A METHOD OF APPRAISING THE VALUE OF FOREST LAND AND EVEN-AGE GROWING STOCK

Submitted by Philip B. Thomas
in partial fulfillment of
requirements for Master of
Forestry degree. Febr.,1948

A METHOD OF APPRAISING THE VALUE OF FOREST LAND AND EVEN-AGE GROWING STOCK

By
Philip B. Thomas

Submitted in partial fulfillment of
requirements for Master of Forestry degree.
School of Forestry and Conservation
University of Michigan
February, 1948

INTRODUCTION

Existing methods of stand classification are deemed to be inadequate because they don't give the worth of present and future crops as estimated by the best available valuation techniques.

For classifying even-age stands being managed for pulpwood the soil and growing stock should be appraised by use of soil expectation and forest expectation formulas. While this is cumbersome for rapid classification it is easily done when stands are rated against a "standard" for the same age and rotation. This relationship has been found to be proportional and subject to graphing. Use of the system of graph combinations herein illustrated permits rapid, accurate assignment of values to pulpwood stands.

Additionally, it is found that more information is needed on the stand being cruised and valued which is not obtained by present methods. It is suggested that special crews ascertain growth rates to be expected under management. The forester must also have management data relative to interest rate, rotation, price per unit, annual expenses, and planting costs for use in the formulas.

This use of a graphic method to interpret formulas turns a great deal of figuring into fairly simple mechanical manipulation. Adoption of this method would give the large forest owner an accurate estimate of value where it is quite possible he might make none at all if the work involved were too great. Correctly used it should be far more accurate than guessing at the value of a timber stand. For most purposes of forest management this reasonable approximation of value will be found much more satisfactory.

THE PROBLEM

A method is needed to aid managers of forest land in determining the classification of their various lands and in placing a proper value upon them. The various factors that could enter into a classification must be taken into account and used so that the guesswork in such a business is eliminiated to greatest possible degree. Foresters have long been generally able to determine which are their best lands merely from experience, but in the determination of the classifications of the land of a large organization a more exact method is needed because so many people may be concerned in the assembly and evaluation of data.

Pulpwood lands offer opportunity to develop a method that may be of use to foresters. The rotation generally is short, even in the Lake States, because of the utilization of small diameters and fairly rapid growth. The problem may be simplified by considering one species as an example of the many that are commonly taken for pulpwood. Even-age management is a very common practice, although some pulp species can be grown under one of several silvicultural systems. It is not out of line for our problem to have a pulpwood stand in even-age condition composed entirely of a single species of rapid growth such as white spruce. The attempted solution of the problem in this work is restricted by that conception.

A forester must have more data than can be obtained from a timber cruise to make a more exact classification. The usual method uses field data obtained by timber cruise to classify in the office the ownership of the company. This aid in forming management plans from field data cannot be regarded as adequate for a large organization that intends to undertake more intensive forestry. Knowledge of the volume per acre and the location of the stands is only a part of the information that is needed. Information should be obtained concerning growth rates, length of rotation, stocking now and in the future, and financial data. Foresters need a system to utilize all of this available data so that blocks of timber may be rapidly valued and classified.

Not only must the present volume upon the land be taken into account but an estimate should be made of the future stand that can be expected. This is most important for the determination of long range management plans which intend to establish a valuable forest stand. For this purpose the timber estimate and the valuation should place more emphasis on the varying growth rates and the stocking of the stands of timber. The growth rate determines the rate at which the capital of the company, as it is considered to be in forest land, is increasing. There is no doubt that management desires to have its investments earn at the highest possible interest rates. Forest management enables the forester to increase this earning rate for the company and to obtain better use from a given area of land. Stocking is an expression of the condition of the growing stock in the forest. Forest management attempts to regulate the stocking in all ages to obtain the correct conditions for best growth in quantity and quality in the stand.

