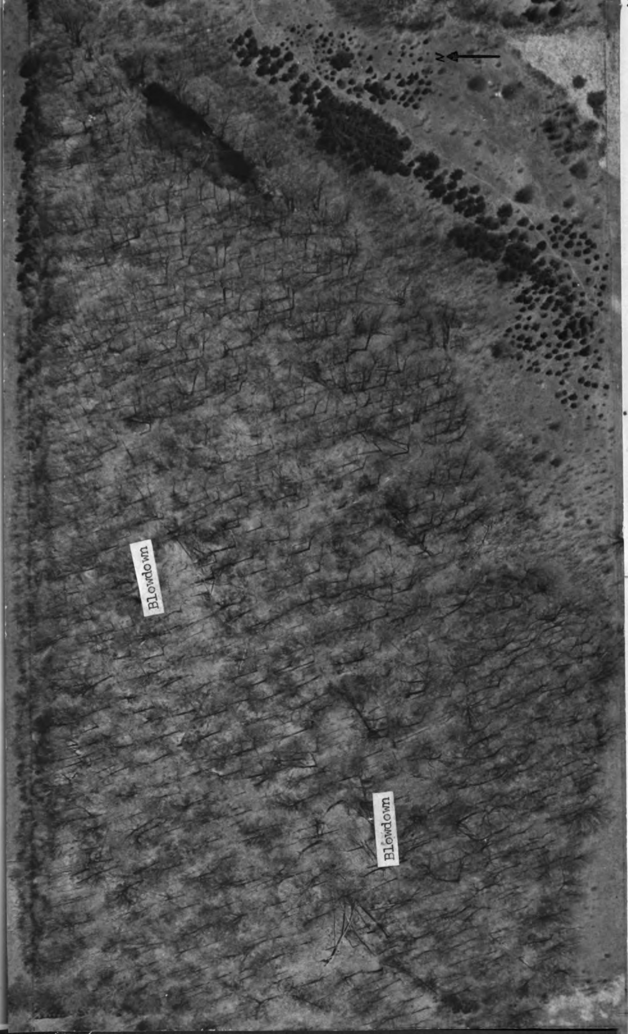
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Table 22. Station B-3.[1/] Soil moisture in inches, 0-9 foot depths, Toumey Woodlot, April 1961, to July 1962

(1961)

Depth (ft.)	4/8	7/21	7/28	8/4	8/11	8/18	8/25	9/8	9/15	12/29
1	2.52	2.28	2.16	2.64	2.46	2.16	2.58	2.70	2.58	2.34
2	2.82	2.46	2.52	2.46	2.52	2.40	2.52	2.70	2.70	2.52
3	2.94	2.70	2.70	2.64	2.52	2.46	2.58	2.64	2.70	2.76
4	3.00	2.52	2.34	2.22	2.16	2.10	1.98	2.10	2.10	2.46
5	1.62	1.44	1.44	1.32	1.32	1.26	1.14	1.20	1.14	1.14
6	0.66	0.96	1.02	1.02	0.96	0.96	0.84	0.90	0.90	0.84
7	0.60	0.96	0.90	0.90	0.96	0.96	0.90	0.90	0.90	0.78
8	0.66	0.96	1.08	1.02	1.02	1.08	0.96	0.96	1.02	0.90
9	0.60	0.90	0.90	0.96	0.90	0.96	0.84	0.90	0.90	0.78

(1962)

Depth (ft.)	1/20	2/9	4/14	4/21	4/26	5/3	5/12	5/17	7/7
1	2.22	2.58	2.64	2.70	2.64	2.70	2.58	2.46	2.58
2	2.64	2.52	2.70	2.70	2.64	2.76	2.70	2.70	2.64
3	2.94	2.76	2.88	2.94	2.94	3.00	3.00	2.88	2.88
4	2.76	2.76	2.94	2.94	2.82	3.00	2.88	2.76	2.58
5	1.26	1.32	1.86	1.92	1.86	2.10	1.92	1.86	1.32
6	0.90	0.90	0.96	0.96	1.02	1.08	1.08	1.02	0.66
7	0.84	0.78	0.84	0.84	0.84	0.84	0.90	0.90	0.66
8	0.96	0.96	0.90	0.90	0.96	0.96	0.96	0.90	0.66
9	0.84	0.78	0.78	0.84	0.90	0.78	0.84	0.84	0.60

[1/] This station not included in determination of soil moisture regime in Toumey Woodlot, because of abnormal low values of moisture content in the profile, especially at 6- to 9-foot depths.

Table 23. Station B-9. Soil moisture in inches, 0-9 foot depths, Toumey Woodlot, April 1961, to July 1962

(1961)

Depth (ft.)	4/8	7/21	7/28	8/4	8/11	8/18	8/25	9/8	9/15	12/29
1	2.52	1.44	1.26	1.32	1.26	1.08	1.98	2.04	1.74	2.22
2	2.58	1.98	1.44	1.86	1.74	1.68	1.62	1.98	1.80	2.10
3	2.58	2.10	1.92	1.62	1.98	1.92	1.74	1.86	1.92	1.92
4	1.68	2.16	1.98	1.92	1.92	1.92	1.62	1.80	1.74	1.74
5	1.68	2.28	2.04	2.04	1.98	1.98	1.68	1.86	1.92	1.86
6	1.86	2.16	2.04	1.56	2.04	1.98	1.74	1.98	1.92	1.86
7	1.86	1.92	1.92	1.86	1.92	1.86	1.68	1.80	1.92	1.86
8	2.16	2.22	2.16	2.16	2.16	2.34	1.98	2.16	2.16	2.16
9	2.16	2.28	2.28	2.28	2.28	2.28	1.98	2.28	2.22	2.16

