ABSTRACT

J.E. AMBROSE

SOFT MAPLE (Acer rubrum L. and Acer saccharinum L.)

PRODUCTIVITY STUDIES

M.Sc.

Department of
Woodlot Management

The potential productivity of soft maple coppice stands on imperfectly drained soils in Southwestern Quebec has been determined for a rotation age of 50 years.

Data from detailed stem analysis of 122 trees from 10 plots formed the basis of this study. All data were analyzed by computer. Backman's projection model was used for predicting volume and height growth for ages up to 50 years.

The ten established plots were placed in the first three forest capability classes of the Canada Land Inventory classification. Soft maple on soils of the higher moisture regime (5, 5+) has the potential to produce volumes up to 7200 gross cu. ft. at rotation age.

SOFT MAPLE (*Acer rubrum* L. and *Acer saccharinum* L.)

PRODUCTIVITY STUDIES

by

J.E. Ambrose

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J.E. Ambrose

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I. INTRODUCTION

A. GENERAL

In Southwestern Quebec, as elsewhere in Eastern Canada, the need for optimum land use is evidenced by the abundance of farm and forest areas that are producing below their estimated potential. Causes of this include such factors as land ownership patterns, management techniques, past government policies and in general, as Lord (1965) points out, lack of knowledge, particularly regarding woodland practices.

From personal observations the growth of the two soft maples, red and silver (*Acer rubrum* L., and *Acer saccharinum* L., respectively) indicate economic possibilities for intensive forest management on some of the presently low production imperfectly drained soils of Southwestern Quebec. The purpose of this study is to determine the potential productivity of soft maple on some of the imperfectly drained soils and the methodology adopted for the study includes the use of stem analysis and a projection model. Ecosystems of particular interest are the second growth soft maple cover types.

B. POTENTIAL PRODUCTIVITY -- DEFINITION AND APPLICATION

To determine optimum use for any unit of land it is necessary to know what that particular unit of land is inherently capable of producing. Potential biological production, according to Hills,[1] can be defined as the rate of biological production which produces crops of maximum quantity and of highest quality with the most economic degree of effort including that which maintains the productive capacity of the site.

A good working tool for determining optimum land use is the land use capability classification (McCormick, 1966) but capability classes can only be applied to those sites for which potential productivity has already been determined quantitatively. Using the capability classes as a base, the resource planner is able to consider present time values for variable economic and social factors in order to arrive at an optimum land use.

For example: If a tract of land of uniform site has a high capability rating for producing timber, an overall rating for the use of this land for timber production, in view of the present lack of economic and social demands for other uses, may be very high. At a later period, demand for the use of the land as a recreational facility may increase. Although the timber capability of the land will not change, the overall use rating

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[1]Personal communication.

of the land will, and would likely be superseded by an overall forestry use rating which implies a combination of timber production and recreational use.

It is evident from this example that an ecological analysis of the site is required in order to arrive at productivity values for different land crops or uses. To the productivity evaluation is complemented the fluctuating economic and social values at a given time, thus yielding a land use rating for that particular site at that time.

The foregoing has illustrated the importance of knowing a site's potential productivity and the position that it holds within the framework of land use planning.

C. STUDY AREA

Those areas which had been previously examined by Lord (1965) in his landownership study were further investigated for this productivity study. Portions of the two counties, Soulanges and Huntingdon, fulfilled the requirements of a second growth soft maple cover type on imperfectly drained soils. More precisely, the two areas of concentration were the old Soulanges canal area within Soulanges county, and various woodlots in the Chateauguay Valley region of Huntingdon County. (App. 1 shows general study areas and plot locations.)

D. ECOLOGICAL FRAMEWORK

1. Geology

All study plots except No. 13 are located within the geological region commonly known as the St. Lawrence Lowlands (Dreser and Denis, 1944). Plot No. 13 is approximately two miles east of Covey Hill, on the northernmost outpost of the Adirondack Highlands. The two regions are underlain by igneous and metamorphic pre-Cambrian rock and subsequent layerings of Potsdam sandstone and various limestones (Dreser and Denis, op. cit.). The deposition of marine clays and sands of the former Champlain Sea are responsible for the St. Lawrence Lowlands' almost perfectly level topography. Plot Nos. 11, 12 and 13 are located on deposits of glacial till.

2. Soils

According to J.F.G. Millette[2] the soils of Soulanges County are alluvial, and mainly of the gleisolic order. Huntingdon county soils are quite variable due to the topography, with the soils of the hummocks being mainly of the brunisolic and podsolic orders derived from glacial till while alluvial gleisols exist in the lowlands.

3. Vegetation

As reported by Rowe (1959) in his description of the Upper St. Lawrence Section (L-2) of the Great Lakes-St. Lawrence Forest region:

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[2]Personal communication.

> In general, the physiographic boundaries of the Section coincide with a vegetational change from predominantly deciduous forest within to mixed deciduous-and-conifer forest without.
>
> The dominant cover type is composed of sugar maple (*Acer saccharum*) and beech (*Fagus grandifolia*), with red maple (*Acer rubrum*), yellow birch (*Betula lutea*), white elm (*Ulmus americana*), basswood (*Tilia americana*), white ash (*Fraxinus americana*), large tooth aspen (*Populus grandidentata*), and red and bur oaks (*Quercus rubra*, *Q. macrocarpa*), with local occurrences of white oak (*Quercus alba*), red ash (*Fraxinus pennsylvanica*), wire birch (*Betula populifolia*), rock elm (*Ulmus thomasii*), blue beech (*Carpinus caroliniana* var. *virginiana*) and bitternut hickory (*Carya cordiformis*). Butternut (*Juglans cinerea*), cottonwood (*Populus deltoides*) and slippery elm (*Ulmus rubra*) have a sporadic distribution in river valleys, and some small pure stands of black maple (*Acer nigrum*) and silver maple (*A. saccharinum*) are reported on fertile, fine textured lowland soils. Poorly drained depressions frequently carry a hardwood swamp type in which black ash (*Fraxinus nigra*) is prominent.

Rowe continues to describe the minor occurrence of some of the coniferous species within this primarily hardwood forest section. The vegetation of interest in this study is classified under Dansereau's System (Dansereau, 1959) as:

Ac r Aceretum Rubri Ic-(E(C))

Dansereau describes the association as follows:

> On the imperfectly drained soils the red and silver maple dominates but where the topography undulates and thus allows reasonable drainage, the type will grade into sugar maple and red oak types. In many instances where the site is occupied by a dominant soft maple cover type, evidence shows the invasion of pioneer types of grey birch and poplar.

Ladouceur (1967) in his study of red maple in the province of Quebec, describes the association of red maple that is of concern in this study as a sub-association "Aceretum rubri betuletum populifoliae."

4. Climate

Chapman and Brown (1966) describe the area as one of a regular procession of high and low pressure systems moving over the region from west to east throughout the year. The precipitation is uniform throughout the year and periods of either excessively dry or wet weather are not common. Ten or twelve days a month of measurable rainfall is the average at most stations within the area. The average annual precipitation for the area is 36 inches with temperatures ranging from a mean January temperature of $14^{o}F$ to a mean July temperature of $68^{o}F$. For the overall study area the corn heat unit values range from 2500-2700.

II. LITERATURE REVIEW

A. APPLICATION OF PRODUCTIVITY

Biological productivity measurements have been carried out by a number of workers using a variety of techniques. Whether the crop measured is one of agriculture, timber or wildlife, yield values are essential before any degree of management can be undertaken.

As quoted from Rennie (1963): "increasing pressure on land for various uses will prompt progressive communities to interpret their demands to attain the maximum value from a given area, thus making it essential for all land to be appraised for different types of utilization." In response to the challenge of alternate uses for land in Southern Ontario, Williams (1968) presents a case for land classification based upon the potential productivity for forest crops and Worrell (1956) implies the need for knowledge of productivity rates in his discussion of optimum intensity of forest land use on a regional basis.

Kabzems and Senyk (1967) are convinced that potential productivity of forest land has not been adequately, if at all, recognized and utilized in present day forest management practices and as forest management and land use become more intensive, Jackson (1965) points out the need for clear distinction between the ecological and physiological limits of productivity. Probably the most dynamic of all workers who have promoted the need for potential productivity studies of the physiographic site is Hills (1961).

B. SITE INDEX CORRELATIONS

Ultimately the planner would like to correlate a productivity rating, in quantitative terms, with one or more existing site factors. Many workers (Coile and Schumacher, 1953; Young, 1954; Doolittle, 1957; and Hannah, 1969) have correlated the overall site quality, as measured by site index, with various soil physical properties. As well, several researchers (Doolittle, 1957; McClurkin, 1963; Trimble, 1964; Carmean, 1967; and Broadfoot, 1969) have shown correlations of site index with mappable soil and topographic features.

Pawluk and Arneman (1961), Mader and Owen (1961), and Love and Williams (1968), indicated definite relationships between moisture regime and site index for the respective species and sites studied. Mader and Owen (op. cit.) and Love and Williams (op. cit.) also showed a definite relationship between volume production and soil moisture or drainage.

C. SITE-YIELD RELATIONSHIP

Locke (1941) suggested the approach of correlating soil physical properties, direction of slope and degree of stocking with existing yield tables. Modification of soil surveying techniques in order to facilitate timber yield predictions has been suggested by Van Eck and Whiteside (1958) and Duffy (1962). A hierarchal arrangement of the landscape has been proposed by Hills and Pierpoint (1960), Hills (1961), Cox et al. (1960) and Rowe (1962) for the purpose of land classification. Hills' work emphasizes the need for potential productivity studies based on the ecosystem approach. Becking (1962) reviewed the works of Patterson who related potential productivity primarily to climatic factors, and concluded that the climatic index that Patterson developed can only be used as a rough general estimation for productivity in general climatic regions.

D. PRODUCTIVITY PREDICTIONS

The reviewed literature so far deals only with the correlation of physical properties with yields that are already known for various sites. The problem dealt with in this study is one of predicting potential productivity in the case where yield information is not available.

Kleist (1961) described the function and mechanics of Backman's projection model[3] and applied it successfully to outline development of even-aged white and red pine stands in Ontario. Later the projection model was adopted by Love and Williams (1968) and Love (1969) to predict red pine plantation growth and heavy hardwood growth respectively, in Southern Ontario.

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[3]See III, C, 2 for description of Backman's projection model.

Ralstan and Korstian (1962), using Spurr's hypothesis that "volume growth can be estimated with reasonable precision if changes in stand height and basal area can be predicted accurately," were able to predict pulpwood yields in loblolly and shortleaf pine plantations. Based on the variations in stocking, average stand diameter and cordwood over basal area ratios associated with height changes of the dominant stand, the authors established by means of multiple regression, a system of equations for predicting pulpwood yields. Both Ralstan and Korstian (*op. cit.*) and Love and Williams (*op. cit.*) admit that the obtained field data lack information regarding future mortality of any one stand and are reserved in their prediction of future yields.

Beekhuis (1966) developed a yield prediction method based on the increase in stand height between successive thinnings and on the average height and net basal area of the stand during the interval. This method enabled him to predict yield under a wide variety of thinning regimes.

In making volume predictions it is extremely difficult to deal with natural mortality that will occur in the future. Beekhuis (*op. cit.*) dealt with this by expressing the average distance between trees as a percentage of stand height to indicate the degree of crowding. "A relative spacing minimum, after initial rapid decrease in young crops, indicates maximum density in other conifers, and this concept was accepted for *Pinus radiata* in order to account for mortality." Love (1969) dealt with mortality objectively in his study of the heavy hardwoods of Southern Ontario. By using a projection model he was able to show that the differences in volume, at any one age between fully stocked stands on similar sites, were attributed to mortality.

E. STEM ANALYSIS

The study of tree rings is not new. As early as 1811 archeological experts began utilizing tree rings for dating and the concept of investigating past meteorological records in trees was initiated in 1883. (Studhalter, 1956) Both he and Glock (1955) give thorough reviews of ring analyses; the latter author in connection with tree growth. Standard mensurational texts invariably review the use of tree ring measurement, and stem analysis generally, for the study of tree growth dimension and form.

More recently, Phipps (1965) carried out a ring analysis on selected tree stems, including red maple, in Ohio, for studying growth form of individual trees and certain environmental influences on growth. Curtis (1964), Solomon (1968) and Heger (1968) utilized the stem analysis approach for establishing site index curves for a number of species. Hannah (1969) computed the volume production of stemwood in red pine plantations using stem analysis and correlated net production with soil profile characteristics. Love and Williams (1968) used the approach as a basis for determining red pine productivity in Southern Ontario and Love (1969) used the same method for studying the potential productivity of the heavy hardwoods in the same region.

F. SILVICS OF SOFT MAPLE

1. Distribution

The distribution map shown by Harlow and Harrar (1958) indicates that both red and silver maple are distributed quite widely throughout eastern North America with the former species possessing one of the widest distributions of any species east of the midwest.

2. Site

Hutnik and Yawney (1961) state that red maple occurs over a wide range of soil textures and soil moisture conditions and, in fact, is more common under the extreme soil moisture conditions; either very dry or very wet. However, they state "red maple of sprout origin is capable of growing twice as fast on wet organic soils as on mineral soils or on organic soils of a lower moisture regime."

Silver maple appears on the imperfectly and poorly drained soils, both organic and mineral, and is found only occasionally as a minor component on the well-drained sites. Red maple, although reasonably tolerant to flooding, is less so than silver maple. Several workers have carried out inundation studies with the soft maples and other species found on wet sites. Hosner (1957) concluded that flooding was not a major factor in causing selective regeneration in the wetter bottomland forests, except possibly in swampy areas where water had been ponded for longer than a month during the growing season. He showed that flooding of bottomland hardwoods up to periods of 32 days did not appreciably affect the germination of soft maples. Hosner (1961) and Larsson (1969) showed that flooding has no adverse effect upon germination, other than delay, until the litter was exposed. McDermott (1959) discovered similar effects with red maple seedlings; noting that the seedlings recovered quickly from sustained saturation when exposed to subsequent well drained conditions. Larsson *et al*. (1964) using dendrometer tapes on several selected trees, showed that diameter growth of silver maple was greater in a season of flooding than in a dry season.

3. Succession

Hutnik and Yawney (*op. cit*.) suggest that red maple functions as an intermediate species in the succession but on the imperfectly drained soils of Southwestern Quebec the species, in second growth, plays the role of a pioneer due to the nature of its coppice establishment. Although there are no older mature stands within the study area to illustrate a climax forest, it is very likely that red maple would represent a climax forest on these imperfectly drained sites and give way to more shade tolerant species on the drier sites. Silver maple appears to operate in a one phase succession (usually in association with white elm (*Ulmus americana* L.)) due to its high tolerance to inundation.

4. Reproduction

Soft maple regenerates naturally by two methods: sexual and vegetative. Vegetative regeneration, or in the case of soft maple, coppicing, is brought about by a stand disturbance such as clear cutting or partial cutting. Soft maples are very prolific sprouters and, according to Hutnik and Yawney (1961), are second only to basswood (Tilia americana L.) within the northern hardwood region. Excessive sprouting can be prevented by carrying out cutting operations in the late spring or early summer. The same authors point out that the initial rapid growth, due to the already established root system of the parent tree, falls off as competition amongst individuals within a coppice clump increases. Solomon and Blum (1967) correlate stump diameter and vigor with number of sprouts and average height of sprouts respectively for red maple and arrive at practical conclusions for the wildlife and timber managers. Larsson[4] says that the early vigor from sprouting of silver maple will maintain itself for about 19 years, after which a thinning should be prescribed in order to retain the high growth rate.

Several researchers have attempted to propagate the soft maples artificially, with varying degrees of success. Snow (1941) showed that cuttings taken midway through the growing season (June 28) had a rooting efficiency of 75 per cent

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[4]Personal communication.

when optimum auxin treatments were applied. Pawley (1948) suggested that poor quality soft maple could be improved by grafting genetically superior scions on to the poor stock. He successfully grafted red x silver hybrid on four-month-old undisturbed silver maple wildings and was also successful with a graft of sugar maple (Acer saccharum Marsh.) on red maple.

5. Growth

Regarding the species' overall growth pattern, mensurational data is very scarce. It is generally accepted that coppice stands have a relatively short life span, with maturity being reached within fifty years.

Thomson (1952) showed that red maple reacts very favorably to thinning. In studies carried out in a second growth 35-year-old red maple coppice stand, he found that there was a two-fold increase on standing volume ten years following a heavy thinning in which all stems but one were removed from each clump. In a mixed stand on a well-drained site, Wilson (1953) showed that thinning, including coppice red maple, improved the diameter growth of the red maple; much more than that of any of the other species in the stand. Larsson et al. (1964) found that diameter growth of silver maple was favorably stimulated for up to nine years following heavy mechanical thinning in which all stems but one were removed from each clump.

6. Pathology

The desirable early rapid growth displayed by coppice stems is offset by the high incidence of decay in these stems. Shigo (1965) studies the decay and discoloration in sprout red maple and discovered that a high percentage of the sprouts examined were of low quality. Branch stubs provided infection courts and basal decay set in on the stump following removal of the parent tree. Shigo attributes this fungal infection of the butts to Stereum gausapatum Fr. Roth and Hepting (1943) ascribe the high rate of infection in coppice oak to the same fungus. Some pathological studies such as those carried out by Eslyn (1962) and Roth and Hepting (1969) relate internal stem decay to various morphological characteristics; a relationship which can be useful when considering the management of soft maple.

7. Soft Maple Potential Under Management

Management of soft maple on wet sites has been largely neglected, primarily because the species generally produce low quality wood. Ladouceur (1966) suggests that these degraded red maple association forests will have to be rehabilitated and this is inevitable with the industrial demand for raw material on the increase.

Larsson, et al. (1964) have carried out various measurements and breeding experiments with the soft maples, in particular silver maple, since the early 1950s. Thomson (1952), Wilson (1953), Minckler (1958) and Larsson (op. cit.) are the only workers who have published results showing the favorable response of thinning soft maple, with Thomson (op. cit.) and Larsson (op. cit.), having done their research in second growth coppice stands. Thomson (op. cit.) shows very favorable returns of 7 1/2 per cent annual growth increment, upon the thinning of coppice red maple and Larsson[5] recommends heavy thinnings of coppice growth as early as 19 years of age, assuming that the final market is for sawlogs.

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[5]Personal communication.

III. METHODOLOGY

A. GENERAL

Within the study area, benchmarks[6] and a full complement of stands of soft maple of different ages for any one site were absent. Without these, a potential productivity study cannot be undertaken by means of measuring present volume alone.

For this study a stem analysis approach, which indicates stand growth patterns, has been adopted. A projection model has been used to predict future volumes based upon the growth patterns indicated by the stem analysis.

The procedure that was used involved the establishment of a number of plots on different imperfectly drained sites. From each plot several trees were selected for a stem analysis study which yielded past growth trends. After the growth trend data had been corrected for mortality the projection model was applied to the data and volumes up to age 50 years were predicted.

B. FIELD AND LABORATORY PROCEDURE

1. Preliminary Study

Prior to the establishment of plots the two areas under

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[6]Mature or overmature fully stocked stands of the desired species on the site(s) being studied.

consideration (Soulanges Canal and Chateauguay Valley) were subjected to a thorough ground reconnaissance. Notation of species composition and stand stocking was of first importance, followed by origin of stock, degree of stand disturbance, site topography, height of dominants, stand structure and specific age.

2. Plot Selection Criteria

In determining the potential productivity for any site it is imperative that the areas to be considered for an intensive examination fulfill the requirements of full stocking (Fig. 1) and minimal environmental disturbance since stand inception. Stands were classified for stocking on a subjective basis only and the final judgment of stocking was made following close examination of all stands that were to be considered. The difficulty with judging stocking levels in the majority of the sample areas was amplified by the nature of coppice growth. A coppice stand's structural traits are quite different from those of a high forest in which stocking can be directly related to crown closure and standing basal area.

Further criteria for plot selection included age and stand composition. The stands selected had to meet the requirements of even-aged structure and second growth and a minimum of 85 percent of the total live stems had to be comprised of soft maple. In order to carry out an ideal potential productivity study, on each site selected, a set of plots covering all age classes, along with benchmark plots, would be desirable.

Fig. 1. Fully stocked stand of soft maple.
Plot 1.

Fig. 1. Fully stocked stand of soft maple.
Plot 1.

Unfortunately the past history of cutting practices dictated only a narrow range of ages that could be selected. In this study a cross section of sites was sampled but it was impossible to obtain a series of age classes for any one site. However, disregarding sites, plot ages ranged from 18 years to 45 years.

3. Plot Establishment

Once the general area for plot establishment had been chosen, work by Turner (1968) and Weetman and Lowry[7] suggested that sample areas of 1/30th acre would be adequate. The method used by Turner (op. cit.) was tested by establishing a centre point and measuring the diameter at breast height (d.b.h.) of all trees within 1/40th acre circular plot. The plot area was increased to 1/30th acre, 1/25th acre, 1/20th acre, 1/15th acre and 1/10th acre by increasing the radius appropriately. Basal areas were calculated for all plots on a per acre basis but no significant difference was found between the basal areas per acre for any two plot sizes. Except for plots no. 1 and no. 2 circular plots were employed because one worker could establish and measure a plot without becoming involved with the problems inherent in the establishment of rectilinear plots. Random sampling for the selection of plots could not be applied because of the requirement of fully stocked stands.

The assumption has been made that local sites within any macrosite are homogeneous.

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[7] Personal communication.

4. Plot Measurements

Following establishment, a general description of the plot and its surroundings was made regarding species composition, age structure, site aspect and stand origin (App. 2 gives plot descriptions). Each stem within the plot boundary was tallied for its d.b.h. (diameter at 4.5') and categorized as either living or dead (standing or otherwise).

5. Individual Tree Sampling

In order that the stand's past history of growth could be studied in detail and that projection models could be applied to predict the stand's growth into the future, a sample of trees from each plot was selected for detailed stem analysis. Because of the time involved with the study of growth rings, a minimum of eight sample trees from each plot was selected, with the number of sample trees per plot ranging from eight to sixteen. Similar growth studies now being carried out by A.F. Beckwith of the Ontario Dept. of Lands and Forests indicate that a minimum of eight trees per plot is necessary to illustrate the true growth pattern of both the individuals in the stand and the stand as a whole.

The sample trees from each plot represented the full diameter class range of living trees tallied with the pattern of selection following the bell-shaped curve of diameter distribution of an even-aged stand. All trees with a minimum of average stand diameter were classified as dominants or co-dominants with the difference in height between these two height classes being insignificant. Boles of trees selected for sampling had to be as cylindrical as possible in order to obtain accurate periodic increment measurements. This requirement is difficult to fulfill due to the growth habit of coppice stems (Fig. 2 and Fig. 3).

In the selection of sample trees, unless the stand was of seed origin (probable in plot no. 13) single tree clumps were considered atypical in a stand of coppice origin and were avoided. Since there was only a relatively small selection of sample trees per plot it was accepted that these samples would be representative of trees within the plot.

After selecting a stem for laboratory analyses, it was mapped in relation to its neighboring trees and then felled, leaving a stump as close to the ground as the nature of a coppice clump would allow (Fig. 3). Cross section discs measuring approximately 1 1/2" in thickness were removed from the tree at stump height, breast height and at eight foot intervals above breast height to the top of the tree (Fig. 4 illustrates a felled and sectioned tree). Discs of each tree from each plot were coded in ascending order from the stump disc (e.g., 2-3-4 represents the fourth disc of the third sample tree in plot no. 2). In the case of sample trees with a branch or branches containing an eight foot log with a top diameter of 2.5" the branch(es) were sectioned up also and numbered accordingly with an additional digit indicating branch number. Other field measurements taken on the sample trees included: stump height, d.b.h.o.b. (diameter breast height outside bark), and length of top (that portion

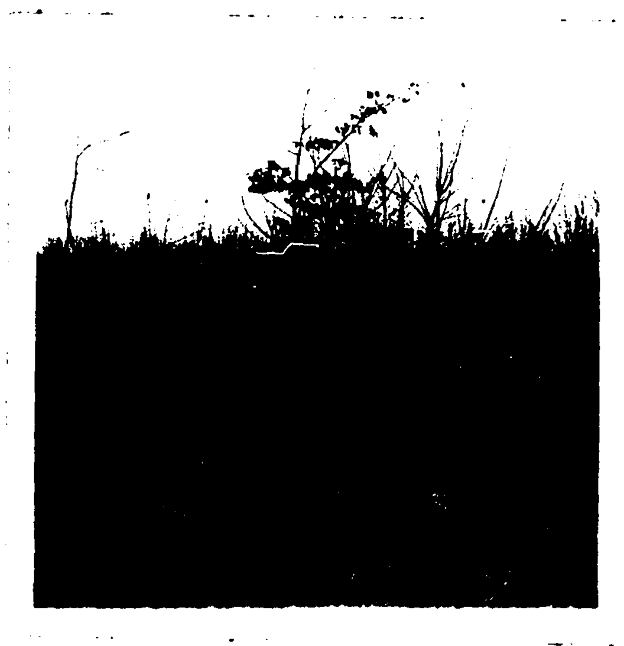


Fig. 2. Soft maple coppice 3 years old.

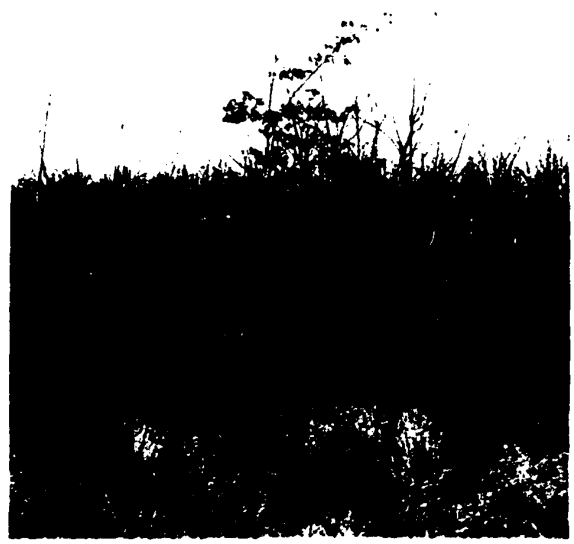


Fig. 2. Soft maple coppice 3 years old.

Fig. 3. Soft maple coppice 28 years old.

Fig. 3. Soft maple coppice [illegible] years old.

Fig. 4. Fully stocked stand of soft maple. Plot 6, 28 years old. Note felled and sectioned stems and soil pit.

Fig. 4. Fully stocked stand of soft maple. Plot 6, 28 years old. Note felled and sectioned stems and soil pit.

beyond the last complete eight foot section in the main stem or branch).

6. Soil Study

For each plot a soil pit was dug in a location representative of the topography and local microsite of the plot (see Fig. 5). The following features were examined:

(1) nature of horizons including depth, texture, color, stoniness and regularity,

(2) moisture regime,

(3) depth to carbonates.

7. Stem Analysis

A total of 1049 discs of 122 trees from 10 different plots were collected in the field. If the samples were not to be examined immediately, they were frozen to prevent shrinkage and decay.