The problem, therefore, is to find a more exact method of placing values upon pulpwood land which will enable the forester to give the necessary weight to growth, stocking, and yield in the light of economic considerations. This method outlined in the following pages should give management a truer picture of the value of their immature pulpwood stands. Classification of timber tracts in the light of value will then be greatly facilitated.

THE OBJECTIVES

The objective is to build a system of placing proper values upon even-age forest stands. The system when once set up should be simple enough so that the value and classification of large areas of forest land fitting the conditions of the system may be readily accomplished. Factors such as interest rate, stumpage value, planting cost, administrative expenses and taxes, and rotations under management are the things that are more or less set, even though the stocking, growth rates, and volumes may vary. The system may be built upon the constant factors and give the valuation in terms of the variables. The simplicity should be such that one could take the tables and charts and merely look up the values and do a minimum amount of figuring to arrive at the value. Knowledge of the method of determining the system should not be needed in using it. This would allow one person to supply the charts and figures to someone else or to several field offices where the classification could be established.

Another objective is to determine which data must be gathered in the field to use in this method. Additional data can be picked up by the cruising parties by a slight change in methods which will provide much more informational material than is now the case. The management will have to provide certain figures for the method depending upon the future plans of the concern and the present average market conditions. The forester is the one who must know the data to be gathered in the field and he must direct the parties in obtaining it.

REQUIRED DATA

Field Data

The forester has the means available for gathering certain data that is needed in much forest management work. The method used for obtaining this material usually is the timber cruise. All of the information that is needed for determining this classification can not be obtained under present conditions. Yet the only place and way that the information can be obtained is right on the ground by the cruising party. Then it is known that the data applies to the area being valued and it can be used accordingly. The collection of this additional data will aid in matching areas of similar value both in the office and in the field. It may be that field parties will be able to prepare classification maps based on value. The empirical yield data need only be prepared for stands of the particular conditions found in the tract.

Usually it will be found that the present growth rate is not satisfactory. What can the forester reasonably expect to get? He may use experience or even better he can determine the growth of stands of similar species and site which have had the very best opportunities for growth. These stands will be found where a partial cutting has opened the stand enough for maximum growth while keeping a spacing close enough to develop good form. The forester may reasonably expect the same growth on his managed stands providing he applies the proper silvicultural measures. It may very well be that an ordinary timber cruising party will not be able to obtain this information concerning expected growth rates. A special field party should then be assigned to determine trees growing at the optimum rates for the condition of the stand being valued.

The cruising party should find the average growth rate of the stand so that the forester knows the present conditions. This is a clew as to the minimum growth that may be expected.

Growth rate and diameter of utilization can be used by the forester as basis for determining the optimum rotation. Technical changes in utilization such as installation of a larger chipper might cause management to direct a change in the rotation.

Other information which the timber cruise now may or may not yield but which the forester should have is the average age of the stand, the diameter range, number of trees per acre, and a stocking figure. The yield per acre should be known if the stand is of merchantable size. Immature stands will need to have their volumes estimated at rotation age under some plan of forest management. The data of stocking can be expressed in one of several different ways. Young reproduction may be expressed as a per cent of "full" stocking. For more mature stands "basal area per acre" is a stocking expression, as is "spacing figure" and "spacing factor." Both of the latter indicate the ratio existing between diameter breast high and the spread of the crown. "Spacing factor" is the ratio of the average distance in feet between trees (D), to the average diameter breast high (d), of the trees in inches. "Spacing figure" is the ratio of the average distance in feet between trees to the average diameter breast high of the trees in feet. Perhaps the most useful expression of stocking is the spacing factor because, while it is readily connected to basal area by curve or table, it also expresses the concept of the spacing-diameter ratio. The formula for the spacing factor, S.F. = D/d, can be quickly solved to give the unknown if two of the factors are known. While the usefulness of the spacing factor is indicated here, this work has used basal area as an expression of stocking because it is more generally understood.

Valuation Data

The method will require that the field data be weighed by established forest valuation procedure to show the place of any particular stand in the management plans of the company. This requires that the forester obtain and use certain values that management can make available.