(1962)

Depth (ft.)	1/20	2/9	4/14	4/21	4/26	5/3	5/12	5/17	7/7
1	2.28	2.40	2.52	2.40	2.40	2.64	2.46	2.22	2.04
2	2.28	2.64	2.46	2.52	2.58	2.64	2.64	2.52	2.10
3	1.98	1.98	2.52	2.64	2.64	2.64	2.70	2.64	2.16
4	1.74	1.80	2.64	2.70	2.70	2.70	2.76	2.64	2.34
5	1.86	1.86	2.64	2.58	2.70	2.76	2.76	2.58	2.28
6	1.92	1.98	2.34	2.46	2.52	2.70	2.70	2.58	2.46
7	1.74	1.74	2.40	2.40	2.40	2.46	2.52	2.40	2.34
8	2.10	2.10	2.16	2.22	2.28	2.34	2.46	2.46	2.40
9	2.16	2.22	2.22	2.16	2.22	2.28	2.40	2.22	2.40

Table 24. Station C-5. Soil moisture in inches, 0-9 foot depths, Toumey Woodlot, April 1961, to July 1962

(1961)

Depth (ft.)	4/8	7/21	7/28	8/4	8/11	8/18	8/25	9/8	9/15	12/29
1	2.34	2.22	2.28	2.46	2.22	1.98	2.70	2.28	2.34	2.34
2	2.52	2.40	2.58	2.70	2.58	2.46	3.06	2.64	2.64	2.64
3	2.64	2.40	2.70	2.76	2.76	2.70	2.76	2.70	2.70	2.76
4	2.58	2.40	2.58	2.58	2.58	2.46	2.64	2.64	2.64	2.58
5	2.34	1.74	1.80	1.86	1.80	1.68	1.80	1.80	1.74	1.98
6	1.98	1.74	1.92	1.86	1.80	1.74	1.62	1.62	1.62	1.74
7	0.96	0.84	0.84	0.78	0.78	0.72	0.84	0.72	0.78	0.72
8	1.26	0.90	1.02	1.02	0.96	0.96	0.96	0.96	0.90	0.78
9	1.26	1.02	1.08	1.08	1.02	1.02	1.02	0.96	0.96	0.84

(1962)

Depth (ft.)	1/20	2/9	4/14	4/21	4/26	5/3	5/12	5/17	7/7
1	2.22	2.58	2.64	2.40	2.46	2.52	2.22	2.28	2.46
2	2.58	2.52	2.52	2.64	2.58	2.70	2.52	2.64	2.88
3	2.76	2.70	2.70	2.76	2.76	2.76	2.70	2.76	3.00
4	2.58	2.52	2.46	2.58	2.64	2.70	2.52	2.64	2.76
5	2.16	2.46	2.46	2.46	2.52	2.58	2.40	2.40	2.34
6	1.92	1.92	1.86	2.16	2.10	2.10	2.04	2.04	1.98
7	1.14	0.84	1.32	1.38	1.32	1.32	1.32	1.26	0.72
8	0.78	0.78	1.38	1.44	1.44	1.44	1.44	1.44	0.96
9	0.90	0.84	1.32	1.38	1.44	1.44	1.32	1.38	1.14

Table 25. Station D-10. Soil moisture in inches, 0-9 foot depths, Toumey Woodlot, April 1961, to July 1962

(1961)

Depth (ft.)	4/8	7/21	7/28	8/4	8/11	8/18	8/25	9/8	9/15	12/29
1	2.22	1.32	1.14	1.32	1.14	1.02	2.22	1.92	1.62	2.04
2	2.10	1.32	1.20	1.26	1.08	1.02	1.50	1.68	1.50	1.98
3	2.46	2.04	1.98	1.14	1.80	1.80	1.74	1.80	1.80	2.04
4	2.04	2.04	2.04	1.98	1.92	1.80	1.80	1.80	1.80	1.80
5	1.68	1.92	1.80	1.86	1.68	1.68	1.62	1.68	1.62	1.56
6	1.86	2.16	2.16	2.10	2.04	2.16	2.10	2.04	2.04	2.04
7	1.98	2.22	2.22	2.22	2.10	2.16	2.10	2.10	2.16	2.10
8	2.04	2.28	2.28	2.22	2.22	2.22	2.16	2.22	2.22	2.04
9	1.74	2.22	2.16	2.16	2.16	2.04	1.98	1.98	1.98	1.86

(1962)

Depth (ft.)	1/20	2/9	4/14	4/21	4/26	5/3	5/12	5/17	7/7
1	1.92	2.46	2.40	2.40	2.22	2.58	2.22	2.16	1.68
2	1.92	1.86	2.40	2.40	2.34	2.46	2.34	2.28	1.50
3	2.10	2.16	2.64	2.58	2.70	2.82	2.70	2.64	2.16
4	1.86	1.86	2.88	2.76	2.76	2.88	2.94	2.82	2.16
5	1.62	1.62	2.16	2.16	2.16	2.22	2.22	2.22	1.98
6	1.98	1.92	2.16	2.16	2.10	2.16	2.22	2.22	2.16
7	2.04	1.98	2.10	2.10	2.16	2.16	2.58	2.22	2.34
8	2.22	2.10	2.16	2.22	2.16	2.16	2.16	2.22	2.22
9	1.74	1.74	1.98	1.92	1.98	2.34	2.34	2.40	2.52

Table 26. Station E-5. Soil moisture in inches, 0-9 foot depths, Toumey Woodlot, April 1961, to July 1962

(1961)