Each sample prior to measurement was planed or sanded to facilitate the examination of the annual growth rings. The procedure for the measurement of each disc was as follows:

The average d.i.b. (diameter inside bark) was found by recording two diameter measurements at right angles to one another. Using the average diameter, a line corresponding to the average radius was scribed from the disc's physiological centre (pith) to the inside bark. With the aid of a binocular microscope, ranging in power from x6 to x50, each annual growth ring was defined and five year accumulations, counting from the inside bark and proceeding towards the pith, were marked off along the radius line. Radial measurements were then recorded for: present age, age five years ago, age ten years ago, etc., back to age zero. In this study annual rings were defined only to the accuracy which the combination of binocular microscope and the experience of the worker would permit, but for the majority of samples there was no problem with annual ring distinction. False rings and "lean years" were interpreted with as much objectivity as possible without going into the elaboration of slide preparation and the identification of microscopic features which are used to differentiate springwood and summerwood.

Age differences from tree to tree within any one plot were accounted for by the successional sprouting that often takes place for several years following the removal of the parent crop.

For a few trees the stump disc, and infrequently the breast height disc, contained advanced decay that made it impossible to define the annual growth rings within those samples for the initial 5 to 15 years of the life of the tree. If approximate values could not be estimated for the decayed portion then the appropriate position on the record sheet was left void. All records of species, ages, section lengths and diameters at five year intervals for each disc were entered onto key punch cards for the purpose of computing tree section volumes and, ultimately, whole tree volumes.

C. CONSIDERATIONS FOR VOLUME PROJECTION

For use as a true indicator of the site's potential, total stem productivity at rotation age was determined. According to Love and Williams (1968) total volume is more favorable because of its constant value with time, whereas merchantable volume will change with fluctuating utilization standards.

Due to the scarcity of age classes for any one physiographic site, the potential productivity values for the sites studied were determined with the aid of a prediction model which was used along with dead stem counts for determining past stand growth patterns.

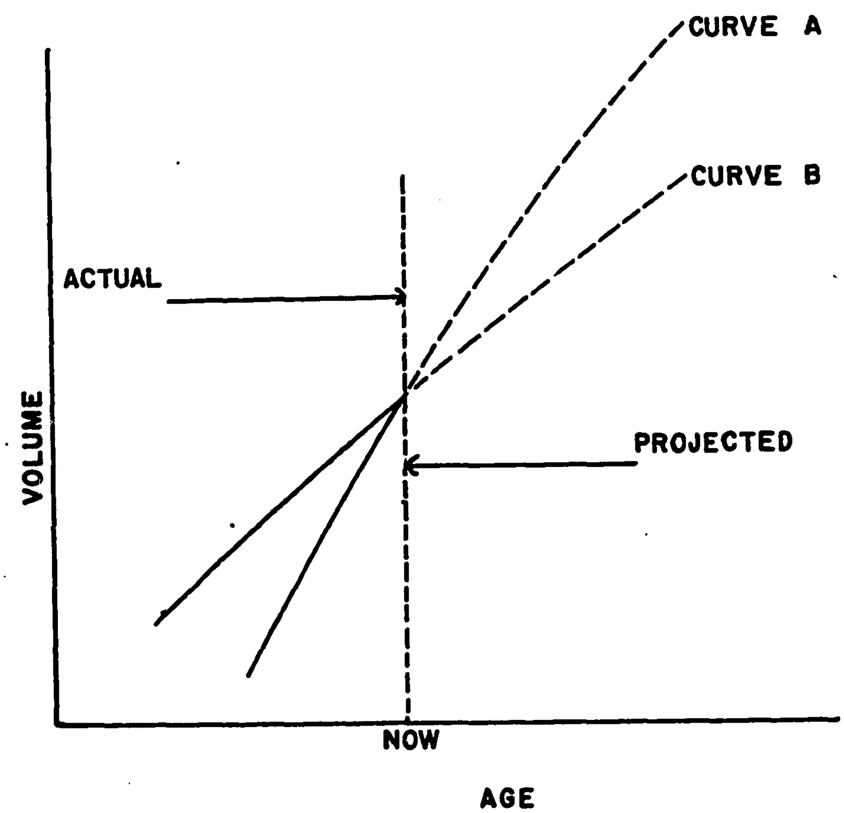
1. Mortality

In any one plot the live trees measured indicate the productivity of that site at the time of measurement but in the future, mortality will take its toll on a proportion of the present stand. At any time prior to the time of measurement a tally of live stems would have shown a greater number of stems than are now present and a greater volume than is indicated by the hardwood volume tables shown in Tables 3 and 4.

It is essential that the true volume/age pattern for time prior to "now" ("now" refers to time of cutting) be established or else predictions of future volumes, in accordance with the projection model (see Section III, C, 2) will be in error. Fig. 5 illustrates, in general, what would occur if only the live stems "now" were used for constructing future volume/age

FIGURE 5

EFFECT OF PAST MORTALITY ON FUTURE YIELD PREDICTIONS



Curve A: Volume/age curve (actual) is based only upon the live stems "now", and is relatively steep. Following the application of Backman's projection model, the resulting curve for future ages yields unrealistic volume/age relationships.

Curve B: Volume/age curve (actual) is based upon the live stems "now" and the dead stems "now" adjusted for the past ten years. Following the application of Backman's projection model, the resulting curve for future ages yields realistic volume/age relationships.

curves and shows the necessity for considering the role of dead stems as contributors to live stem productivity in past periods.

To reconstruct the actual volume/age pattern for a stand's past history it was assumed that all dead stems measured at the time of plot analysis were contributing to live stem volume ten years ago. This assumption is based upon the fact that most tree stems, particularly those of small diameters, upon death will deteriorate beyond recognition over a period of ten years. Accepting this, in any one plot, half of the tallied dead stem volume was living five years prior to the time of measurement and all stems tallied as dead were living ten years prior to the time of measurement. For periods prior to ten years ago, the dead stem volume tallied "now" would be treated as live and would be decreased in accordance with the periodic increment reductions calculated from the stem analysis.

To trace back the volume/age trend curve prior to ten years ago is unreliable since dead stems present at that time were not tallied "now" in accordance with the assumption made above. There is no indication as to what extent dead stems of ten years ago have contributed to the total productivity of the stand.

2. Backman's Projection Model

Volume predictions to age 50 years have been made with the aid of Backman's projection model (Fig. 6) in the same manner as has been carried out by Love and Williams (1968) and

Love (1969). Although a rotation age in excess of 50 years may be desirable in accordance with possible changing market trends, using an age of 50 years will minimize any inaccuracies that may be caused by applying a projection over a longer period. Backman's projection model, according to Kleist (1961), accepts the sigmoidal pattern of total production over age and volume increment is plotted over time to obtain the increment curve. By using double logarithmic scale a logarithmic parabola is developed which leads to the relationship that the logarithm of increment is proportional to the square of the logarithm of time. A straight line relationship is developed by plotting percent of ultimate value, rather than absolute value, over time. This procedure has been carried out by using log. x probability scale (see Fig. 6 and App. 7) for all plots except plot no. 13, using the values from Table 3 corrected for mortality as described in Section III, C, 1. The ultimate value of stand volume was arrived at by trial and error and the straight line relationship will not evolve unless only the true ultimate value is used.

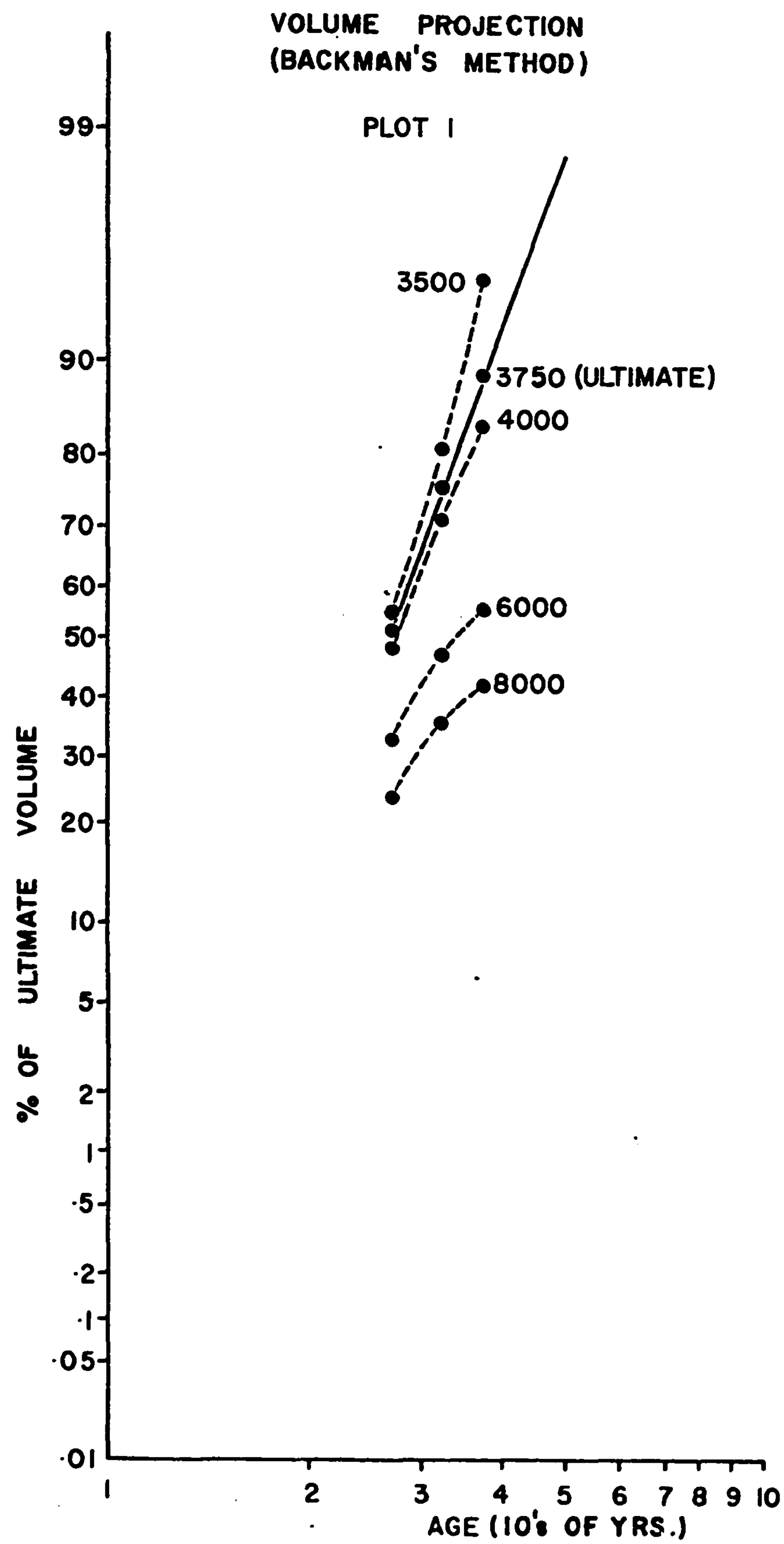
The projection model is conditional to use if only:

1. Culmination of current annual increment (CAI) has been reached.

2. No permanent significant changes have occurred in the environment due to thinnings, amelioration or deterioration of the site.

Upon determining the correct ultimate value, the straight line relationship created when per cent ultimate is plotted over

FIGURE 6


VOLUME PROJECTION
(BACKMAN'S METHOD)
PLOT I
3500
3750 (ULTIMATE)
4000
6000
8000
99
90
80
70
60
50
40
30
20
10
5
2
1
·5
·2
·1
·05
·01
% OF ULTIMATE VOLUME
1
2
3
4
5
6
7
8
9
10
AGE (10's OF YRS.)

time can be projected. Per cent ultimate for any future time can be read from the graph to a maximum of 95.8%.

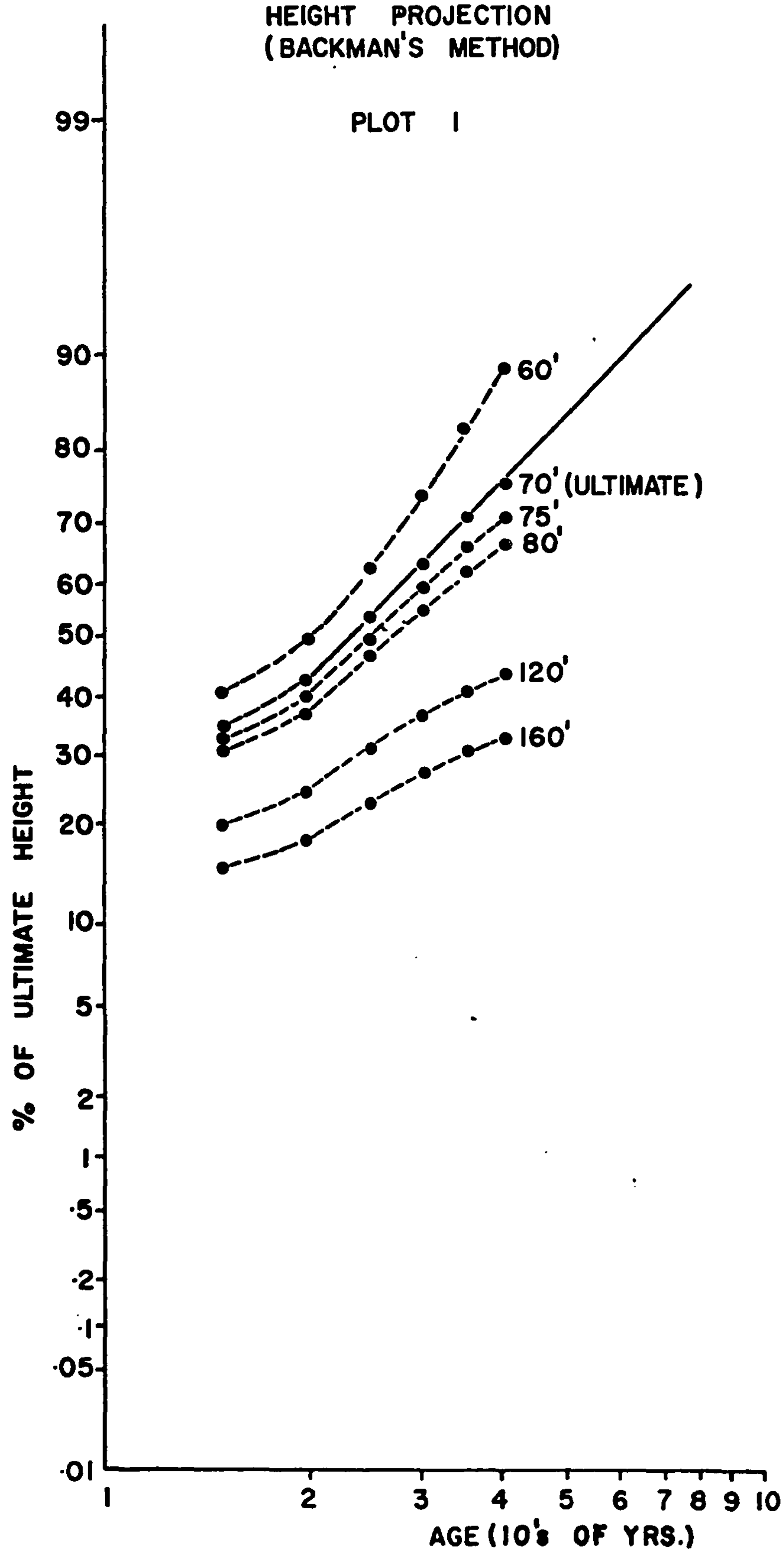
D. SITE INDEX DETERMINATIONS

The one function of growth unanimously accepted as an indicator of site quality, is height. Using the program output data of height and age it is possible to produce highly accurate site index curves for each plot. The four tallest trees of each plot at each five year interval from age ten onwards were averaged for height. The resulting curve of height plotted over time gives the site index curve for that plot. Having established site index curves for each plot up to the time of cutting, Backman's projection model was applied to predict heights at future ages up to age 50 years. Fig. 7 illustrates projected heights of the trees of plot no. 1 into the future and App. 8 shows the same for all plots.

FIGURE 7

HEIGHT PROJECTION
(BACKMAN'S METHOD)

PLOT I



IV. RESULTS

A. PLOT INVENTORIES

The results for each plot inventory for both live and dead stems are shown in the graphs of Fig. 8. The bell shaped diameter distribution shown for each plot is typical of even aged stands.

B. SOIL DESCRIPTIONS

Soil profile descriptions are given in App. 3.

C. COMPUTER OUTPUT DATA

A computer program that was designed for a similar productivity study on the heavy hardwoods of Southern Ontario was utilized for examining the data from this study.

From the stem analyses individual tree volumes were calculated for the time at cutting (designated in all tables as "now") and for each five year interval prior to cutting. Table 1 illustrates these individual tree volumes for plot no. 1 and App. 4 contains individual tree volumes for all study plots. Using the individual tree volumes of each plot, volume tables for the range of diameters of the live trees were produced for the same time intervals. Fig. 9 is a computer output graphic illustration (period regression curves) showing the form

FIGURE 8

DIAMETER CLASS DISTRIBUTION
(PER ACRE)

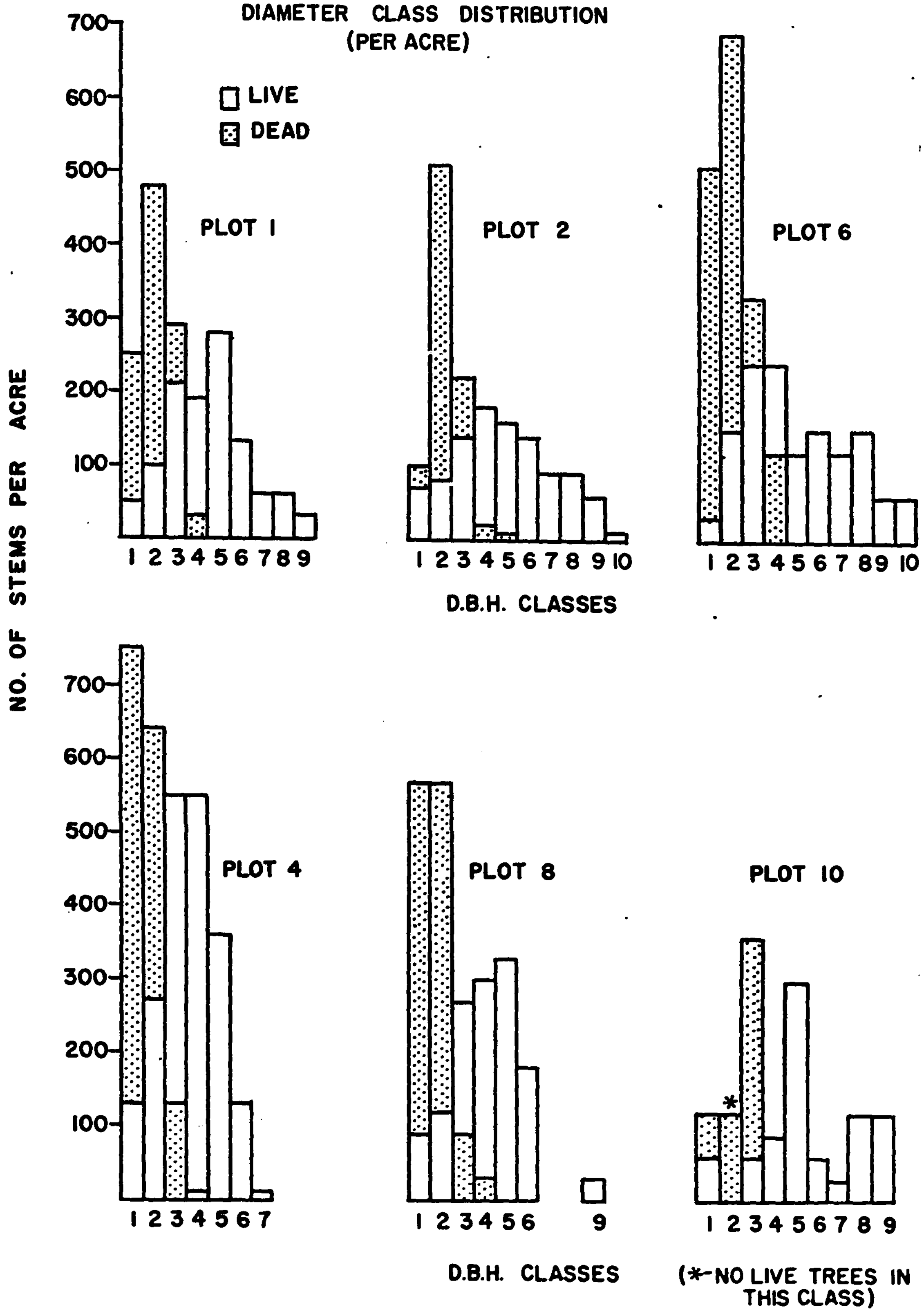
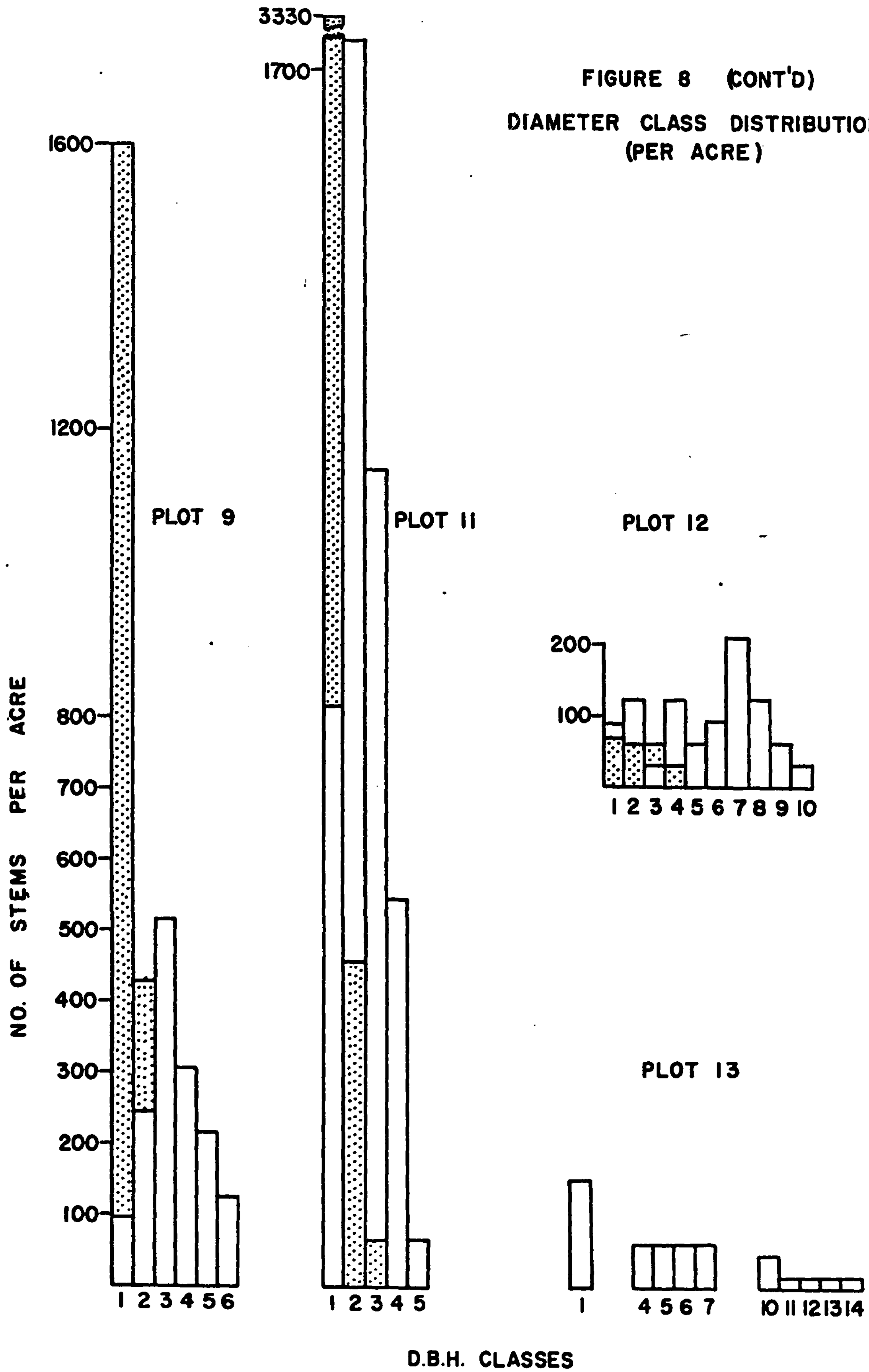


FIGURE 8 (CONT'D)

DIAMETER CLASS DISTRIBUTION (PER ACRE)



of volume over diameter at different time intervals for plot no. 1. App. 6 contains similar illustrations for all plots. The plotting of values for the regression curves is only accurate within the limitations of the computer. Volume table values, as shown in Table 2 for plot no. 1, were calculated mathematically. Tables 3 and 4 show volume tables for the individual plots, based upon the regressions, used for the volume table values, stand stocking and diameter distribution (Fig. 8). Diameter and height values for individual trees were also calculated for five year intervals prior to "now" and these are illustrated in Table 5 for plot no. 1 as well as in App. 5 for all study plots.

D. DETERMINATION OF POTENTIAL PRODUCTIVITY

Following the determination of the correct ultimate volumes as indicated by the straight line relationships of Fig. 6 and the figures of App. 9, percentages of the ultimate value for different ages for each plot were read off and converted to absolute volumes. Volumes for different ages were then plotted over age, yielding the curvilinear relations shown in Fig. 9, which shows for the plots studied, the potential productivity for different ages to the rotation age of 50 years.

Special treatment has been given to plot no. 9 because of its young age. Backman's projection model cannot correctly be applied because the increment trend of the stand up to the time of cutting has not shown a culmination in CAI. Although

Table 1. Plot 1-age 37 yrs. Hardwood volumes (cu. ft.) at time of cutting and at each five year interval prior to cutting.