First, is the rate of interest to be used in figuring the valuations. The interest rate is a measure of value that can be adjusted by management to any figure that is most suited. Management's own earning rate, or the interest rate of bonds held by the company, might serve as a key to the rate that should be used. It can be pointed out that the value of the property will be very materially affected by the rate of interest used in discounting future values to the present. The use of a high rate of interest in the compound interest calculations means that the denominator of the discount formulas is larger and consequently the present value will be smaller. A simple illustration will show this. The formula for discounting an income to be received in the future to the present time is: $Co = Cn/1.0p^n$, wherein Co is the present value, Cn is the expected income in n years, and $1.0p^n$ is the compound interest function of p% at n years hence. To find the present value of $100 coming in 20 years at 3% and 6%:

$$3\% \quad Co = \$100/1.03^{20} = \$100/1.8061 = \$55.37$$

$$6\% \quad Co = \$100/1.06^{20} = \$100/3.2071 = \$31.18$$

This illustration shows how a high interest rate reduces the present worth of a future income. Realistic values for immature forest lands are quite dependent upon the use of a reasonable interest rate. An interest rate that is set too high may grossly undervalue the property while too low an interest rate may inflate the value. The proper interest rate will permit a realistic view of the potentialities of the ownership and will be of great service in showing that some land may be marginal or submarginal upon the company's books. Discovery that certain lands are not earning their way will, in the absence of other considerations, show they should be disposed.

The planting costs that the company uses in the calculations should be based upon costs that are current and likely to remain so in the region of the operations. In some cases the concern will not have these figures available but they may be readily secured from some private or government agency that has had occasion to use them. This planting cost per acre includes the cost of the stock, labor costs, and the administrative costs of putting the seedlings in the ground. It will be noticed that the planting cost (expressed as C) occurs only once in the formulas used, indicating that only an initial planting is planned and that in the balance of the time reliance will be placed upon proper silvicultural procedure to obtain natural reproduction. It is anticipated, of course, that this reproduction will come in fairly rapidly and with good enough stocking to utilize the site up to the expectations of management. The forester may use the planting cost (C) twice in the soil expectation formula indicating that management plans that all subsequent stands will be reproduced by planting and no reliance placed upon natural reproduction. This is a silvicultural decision of the forester depending upon his judgment and experience. This work uses planting costs just once in the soil expectation (Se) formula to show the cost of planting up bare land originally. It is felt that afterwards the operator will be inclined to utilize natural means of obtaining his new stand. Reliance upon natural reproduction conforms to present practice.

An important drain upon the gross income from an acre of forest land is the average annual expenses. These are charges that must be met every year, are relatively constant, and can be handled by setting up a capital account to meet them. Such expenses are taxes, administrative costs, and possibly a charge for fire protection. Administrative costs, for example, might properly be the salaries of two foresters and a compassman, totaling $10,000, spread over 100,000 acres of forest land at a charge of $.10 per acre. Fire protection or other charges may be used but they would be spread against each acre in a similar manner. Sometimes such a charge arises when a company utilizes a cooperative protection organization or when there is some plan of self insurance within the concern. It must be a cost assessed against each acre irrespective of the volumes of timber carried upon the land. The average annual expenses may be met by the income at interest from a capital sum which is set up now on the company books. The formula for capitalization of permanent annual income is used to find the capital required at present to provide the income that will meet the annual expenses. This is expressed as $E = e/0.0p$, where E equals the present capital sum, e is the annual expense, and p is the interest rate.