Depth (ft.)	4/8	7/21	7/28	8/4	8/11	8/18	8/25	9/8	9/15	12/29
1	2.40	2.04	1.92	2.16	1.92	1.74	2.28	2.34	2.22	2.40
2	2.64	2.28	2.22	2.28	2.22	2.16	2.22	2.34	2.22	2.64
3	2.76	2.34	2.16	2.28	2.10	2.04	2.04	2.10	2.10	2.58
4	2.76	2.10	2.28	1.92	1.74	1.74	1.68	1.62	1.56	1.74
5	3.00	2.46	2.22	2.22	2.10	1.92	1.92	1.92	1.74	1.80
6	2.88	2.52	2.46	2.46	2.28	2.40	2.22	2.40	2.22	2.16
7	2.46	2.52	2.40	2.46	2.28	2.22	2.16	2.16	1.98	1.86
8	1.68	1.98	1.92	1.80	1.74	1.68	1.62	1.56	1.50	1.38
9	1.20	1.26	1.20	1.20	1.20	1.14	1.08	1.14	1.08	1.14

(1962)

Depth (ft.)	1/20	2/9	4/14	4/21	4/26	5/3	5/12	5/17	7/7
1	2.22	2.46	2.64	2.40	2.46	2.52	2.40	2.34	2.40
2	2.46	2.40	2.70	2.58	2.70	2.70	2.64	2.64	2.58
3	2.52	2.52	2.64	2.64	2.70	2.70	2.70	2.64	2.46
4	1.68	1.92	2.76	2.70	2.70	2.82	2.64	2.76	2.22
5	1.80	1.92	2.70	2.70	2.82	2.88	2.76	2.82	2.40
6	2.04	2.04	2.52	2.52	2.58	2.58	2.64	2.70	2.58
7	1.86	1.80	2.88	2.76	3.00	3.00	2.94	3.00	2.70
8	1.32	1.32	2.04	2.16	2.34	2.64	2.70	2.88	2.58
9	1.08	1.14	1.08	1.14	1.20	1.26	1.68	1.74	1.74

Table 27. Station F-9. Soil moisture in inches, 0-9 foot depths, Toumey Woodlot, April 1961, to July 1962

(1961)

Depth (ft.)	4/8	7/21	7/28	8/4	8/11	8/18	8/25	9/8	9/15	12/29
1	2.16	1.74	1.26	1.32	1.26	1.08	1.74	1.68	1.50	1.74
2	2.46	2.28	2.16	2.16	2.04	1.92	1.86	1.98	1.92	1.92
3	1.62	2.16	1.74	1.68	1.62	1.44	1.50	1.56	1.50	1.50
4	1.56	1.92	1.92	1.86	1.80	1.74	1.74	1.80	1.68	1.80
5	1.86	2.04	1.98	2.04	2.04	1.98	1.98	1.98	1.98	1.98
6	1.92	2.16	2.04	2.16	2.22	2.22	2.10	2.10	2.10	1.98
7	0.72	1.44	1.38	1.38	1.32	1.26	1.14	1.68	1.20	1.38
8	1.98	2.10	2.16	2.10	2.16	2.16	2.22	2.16	2.16	2.04
9	1.92	2.04	2.04	2.10	2.10	1.92	2.04	2.04	1.98	2.04

(1962)

Depth (ft.)	1/20	2/9	4/14	4/21	4/26	5/3	5/12	5/17	7/7
1	1.80	2.10	2.46	2.40	2.22	2.52	2.22	2.04	1.86
2	2.04	2.04	2.40	2.40	2.40	2.58	2.64	2.52	2.16
3	1.56	1.62	1.86	2.58	2.10	2.40	2.40	2.34	1.86
4	1.68	1.68	2.22	2.76	2.40	2.46	2.52	2.40	2.04
5	1.92	1.92	2.16	2.16	2.22	2.22	2.28	2.22	2.16
6	1.98	1.98	2.16	2.16	2.22	2.28	2.28	2.22	2.22
7	1.20	1.14	1.98	2.10	2.70	2.64	3.00	2.94	1.74
8	2.16	2.16	2.16	2.22	2.16	2.58	2.64	2.64	2.28
9	1.86	1.92	1.38	1.92	2.04	2.76	2.94	2.76	2.16

Table 28. Station G-6. Soil moisture in inches, 0-9 foot depths, Toumey Woodlot, April 1961, to July 1962

(1961)

Depth (ft.)	4/8	7/21	7/28	8/4	8/11	8/18	8/25	9/8	9/15	12/29
1	2.04	1.92	1.74	1.86	1.80	1.62	1.98	2.16	1.86	2.10
2	2.46	2.04	1.98	1.98	1.98	1.98	1.92	2.04	1.98	2.52
3	2.46	1.98	1.80	1.86	1.80	1.80	1.86	1.98	1.74	2.40
4	1.98	2.22	2.10	2.16	2.10	2.04	2.10	2.22	2.04	1.98
5	1.14	1.56	1.44	1.44	1.44	1.38	1.62	1.62	1.50	1.38
6	1.56	1.74	1.68	1.68	1.68	1.68	1.68	1.74	1.68	1.68
7	1.62	1.80	1.74	1.68	1.80	1.80	1.80	1.80	1.74	1.74
8	1.38	1.92	1.86	1.74	1.74	1.74	1.68	3.00	1.50	1.38
9	1.26	2.04	1.50	1.50	1.50	1.50	1.62	1.68	1.56	1.50

(1962)