Tree		Now	-5	-10	-15	-20	-25	-30	-35	-40	-45
1		4.213	3.265	2.031	1.048	0.474	0.195	0.079	0.002		
	Br 1	0.870	0.590	0.254	0.060	0.009					
2		1.801	1.467	0.847	0.423	0.208	0.088	0.023	0.008		
3		0.622	0.531	0.311	0.146	0.071	0.018	0.001			
4		0.975	0.847	0.508	0.262	0.135	0.034				
5		5.239	3.942	2.294	1.068	0.539	0.220	0.062	0.005		
	Br 1	0.703	0.375	0.145	0.013						
6		1.965	1.723	1.323	0.877	0.504	0.280	0.179	0.100	0.009	
7		0.555	0.429	0.244	0.113	0.042	0.011				
8		4.128	3.190	1.976	0.897	0.414	0.212	0.091	0.030	0.004	

FIGURE 9

PERIOD REGRESSION CURVES

PLOT I

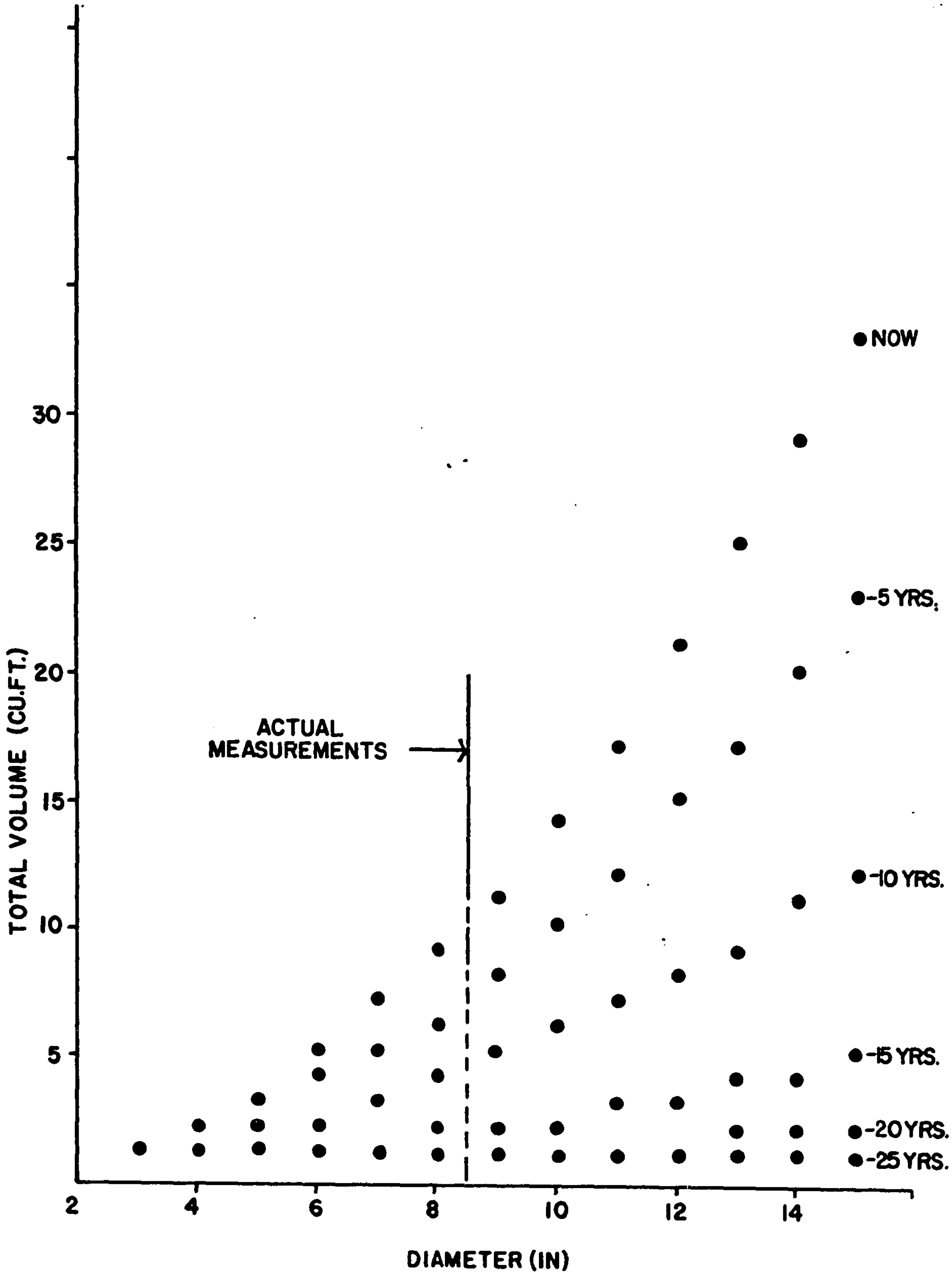


Table 2. Volume per tree (gross total cu. ft.). Plot no. 1.

	dbh	Now	-5	-10	-15	-20	-25	-30
actual analysis	1	0.0	0.1	0.1	0.1	0.0	0.0	0.0
	2	0.4	0.4	0.3	0.2	0.1	0.1	0.1
	3	1.0	0.9	0.6	0.3	0.2	0.1	0.1
	4	2.0	1.6	1.0	0.5	0.3	0.1	0.1
	5	3.3	2.5	1.5	0.7	0.4	0.2	0.1
	6	4.8	3.6	2.1	1.0	0.5	0.2	0.1
	7	6.7	5.0	2.9	1.3	0.6	0.3	0.1
regression	8	8.9	6.5	3.7	1.6	0.7	0.3	0.1
	9	11.4	8.2	4.6	2.0	0.9	0.4	0.1
	10	14.2	10.1	5.6	2.3	1.1	0.4	0.1
	11	17.4	12.3	6.8	2.8	1.2	0.5	0.1
	12	20.8	14.6	8.0	3.2	1.4	0.6	0.1
	13	24.5	17.1	9.3	3.7	1.6	0.6	0.0
	14	28.6	19.9	10.8	4.2	1.9	0.7	0.0
	15	32.9	22.8	12.3	4.8	2.1	0.8	0.0
	16	37.6	25.9	14.0	5.4	2.3	0.9	0.0

Irregularities in smaller dbh classes (see outlined area in Table 2) in which case the volumes at an earlier date are greater than the present (now) are due to the lack of a wide enough range of diameter classes of trees originally selected for the stem analysis. In other words, a regression was applied to trees not reasonably represented by the analysis. This phenomenon appears in the data of five plots but only to a minor degree in the one and two inch diameter classes. The effect that these discrepancies have on the resulting volume/acre is negligible.

Table 3. Plot volumes cu. ft./acre at time of cutting and at each five year interval prior to cutting (live stems only).

Plot	spa	Now	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50	-55
1	1090	3308.0	2541.0	1530.0	743.0	356.0	161.0	76.0	33.0	8.0			
2	1030	3991.3	3427.3	2749.6	1934.0	1207.0	642.2	317.7	100.8	3.9			
4	2000	3175.0	2482.0	1786.8	1054.0	519.7	198.3	34.2	1.6				
6	1272	5201.1	3767.3	2240.8	1018.2	269.4	49.4						
8	1333	2742.6	1989.9	1238.9	588.7	288.4	69.8	11.0					
9	1484	2278.7	1282.4	484.3	57.0								
10	848	4201.3	3327.0	2312.7	1248.5	599.7	240.9	102.3	29.2	0.3			
11	4333	2553.8	1827.2	984.0	374.6	1.3							
12	939	5049.4	4063.8	3209.1	2354.5	1409.2	880.9	412.2	124.3	20.5	0.5		
13	515	3684.4	3197.1	2625.9	2005.0	1352.7	831.3	368.0	191.5	78.8	25.0	10.8	3.6

Table 4. Plot volumes cu. ft./acre at time of cutting and at each five year interval prior to cutting. (dead stems only).

Plot	spa	Now	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50
1	1050	528.0	528.0	376.0	220.0	123.0	59.0	41.0	26.0	8.0		
2	830	548.9	548.9	577.1	589.1	473.3	300.1	163.6	57.0	2.4		
4	1530	435.3	435.3	393.5	270.7	149.0	67.5	15.1	0.4			
6	1666	501.1	501.1	280.2	124.8	76.2	20.7					
8	1272	318.3	318.3	198.1	70.6	39.2	2.4	0.3				
9	1934	241.9	241.9	66.1	3.5							
10	636	515.5	515.5	442.4	244.7	119.4	36.5	14.4	5.1	0.2		
11	3878	332.4	332.4	229.5	137.7	0.5						
12	151	143.4	143.4	119.5	102.8	76.5	52.2	30.0	12.2	2.7	0.1	
13	--	--	--	--	--	--	--	--	--	--	--	

Table 5. Plot no. 1. Hardwood d.b.h.i.b. diameters and heights at time of cutting and at each 5 year interval prior to cutting.
diameter (in.) / height (ft.)

Tree no.	d.b.h.o.b.	Now	-5	-10	-15	-20	-25	-30	-35	-40
1	5.90	5.50	4.80	4.00	3.10	2.20	1.55	0.80		
		53.60	49.92	46.24	37.30	31.44	25.00	18.17	1.20	
	Br 1	2.70	2.30	1.60	0.70					
		37.90	32.06	23.86	16.55	12.83				
2	4.10	3.90	3.55	2.90	2.10	1.60	1.10	0.50		
		49.80	47.11	41.40	33.79	26.37	17.82	12.70	5.87	
3	2.60	2.40	2.25	1.80	1.40	1.10	0.60			
		39.40	36.13	30.27	23.63	17.39	10.65	0.70		
4	3.10	2.90	2.75	2.20	1.75	1.45	0.80			
		41.40	38.83	31.83	25.00	19.87	14.75	0.90		
5	6.80	6.35	5.65	4.70	3.70	2.70	1.80	1.05		
		54.10	48.23	41.40	33.20	22.95	18.17	14.75	9.42	
	Br 1	2.55	1.90	1.10	0.15					
		29.10	24.73	18.87	11.14	1.30				
6	3.70	3.55	3.40	3.15	2.75	2.30	1.90	1.70	1.30	
		45.80	45.61	43.86	39.76	33.20	25.59	19.53	12.70	1.20
7	2.50	2.25	2.10	1.75	1.20	0.70				
		36.90	33.00	29.10	23.97	16.80	7.78			
8	5.40	5.40	4.80	3.85	3.05	2.30	1.70	1.15	0.60	
		54.00	50.06	45.50	38.67	29.10	23.24	16.80	10.65	5.52

the total volume of plot no. 6 at age 18 years is greater than that of plot no. 9 for the same age, the true indicator of site, height at 50 years, shows an index greater for plot no. 9 than for plot no. 6 (Fig. 12). Considering these differences a potential productivity curve for plot no. 9 has been drawn subjectively as shown in Fig. 10. This curve probably shows conservative estimates for volume production at age 50 years.

Regarding plot no. 12, a very high ultimate volume was required in order to obtain the desired straight line relationship for projection purposes. The high ultimate value (24,000 cu. ft.) is attributed to the fact that the stand within which the plot was located has experienced an increase in CAI following what appeared to be a culmination of CAI. This also accounts for the steepness of the productivity curve in Fig. 10. Since the stand was 46 years of age, there was no necessity to apply Backman's model in order to arrive at a volume prediction for 50 years. Instead, the volume at 50 years of age was estimated, using the productivity curve as a guideline.

For practical purposes all plots have been placed into three productivity classes as shown in Table 6. As a result as indicated in Fig. 10 each potential productivity class is represented by two or more of the plots analyzed. The data read from the volume over age curves was used for the construction of general curves for the three productivity classes (Fig. 11). The steepness of the volume over age curve for potential productivity class II in Fig. 11 is primarily attributed to the

FIGURE 10

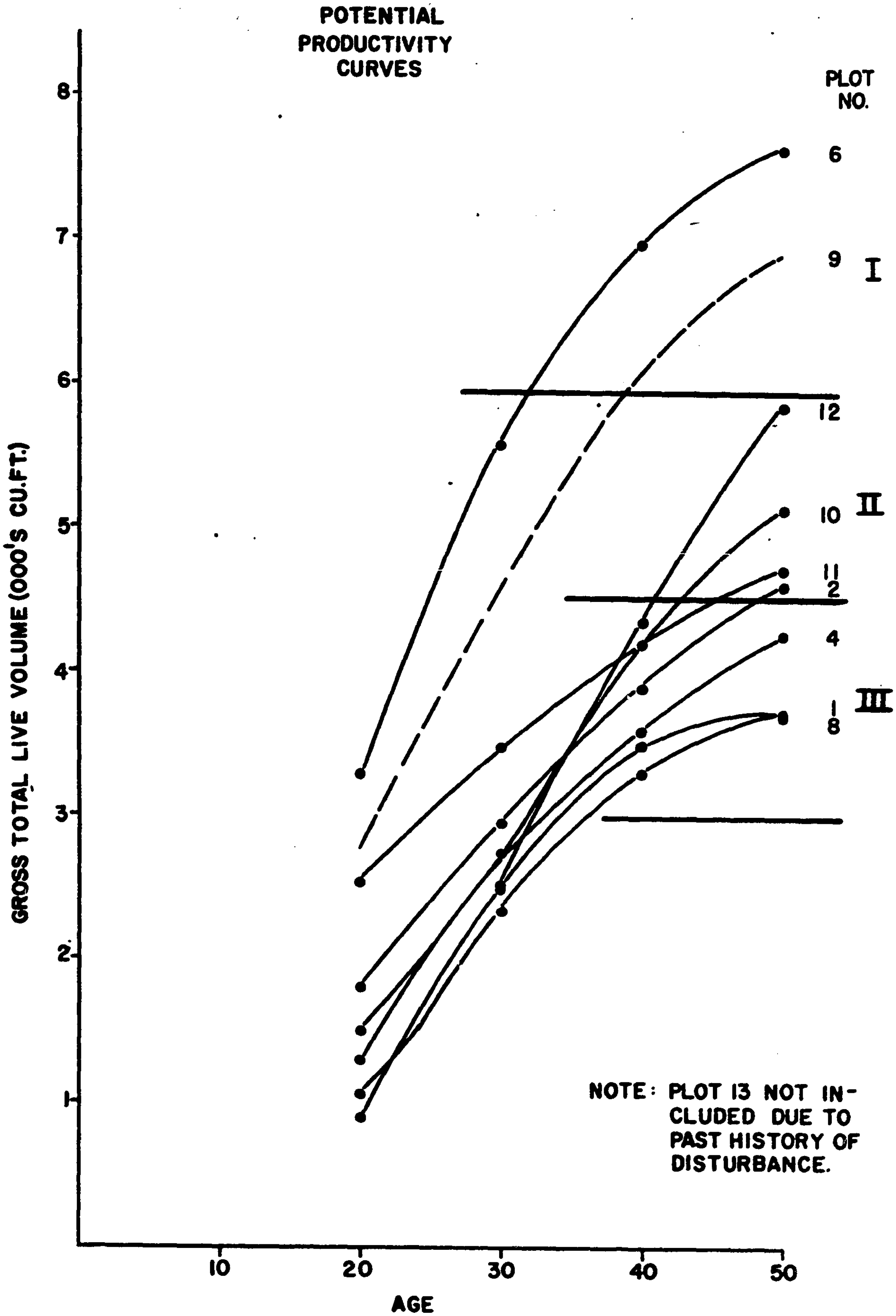
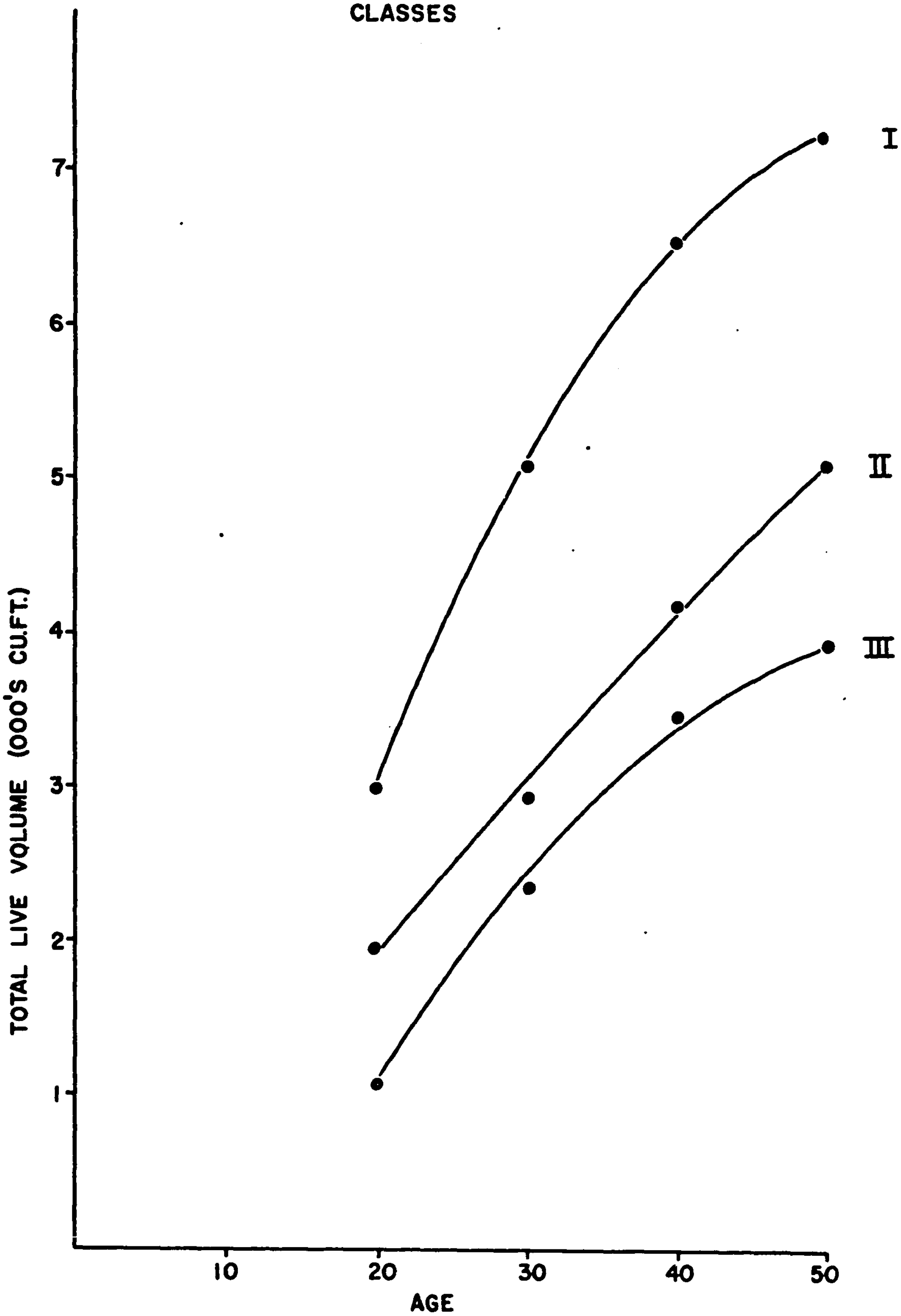

POTENTIAL
PRODUCTIVITY
CURVES
PLOT
NO.
6
9
I
12
10
II
11
2
4
1
8
III
NOTE: PLOT 13 NOT INCLUDED DUE TO PAST HISTORY OF DISTURBANCE.
GROSS TOTAL LIVE VOLUME (000'S CU.FT.)
1
2
3
4
5
6
7
8
10
20
30
40
50
AGE

FIGURE 11

POTENTIAL PRODUCTIVITY CLASSES



steepness of the individual volume over age curve of plot no. 12 (Fig. 10).

Table 6. Potential productivity class volume limits.

Potential Productivity Class	Total Live Volume (cu. ft.) (50 yrs.)
I	6000+
II	4500-6000
III	3000-4500

E. SOFT MAPLE YIELD TABLES

Ideally the yield table should show, for various sites, the development of the stand periodically throughout its history. The table should indicate such features as stand stocking, basal area, volume, and height of dominants at age intervals. Essentially the yield table is the basis from which any timber management or economic decision may be made for a particular site, and is used as a tool for assisting with land use decisions where forestry is to be given any amount of consideration.

Soft maple yield tables developed from the potential productivity curves of Fig. 11 are presented in Tables 7, 8 and 9. With regard to these tables certain limitations as follows should be kept in mind.

(1) Stands are of second growth coppice origin.

(2) Stands are, at a minimum, fully stocked.

SOFT MAPLE YIELD TABLES

Table 7. Potential production class I. cu. ft./acre/yr.

Age	Dominant ht. (ft.)	Volume cu. ft/acre	CAI*	MAI**
20	52	3000	240	150
25	58	4200	180	168
30	64	5100	160	170
35	69	5900	120	169
40	73	6500	80	163
45	77	6900	60	154
50	80	7200		144

Table 8. Potential production class II. cu. ft./acre/yr.

Age	Dominant ht. (ft.)	Volume cu. ft/acre	CAI*	MAI**
20	39	1900	120	95
25	46	2500	100	100
30	52	3000	120	100
35	58	3600	100	103
40	62	4100	100	102
45	67	4600	100	102
50	69	5100		102

Table 9. Potential production class III. cu. ft/acre/yr.

Age	Dominant ht. (ft.)	Volume cu. ft/acre	CAI*	MAI**
20	34	1100	140	55
25	40	1800	120	72
30	45	2400	120	80
35	50	3000	80	86
40	54	3400	60	85
45	57	3700	40	82
50	59	3900		78

*Gross current annual increment.
**Gross mean annual increment.

(3) Stands have not undergone any major change since their inception.

(4) All assumptions made with regard to past and future mortality are realistic.

F. SITE INDEX CURVES

From the graphs of App. 8, values for percentage of ultimate height at different ages were converted to absolute values. These values were plotted over age, resulting in the site index curves shown in Fig. 12. As with the potential productivity curves, the site index curves have also been placed into classes. Fig. 13 shows the grouping of the site index curves into classes I, II and III which are defined as the total height (60', 70' and 80' respectively) at 50 years of age.

FIGURE 12

SITE INDEX CURVES

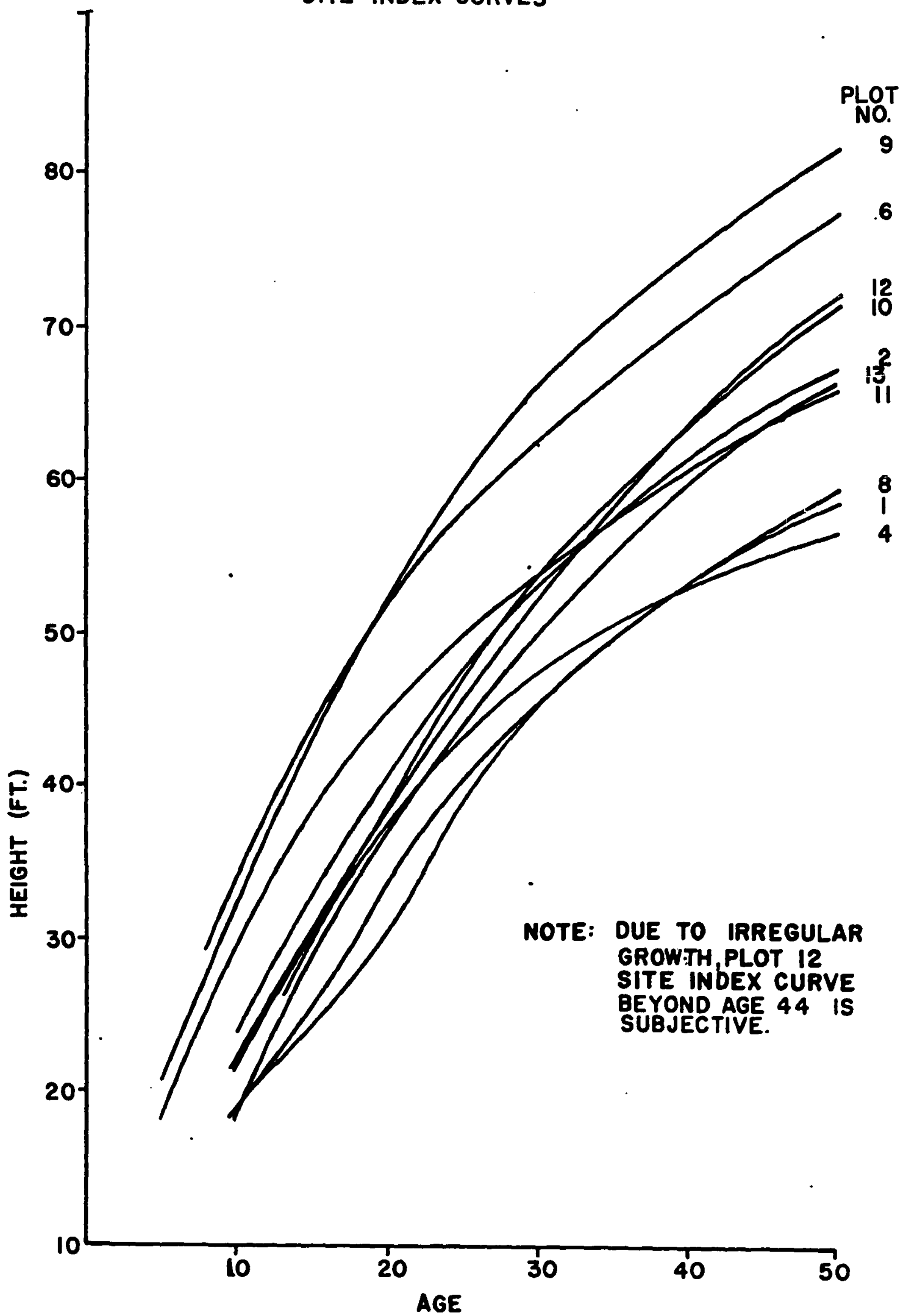
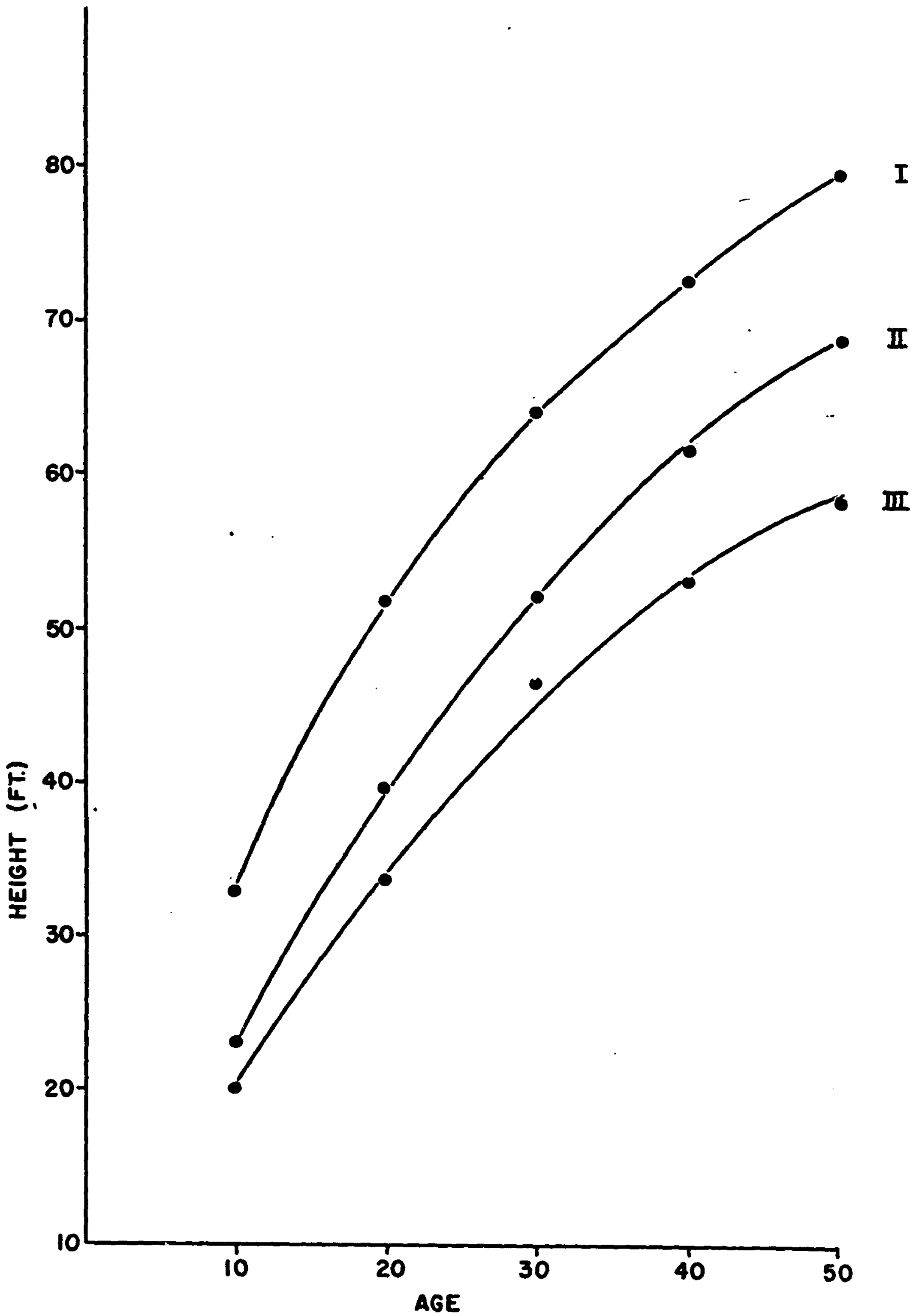


FIGURE 13

SITE INDEX CLASSES



V. SOME APPLICATIONS OF RESULTS

A. CORRELATION BETWEEN SITE INDEX AND PRODUCTIVITY CLASS

With the site index classes of I, II and III being assigned to the curves of Fig. 13 for 60, 70 and 80 site indices respectively, a perfect correlation between the site index classes and the potential productivity classes is observed in Table 10. For all plots, potential productivity classes are numerically equivalent to their site classes. Thus, if a stand's age and height are known a reasonable estimate of the site's potential productivity can be made.