The price of stumpage of the product gives the basis in value to apply to the yield of each acre. One method of determining stumpage values developed by Matthews deducts a cutting cost per cord from the surplus left after taking the fixed per cord costs, known as Class B Costs, from the mill price per cord. These Class B costs are those which are fixed per cord such as skidding, loading, hauling, unloading, supervision, and margin. This is not the only way to decide the stumpage values although it is the method used in this work. Later work may indicate a more reliable method that could properly be used in these determinations. It is essential to arrive at the stumpage value in some exact and systematic manner so that too great market fluctuations are avoided. Apparently for the purposes of this method of valuation it is most desirable to use a method which gives a differential stumpage value for the different diameter limits. It is felt that the more exact methods of determining the balance needed to meet stumpage will become more prevalent as closer utilizations are worked toward by forestry-minded companies.

THE GENERAL METHOD

Management in dealing with the forest is interested in knowing the value at present of the future yields from its investments in the timber crop and in the land. This present value is a key to the classification of forest land because the highest classifications go to the lands producing best in the future, which, of course, are most valuable now. This method attempts to take into account the yield of the present immature growing stock, coming in a few more years, as well as the present worth of all of the future yields in subsequent rotations. The value of bare soil, called soil expectation value (Se), is a measure of the worth of the various plans of management, and is dictated by the plan of use of the land. Land is valueless in the absence of a plan for its use, but if we consider various plans in the light of their value today we can come to put a value upon the soil itself. The soil expectation formula gives the present worth of expected incomes from future rotations. This formula is expressed by Matthews as: $Se = (Yr/1.0p^r-1) - (C+E)$. This method of valuation requires that several "Se" values be determined to serve as a comparison of the long-time worth of several plans. These "Se" values are expressed in Schedule II for different growth rates, diameter limits, and interest rates. Management should select at the expected rate of growth under forest management the diameter limit and the interest rate for calculations.

A valuation of the expected income must take into account the soil expectation value and the income from the present growing stock when it reaches maturity. This can be computed by use of the forest expectation formula which discounts the yield from the present rotation and the "Se" value as well as the expenses accumulated on the present rotation. Matthews shows the forest expectation formula to be:

$$ {}^{m}Fe = \frac{(Yr + Se) - E(1.0p^{r-m}-1)}{1.0p^{r-m}} $$

All of the factors of the "Se" formula can be inserted in this to show the complete relationship affecting the single formula if it need be used. The forest expectation values are shown in the various Schedule III's for two interest rates and for two combinations of growth rates. The diameter limit of 8 inches in this case was selected as optimum from Schedule II. Schedule III is a set of valuations of several reproduction conditions that might be determined from a cruise. The age and the stocking in each case are taken into account, the soil expectation value is brought forward from Schedule II, and by use of the formula for present worth of soil and growing stock we arrive at a value in Schedule III for the growing stock in the light of a definite plan for its use.

The concept of a "standard" and the figuring of the soil expectation value at various per cents of the "standard" is the basis for the charts which follow in the section on Method of Use. The various formulas are used to set a "standard" which serves as a measure for the more modest expectations of management. The yields shown in Schedule I are the "standard" for this work and in the accompanying schedules and tables 100% represents the "standard" based on the yields in Schedule I. The practical expectations of the forester are yields at a lesser per cent approaching the "standard" only as closely as conditions will allow.

It is felt that a yield quite often found in the forest would be about 25% of that found in the "standard." Both the soil expectation values and the forest expectation values have been worked through at 25% of the "standard" and at the full 100% "standard." Ordinarily if the volume on an acre is less than full stocking it is shown in a lessened basal area per acre. Here it is considered that there is only 25% of the volume at the same basal area. The loss in volume is in the arrangement of the stand in "groups and patches." The stocking is normal within each patch of timber but an area of land is not filled to its capacity for growing stock.