Depth (ft.)	1/20	2/9	4/14	4/21	4/26	5/3	5/12	5/17	7/7
1	1.92	1.80	2.16	2.04	2.16	2.28	2.04	2.04	2.16
2	2.34	2.34	2.40	2.40	2.52	2.64	2.40	2.46	2.58
3	2.46	2.34	2.46	2.46	2.52	2.70	2.46	2.58	2.46
4	2.16	2.16	2.40	2.52	2.46	2.70	2.40	2.46	2.52
5	1.32	1.32	2.10	2.16	2.16	2.40	2.10	2.10	1.86
6	1.62	1.62	1.98	1.98	1.92	2.04	1.92	1.98	1.92
7	1.74	1.68	1.98	2.04	2.04	2.04	1.92	1.98	1.86
8	2.10	1.86	2.28	2.40	2.34	2.46	2.46	2.40	2.40
9	1.62	1.50	1.62	1.74	1.92	2.10	2.22	2.52	2.28

Table 29. Station H-4. Soil moisture in inches, 0-9 foot depths, Toumey Woodlot, April 1961, to July 1962

(1961)

Depth (ft.)	4/8	7/21	7/28	8/4	8/11	8/18	8/25	9/8	9/15	12/29
1	2.28	2.16	1.98	2.28	2.16	1.98	2.22	2.16	2.16	2.10
2	1.86	1.80	1.74	1.98	1.92	1.74	2.04	1.92	1.80	1.80
3	2.34	2.16	1.98	1.98	2.16	1.98	2.22	2.04	2.22	2.28
4	2.58	2.04	1.92	1.98	1.92	1.92	2.40	2.46	2.28	2.58
5	2.64	1.98	1.92	1.98	1.98	1.86	2.16	2.22	2.16	2.58
6	2.40	2.34	2.28	2.34	2.28	2.40	2.22	2.28	2.22	2.40
7	2.34	2.22	2.28	2.28	2.40	2.22	2.16	2.16	2.22	2.28
8	2.16	2.28	2.22	2.28	2.34	2.22	2.22	2.28	2.22	2.22
9	1.74	1.86	1.80	1.74	1.80	1.80	1.80	1.80	1.68	1.80

(1962)

Depth (ft.)	1/20	2/9	4/14	4/21	4/26	5/3	5/12	5/17	7/7
1	2.04	1.92	2.34	2.22	2.16	2.28	2.04	2.16	2.22
2	1.74	1.62	1.86	1.86	1.92	2.10	1.86	1.92	2.16
3	2.22	2.10	2.28	2.28	2.34	2.40	2.28	2.28	2.34
4	2.52	2.46	2.58	2.64	2.64	2.64	2.64	2.52	2.04
5	2.70	2.58	2.76	2.64	2.76	2.70	2.64	2.70	2.22
6	2.46	2.40	2.52	2.46	2.46	2.52	2.46	2.46	2.58
7	2.40	2.28	2.40	2.40	2.34	2.40	2.28	2.40	2.28
8	2.34	2.22	2.34	2.28	2.34	2.34	2.28	2.28	2.52
9	2.10	1.98	2.04	1.98	1.92	1.86	1.86	1.74	1.62

Table 30. Station H-8. Soil moisture in inches, 0-9 foot depths, Toumey Woodlot, April 1961, to July 1962

(1961)

Depth (ft.)	4/8	7/21	7/28	8/4	8/11	8/18	8/25	9/8	9/15	12/29
1	2.40	1.80	1.44	1.62	1.38	1.20	2.46	2.04	1.74	2.28
2	2.16	1.80	1.68	1.74	1.62	1.62	1.80	1.80	1.74	1.98
3	2.10	1.92	1.80	1.86	1.68	1.62	2.10	1.80	1.80	1.80
4	1.62	1.92	1.80	1.80	1.68	1.62	1.98	1.74	1.68	1.68
5	1.74	1.92	1.92	1.80	1.74	1.68	1.68	1.68	1.68	1.62
6	1.92	2.28	2.10	2.16	2.04	2.04	2.10	2.04	2.10	1.98
7	2.04	2.52	2.28	2.28	2.28	2.10	2.28	2.28	2.22	2.22
8	2.10	2.52	2.40	2.40	2.34	2.22	2.28	2.22	2.40	2.22
9	2.10	2.40	2.34	2.34	2.34	2.28	2.28	2.28	2.28	2.22

(1962)

Depth (ft.)	1/20	2/9	4/14	4/21	4/26	5/3	5/12	5/17	7/7
1	2.34	2.34	2.64	2.64	2.64	2.64	2.40	2.40	2.04
2	1.98	2.04	2.40	2.28	2.46	2.34	2.28	2.28	2.04
3	1.92	2.04	2.64	2.70	2.70	2.76	2.58	2.52	1.98
4	1.74	1.68	2.64	2.64	2.70	2.76	2.58	2.64	2.04
5	1.62	1.62	2.22	2.22	2.28	2.40	2.22	2.22	2.16
6	1.98	1.98	2.52	2.52	2.64	2.70	2.52	2.58	2.46
7	2.22	2.16	2.58	2.58	2.70	2.70	2.64	2.58	2.58
8	2.22	2.28	2.46	2.46	2.64	2.52	2.64	2.64	2.58
9	2.22	2.22	2.28	2.34	2.40	2.46	2.58	2.70	2.58

Table 31. Station J-5. Soil moisture in inches, 0-9 foot depths, Toumey Woodlot, April 1961, to July 1962

(1961)

Depth (ft.)	4/8	7/21	7/28	8/4	8/11	8/18	8/25	9/8	9/15	12/29
1	2.52	2.22	2.10	2.28	2.10	1.98	2.22	2.16	2.16	2.10
2	3.06	2.28	2.22	2.34	2.34	2.34	2.46	2.46	2.40	2.46
3	2.76	2.28	2.16	2.16	2.16	2.04	2.40	2.34	2.34	2.28
4	2.76	2.22	2.16	2.22	2.16	2.10	2.34	2.22	2.22	2.22
5	2.16	1.98	1.98	1.98	1.98	1.98	2.04	2.04	1.98	1.92
6	2.22	2.16	1.98	2.04	2.04	2.04	2.04	2.04	2.04	1.98
7	2.34	2.16	2.04	2.16	2.16	2.22	2.16	2.16	2.10	2.04
8	2.52	2.22	2.16	2.16	2.10	2.28	2.22	2.10	2.16	2.04
9	1.32	1.44	1.50	1.50	1.50	1.56	1.50	1.50	1.50	1.38