Table 10. Relationship between site index and productivity class.

Site class	Ht. range of dominants (ft.)	Productivity class	Vol. (total) range (cu. ft.)
I	80-90	I	6000+
II	70-80	II	4500-6000
III	60-70	III	3000-4500

B. RELATIONSHIP BETWEEN MOISTURE REGIME AND POTENTIAL PRODUCTIVITY MEASURES

Total production at 50 years and site index (height at 50 years) were plotted over moisture regime, for each plot

(Figs. 14 and 15 respectively). Linear regression equations were established in each case. The R^2 value[8] (coefficient of determination) indicates that there is a strong correlation between volume and moisture regime and between site index and moisture regime. In each case, if plot. no. 12 is excluded from the calculations, the R^2 value increases from 0.89 to 0.96 and from 0.88 to 0.94 for the dependent variables of volume and site index respectively. It is felt that there is strong justification for not including plot no. 12 in the linear regression calculations because of the peculiar growth pattern exhibited (described in Section IV, D).

In either case, volume on moisture regime or site index on moisture regime, the relationships support Applequist's (1960) statement that "certain species on wet sites do not necessarily yield higher returns when situated on dry sites."

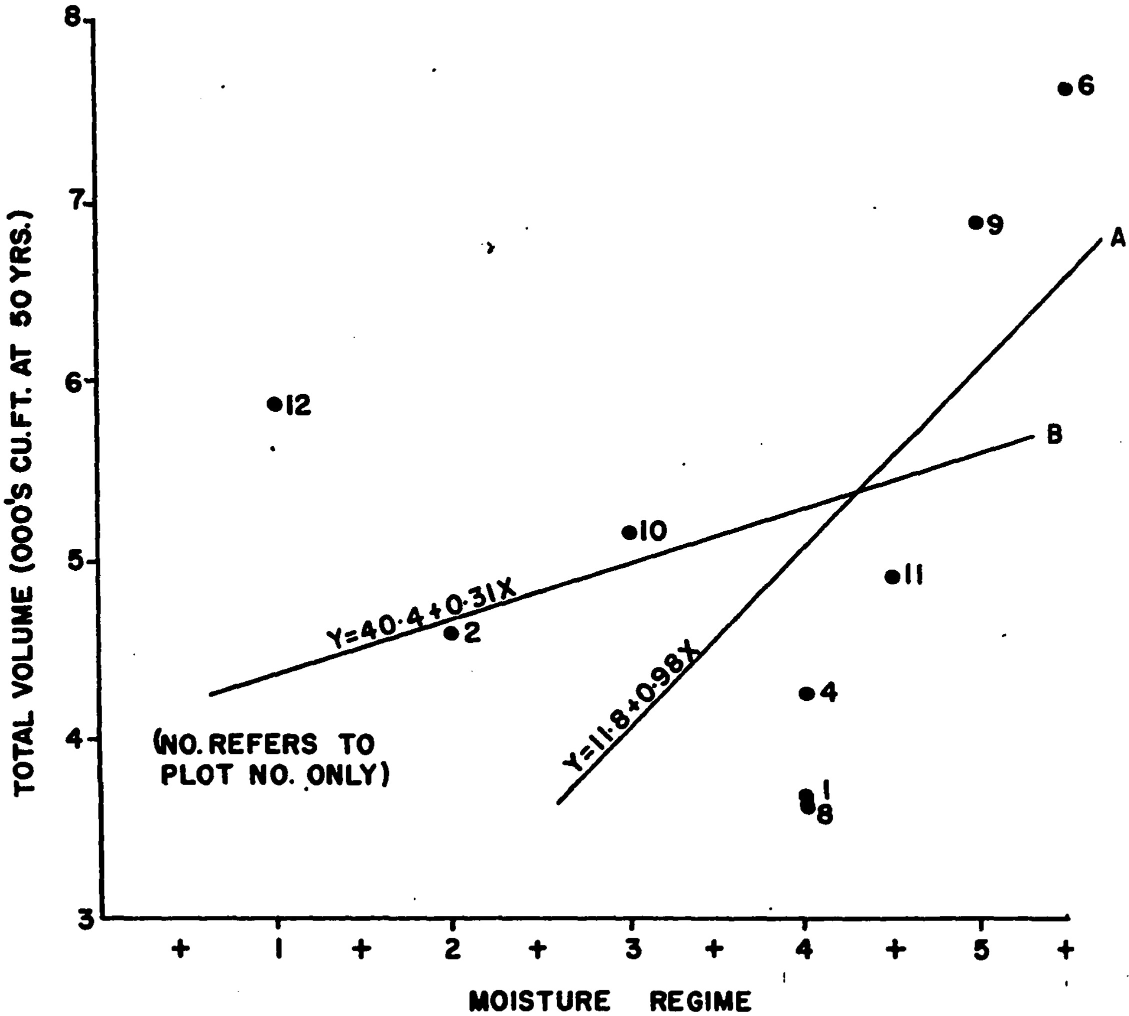
C. RELATIONSHIP BETWEEN COLLECTED PRODUCTIVITY DATA AND THE CAPABILITY CLASSES OF THE CANADA LAND INVENTORY (CLI)

The forest use capability classes as outlined by the Canada Land Inventory (CLI) (McCormack, 1966) can be readily applied to the sites studied in this research. The capability classes (seven in total) are defined by a range of mean annual increments, based upon the volume of merchantable wood of a suitable indicator species that can be expected from managed

[8] R^2 (coefficient of determination) is the measure of the amount of the variation in the Y or dependent variable that is accounted for by the independent variable used to formulate the equation.

FIGURE 14

RELATIONSHIP BETWEEN
TOTAL VOLUME (AT 50 YRS.)
AND MOISTURE REGIME

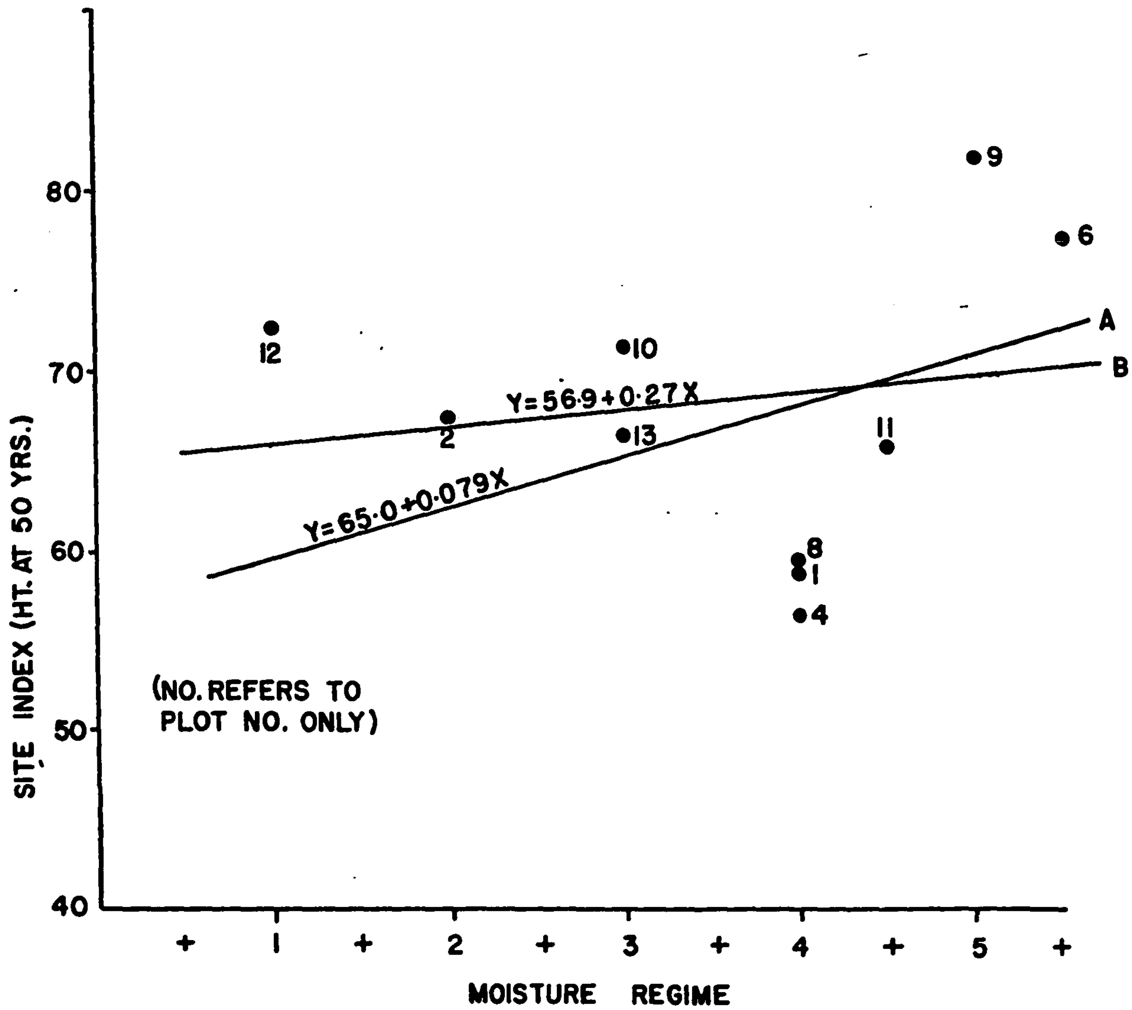


A: ALL PLOTS EXCEPT NO. 12

B: ALL PLOTS

FIGURE 15

RELATIONSHIP BETWEEN
SITE INDEX AND MOISTURE REGIME



A : ALL PLOTS EXCEPT NO.12
B : ALL PLOTS

stands at rotation age. From personal experience the soft maples are considered to be the optimum indicator species for the imperfectly drained soils of the areas studied. It is highly unlikely that any other species would be able to tolerate the inundation that the soft maples are subjected to during the initial period of the growing season.

Honer's (1967) conversion model which employs the ratio of squared diameters was used for converting each sample tree's gross cubic volume to merchantable volume (App. 9 shows application and results of the conversion model). Using merchantable volumes of the sample trees, merchantable volumes for the different plots studied were calculated and ultimately, merchantable volumes for the different productivity classes were determined. Table 11 shows the relationship between the mean annual increment for the productivity classes of this study and the mean annual increment of the CLI.

Table 11. Relationship between yield classes, potential productivity classes, and the forest use capability classes of the Canada Land Inventory.

CLI capability classes	Defined M.A.I. (merch. at rotation age) cu. ft.	Yield class	Potential productivity class	Total volume production (50 yrs.) cu. ft.	Merch.* volume production (50 yrs.) cu. ft.	M.A.I. merch. (50 yrs.) cu. ft.
1	110	exceptional	I	7220	6320	127
2	90-110	1	I			
3	70-90	2	II	5075	4230	85
4	50-70	3	III	4920	3120	62
5	30-50	4	IV			
6	10-30					
7	0-10					

*See App. 9 for method of merchantable volume determination.

VI. DISCUSSION

The study has revealed, quantitatively, the inherent ability of imperfectly drained soils in Southwestern Quebec to produce second growth coppice soft maple. Primarily, the value of the study lies in the practical application of productivity values to various sites within the general land type or within other similar land types of the same site region. Forecasted yields at various ages, for land that is presently forested, can be made by correlating site index with productivity. A reliable correlation can be made between moisture regime and potential productivity but further investigation, including the establishment of a greater number of plots on a wide range of sites, would be desirable.

Analysis of data reveals growth trends of individual trees and of stands as a whole. This information can be used as a basis for the establishment of management guidelines for soft maple on such sites as were studied.

Using the potential productivities as a base, the current value of forest land can be determined in much the same way as was done by Love and Williams (1968). By making available an inventory of calculated potential productivities for the various sites, the land manager is able to predict the potential productivity on a regional basis.

The potential productivity data presented constitutes one of the factors required for determining the optimum use of a particular site.

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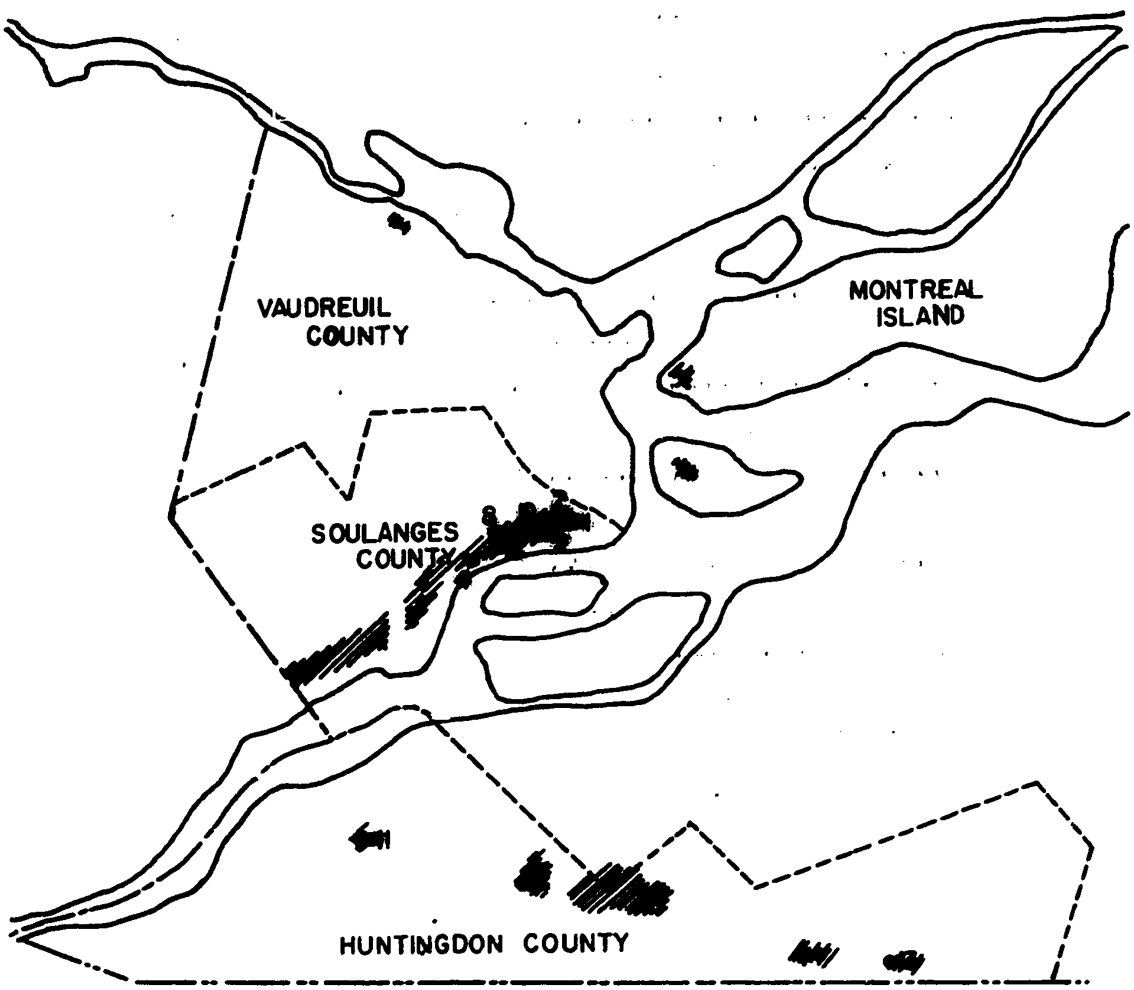
APPENDIX I

FIG. A1 LOCATION OF STUDY AREAS



INTENSIVE RECONNAISSANCE AREAS

• ESTABLISHED PLOTS

SCALE: 1" = 9 MILES

Appendix 2, Plot descriptions.

Plot no.	Plot size (acres)	Plot shape	Age	Present B.A/acre (sq. ft.)	Major* species	Minor* species	Soil** texture	Moisture regime	Aspect
1	0.10	rect.	37	96.4	rM	rO,gB	clay	4	flat
2	0.10	rect.	41	155.3	rM	iR	clay	2	south
4	0.10	rect.	35	162.6	rM	gB	sand clay	4	flat
6	0.033	circl.	28	207.2	sM rM	wEl	clay	5+	flat
8	0.033	circl.	33	140.7	rM sM	blA WEl	clay	4	flat
9	0.033	circl.	18	111.3	rM	--	clay	5	flat
10	0.033	circl.	40	168.2	rM	Be	sand clay	3	flat
11	0.033	circl.	20	159.4	rM sM	blA WEl	sand clay	4+	flat
12	0.033	circl.	44	182.7	rM	hM	sand	1	north
13	0.066	circl.	51	138.5	rM	He	sand	3	S-E

*rM-red maple; sM-silver maple; rO-red oak; gB-grey birch; WEl-white elm; blA-black ash; hM-hard maple; He-hemlock; iR-ironwood; Be-beech.

**parent material.

APPENDIX 3

SOILS DESCRIPTIONS

Plot 1

Horizon	Thickness	Total depth	Remarks
A	2"	2"	
B	5"	7"	-down to top of clay; heavy mottling
B-C	3"	10"	-clay with heavy mottling
C		to 22"	-parent material; clay

moisture regime: 4
depth to carbonates: none

Plot 2

Horizon	Thickness	Total depth	Remarks
A	2 1/2"	2 1/2"	
B	6"	8"	-loam -- sandy loam
C	8"	16"	-medium to fine sand; blocking, as forming to sandstone; mottled just above D layer
D	11 1/2"+		-clay (moderate structure)

moisture regime: 2
depth to carbonates: none

Plot 4

Horizon	Thickness	Total depth	Remarks
A	4 1/2"	4 1/2"	
B_1	1"-1 1/2"	5 1/2"-6"	-leached, ash grey
B_2	6 1/2"	12 1/2"	-dark brown sand
C	16"-20"	30 1/2" (approx.)	-medium sand, light brownish grey and mottled throughout
D		+	-clay

moisture regime: 4
depth to carbonates: none
-few stones found throughout the sand

Plot 6

Horizon	Thickness	Total depth	Remarks
A_1	2 1/2"	2 1/2"	-organic
A_2	4"	6 1/2"	-black, decomposed organic matter
B-C	5 1/2"	12"	-ash grey -- light brown sand with heavy mottling C layer is a medium sand
D		+	clay with a mixing of sand in the upper portion -- heavy structure and mottling

moisture regime: 5+
depth to carbonates: none
line of distinction between C and D is very irregular

Plot 8

A	3"	3"	-organic
B	3"	6"	-clay loam; grey
C		+	upper section

moisture regime: 4
depth to carbonates: none
-about 50% of the upper C is brown -- this could be a transition layer of B-C

Plot 9

A	1 1/2"	1 1/2"	-organic layer
B_1	2"	3 1/2"	-grey loamy clay
B_2	3 1/2"	7"	-heavily mottled; 80% of clay is iron brown
C			-grey clay of moderate structure

moisture regime: 5
depth to carbonates: none

Plot 10

A	3 1/2"	3 1/2"	-1/2" litter over 3" humus
B_1	3 1/2"	7"	reddish sandy loam
B_2	5"	12"	-buff color sand; some mottling
C	12"	24"	-light brown-ash grey medium-fine sand, some mottling
D	below 24"		-clay with mottling

Horizon	Thickness	Total depth	Remarks
			moisture regime: 3 depth to carbonates: none -depth to clay is very variable; as high as 12" with very little amount of sand
	Plot 11		
A	7 1/2"	7 1/2"	-organic
B-C	7 1/2"	15"	-medium sand with small quantities of clay which reacted with acid; many rocks and boulders of varying sizes and shapes (all were non-calcareous)
D			-clay, with sand, rocks and small stones; some lenses of coarse sand which were highly calcareous; some areas of the clay very hard and massive as in a pan layer
			-moisture regime: 4+ -depth to carbonates: 10" (calcareous clay within the B-C layer)
	Plot 12		
A	5-9"	5-9"	
B_1	3"	8-12"	-sand; leached ash grey; very irregular in pattern
B_2	1"	9-13"	-thin layer of dark brown sandy loam; high quantity of gravel
C	below 13"		-orange brown sand with a high quantity of gravel
			moisture regime: 1 depth to carbonates: none
	Plot 13		
A	3 1/2"	3 1/2"	
B	5"	8 1/2"	-brown; sand pan
C	below 8 1/2"		-sandstone; heavy mottling
			moisture regime: 3 depth to carbonates: none -large quantity of rocks and stones throughout profile

Table A1. Plot 1-age 37 yrs. Hardwood volumes (cu. ft.) at time of cutting and at each five year interval prior to cutting.

Tree		Now	-5	-10	-15	-20	-25	-30	-35	-40	-45
1		4.213	3.265	2.031	1.048	0.474	0.195	0.079	0.002		
	Br 1	0.870	0.590	0.254	0.060	0.009					
2		1.801	1.467	0.847	0.423	0.208	0.088	0.023	0.008		
3		0.622	0.531	0.311	0.146	0.071	0.018	0.001			
4		0.975	0.847	0.508	0.262	0.135	0.034				
5		5.239	3.942	2.294	1.068	0.539	0.220	0.062	0.005		
	Br 1	0.703	0.375	0.145	0.013						
6		1.965	1.723	1.323	0.877	0.504	0.280	0.179	0.100	0.009	
7		0.555	0.429	0.244	0.113	0.042	0.011				
8		4.128	3.190	1.976	0.897	0.414	0.212	0.091	0.030	0.004	

Table A2. Plot 2-age 41 yrs. Hardwood volumes (cu. ft.) at time of cutting and at each five-year interval prior to cutting.

Tree	Now	-5	-10	-15	-20	-25	-30	-35	-40	-45
1	10.172	8.315	6.294	4.140	2.429	1.259	0.568	0.167	0.009	
2	4.111	3.604	2.979	2.118	1.293	0.728	0.329	0.092	0.008	
3	7.316	6.042	4.577	3.501	1.943	0.903	0.448	0.122	0.001	
4	3.763	3.323	2.753	1.905	1.289	0.713	0.379	0.108		
5	10.897	8.723	6.415	3.414	1.551	0.577	0.252	0.059	0.003	
6	8.522	7.076	5.524	3.507	2.080	0.976	0.354	0.100	0.001	
7	2.242	2.043	1.717	1.259	0.807	0.443	0.183	0.073		
8	5.504	4.696	3.747	2.502	1.654	0.937	0.588	0.210	0.005	

Table A3. Plot 4-age 35 yrs. Hardwood volumes (cu. ft.) at time of cutting and of each five-year interval prior to cutting.

Tree	Now	-5	-10	-15	-20	-25	-30	-35	-40
1	2.737	1.927	1.401	0.788	0.421	0.159	0.019		
2	1.290	1.128	0.891	0.519	0.285	0.100	0.015		
3	1.013	0.861	0.660	0.401	0.161	0.033			
4	3.741	2.618	1.663	1.061	0.563	0.215	0.023		
5	1.275	1.073	0.848	0.505	0.257	0.115	0.022		
6	1.130	0.989	0.773	0.453	0.235	0.127	0.035		
7	2.438	2.074	1.612	1.045	0.519	0.186	0.031		
8	4.232	3.216	2.220	1.212	0.579	0.217	0.033		
9	4.303	2.855	1.774	0.877	0.393	0.098	0.021		
10	1.365	1.064	0.719	0.463	0.213	0.082	0.010		
11	0.758	0.694	0.499	0.324	0.173	0.050	0.002		
12	2.695	2.113	1.618	0.974	0.512	0.252	0.060	0.001	
13	2.439	1.620	1.068	0.554	0.233	0.068	0.006		
14	2.166	1.605	0.992	0.501	0.204	0.061			
15	3.076	2.209	1.401	0.761	0.328	0.109	0.009		
16	5.305	3.659	2.392	1.261	0.517	0.141	0.007		

Table A4. Plot 6-age 28 yrs. Hardwood volumes (cu. ft.) at time of cutting and at each five-year interval prior to cutting.

Tree	Now	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50
1	4.045	3.263	1.953	0.736	0.269	0.058					
2	3.560	2.975	1.951	0.926	0.321	0.059					
3	6.828	4.878	2.686	1.161	0.419	0.048					
4	4.843	3.748	2.276	0.987	0.340	0.043					
5	1.934	1.652	1.150	0.689	0.328	0.051					
6	1.870	1.377	0.940	0.489	0.210	0.029					
7	1.516	1.325	0.990	0.448	0.159	0.010					
8	7.544	4.675	2.264	0.859	0.303	0.049					
9	9.328	5.982	3.604	1.984	0.951	0.117					
Br 1	0.964	0.727	0.347	0.051							
10	10.095	6.754	3.719	1.494	0.382	0.026					
Br 1	1.201	0.587	0.151	0.013							
11	4.813	3.399	2.138	1.005	0.364	0.037					
12	1.405	1.259	0.715	0.310	0.070						
13	0.934	0.766	0.381	0.179	0.052						
14	14.440	10.451	6.633	3.284	1.076	0.100					
Br 1	2.173	2.035	1.503	0.582	0.102						
15	1.082	0.977	0.718	0.392	0.137	0.007					

Table A5. Plot 8-age 33 yrs. Hardwood volumes (cu. ft.) at time of cutting and at each five year interval prior to cutting.