A consideration of the formula for forest expectation value in its expanded form,

$$^{m}F_e = \frac{Yr + \left[\left(Yr/1.0p^{r}-1\right) - (C + E)\right] - E(1.0p^{r-m}1)}{1.0p^{r-m}}$$

shows it may be expressed as follows:

$$^{m}F_e = \frac{Yr_1 + (Yr_2/1.0p^{r2}-1) - C - E - E(1.0p^{r1-m}-1)}{1.0p^{r1-m}}$$

$$\text{or} \quad ^{m}F_e = \left[\frac{Yr_1 + (Yr_2/1.0p^{r2-m}-1)}{1.0p^{r1-m}}\right] - \left[\frac{C + E + E(1.0p^{r1-m}-1)}{1.0p^{r1-m}}\right]$$

This expression separates the various expenses, which remain constant for a given interest rate, age, and rotation, from the discounted value of the yields. These latter are the yield from the timber at present upon the land, (Yr_1), and the discounted value of all of the future yields, ($Yr_2/1.0p^{r2}-1$). Call these respectively the first and second yields. Now it can be seen that if we consider these yields variable we are able to show three cases for the yield:

Case I. The first yield (Yr_1) is constant, or remains at a given percent of stocking while the second yield ($Yr_2/1.0p^{r2}-1$) varies from 100% down.

Case II. The second yield ($Yr_2/1.0p^{r2}-1$) is constant while the first yield (Yr_1) varies because of differences in stocking.

Case III. Both the first and the second yields vary and many relations arise as a combination of cases I and II.

A graphing of the above cases resulted in what is shown as the "Present Worth Grid" which has been made available for two growth rates and for two interest rates. It was found that the relationship expressed in Case I graphed in vertical lines for each "Per Cent of Present Stocking" or value of yield and that the relationship expressed in Case II graphed in diagonal lines for each per cent of the "Discounted Value of Future Yields." Charting cases I and II together in this manner is the expression of Case III.

The usefulness of the "Present Worth Grid" appears to be that it is a ready method of obtaining the forest expectation value of any timber stand coming within the conditions prescribed by the field and valuation data. It is a mechanical means of solving the forest expectation formula if the per cent of the "Se" value before deducting expenses and planting costs (soil expectation factor) of the stand in relation to the "standard" soil expectation factor is known. This relationship of the "Se" factor can be obtained from the "Soil Expectation Factor Chart" which graphs these soil expectation factors or discounted value of future yields ($Yr_2/1.0p^{r2}-1$) for the different diameter limits. The matching of the per cent figure of the discounted future yield with the present yield either in stocking per cent or money yield gives the present worth or forest expectation value which can be read directly. More detailed application of the use will be taken up in the section entitled "Method of Use."

The various Schedule III's and the Present Worth Grid are expressions of the same thing. Each gives values for the forest expectation value but Schedule III is more rigid than the Present Worth Grid. One can locate the values from column (8) of Schedule III upon the Present Worth Grid and also any values in between the classes given in Schedule III. Many different tracts can be valued and classified by the combination of these two systems. It is intended that the Present Worth Grid be used to value various tracts of forest land. Then, knowing the worth of the parcels of their property, management may proceed to classify it. Schedule III divides stands into classes based upon age and stocking. Stands as they meet the conditions of age and stocking are given a classification and a value. Where the grid system is used the stands are not classified directly after valuation, but an owner should find it easy to determine his best stands. The values as determined by the grid system may very well be matched with the classes as given in Schedule III to fit into the classification. It may be that an owner would want to take into account other considerations and would use the present worth of the soil and growing stock as a basis. Such a consideration might be the distance to the market.

THE METHOD OF USE

The preparation of all of the various charts and forms is the most difficult part of the method. The field data from the timber cruise and other studies gives the basal area of the stand, the distribution whether in groups and patches, information leading to the rotation age, the age of the present stand, the present and anticipated growth rates, and the volume estimates of the present and future stands. Valuation data comes from the offices of the forester and his superiors. All of the field and valuation data must be assembled into the various tables and graphs building from one schedule to another with the aid of the formulas. One can determine how this is done by following through from one schedule to another.