(1962)

Depth (ft.)	1/20	2/9	4/14	4/21	4/26	5/3	5/12	5/17	7/7
1	2.16	2.04	2.34	2.22	2.16	2.34	2.22	2.22	2.16
2	2.46	2.46	2.58	2.52	2.46	2.64	2.58	2.58	2.58
3	2.40	2.22	2.52	2.46	2.40	2.46	2.52	2.40	2.40
4	2.28	2.28	2.46	2.46	2.34	2.46	2.40	2.28	2.28
5	1.98	1.92	2.16	2.10	2.04	2.16	2.16	2.04	2.10
6	1.98	1.92	2.16	2.16	2.16	2.16	2.16	2.16	2.10
7	2.10	2.04	2.28	2.22	2.16	2.16	2.28	2.22	2.22
8	2.10	2.16	2.28	2.22	2.22	2.22	2.28	2.22	2.22
9	1.62	1.50	1.80	1.68	1.68	1.68	1.74	1.68	1.56

Table 32. Common and scientific names of all herbaceous and non-arboreal species in Toumey Woodlot 1/

Scientific Name	Common Name
Actaea Pachypoda Ell.	White baneberry
Arisaema triphyllum (L) Schott	Small Jack-in-the-pulpit
Carex spp.	Sedge
Circaea quadrisulcata (Maxim.) Franch & Sav., var. canadensis (L) Hara	Enchanter's nightshade
Cirsium vulgare (Savi.) Tenore	Bull or Common thistle
Cryptotaenia canadensis (L) DC.	Honewort
Euonymus obovatus Nutt.	Running strawberry-bush
Hydrophyllum appendiculatum Michx.	Waterleaf
Hystrix patula Moench	Bottle-brush grass
Impatiens capensis Meerb.	Snapweed or Spotted touch-me-not
Osmorhiza claytoni (Michx) C. B. Clarke	Sweet cicely
Parthenocissus quinquefolia (L)Planch.	Virginia creeper or woodbine
Phlox divaricata L.	Phlox
Phryma leptostachya L.	Lopseed
Phytolacca americana L	Pokeweed
Pilea pumila (L) Gray	Richweed or Clearweed
Podophyllum peltatum L.	May-apple or Mandrake
Polygonatum pubescens (Willd.) Pursh	Solomon's-seal
Rubus spp.	Bramble
Sambucus canadensis L.	Common elder
Sanguinaria canadensis L.	Bloodroot
Sanicula Trifoliata Bickn.	Black snakeroot
Smilacina racemosa (L) Desf.	False Solomon's-seal
Solidago caesia L.	Blue-stem goldenrod
Toxicodendron radicans (L) Kuntze	Poison Ivy
Viola spp.	Violet
Vitis spp.	Grape

1/ After Fernald, M. L. 1950. Gray's Manual of Botany. 8th ed. American Book Co., New York. 1632 pp.

Table 33. Common and scientific names of all tree species in Toumey Woodlot 1/

Scientific Name	Common Name
Acer nigrum Mich. f.	Black maple
Acer rubrum L.	Red maple
Acer saccharinum L.	Silver maple
Acer saccharum Marsh.	Sugar maple
Amelanchier arborea (Mich. f.) Fern.	Serviceberry
Carpinus caroliniana Walt.	American hornbeam or blue beech
Carya cordiformis (Wangenh.) K. Koch	Bitternut hickory
Celtis occidentalis L.	Hackberry
Fagus grandifolia Ehrh.	American beech
Fraxinus americana L.	White ash
Fraxinus nigra Marsh.	Black ash
Fraxinus quadrangulata Michx.	Blue ash
Ostrya virginiana (Mill.) K. Koch	Eastern hophornbeam
Platanus occidentallis L.	American sycamore
Prunus serotina Ehrh.	Black cherry
Quercus alba L.	White oak
Quercus rubra L.	Red oak
Salix spp.	Willow
Tilia americana L.	American basswood
Ulmus americana L.	American elm
Ulmus rubra Mühl.	Slippery elm
Zanthoxylum americanum Mill.	Prickly ash

1/ After Little, E. L. 1953. *Check list of native and naturalized trees of the United States.* U. S. Dept. Agr. Handbook No. 41, 472 pp.

Table 34. Sugar Maple. Sampled tree growth data, Toumey Woodlot, 1940, 1950, and 1960