Tree	Now	-5	-10	-15	-20	-25	-30	-35	-40
1	2.317	1.765	1.086	0.502	0.285	0.048	0.009		
2	2.293	1.639	0.944	0.389	0.217	0.032	0.008		
3	1.848	1.397	0.834	0.373	0.170	0.051	0.009		
4	1.842	1.360	0.808	0.367	0.147	0.026	0.002		
5	4.074	2.908	1.674	0.742	0.254	0.078	0.014		
6	3.439	2.369	1.319	0.557	0.264	0.032	0.004		
7	4.413	3.318	2.370	1.302	0.723	0.210	0.031		
8	2.745	1.902	1.214	0.634	0.321	0.105	0.016		
9	2.297	1.624	1.046	0.461	0.220	0.050	0.006		
10	3.579	2.679	1.660	0.906	0.453	0.129	0.021		
11	2.910	1.944	1.230	0.551	0.254	0.078	0.015		
12	0.585	0.521	0.415	0.269	0.123	0.028	0.001		

Table A6. Plot 9-age 18 yrs. Hardwood volumes (cu. ft.) at time of cutting and at each five year interval prior to cutting.

Tree	Now	-5	-10	-15	-20	-25	-30
1	3.126	1.819	0.724	0.114			
2	1.325	0.851	0.336	0.057			
3	4.182	2.418	1.157	0.176			
4	2.693	1.333	0.571	0.093			
5	2.019	1.143	0.400	0.032			
6	1.102	0.524	0.160	0.013			
7	1.780	0.998	0.399	0.054			
8	1.773	0.757	0.252	0.029			
9	1.606	0.953	0.405	0.054			
10	2.862	1.628	0.599	0.067			
11	1.000	0.673	0.214	0.014			
12	1.582	0.943	0.426	0.050			
13	0.964	0.585	0.150	0.002			
14	0.854	0.561	0.178	0.004			
15	4.150	1.961	0.599	0.029			

Table A7. Plot 10-age 40 yrs. Hardwood volumes (cu. ft.) at time of cutting and at each five year interval prior to cutting.

Tree		Now	-5	-10	-15	-20	-25	-30	-35	-40	-45
1		4.412	3.602	2.654	1.804	1.033	0.464	0.161	0.067		
2		7.457	5.971	4.142	2.391	1.281	0.565	0.246	0.082	0.001	
3		8.528	5.681	3.344	1.563	0.590	0.247	0.087	0.025		
4		2.963	2.616	1.947	1.010	0.537	0.244	0.124	0.040		
5		1.880	1.642	1.024	0.510	0.205	0.089	0.022			
6		5.359	4.160	2.965	1.358	0.759	0.342	0.195	0.033		
7		7.762	6.590	4.829	2.374	1.023	0.337	0.124	0.036		
8		7.111	5.696	3.777	2.017	0.822	0.250	0.085	0.021		
9		10.947	8.942	6.180	3.892	2.088	0.925	0.401	0.105		
10		10.977	8.278	5.599	2.819	1.296	0.557	0.262	0.046		
	Br 1	0.491	0.283	0.103	0.002						
11		14.224	10.183	6.228	3.151	1.469	0.691	0.296	0.094		
12		3.539	2.934	2.173	1.209	0.558	0.167	0.072	0.018		
13		7.410	5.474	3.876	2.233	1.061	0.446	0.209	0.058		
14		3.612	2.922	2.026	1.039	0.403	0.122	0.042	0.010		

Table A8. Plot 11-age 20 yrs. Hardwood volumes (cu. ft.) at time of cutting and at each five year interval prior to cutting.

Tree	Now	-5	-10	-15	-20	-25	-30	-35	-40
1	2.695	1.783	0.822	0.216	0.001				
2	1.181	1.123	0.549	0.160	0.001				
3	0.646	0.488	0.264	0.069					
4	1.396	0.846	0.374	0.140					
5	0.366	0.305	0.162	0.059					
6	1.129	0.695	0.331	0.113					
7	0.724	0.521	0.253	0.080					
8	2.142	1.353	0.825	0.234					
9	1.917	1.147	0.420	0.101					
10	0.472	0.314	0.149	0.048					
11	1.028	0.799	0.432	0.175					
12	1.301	0.992	0.682	0.289	0.001				

Table A9. Plot 12-age 44 yrs. Hardwood volumes (cu. ft.) at time of cutting and at each five year interval prior to cutting.

Tree		Now	-5	-10	-15	-20	-25	-30	-35	-40	-45
1		7.331	5.547	4.373	2.951	1.585	0.905	0.372	0.087	0.004	
2		9.950	7.521	5.509	3.911	2.245	1.354	0.541	0.131	0.012	
3		2.779	2.391	2.058	1.650	1.173	0.919	0.498	0.217	0.034	
4		14.940	12.551	10.006	6.952	3.981	2.502	1.095	0.242	0.012	
	Br 1	0.709	0.458	0.265	0.127	0.030	0.001				
5		3.970	3.571	2.782	1.996	1.208	0.671	0.325	0.056	0.013	
6		5.203	4.098	3.263	2.422	1.504	0.957	0.432	0.102	0.034	
7		9.517	7.487	5.753	4.207	2.338	1.366	0.632	0.184	0.029	0.001
8		3.736	3.241	2.661	2.146	1.543	1.097	0.615	0.225		
9		9.961	7.691	5.675	4.096	2.259	1.352	0.565	0.149	0.015	
	Br 1	0.695	0.422	0.224	0.101	0.004	0.001				
10		4.558	3.970	3.327	2.453	1.507	0.986				
11		9.040	7.705	6.510	4.794	3.032	1.860	0.925	0.318	0.065	
12		12.278	9.586	7.585	5.578	2.975	1.756	0.656	0.160	0.030	0.001

Table A10. Plot 13-age 51 yrs. Hardwood volumes (cu. ft.) at time of cutting and at each five year interval prior to cutting.

Tree		Now	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50	-55
1		9.276	7.984	6.625	4.984	3.665	2.551	0.643	0.209	0.022	0.002		
	Br 1	0.790	0.707	0.550	0.329	0.123	0.028	0.001					
2		16.601	14.186	11.579	9.805	6.575	4.020	1.705	0.840	0.272	0.074		
	Br 1	2.706	2.264	1.826	1.381	0.929	0.490	0.169	0.007				
	Br 2	0.584	0.422	0.248	0.152	0.081	0.008						
3		21.098	18.387	15.592	11.956	7.704	4.101	1.356	0.526	0.178	0.006		
4		3.791	3.458	2.954	2.106	1.279	0.545	0.209	0.081	0.014			
5		7.777	6.477	5.051	3.574	2.167	1.159	0.357	0.101	0.020			
6		11.977	10.263	8.192	6.118	3.885	2.251	0.916	0.448	0.155	0.034		
	Br 1	3.827	3.344	2.735	2.102	1.279	0.766	0.243	0.091	0.002			
	Br 2	1.601	1.214	0.815	0.501	0.266	0.097	0.002					
7		11.394	10.258	8.775	7.008	5.148	3.366	1.605	0.712	0.266	0.66	0.022	0.001
8		9.797	9.009	7.734	6.149	4.373	2.876	1.832	1.195	0.673	0.233	0.065	0.004
9		16.894	14.192	11.597	9.115	6.464	4.456	2.639	1.848	0.977	0.321	0.063	
	Br 1	0.908	0.726	0.525	0.346	0.183	0.085	0.023					
10		8.374	7.101	5.771	4.236	2.753	1.618	0.735	0.412	0.111	0.027	0.003	

Table A11. Plot no. 1. Hardwood d.b.h.i.b. diameters and heights at time of cutting and at each 5 year interval prior to cutting.
diameter (in.)
height (ft.)

Tree no.	d.b.h.o.b.	Now	-5	-10	-15	-20	-25	-30	-35	-40
1	5.90	5.50	4.80	4.00	3.10	2.20	1.55	0.80		
		53.60	49.92	46.24	37.30	31.44	25.00	18.17	1.20	
	Br 1	2.70	2.30	1.60	0.70					
		37.90	32.06	23.86	16.55	12.83				
2	4.10	3.90	3.55	2.90	2.10	1.60	1.10	0.50		
		49.80	47.11	41.40	33.79	26.37	17.82	12.70	5.87	
3	2.60	2.40	2.25	1.80	1.40	1.10	0.60			
		39.40	36.13	30.27	23.63	17.39	10.65	0.70		
4	3.10	2.90	2.75	2.20	1.75	1.45	0.80			
		41.40	38.83	31.83	25.00	19.87	14.75	0.90		
5	6.80	6.35	5.65	4.70	3.70	2.70	1.80	1.05		
		54.10	48.23	41.40	33.20	22.95	18.17	14.75	9.42	
	Br 1	2.55	1.90	1.10	0.15					
		29.10	24.73	18.87	11.14	1.30				
6	3.70	3.55	3.40	3.15	2.75	2.30	1.90	1.70	1.30	
		45.80	45.61	43.86	39.76	33.20	25.59	19.53	12.70	1.20
7	2.50	2.25	2.10	1.75	1.20	0.70				
		36.90	33.00	29.10	23.97	16.80	7.78			
8	5.40	5.40	4.80	3.85	3.05	2.30	1.70	1.15	0.60	
		54.00	50.06	45.50	38.67	29.10	23.24	16.80	10.65	5.52

Table A12. Plot no. 2. Hardwood d.b.h.i.b. diameters and heights at time of cutting and at each 5 year interval prior to cutting.
diameter (in.)
height (ft.)

Tree no.	d.b.h.o.b.	Now	-5	-10	-15	-20	-25	-30	-35	-40
1	8.50	7.65	7.05	6.50	5.65	4.55	3.70	2.75	1.85	
		56.40	55.36	54.32	50.42	42.22	31.83	22.54	15.43	7.78
2	5.60	5.30	5.05	4.80	4.40	3.75	3.00	2.15	1.15	
		58.50	55.83	52.53	46.67	40.81	34.02	25.00	15.98	6.55
3	7.10	6.85	6.40	5.30	4.95	4.40	3.40	2.35	1.30	
		57.70	53.70	49.97	46.25	40.03	29.10	23.24	15.98	5.45
4	6.10	4.80	4.55	4.25	3.70	3.25	2.65	2.10		
		61.90	56.04	50.19	44.47	39.35	32.38	24.18	16.80	
5	8.90	7.80	7.05	6.10	4.65	3.35	2.25	1.75	1.00	
		65.30	61.90	55.07	49.60	42.77	33.79	26.37	14.75	7.23
6	7.50	6.80	6.35	5.80	5.00	4.00	2.95	2.00	1.05	
		61.90	58.97	56.04	51.65	42.77	35.25	25.82	16.80	1.30
7	4.20	4.10	4.05	3.90	3.70	3.35	2.65	1.90		
		54.10	50.42	46.32	41.86	37.30	31.44	20.90	9.06	
8	6.10	5.70	5.35	5.00	4.30	3.65	3.00	2.40	1.55	
		61.90	58.17	54.45	48.23	41.40	35.25	30.12	22.54	7.40

Table A13. Plot no. 4. Hardwood d.b.h.i.b. diameter and heights at time of cutting and at each 5 year interval prior to cutting.
diameter (in.)
height (ft.)

Tree no.	d.b.h.o.b.	Now	-5	-10	-15	-20	-25	-30	-35	-40	-45
1	4.80	4.50	3.90	3.55	2.85	2.30	1.60				
		49.00	46.19	42.21	36.50	28.50	18.90	10.50			
2	3.30	3.40	3.20	2.85	2.30	1.80	1.20				
		40.90	39.21	37.52	33.83	27.17	20.50	9.83			
3	3.40	2.85	2.65	2.40	2.00	1.50					
		42.30	38.67	34.72	30.28	20.50	12.50				
4	5.70	5.20	4.50	3.85	3.35	2.70	1.85				
		48.90	45.23	39.93	34.21	28.50	18.90	10.50			
5	3.70	3.20	3.10	2.80	2.30	1.80	1.30				
		44.40	41.36	38.32	33.30	25.83	18.50	9.30			
6	3.30	3.20	3.00	2.75	2.40	1.90	1.50				
		44.20	40.70	37.20	31.93	24.50	16.50	9.83			
7	4.70	4.50	4.35	3.85	3.15	2.45	1.70				
		46.20	42.50	39.17	35.17	28.50	20.50	10.50			
8	6.10	6.05	5.35	4.60	3.65	2.70	1.85				
		47.80	44.50	40.06	35.36	29.64	20.50	10.50			

Table A13. (continued)

Tree no.	d.b.h.o.b.	Now	-5	-10	-15	-20	-25	-30	-35	-40
9	6.00	5.65	4.80	3.95	3.05	2.25	1.10			
		48.40	44.50	40.06	34.50	25.30	17.30	9.30		
10	3.60	3.75	3.35	2.90	2.45	1.85	1.25			
		40.60	37.18	33.83	30.50	25.30	16.50	8.50		
11	2.90	2.70	2.60	2.25	1.95	1.55	0.75			
		31.70	29.57	27.43	25.30	20.50	12.50	0.30		
12	4.90	4.60	4.15	3.70	3.10	2.30	1.80	0.90		
		48.70	44.50	39.50	34.21	28.50	21.83	12.50	1.40	
13	4.50	4.25	3.65	3.15	2.40	1.70	1.00			
		46.40	41.30	37.30	28.50	21.83	12.50	5.83		
14	4.40	3.90	3.35	2.70	2.10	1.50	0.95			
		48.00	45.08	40.50	34.90	26.50	16.50	0.30		
15	5.10	4.80	4.25	3.50	2.85	2.05	1.35			
		48.50	44.50	38.79	32.50	24.50	15.70	6.50		
16	6.70	6.30	5.35	4.45	3.50	2.30	1.50			
		53.80	48.94	44.50	36.50	29.83	17.83	6.50		

Table A14. Plot no. 6. Hardwood d.b.h.i.b. diameters and heights at time of cutting and at each 5 year interval prior to cutting.
diameter (in.)
height (ft.)

Tree no.	d.b.h.o.b.	Now	-5	-10	-15	-20	-25	-30
1	5.50	5.00	4.50	3.55	2.55	1.90		
		52.90	52.50	44.50	36.50	24.50	14.10	
2	5.10	4.80	4.65	4.25	3.10	2.10		
		56.80	53.73	46.50	38.10	25.83	14.50	
3	6.90	6.30	5.65	4.60	3.45	2.30		
		59.80	55.24	49.30	39.17	28.50	14.50	
4	6.20	5.55	4.80	4.05	3.00	2.05		
		56.90	52.50	46.79	38.50	25.83	12.50	
5	3.90	3.70	3.60	3.20	2.60	2.05		
		52.60	48.50	41.83	33.07	25.83	12.50	
6	4.00	3.80	3.10	2.75	2.20	1.65		
		45.10	41.83	38.50	33.30	24.50	14.50	
7	3.60	3.50	3.40	3.10	2.35	1.55		
		44.20	41.24	38.28	33.30	20.50	8.50	
8	7.50	7.25	5.95	4.50	3.10	2.15		
		59.30	52.50	44.50	36.50	25.83	14.50	
9	8.10	7.75	6.55	5.80	4.45	3.95		
		60.20	55.39	49.30	40.50	30.50	16.50	

Table A14 (continued)

Tree no.	d.b.h.o.b.	Now	-5	-10	-15	-20	-25	-30
	Br 1	3.10	2.65	1.80	0.50			
		32.90	28.21	22.20	13.40	1.40		
10	8.60	8.15	6.90	5.50	3.90	2.15		
		60.60	55.17	46.50	34.90	25.83	12.50	
	Br 1	3.45	2.50	1.15				
		30.50	25.00	18.33	1.00			
11	6.10	5.60	4.85	3.95	3.00	2.00		
		55.90	47.70	40.50	33.30	24.50	12.50	
12	3.70	3.60	3.55	3.00	2.20			
		42.30	39.08	33.83	22.50	10.90		
13	2.90	2.80	2.65	2.00	1.55			
		39.70	37.92	33.83	22.50	14.10		
14	10.20	9.85	8.70	7.30	5.50	3.60		
		60.00	55.31	49.30	41.30	31.17	20.50	
	Br 1	3.30	3.20	2.70	1.60			
		34.90	29.40	25.02	21.38	13.87		
15	3.20	3.00	2.85	2.55	2.05	1.35		
		42.20	39.61	37.02	30.10	18.90	8.50	

Table A15. Plot no. 8. Hardwood d.b.h.i.b. diameters and heights at time of cutting and at each 5 year interval prior to cutting.
diameter (in.)
height (ft.)

Tree no.	d.b.h.o.b.	Now	-5	-10	-15	-20	-25	-30	-35
1	4.60	4.40	4.10	3.40	2.55	2.00	0.95		
		47.30	41.50	36.50	28.50	22.79	12.50	5.83	
2	4.50	4.30	3.75	3.00	2.15	1.70	0.70		
		46.40	40.50	35.17	28.50	21.83	12.50	7.50	
3	4.10	3.85	3.45	2.85	2.10	1.50	0.90		
		45.40	41.59	37.95	28.50	21.83	15.93	8.50	
4	4.10	3.80	3.35	2.80	2.15	1.40	0.70		
		46.30	41.83	37.39	30.10	23.17	12.50	5.83	
5	6.20	5.95	5.20	4.15	3.00	2.00	1.20		
		48.70	42.21	36.50	29.83	23.17	17.07	10.50	
6	5.70	5.25	4.60	3.80	2.65	1.95	0.95		
		47.30	41.50	36.50	27.36	21.64	11.36	5.64	
7	6.00	5.70	4.95	4.25	3.55	2.95	1.75		
		47.90	42.50	39.17	34.50	25.30	18.21	12.50	
8	5.10	4.80	4.15	3.50	2.70	2.05	1.20		
		47.80	43.50	38.50	31.70	24.50	17.30	7.17	
9	4.60	4.20	3.75	3.10	2.10	1.60	0.90		
		49.50	42.90	35.36	29.64	23.17	15.70	6.50	

Table A15. (continued)

Tree no.	d.b.h.o.b.	Now	-5	-10	-15	-20	-25	-30	-35
10	5.90	5.40	4.80	3.90	3.00	2.40	1.50		
		46.90	41.07	35.50	30.50	24.50	17.30	9.30	
11	5.00	4.65	3.85	3.20	2.30	1.70	1.10		
		50.80	44.50	38.79	30.50	23.17	17.07	10.50	
12	2.70	2.50	2.40	2.25	1.80	1.20	0.60		
		37.70	36.70	28.50	23.50	17.83	10.90	0.60	

Table A16. Plot no. 9. Hardwood d.b.h.i.b. diameters and heights at time of cutting and at each 5 year interval prior to cutting.
diameter (in.)
height (ft.)

Tree no.	d.b.h.o.b.	Now	-5	-10	-15	-20
1	5.30	4.80	4.05	2.90	1.30	
		51.50	42.50	32.50	20.50	
2	3.70	3.40	2.90	1.90	1.00	
		46.80	39.17	30.50	15.17	
3	5.90	5.60	4.70	3.65	1.70	
		51.80	42.50	32.50	20.50	
4	4.60	4.50	3.35	2.40	1.00	
		49.20	40.50	28.50	15.17	
5	4.00	3.80	3.20	2.20	0.70	
		51.80	44.50	28.50	14.50	
6	2.90	2.75	2.15	1.40	0.55	
		43.00	36.50	23.17	9.83	
7	4.00	3.80	3.00	2.10	0.90	
		43.10	34.50	25.30	15.17	
8	4.00	3.90	2.80	1.80	0.65	
		46.20	36.50	26.50	15.17	
9	3.80	3.70	3.10	2.25	1.00	
		45.40	36.50	26.50	15.17	

Table A16. (continued)

Tree no.	d.b.h.o.b.	Now	-5	-10	-15	-20
10	5.00	4.85	4.00	2.80	1.15	
		47.00	38.50	26.90	16.50	
11	3.40	3.25	2.80	1.65	0.30	
		41.80	34.50	23.17	12.50	
12	3.80	3.70	3.00	2.25	0.95	
		44.10	36.50	25.30	15.17	
13	2.90	2.70	2.45	1.30	0.30	
		45.20	36.50	25.30	8.50	
14	2.80	2.60	2.25	1.40		
		42.00	36.50	26.50	0.90	
15	6.10	5.55	4.15	2.75	0.90	
		50.30	40.50	26.50	12.50	

Table A17. Plot no. 10. Hardwood d.b.h.i.b. diameters and heights at time of cutting and at each 5 year interval prior to cutting.
diameter (in.)
height (ft.)

Tree no.	d.b.h.o.b.	Now	-5	-10	-15	-20	-25	-30	-35	-40	-45
1	5.60	5.30	4.80	4.45	4.00	3.40	2.55	1.75			
		60.50	56.50	52.50	44.50	37.83	28.50	20.50	14.79		
2	7.20	6.85	6.45	5.60	4.60	3.65	2.65	1.85	1.00		
		62.30	56.94	52.50	45.83	38.10	28.50	21.83	15.17	1.20	
3	7.70	7.30	6.15	5.05	3.90	2.30	1.60	1.00	0.55		
		64.20	55.70	48.50	40.50	30.50	23.93	17.30	9.30	0.90	
4	4.70	4.45	4.45	4.15	3.40	2.85	2.10	1.45	0.70		
		54.80	52.50	47.50	39.17	28.50	20.50	16.50	12.50	0.80	
5	4.00	3.75	3.65	3.10	2.35	1.70	1.10				
		51.40	47.57	43.17	36.50	25.07	18.90	11.17			
6	6.20	5.95	5.45	4.80	3.70	3.05	2.40	1.95			
		55.90	53.07	47.17	36.50	29.83	19.17	15.83	12.50		
7	7.90	7.30	7.00	6.30	4.80	3.35	2.10	1.35	0.60		
		58.40	53.48	48.50	42.90	33.83	23.70	17.07	10.50	0.40	
8	7.30	6.90	6.15	5.05	3.95	2.95	1.85	1.20			
		61.50	55.93	50.21	44.50	34.50	25.30	17.83	10.90		
9	9.10	8.60	7.85	6.90	5.90	4.80	3.40	2.40			
		63.30	59.36	53.64	46.10	38.10	31.17	22.50	16.50		

Table A17 (continued)

Tree no.	d.b.h.o.b.	Now	-5	-10	-15	-20	-25	-30	-35	-40	-45
10	8.60	7.50	6.90	6.00	4.95	3.95	3.10	2.30			
		63.30	60.50	52.50	44.50	36.50	27.36	21.64	14.10		
	Br 1	2.20	1.65	0.90							
		25.50	19.37	13.27	0.70						
11	10.20	9.75	8.20	6.95	5.40	4.00	3.00	2.05	1.20		
		64.80	60.50	53.83	44.50	36.50	28.50	22.79	16.50	0.20	
12	5.20	4.80	4.50	4.00	3.20	2.30	1.55	1.05			
		53.80	49.83	45.39	38.10	31.17	20.50	16.06	10.50		
13	7.60	7.00	6.20	5.60	4.80	3.60	2.60	2.00			
		60.70	55.17	49.07	42.90	34.90	27.36	21.64	14.10		
14	5.20	4.90	4.40	3.70	2.75	1.85	1.30	0.85			
		53.80	50.50	45.50	39.17	31.70	22.50	16.50	10.50		

Table A18. Plot no. 11. Hardwood d.b.h.i.b. diameters and heights at time of cutting and at each five year interval prior to cutting.
<u>diameter (in.)</u>
height (ft.)

Tree no.	d.b.h.o.b.	Now	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50
1	5.00	5.10	4.35	3.50	2.10							
		43.00	38.36	28.50	20.50	0.80						
2	4.20	4.05	3.35	2.55	1.65	0.15						
		42.20	37.45	30.10	20.50	7.17						
3	2.70	2.35	2.25	1.85	1.05							
		42.50	34.90	26.50	16.50	0.60						
4	3.70	3.40	2.80	2.00	1.30							
		42.00	38.07	28.50	20.50	0.70						
5	2.20	1.90	1.80	1.40	1.00							
		35.50	31.12	25.83	17.83							
6	3.40	3.20	2.60	2.00	1.30							
		43.50	38.50	30.50	20.50	0.60						
7	2.80	2.55	2.25	1.70	1.10							
		40.20	37.12	28.50	20.50							
8	4.60	4.35	3.60	3.00	1.85							
		46.60	39.93	32.50	22.50							
9	4.40	4.05	3.15	2.15	1.25							
		47.10	41.30	31.17	20.50							

Table A18. (continued)

Tree no.	d.b.h.o.b.	Now	-5	-10	-15	-20
10	2.40	2.10	1.85	1.50	0.95	
		37.00	32.50	25.83	15.70	
11	3.30	3.10	2.85	2.30	1.70	
		42.80	38.30	20.50	20.50	
12	3.60	3.40	2.90	2.45	1.95	
		40.80	37.22	30.10	22.10	1.00

Table A19. Plot no. 12. Hardwood d.b.h.i.b. diameters and heights at time of cutting and at each 5 year interval prior to cutting.
diameter (in.) / height (ft.)

Tree no.	d.b.h.o.b.	Now	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50	-55
1	7.00	6.50	5.75	5.20	4.45	3.55	3.00	2.10	1.20	0.20			
		66.70	61.53	55.17	49.07	43.17	36.50	28.50	17.83	6.50			
2	7.70	7.30	6.70	5.85	4.85	4.00	3.25	2.30	1.20	0.20			
		67.40	61.65	56.94	52.50	46.79	40.50	31.17	18.50	8.50	0.60		
3	4.70	4.25	4.05	3.70	3.50	3.35	3.10	2.55	1.90	0.70			
		68.10	64.30	60.50	47.93	42.50	37.50	28.50	18.50	8.50			
4	10.40	9.65	8.90	8.05	6.75	5.50	4.90	3.50	2.01	0.50			
		67.50	58.90	52.03	49.68	47.32	44.97	33.83	20.50	8.50			
	Br 1	2.80	2.25	1.65	1.05	0.20							
		28.40	23.05	19.98	16.90	10.23	0.90						
5	5.70	5.25	5.00	4.35	3.85	3.05	2.25	1.55	0.80	0.25			
		54.90	51.50	49.00	46.50	40.50	31.93	23.17	15.17	6.50			
6	5.80	5.60	5.20	4.60	3.95	3.05	2.50	1.80	1.20	0.65			
		66.30	60.50	55.50	49.83	43.36	37.64	31.17	18.50	9.83			
7	7.40	6.90	6.50	6.05	5.50	4.80	3.95	3.20	1.95	0.90	0.20		
		66.60	59.77	56.14	52.50	43.36	37.64	28.50	16.50	9.83	5.39		

Table A19. (continued)

Tree no.	d.b.h.o.b.	Now	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50	-55
8	5.00	4.65	4.45	4.30	4.10	3.75	3.30	2.70	1.75				
		60.50	53.83	50.04	46.96	43.36	37.64	31.17	22.50				
9	8.30	7.80	7.00	6.10	5.30	4.15	3.50	2.60	1.55	0.44			
		65.20	57.83	53.39	48.94	44.50	37.83	31.17	18.90	9.83			
	Br 1	2.40	1.90	1.30	0.70								
		29.90	24.80	20.36	15.47	0.80	0.80						
10	6.10	5.70	5.40	5.00	4.55	3.90	3.40						
		62.00	55.93	51.05	47.41	43.50	38.50						
11	7.90	7.35	7.35	7.00	6.55	5.80	4.55	3.55	2.50	1.45			
		66.90	58.72	54.28	49.07	43.61	39.17	32.50	22.50	12.50			
12	8.70	8.20	7.45	6.85	6.15	4.85	3.85	2.50	1.45	0.50			
		65.30	58.72	54.28	49.07	43.50	38.50	31.70	20.50	12.50	0.70		

Table A20. Plot no. 13. Hardwood d.b.h.i.b. diameters and heights at time of cutting and at each 5 year interval prior to cutting.
diameter (in.)
height (ft.)

Tree no.	d.b.h.o.b.	Now	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50	-55
1	8.20	7.65 65.80	7.15 61.38	6.65 57.83	5.95 54.50	5.45 49.30	4.85 42.50	----missing---- 33.50	26.10	14.90	0.50		
	Br 1	2.70 27.50	2.55 25.33	2.25 22.61	1.60 19.76	0.85 16.90	0.25 11.19	0.90					
2	11.00	10.10 66.30	9.60 64.07	9.05 61.84	8.45 58.21	7.85 52.50	6.55 43.36	4.55 37.64	3.30 30.10	1.75 18.90	0.55 10.50		
	Br 1	4.80 43.60	4.45 41.80	4.05 38.72	3.55 35.65	2.95 31.13	2.20 24.47	1.35 17.80	1.80				
	Br 2	2.30 24.20	1.90 20.80	1.40 17.40	0.95 14.54	0.45 11.69	1.40	1.40					
3	12.20	11.25 66.50	10.80 63.50	10.05 60.50	9.10 56.06	7.85 51.17	5.85 44.50	3.80 36.50	2.90 25.30	2.00 15.17	0.25 6.10		
4	5.20	4.90 61.00	4.80 55.17	4.60 50.32	4.15 46.68	3.60 39.17	2.50 31.17	1.65 23.70	1.15 17.07	0.50 10.90			
5	7.50	7.10 63.20	6.70 60.50	6.10 56.06	5.25 51.36	4.45 45.64	3.50 39.17	2.10 30.50	1.25 20.50	0.60 12.50	0.50		

Table A20. (continued)

Tree no.	d.b.h.o.b.	Now	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50	-55
6	10.00	9.20	8.80	8.10	7.20	5.85	4.65	3.35	2.61	1.60	0.70		
		62.20	61.49	60.78	56.50	48.50	41.50	36.50	28.50	18.50	8.50		
	Br 1	5.35	5.15	4.85	4.45	3.60	2.90	1.60	0.90				
		51.00	49.36	46.03	41.59	36.13	30.41	24.70	16.70	0.70			
	Br 2	3.75	3.25	2.60	2.05	1.40	0.70						
		36.70	34.95	33.20	29.50	24.50	16.50	0.50					
7	8.90	7.95	7.65	7.20	6.75	5.90	4.75	3.40	1.95	0.70			
		62.80	59.60	56.93	52.49	48.90	44.40	38.27	27.60	17.60	3.60	3.60	
8	8.50	7.75	7.55	7.20	6.75	5.80	4.75	4.00	3.45	2.75	1.85	1.10	0.25
		64.10	61.85	58.90	54.90	51.27	48.19	45.12	38.10	31.17	23.70	14.50	6.10
9	11.00	10.25	9.65	8.80	7.85	6.65	5.50	4.30	3.85	3.10	2.10	1.05	
		69.80	67.05	63.41	59.17	52.50	49.17	45.83	40.50	32.50	22.50	14.10	
	Br 1	2.70	2.45	2.10	1.65	1.10	0.70	0.25					
		31.40	29.20	27.00	24.80	21.16	17.53	10.40	0.80				
10	7.90	7.40	6.95	6.55	5.90	5.10	4.25	3.20	2.65	1.45	0.85	0.35	
		57.40	53.90	49.50	44.50	40.86	37.23	30.10	23.93	16.50	10.32	6.68	