Tree No.	Diameter Breast Height			Total Height			Crown Class[1/]			Bark Thickness			Age in
	1940	1950	1960	1940	1950	1960	1940	1950	1960	1940	1950	1960	1960
		-inches-			-feet-						-inches-		-years-
1	1.7	2.5	2.8	13.0	21.0	28.0	S	S	S	0.05	0.06	0.10	42
2	3.0	3.7	3.7	24.0	31.0	32.0	1	1	1	0.17	0.18	0.20	49
3	5.1	6.0	6.6	50.0	51.0	57.0	S	1	1	0.16	0.22	0.20	58
4	5.6	6.8	7.2	49.0	56.0	61.0	S	S	S	0.25	0.30	0.30	100
5	6.0	6.8	7.4	47.0	66.5	72.0	S	S	S	0.21	0.24	0.30	73
6	6.7	7.3	7.4	67.0	79.0	85.0	1	S	S	0.25	0.33	0.32	96
7	8.5	8.8	9.3	58.0	65.0	70.0	S	1	1	0.28	0.40	0.46	78
8	10.5	13.3	16.6	69.5	73.0	75.0	CD	CD	D	0.35	0.40	0.41	98
9	11.0	12.5	13.3	66.0	80.0	88.0	1	CD	CD	0.37	0.49	0.50	117
10	12.9	13.9	15.1	69.5	72.0	73.0	CD	CD	CD	0.40	0.42	0.42	113
11	14.1	15.3	16.2	84.0	106.0	116.0	CD	CD	D	0.48	0.50	0.55	112
12	15.2	16.7	17.5	86.0	97.0	104.0	CD	CD	D	0.55	0.57	0.65	135
13	17.3	18.2	18.2	96.0	105.0	108.0	CD	CD	CD	0.95	1.10	1.15	170
14	18.5	SE *		84.0	--	--	CD	--	--	0.64	--	--	-
15	19.5	21.0	NE *	80.0	98.0	--	CD	CD	--	0.79	0.87	--	-
16	20.0	21.1	S *	80.0	82.0	--	CD	CD	--	0.97	0.99	--	-
17	21.3	22.4	24.5	97.0	101.0	101.0	CD	CD	CD	0.86	0.94	1.00	213
18	22.6	24.5	26.8	101.0	103.0	106.0	CD	D	D	1.15	1.20	1.20	?
19	24.1	24.2	24.9	104.0	90.0	88.0**	CD	D	D	0.80	0.96	0.96	?
20	25.4	26.4	27.0	100.0	113.0	116.0	D	D	D	0.77	1.04	1.10	237
21	26.5	27.3	29.1	78.5	89.0	97.0	D	D	D	0.68	0.72	0.75	?
22	27.0	28.2	29.6	110.0	114.0	107.0**	D	D	D	0.86	0.92	1.00	220
23	30.6	31.1	31.6	110.0	110.0	104.0**	D	D	D	1.36	1.39	1.40	?
24	31.5	SE *		116.0	--	--	D	-	-	0.91	--	--	-
25	32.0	34.6	37.2	110.0	116.0	120.0	D	D	D	--	1.15	1.10	?
26	33.5	34.1	35.6	110.0	116.0	120.0	D	D	D	1.05	1.10	1.10	?
27	33.7	S *		110.0	--	--	D	-	-	1.57	--	--	-
28	34.0	24.7	35.0	110.0	108.0	107.0**	D	D	D	0.87	0.99	1.00	?
29	35.3	37.8	SE *	102.0	106.0	--	D	D	-	1.10	1.44	--	-

* Indicates mortality recorded at time of measurement as well as direction of fall.
** Signifies loss in height as a result of a broken crown.
1/ Crown classification used: S=suppressed; 1=intermediate; CD=codominant; D=dominant.
? Age could not be determined.

Table 35. Beech. Sampled tree growth data, Toumey Woodlot, 1940, 1950, and 1960

Tree No.	Diameter Breast Height 1940	1950	1960	Total Height 1940	1950	1960	Crown Class 1/ 1940	1950	1960	Bark Thickness 1940	1950	1960	Age in 1960
	-inches-			-feet-						-inches-			-years-
1	2.5	2.7	3.5	22.0	23.0	25.0	S	S	S	0.07	0.08	0.08	72
2	4.0	NE*		27.0	--	--	S	-	-	0.08	--	--	-
3	4.6	5.1	5.3	37.5	45.0	47.0	1	S	CD	0.09	0.11	0.10	70
4	7.7	8.0	8.1	38.0	45.0	52.0	S	S	S	0.30	0.35	0.35	126
5	8.0	7.8	W *	43.5	39.0**	--	S	S	-	0.17	0.22	--	-
6	8.4	10.5	12.7	54.5	58.5	70.0	S	1	CD	0.15	0.22	0.25	83
7	9.0	10.2	10.4	82.0	89.0	91.0	CD	1	1	0.16	0.20	0.20	103
8	11.3	12.9	14.0	81.5	85.0	94.0	1	1	1	0.25	0.40	0.45	208
9	11.4	13.1	15.4	68.0	93.5	98.0	1	1	CD	0.21	0.28	0.30	146
10	15.0	16.9	18.7	79.8	93.0	95.0	CD	D	D	0.34	0.43	0.40	174
11	15.7	18.2	20.4	95.0	96.0	102.0	CD	CD	D	0.27	0.31	0.30	148
12	16.9	17.7	19.2	90.0	87.5	90.0	1	1	CD	0.44	0.50	0.54	?
13	18.3	20.7	23.0	97.0	106.0	109.0	CD	CD	D	0.38	0.39	0.40	182
14	19.5	20.9	22.3	107.0	111.0	111.0	CD	CD	CD	0.44	0.47	0.51	?
15	20.1	20.8	22.0	93.0	93.0	98.0	CD	D	D	0.28	0.42	0.45	290
16	21.2	21.6	23.4	96.4	100.5	104.0	CD	CD	D	0.37	0.43	0.55	?
17	22.4	SE *	--	98.2	--	--	CD	-	-	0.30	--	--	-
18	23.2	24.4	25.6	103.0	104.5	107.0	CD	D	D	0.35	0.45	0.50	?
19	2.32	24.6	26.1	104.5	105.0	113.0	CD	CD	D	0.61	0.70	0.70	?
20	25.0	26.5	S *	80.0	74.5**	--	D	D	-	0.45	0.47	--	-
21	27.4	28.6	30.1	104.3	106.0	113.0	D	D	D	0.47	0.55	0.60	182
22	28.5	SE *	--	109.0	--	--	CD	-	-	0.45	--	--	-
23	29.9	31.3	32.7	95.0	108.0	110.0	D	D	D	0.50	0.54	0.50	?
24	36.1	39.4	40.4	93.0	114.0	116.0	D	D	D	1.01	1.15	1.25	?

* Indicates mortality recorded at time of measurement as well as direction of fall.
** Signifies loss in height as a result of a broken crown.
1/ Crown classification used: S=suppressed; 1=intermediate; CD=codominant; D=dominant.
? Age could not be determined.

Table 36. American Basswood. Sampled tree growth data, Toumey Woodlot, 1940, 1950, and 1960

Tree No.	Diameter Breast Height 1940	1950	1960	Total Height 1940	1950	1960	Crown Class 1/ 1940	1950	1960	Bark Thickness 1940	1950	1960	Age in 1960
	-inches-			-feet-						-inches-			-years-
1	1.9	*	--	23.0	--	--	1	-	-	0.09	--	--	-
2	4.7	5.1	5.5	32.0	33.0	36.0	S	S	S	0.18	0.20	0.24	43
3	8.1	9.1	NE*	41.0	55.0	--	CD	1	-	0.42	0.44	--	-
4	9.9	NE*	--	66.0	--	--	1	-	-	0.37	--	--	-
5	10.5	11.1	11.5	76.0	80.0	87.0	1	1	1	0.35	0.36	0.39	?
6	12.2	12.6	13.1	73.0	79.0	84.0	S	1	1	0.31	0.33	0.35	78
7	13.5	15.4	17.0	81.0	84.0	110.0	CD	CD	D	0.33	0.37	0.40	103
8	17.1	18.3	19.0	86.0	101.0	110.0	CD	D	D	0.67	0.69	0.75	103
9	17.4	19.1	19.7	87.0	99.0	108.0	CD	D	D	0.60	0.86	0.90	?
10	17.8	19.3	20.1	94.0	96.0	102.0	CD	CD	CD	0.63	0.71	0.75	117
11	19.0	20.3	21.4	76.0	82.0	92.0	D	D	D	0.90	0.95	0.90	?
12	22.4	23.9	25.5	105.0	111.0	122.0	CD	D	D	0.85	0.87	1.00	?
13	26.9	30.3	S *	110.0	112.0	--	D	D	-	0.89	0.93	--	-
14	25.0	27.0	SE *	98.0	106.0	--	D	D	-	0.97	0.99	--	?
15	30.7	32.9	34.1	108.0	80.0**	80.0	CD	D	CD	1.10	1.15	1.20	?

* Indicates mortality recorded at time of measurement as well as direction of fall, where possible.
** Signifies loss in height as a result of a broken crown.
1/ Crown classification used: S=suppressed; 1=intermediate; CD=codominant; D=dominant.
? Age could not be determined.

Table 37. American Elm. Sampled tree growth data, Toumey Woodlot, 1940, 1950, and 1960

Tree No.	Diameter Breast Height 1940	1950	1960	Total Height 1940	1950	1960	Crown Class 1/ 1940	1950	1960	Bark Thickness 1940	1950	1960	Age in 1960
	-inches-			-feet-						-inches-			-years-
1	2.0	*	--	21.0	--	--	S	-	-	0.11	--	--	-
2	3.8	4.1	NE*	35.0	--	--	S	-	-	0.40	--	--	-
3	4.3	6.1	7.3	32.0	34.0	40.0	1	S	1	0.29	0.30	0.30	40
4	4.8	*	NE*	36.0	--	--	S	-	-	0.26	--	--	-
5	7.9	*	--	48.0	--	--	1	-	-	0.29	--	--	-
6	8.9	E *	--	55.0	--	--	1	-	-	0.41	--	--	-
7	9.5	10.6	12.0	43.0	51.0	57.0	1	S	1	0.38	0.55	0.60	60
8	11.1	*	--	53.0	--	--	S	-	-	0.78	--	--	-
9	11.8	12.4	12.5	72.0	75.0	75.0	1	1	S	0.62	0.67	0.65	115
10	12.8	14.6	15.9	72.0	86.0	90.0	CD	CD	D	0.60	0.63	0.65	?
11	15.1	16.2	17.9	101.0	111.0	111.0	D	D	D	0.87	0.89	0.90	?
12	16.7	16.7	19.4	89.0	92.0	95.0	CD	D	D	0.97	0.88	0.90	132
13	18.7	22.0	25.2	77.0	94.0	116.0	D	D	D	0.74	0.87	0.90	?
14	19.3	21.0	21.8	84.0	89.0	95.0	CD	CD	D	0.84	0.89	0.90	?
15	19.4	21.3	21.9	87.0	101.0	105.0	D	D	D	0.95	0.99	1.00	100
16	20.2	22.7	24.5	76.0	90.0	100.0	D	D	D	0.81	0.86	0.90	130
17	20.8	23.8	S *	94.0	99.0	--	CD	D	-	1.05	1.15	--	-
18	21.1	23.7	26.3	92.0	103.0	105.0	CD	D	D	0.77	0.92	1.00	?
19	22.8	23.4	23.4	98.0	113.0	118.0	CD	D	D	1.05	1.16	1.30	?
20	24.4	26.3	28.2	108.0	111.0	112.0	D	D	D	1.05	1.15	1.20	169
21	24.7	25.9	26.7	102.0	104.0	104.0	D	D	D	1.10	1.25	1.20	?
22	25.9	28.7	27.7	96.0	105.0	100.0**	CD	D	D	0.95	1.10	1.20	100
23	27.3	29.4	31.8	100.0	106.0	110.0	D	D	D	1.11	1.40	1.40	140
24	31.1	32.5	34.8	84.0	105.0	110.0	D	D	D	0.92	0.94	0.90	?
25	33.0	34.5	NE.*	80.0	98.0	--	D	D	-	0.90	0.95	--	?
26	34.2	37.0	38.5	103.0	118.0	110.0**	D	D	D	1.19	1.25	1.20	235

* Indicates mortality recorded at time of measurement as well as direction of fall, where possible.
** Signifies loss in height as a result of a broken crown.
1/ Crown classification used: S=suppressed; 1=intermediate; CD=codominant; D=dominant.
? Age could not be determined.