FIGURE A2

PERIOD REGRESSION CURVES

PLOT I

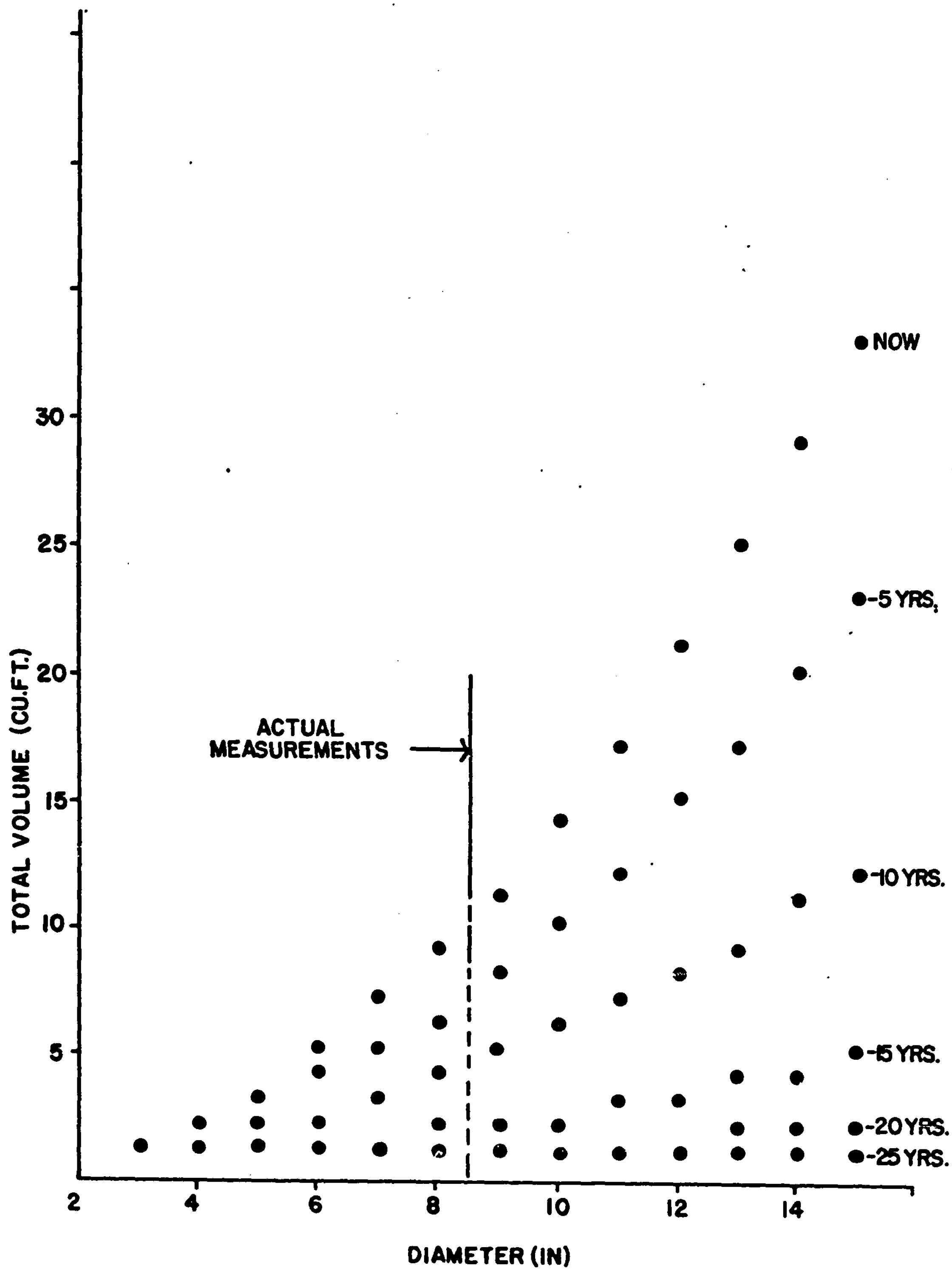


FIGURE A3

PERIOD REGRESSION CURVES

PLOT 2

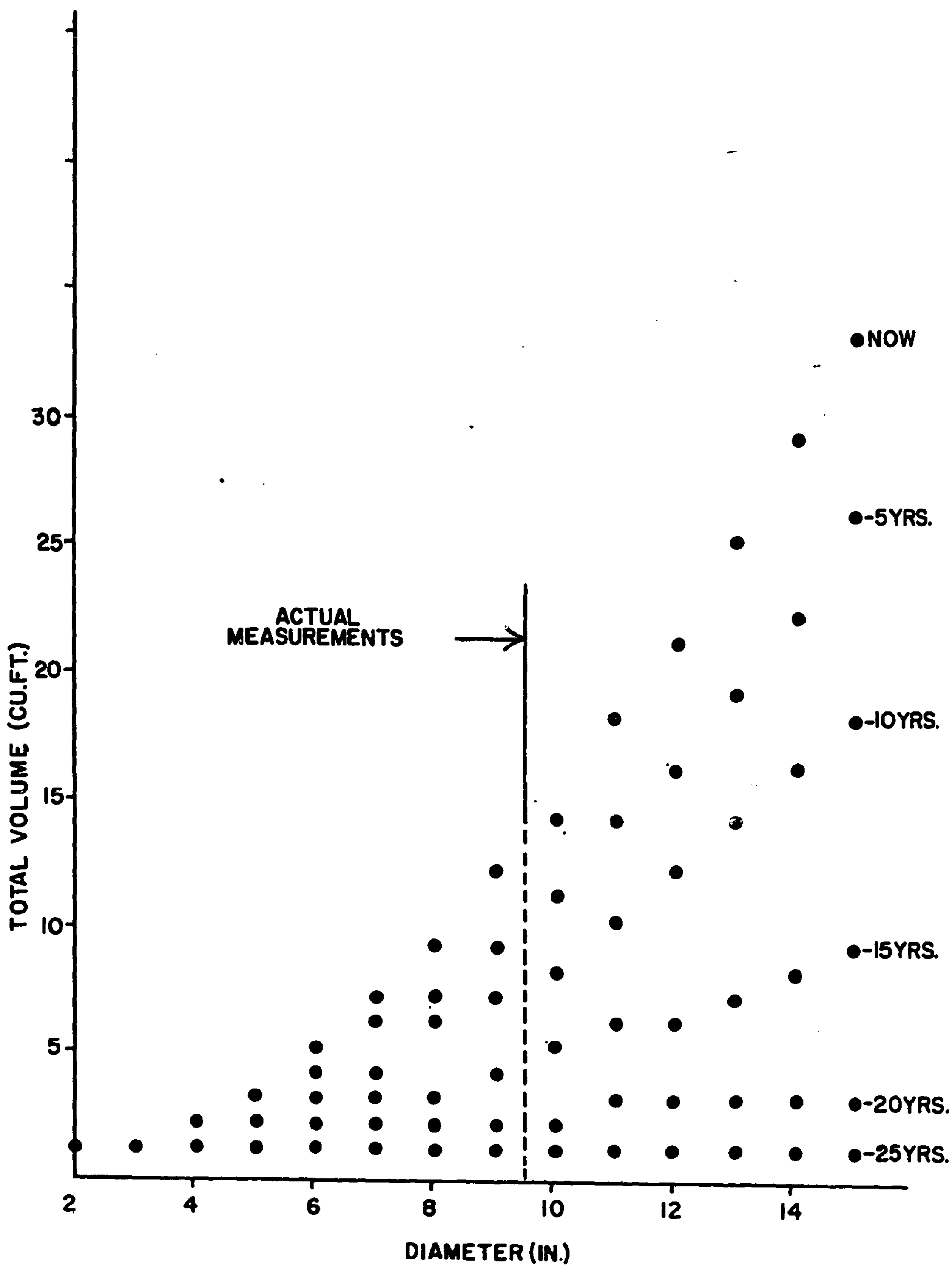


FIGURE A4

PERIOD REGRESSION CURVES

PLOT 4

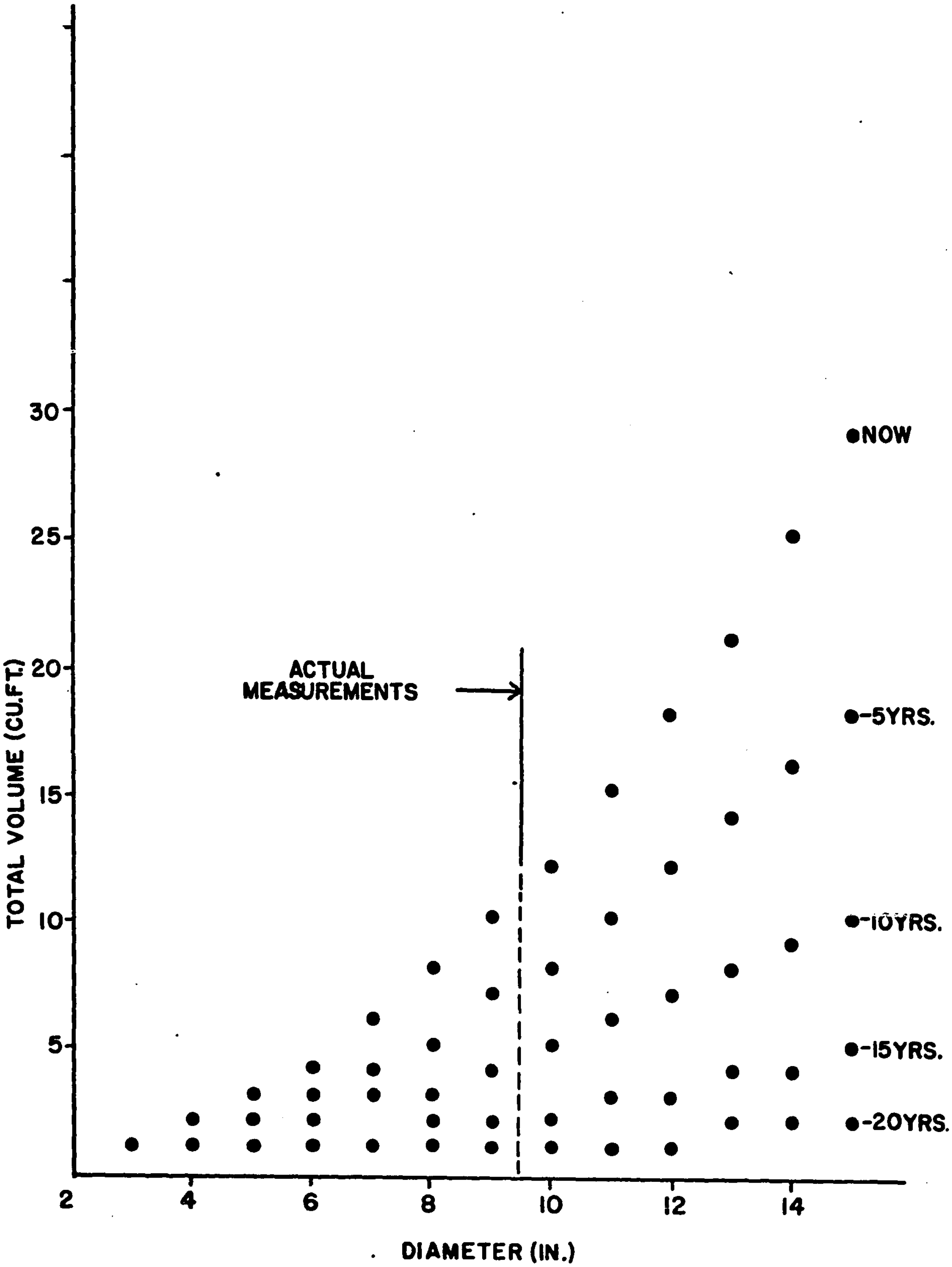


FIGURE A5

PERIOD REGRESSION CURVES

PLOT 6

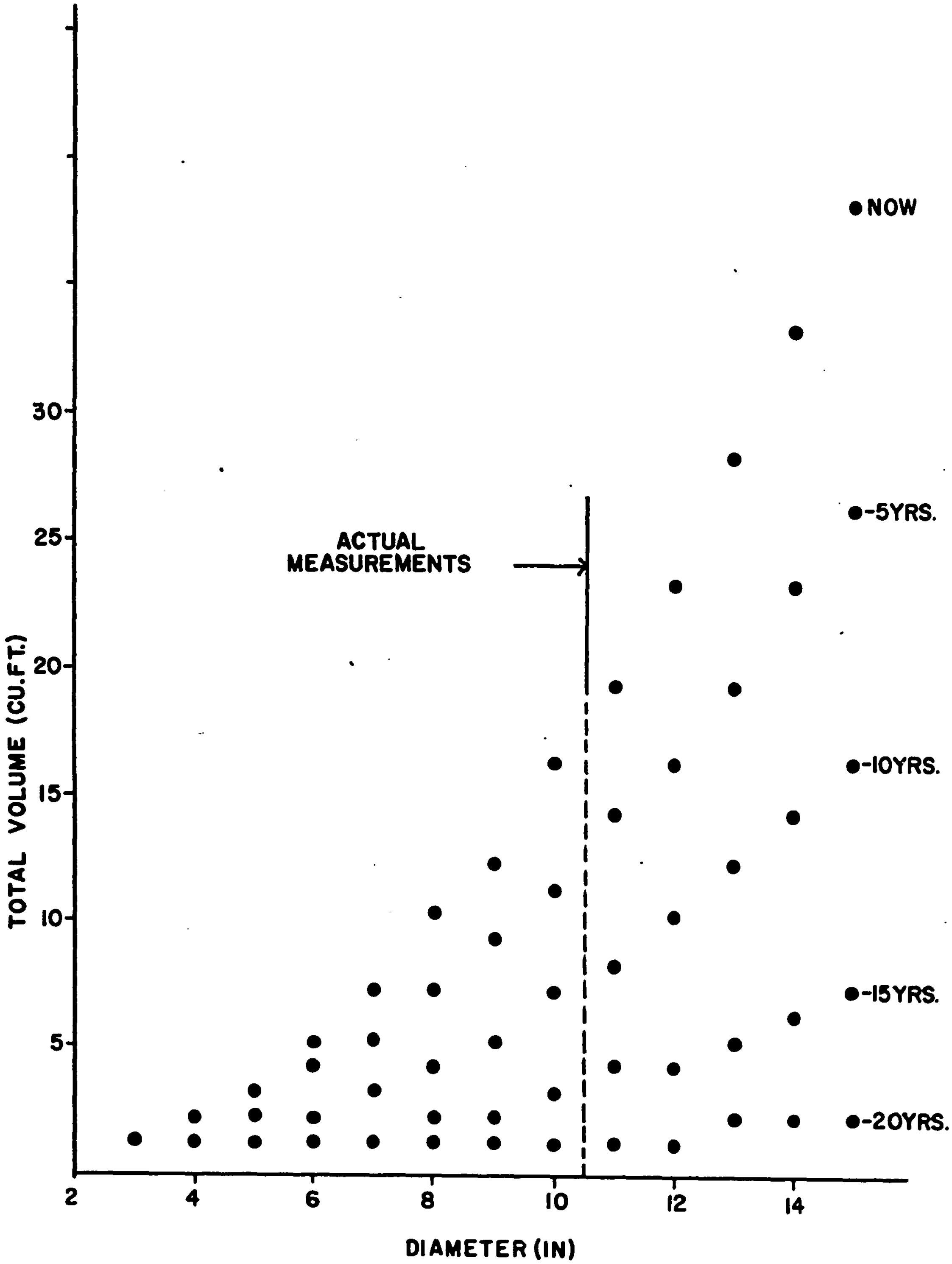


FIGURE A6

PERIOD REGRESSION CURVES

PLOT 8

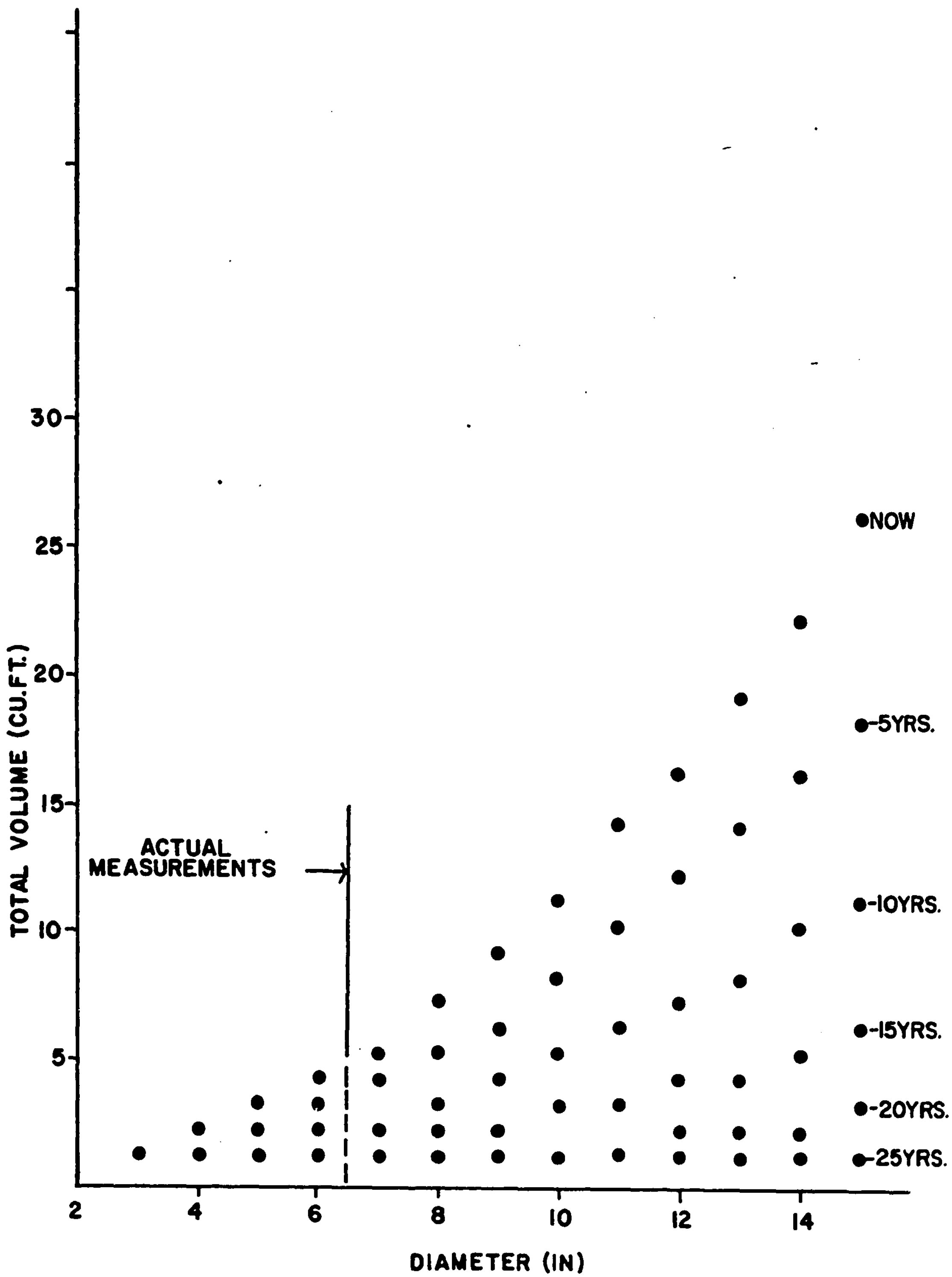


FIGURE A 7

PERIOD REGRESSION CURVES

PLOT 9

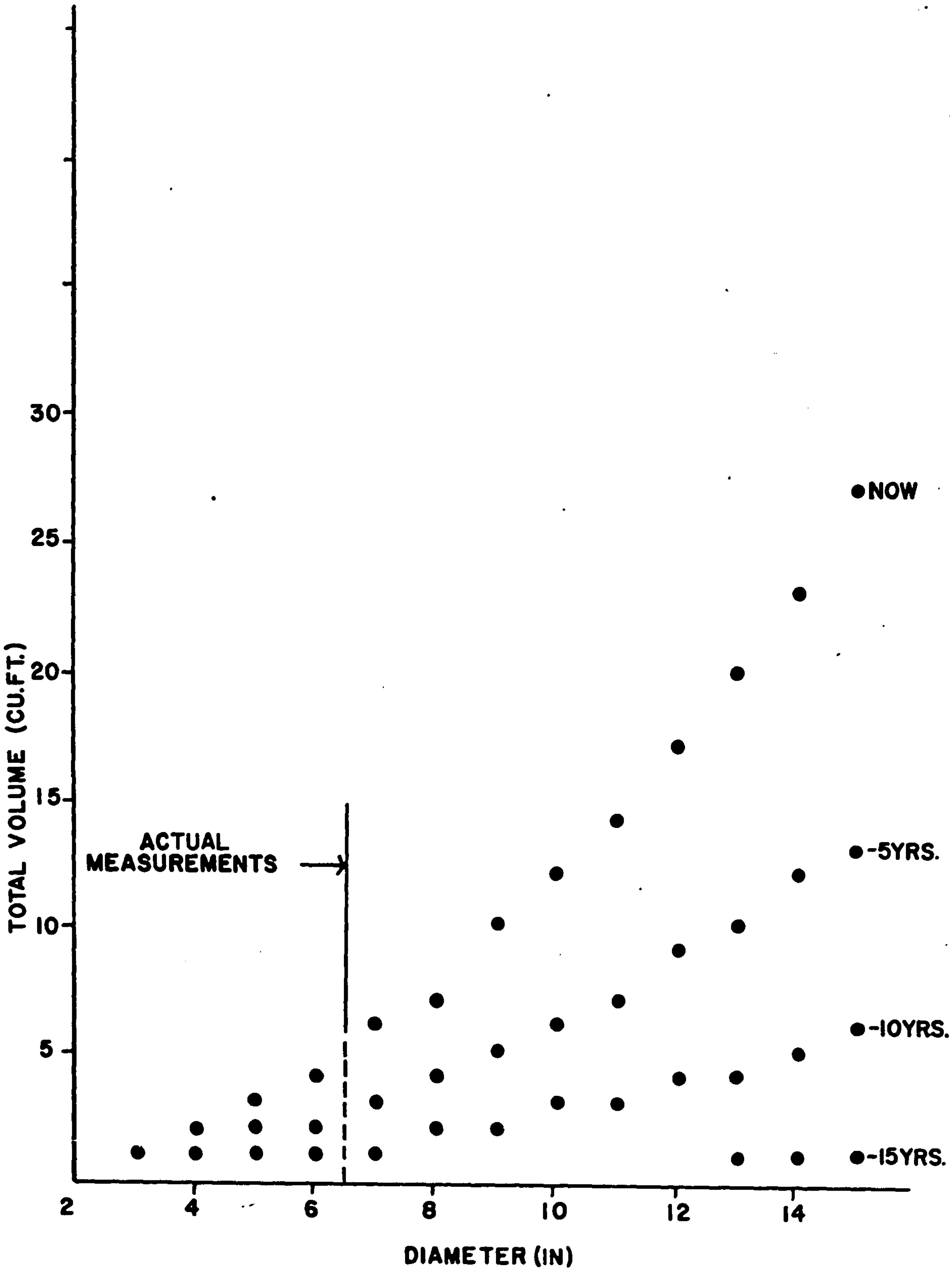


FIGURE A8

PERIOD REGRESSION CURVES

PLOT 10

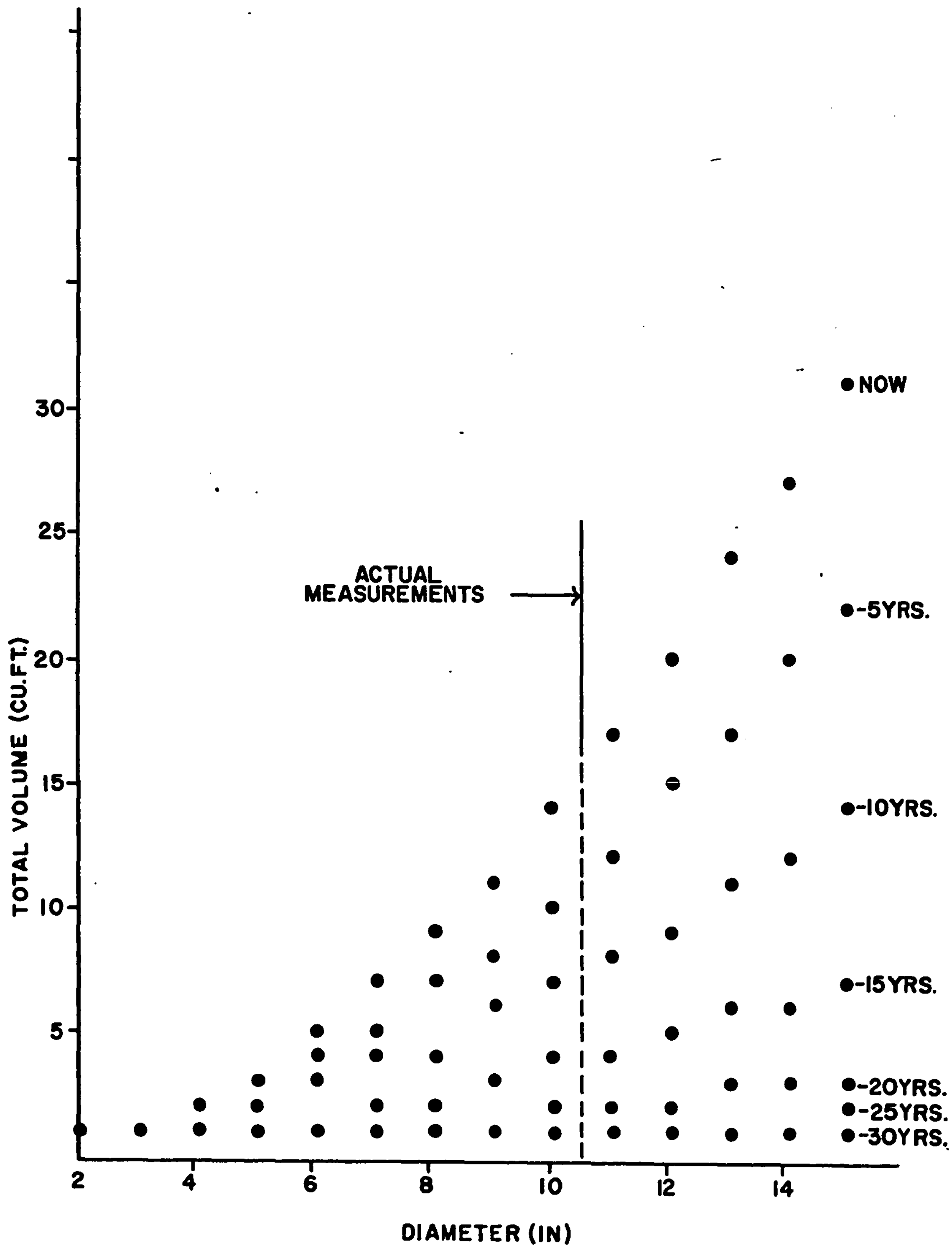


FIGURE A9

PERIOD REGRESSION CURVES

PLOT II

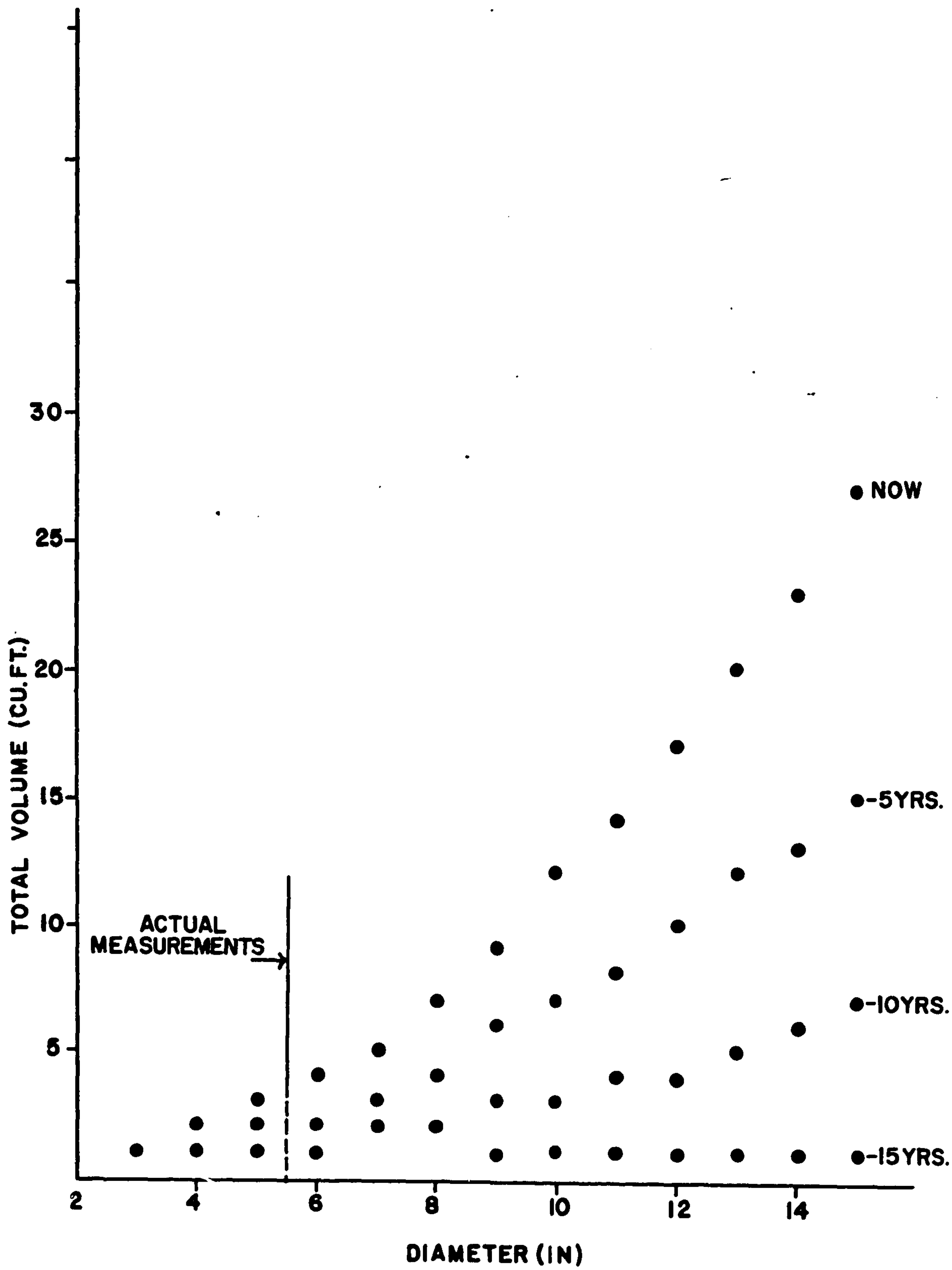


FIGURE A10

PERIOD REGRESSION CURVES

PLOT 12

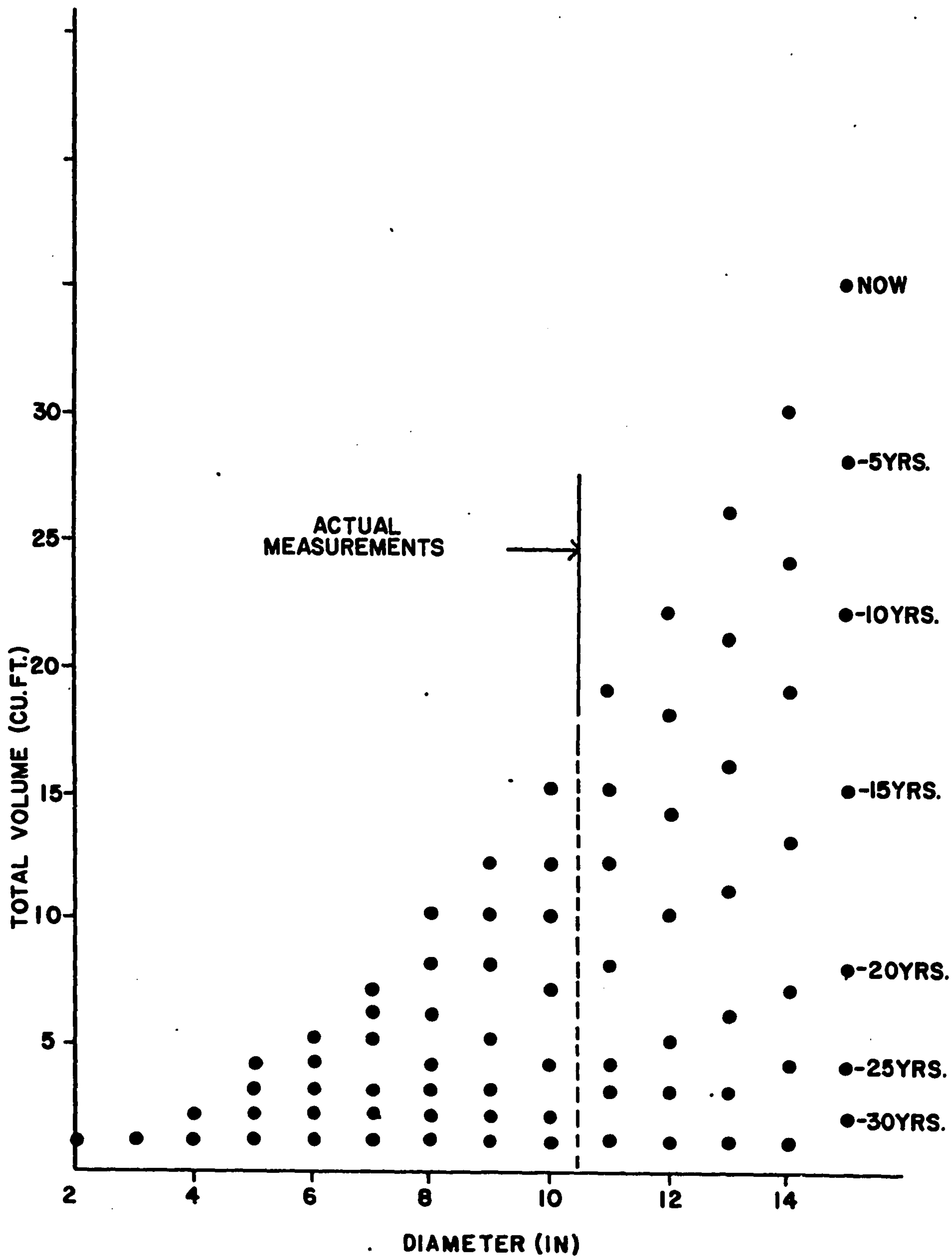


FIGURE A 11

PERIOD REGRESSION CURVES

PLOT 13

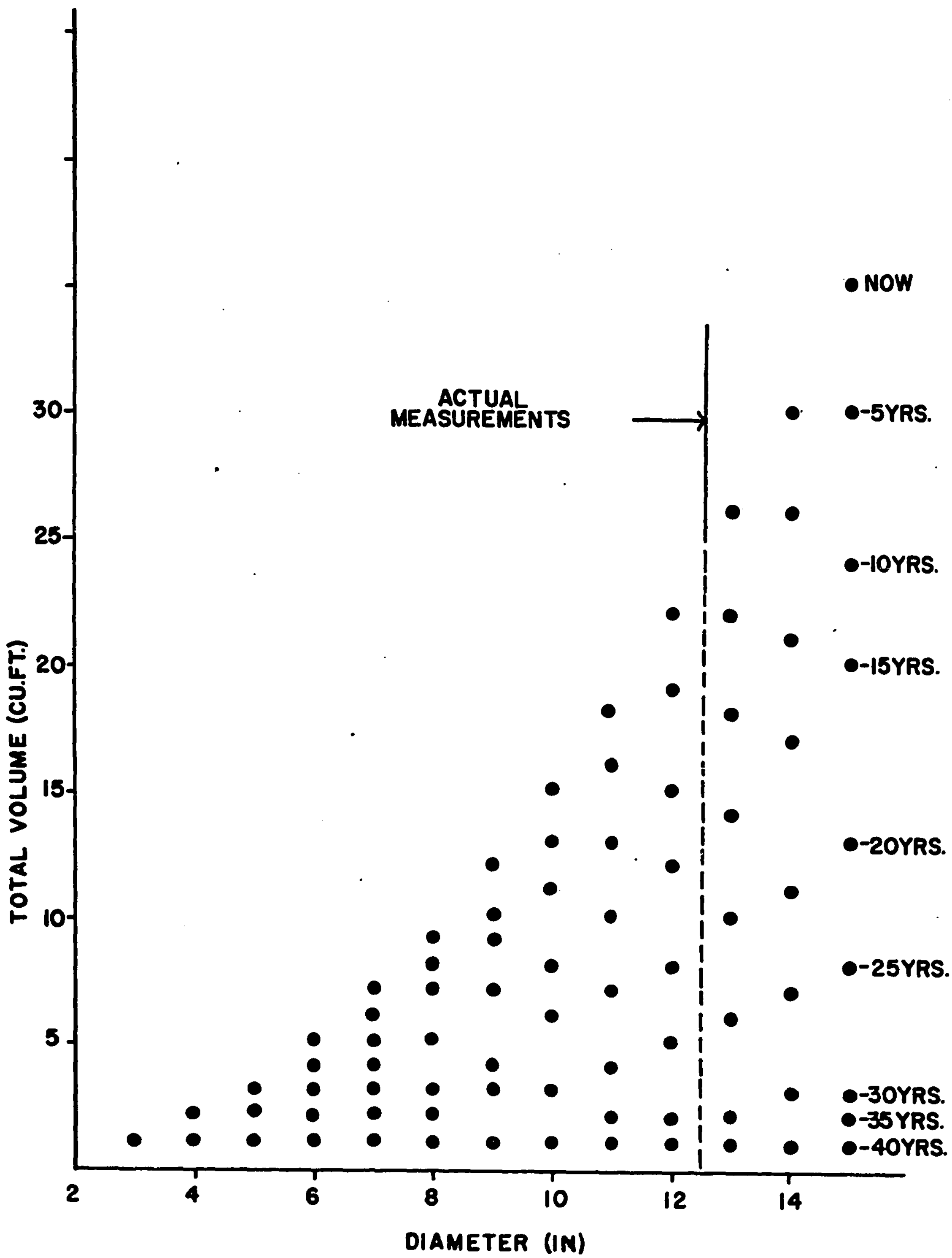


FIGURE A12

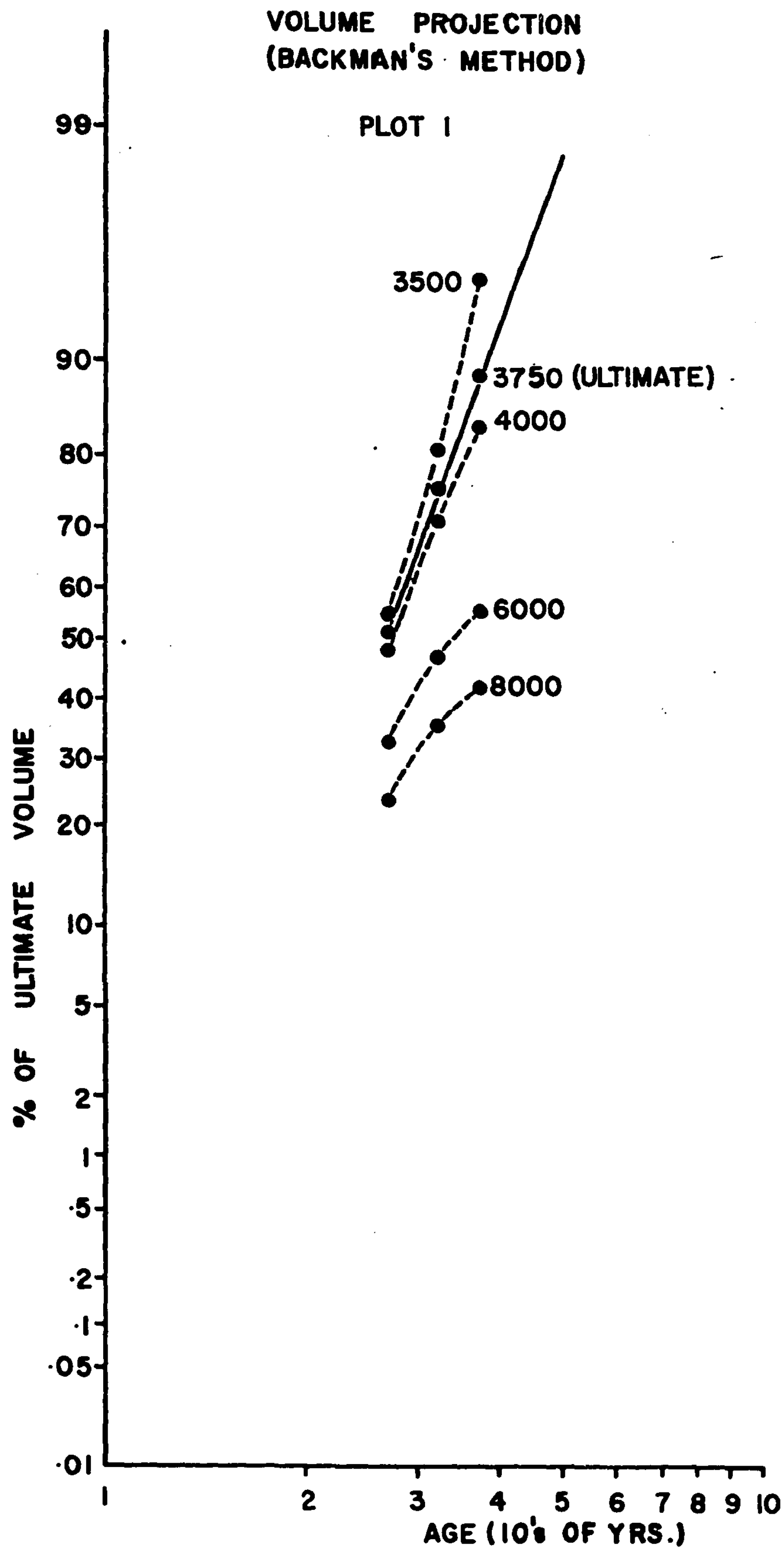

VOLUME PROJECTION
(BACKMAN'S METHOD)
PLOT 1
3500
3750 (ULTIMATE)
4000
6000
8000
% OF ULTIMATE VOLUME
99
90
80
70
60
50
40
30
20
10
5
2
1
·5
·2
·1
·05
·01
1
2
3
4
5
6
7
8
9
10
AGE (10's OF YRS.)

FIGURE A13

VOLUME PROJECTION
(BACKMAN'S METHOD)

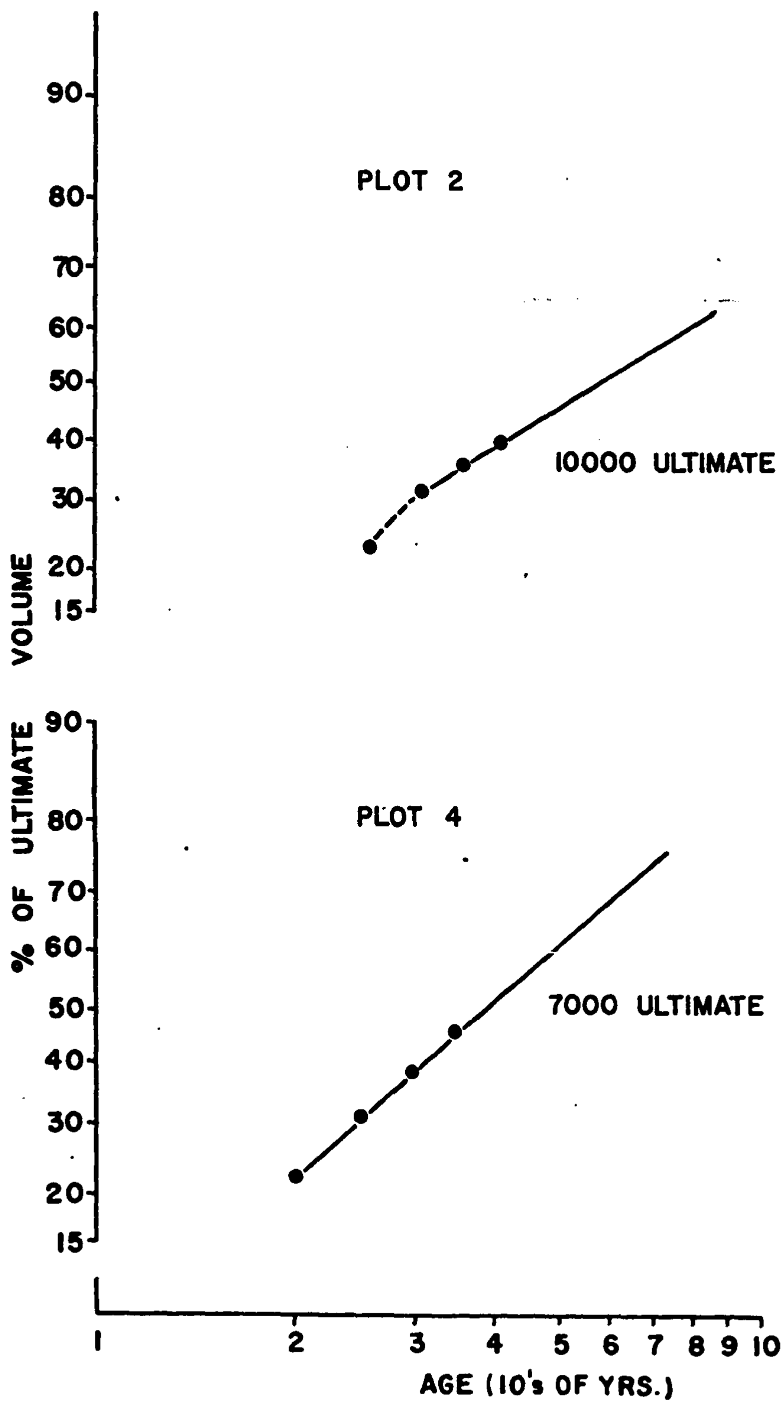


FIGURE A14

VOLUME PROJECTION
(BACKMAN'S METHOD)

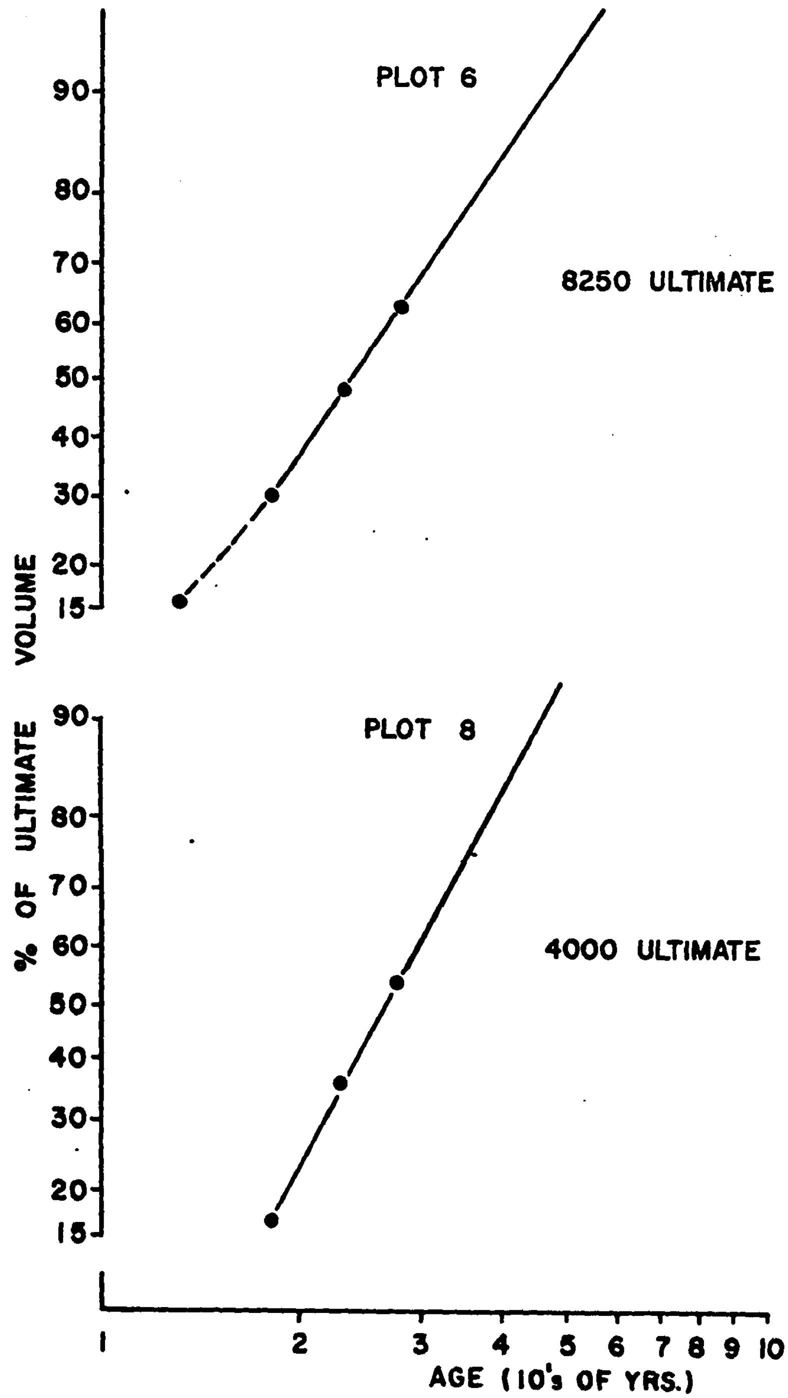


FIGURE A15

VOLUME PROJECTION
(BACKMAN'S METHOD)

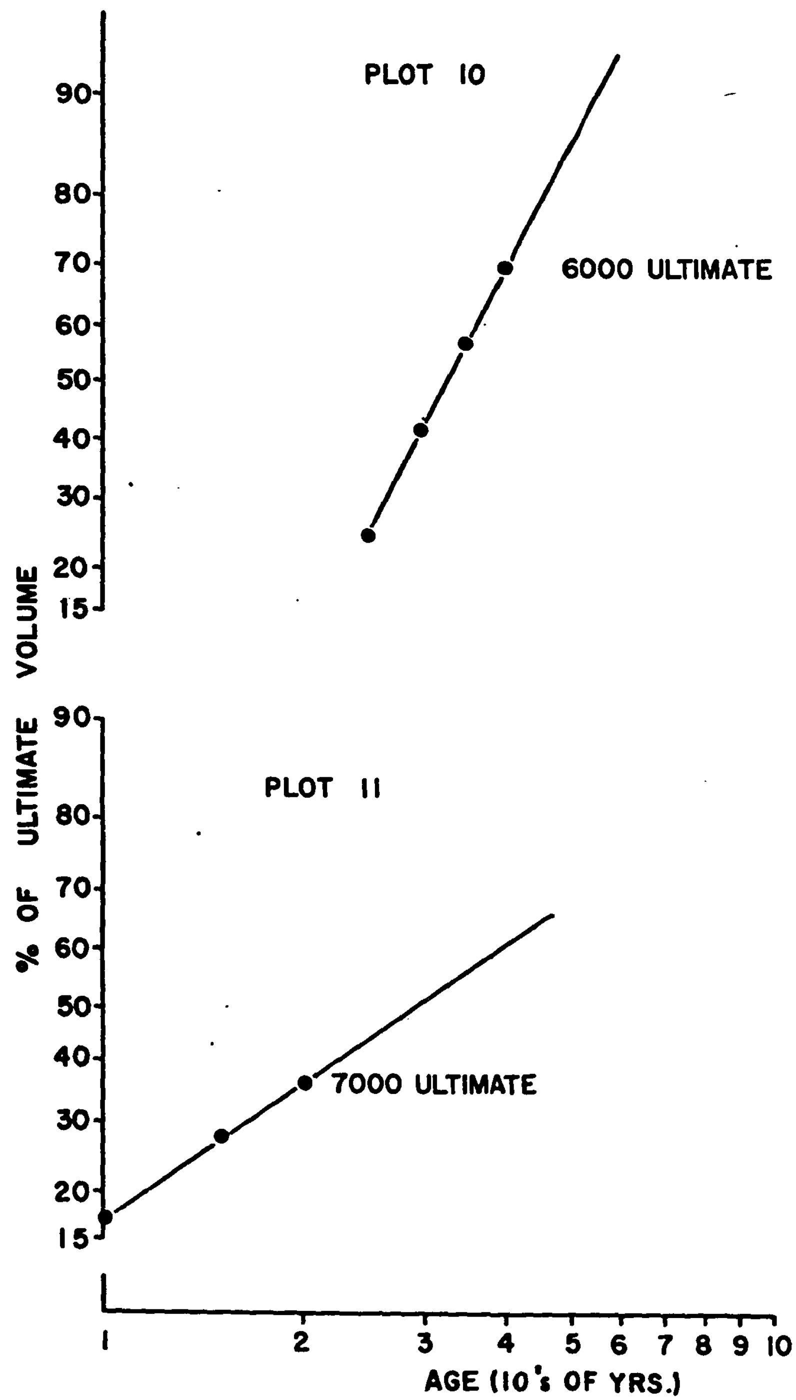


FIGURE A16

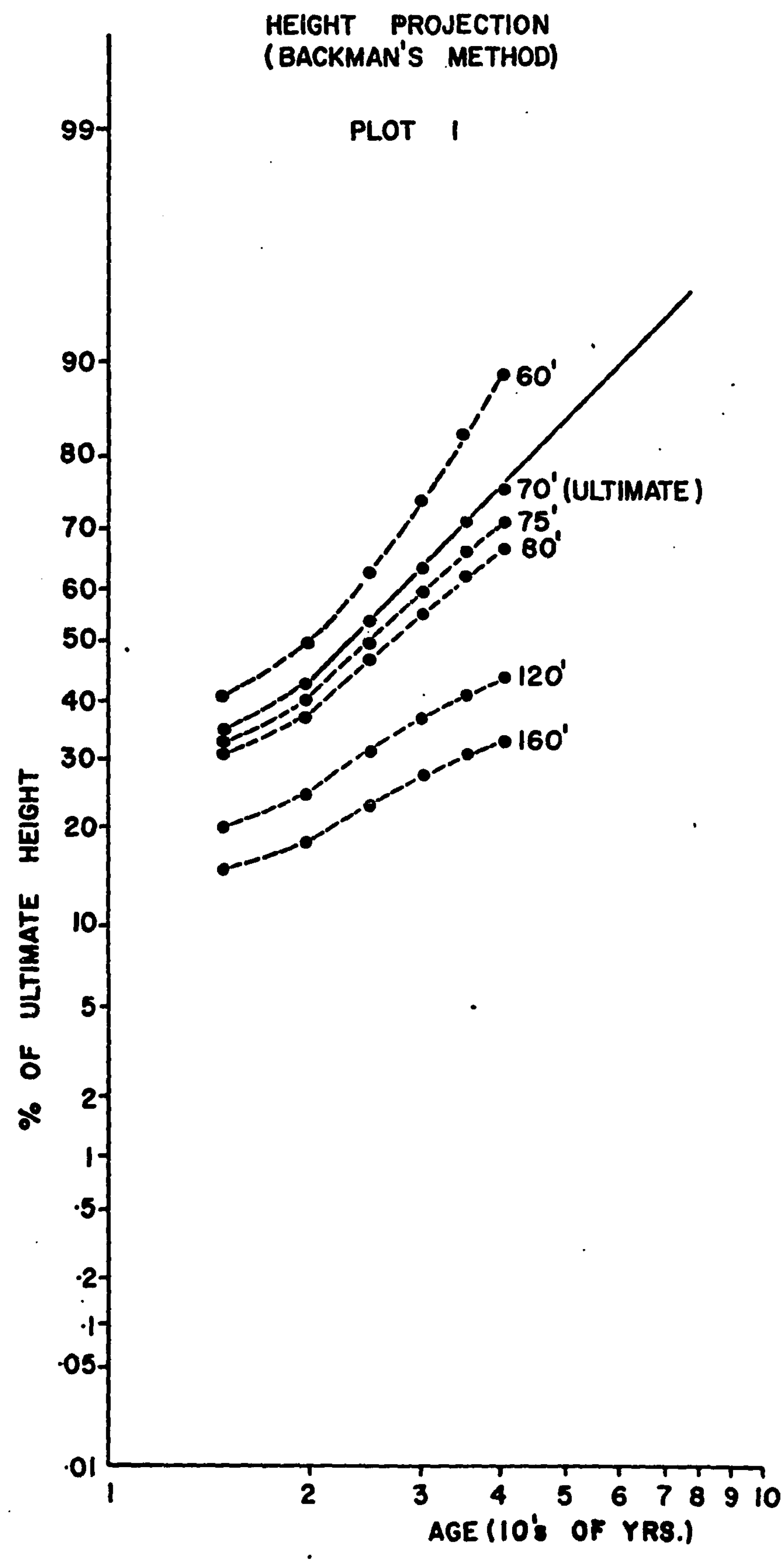

HEIGHT PROJECTION
(BACKMAN'S METHOD)
PLOT I
60'
70' (ULTIMATE)
75'
80'
120'
160'
99
90
80
70
60
50
40
30
20
10
5
2
1
·5
·2
·1
·05
·01
% OF ULTIMATE HEIGHT
1
2
3
4
5
6
7
8
9
10
AGE (10's OF YRS.)

FIGURE A17

HEIGHT PROJECTION
(BACKMAN'S METHOD)

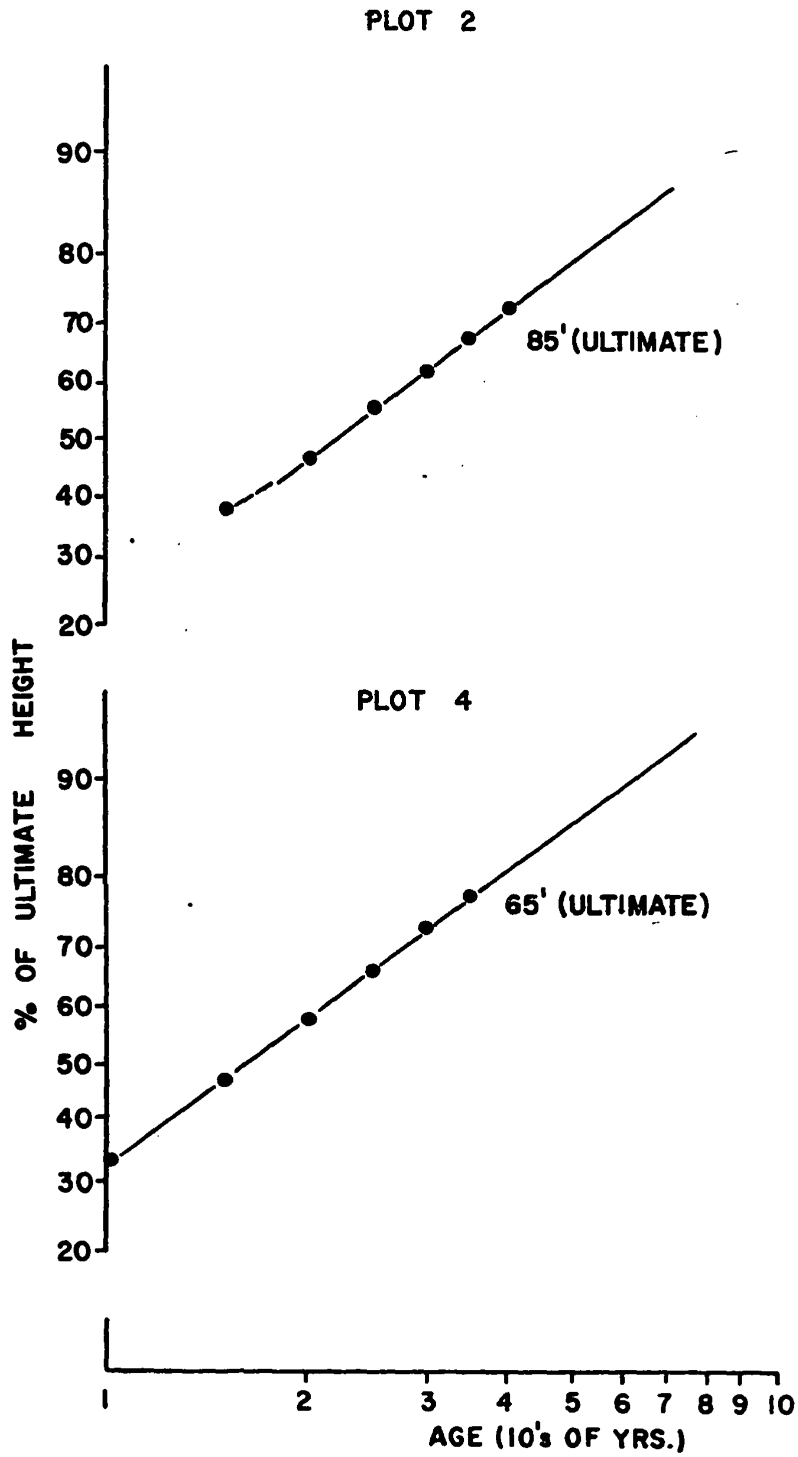


FIGURE A18

HEIGHT PROJECTION
(BACKMAN'S METHOD)

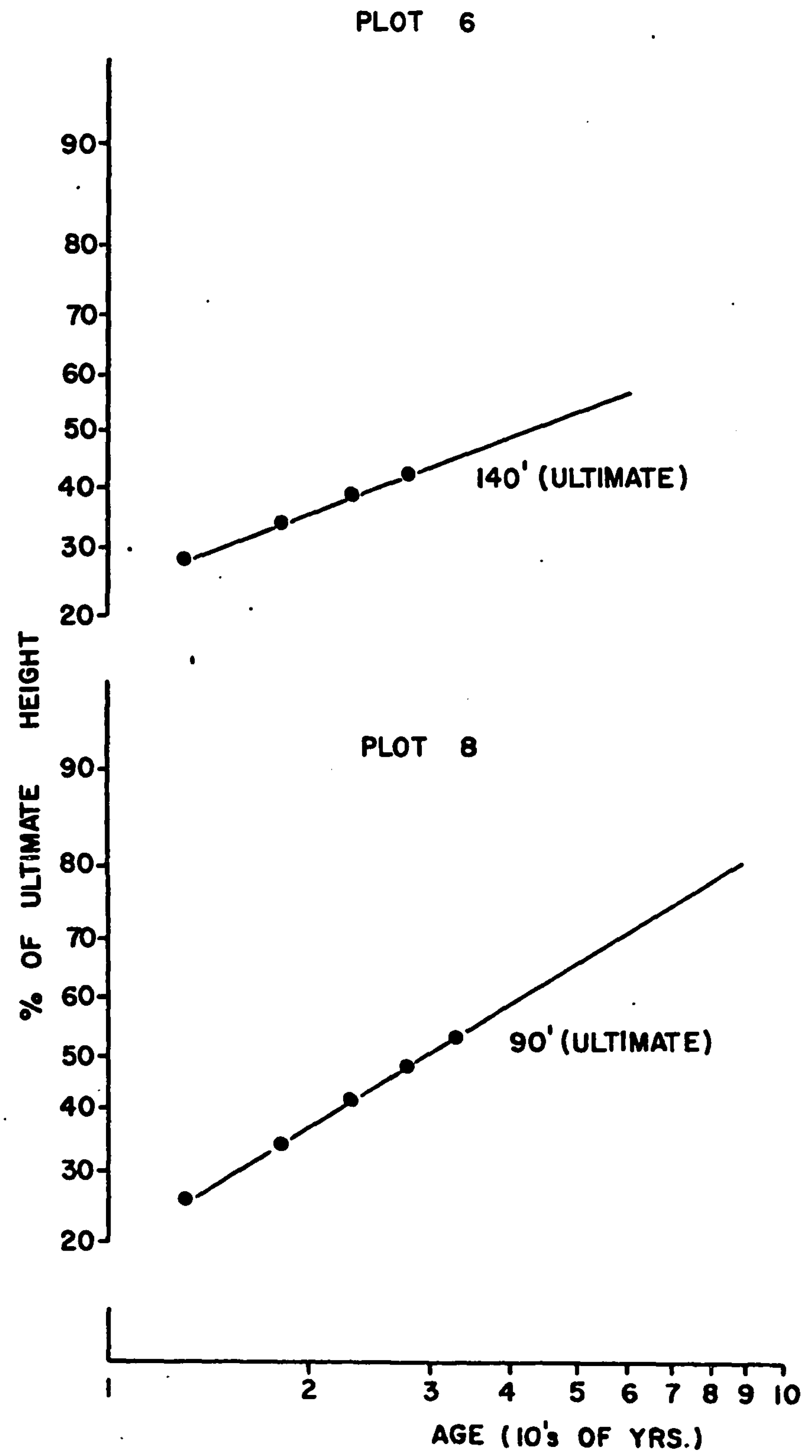


FIGURE A19

HEIGHT PROJECTION
(BACKMAN'S METHOD)

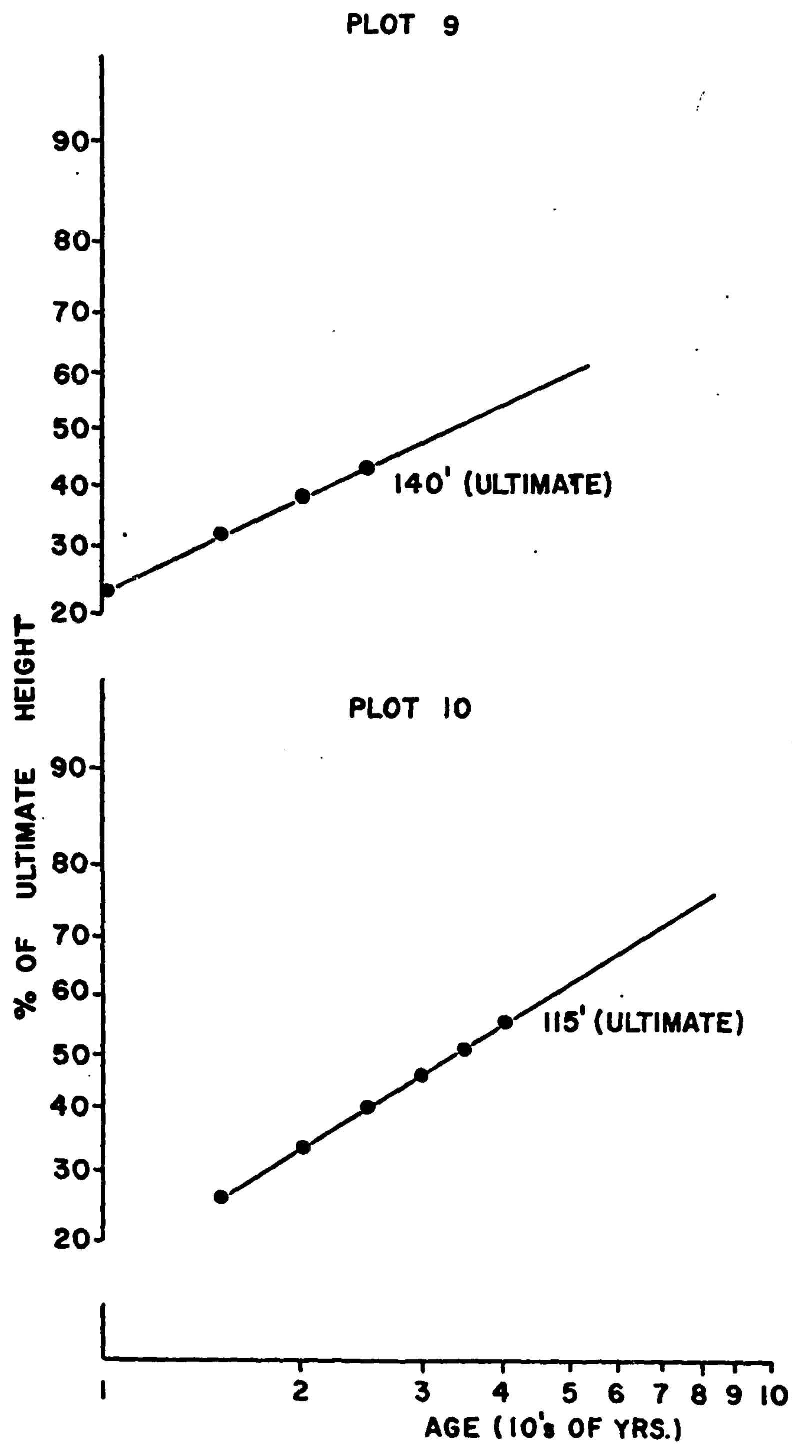
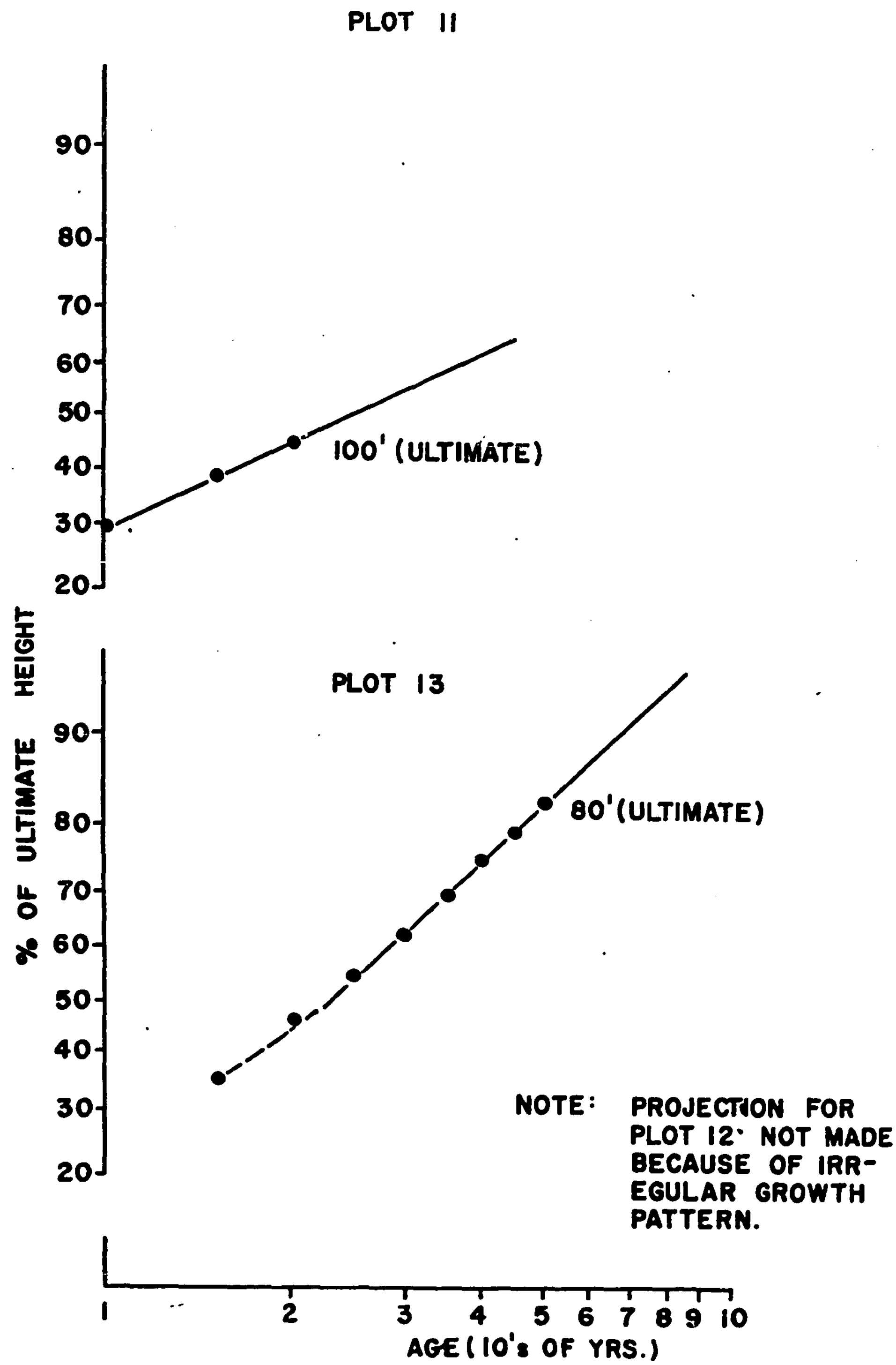


FIGURE A 20

HEIGHT PROJECTION
(BACKMAN'S METHOD)



APPENDIX 9

Conversion of Total Gross Volume to Merchantable Volume

To determine the present merchantable volume of the plots analyzed, Honer's (1967) conversion model which employs the ratio of squared diameters has been used. Briefly, for this model, and two others which utilize different sets of variables, Honer established sets of regression coefficients for different species, for all softwoods combined, for all hardwoods combined and for all species combined. Statistically he showed that for each of the three models tested, the all species equation provided estimates that were as reliable as those obtained from the individual species equations.

The model used in the present study is of the form:

$$Y = a+bX+cX^2 \quad \text{where } Y = \frac{\text{volume to merch. limit}}{\text{total tree volume}}$$

incorporating stump/total volume

$$X = \frac{\text{merch. top d.i.b.}^2}{\text{d.b.h.o.b.}^2}$$

and a, b, and c are regression coefficients having values of 0.9057,-0.0708, and -0.8375 respectively.

From the original raw stem analysis data it was observed that an inside bark diameter of 3.3" corresponded to an outside bark diameter of 3.5" which is the limit for pulpwood that is accepted by Canadian International Paper's hardwood mill at Hawksbury, Ont. Through experience of felling trees for stem analysis it was found that a reasonable average stump height would be 0.5 ft. In reality, due to the degree of clumping, stump heights will vary a great deal over a range of 0.0 ft. to 3.0 ft.

The conversion model was applied to all stem analysis trees and merchantable volumes were expressed as a percent of the total gross volume previously calculated from the stem analysis. As Honer (1967) made no mention of branches, it was assumed that he dealt with main stem volumes only. Branches that were encountered in the present study were dealt with in a separate, but similar manner, from the main stem. The reason for this being that a small branch's total merchantable volume conversion factor would be of lower value than that of the main stem since the factor increases with an increase in stem d.b.h. The conversion factors, which are expressed as a percent of total gross volume, for each tree are grouped in Table A21 by plots and d.b.h. classes. Using the stocking figures of each plot together with total volumes and the percent conversions of Table A21, merchantable volume per plot is expressed as a percent of total gross volume in Table A22.

With consideration given to the relationship of plot age and merchantable volume from Table A22 merchantable volumes, as a percent of total gross volume are forecasted for 50 years of age in Table A23. Final percent figures for 50 years of age have been increased by 5% to allow for more efficient utilization in the future as well as management considerations which will very likely predict thinnings, commercial or otherwise. This percent increase is shown in Table A24.

Table A21. Merchantable conversion factors shown as a percent of total gross volume by plots and d.b.h. classes

Plot no.	D.B.H. class									
	3	4	5	6	7	8	9	10	11	12
1		46	70	80	85					
2		46	70	80	85	88	89			
4	5	50	73	81	85					
6		46	72	80	85	86	88	89		
8		46	75	81						
9	5	46	71	80						
10		46	70	80	85	88	88	89		
11	5	46	70							
12			70	81	85	87	88	89		
13			70	80	85	87	88	89	89	90

Table A22. Plot merchantable volumes expressed as a percent of total gross volume

Plot no.	Age	Total volume (cu. ft.)	Merch. volume (cu. ft.)	Merch./Total %
1	37	3308	2165	64.5
2	41	3991	2449	69.5
4	35	3175	2160	68.0
6	28	5201	3850	74.0
8	33	2743	1566	52.9
9	18	2279	1329	48.4
10	40	4201	3322	78.3
11	20	2554	986	21.5
12	44	5049	4030	79.5
13	51	3684	3070	83.3

Table A23. Merchantable volume prediction at 50 years.

Plot no.	Age	Productivity class I	II	III	Prediction at 50 years (assuming no thinnings)
9	18	48.4			80
6	28	74.0			85
11	20		21.5		80
10	40		78.3		75
2	41		69.5		75
12	44		79.5		75
8	33			52.9	80
4	35			68.0	75
1	37			65.5	80

Table A24. Merchantable volumes[1] expressed as a percent of gross total volume for each productivity class (actual merch. vol. in brackets).

Productivity class	Age 20	30	40	50
I	50 (1500)	75 (5120)	81 (5290)	87.5 (6320)
II	40 (760)	60 (1830)	72.5 (2970)	83 (4230)
III	35 (380)	60 (1470)	70 (2360)	80 (3120)

[1] 5% increase from previously tabulated volumes to cover increase in degree of utilization, effect of thinnings, etc.

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