Table 38. Red Oak. Sampled tree growth data, Toumey Woodlot, 1940, 1950, and 1960

Tree No.	Diameter Breast Height 1940	1950	1960	Total Height 1940	1950	1960	Crown Class 1/ 1940	1950	1960	Bark Thickness 1940	1950	1960	Age in 1960
	-inches-			-feet-						-inches-			-years-
1	2.7	3.0	3.2	28.0	31.0	33.0	S	S	S	0.10	0.13	0.12	49
2	6.1	7.0	7.4	56.0	68.0	76.0	S	1	1	0.28	0.30	0.35	74
3	6.3	8.1	9.2	50.0	64.0	79.0	1	1	1	0.24	0.30	0.30	80
4	7.3	8.4	8.9	60.0	69.0	74.0	S	1	1	0.28	0.41	0.40	83
5	9.3	10.1	11.0	46.0	47.0	62.0	S	1	1	0.44	0.45	0.49	67
6	10.4	13.2	15.4	67.0	77.0	82.0	CD	1	CD	0.27	0.55	0.50	?
7	12.3	15.4	17.8	92.0	98.0	110.0	D	CD	CD	0.48	0.52	0.50	79
8	13.1	14.3	16.0	82.0	102.0	110.0	CD	CD	D	0.42	0.47	0.55	83
9	16.0	18.5	20.5	91.0	93.0	98.0	CD	CD	D	0.44	0.57	0.60	86
10	16.8	18.7	20.2	77.0	94.0	100.0	CD	D	D	0.74	0.79	0.80	?
11	18.3	21.4	21.4	88.0	92.0	101.0	CD	CD	D	0.45	0.58	0.70	79
12	19.5	22.6	26.2	85.0	102.0	118.0	D	D	D	0.55	0.85	0.92	106
13	20.7	23.9	27.8	74.0	85.0	95.0	D	D	D	0.71	0.91	1.00	?
14	22.0	24.2	26.0	77.0	88.0	100.0	D	D	D	0.85	0.98	1.01	?
15	28.8	31.8	32.5	91.0	99.0	108.0	D	D	D	1.00	1.25	1.22	?
16	43.5	45.1	45.5	95.0	115.0	95.0**	D	D	D	1.20	1.28	1.25	?

** Signifies loss in height as a result of a broken crown.

1/ Crown classification used: S=suppressed; 1=intermediate; CD=codominant; D=dominant.

? Age could not be determined.

Table 39. White Ash. Sampled tree growth data, Toumey Woodlot, 1940, 1950, and 1960

Tree No.	Diameter Breast Height 1940	1950	1960	Total Height 1940	1950	1960	Crown Class 1/ 1940	1950	1960	Bark Thickness 1940	1950	1960	Age in 1960
	-inches-			-feet-						-inches-			-years-
1	5.1	5.6	6.2	32.0	53.0	61.0	S	1	1	0.35	0.36	0.40	42
2	9.0	NW*	-	72.0	--	--	1	-	-	0.58	--	--	-
3	9.5	11.0	13.6	73.0	79.0	85.0	CD	1	D	0.62	0.91	1.00	103
4	10.3	13.1	15.9	68.0	84.0	100.0	CD	CD	CD	0.47	0.50	0.55	80
5	13.2	14.9	E *	69.0	73.0	--	CD	1	-	0.58	0.81	--	-
6	16.7	19.0	21.0	88.0	106.0	110.0	D	D	D	0.70	1.00	1.00	?
7	17.6	19.6	SW *	104.0	112.0	--	D	D	-	0.75	1.11	--	?
8	19.2	21.3	22.6	92.0	110.0	116.0	CD	D	D	1.12	1.22	1.20	110
9	22.5	25.3	28.0	105.0	112.0	116.0	D	D	D	0.91	1.05	1.00	86
10	25.0	27.0	SE *	97.0	100.0	--	D	D	-	1.18	1.30	--	-

Table 40. Black Cherry. Sampled tree growth data, Toumey Woodlot, 1940, 1950, and 1960

1	17.6	19.5	NE *	101.0	104.0	--	D	D	-	0.87	0.89	--	89
2	20.3	21.6	22.7	108.0	112.0	116.0	D	D	D	0.66	0.91	0.90	82
3	25.6	27.3	27.7	111.0	114.0	116.0	CD	CD	CD	0.61	0.95	1.00	?

Table 41. Hophornbeam. Sampled tree growth data, Toumey Woodlot, 1940, 1950, and 1960

1	3.9	*	-	42.0	--	--	1	-	-	0.15	-	-	-
2	6.3	*	-	54.0	--	--	1	-	-	0.17	-	-	-
3	7.8	8.7	9.4	49.0	51.0	53.0	1	1	1	0.37	0.40	0.50	69
4	8.6	9.0	NE *	65.0	69.0	--	1	1	-	0.18	0.19	-	-

* Indicates mortality recorded at time of measurement as well as direction of fall, where possible.
** Signifies loss in height as a result of a broken crown.
1/ Crown classification used: S=suppressed; 1=intermediate; CD=codominant; D=dominant.
? Age could not be determined.

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