The method can best be understood by examples which will follow. Generally this is the way to use this material: Ascertain on the Soil Expectation Factor Chart for the proper interest rate the per cent of the soil expectation factor (Se factor) of the "standard" Se factor for the diameter limit in the future rotation. Use this per cent of the soil expectation factor in the Present Worth Grid in conjunction with the per cent of stocking of the present stand. The per cent of the Se factor in the Present Worth Grid is read vertically as the "Discounted Value of Future Yields," while the per cent of present stocking is found on the diagonal line. The common point for these two per cents is read on the scale at the left as the present worth of the soil and growing stock which is synonymous with forest expectation value. The value of the yield, coming in (r - m) years, from the present stand is read along the horizontal scale. If it is so desired this dollar value of present yield may be used instead of the per cent of present stocking. This method shows the present worth of the soil and growing stock, the value of the yield at rotation age, and permits computation of the soil expectation value by subtraction of the planting cost and capital for expenses.

The examples following are only a few of the varying types of stands that might be found. The forester will find it convenient to have tables made up for all of the different conditions that are to be found upon the property. The various species may be found to have different basal areas when they are said to be fully stocked and this should be taken into account for the species or when tables are made for several species at once, which may well be the case.

Example I: This is a stand of white spruce with a basal area of 150 square feet per acre when fully stocked. The estimated growth rate both now and in the future is 0.20 inches annually. The stand is in groups and patches so that the condition of full stocking is achieved now on 33% of the acre and in the future can be expected on 50% of the acre. The rotation is to be 40 years to obtain 8 inch crop trees and the present stand is 20 years old with a diameter range of 3-5 inches.

From the Soil Expectation Factor Chart for 3% interest the 8" value at 50% is found to be 21.8 cords which have a soil expectation factor of $48.20. When planting expenses at $9 per acre and capital for expenses at $8 per acre are subtracted this gives a soil expectation value of $31.20. However, at present it is only necessary to use the per cent figure which is applied to the chart entitled "Present Worth Grid" for the proper growth rates. The point 50% of the "Discounted Value of Future Yields" is matched with the point 33% of the "Per Cent of Present Stocking" and the value of the present worth of soil and growing stock is read at the extreme left as $53.80.

The check for this figure is to substitute in the formula:

$$^{m}Fe = \frac{(Yr + Se) - E(1.0p^{r-m} - 1)}{1.0p^{r-m}} \qquad 1.03^{40-20} = 1.03^{20} = 1.806$$

$$= \frac{(\$72.60 + \$31.20) - \$8(1.03^{40-20} - 1)}{1.03^{40-20}} = \$53.80$$

Example II: Again this is a stand of white spruce growing in groups and patches with a normal basal area of 150 square feet per acre, a rotation of 40 years to grow 8 inch crop trees, and the growth that can be obtained in the present stand and that which may be obtained in the future stands is 0.20 inches annually. The crop on the second and subsequent rotations will yield 35 cords per acre. On the 8 inch line in the Soil Expectation Factor Chart this gives a per cent figure of 80 and the soil expectation factor of $77.50 to correspond with an Se value of $60.50 after deducting total expenses of $17.00. The timber now upon the land will yield an estimated 20 cords per acre 20 years from now worth $100 at $5 per cord. Using the chart entitled "Present Worth Grid" the 80% figure is found under "Discounted Value of Future Yields" and is matched with a $100 "Value of Yield Present Rotation at Maturity-Dollar" to give a "PW of Soil and Growing Stock - Dollars" of $85. So we have easily obtained the soil expectation value, the present worth of the soil and the timber discounted to the present and the money yield of the present crop when it is mature. The proof of the PW or Forest expectation value is shown by the use of the formula:

$$^{m}Fe = \frac{(Yr + Se) - E(1.0p^{r-m}-1)}{1.0p^{r-m}}$$

$$= \frac{(\$100 + \$60.50) - \$8(1.03^{40-20}-1)}{1.03^{40-20}} = \$85$$

Example III: This stand of white spruce with a basal area at maturity of 150 square feet per acre with the timber in groups and patches will give us cause to observe the effect of two different growth rates. During the second and following rotations it is expected that a rate of growth of 0.20 inches can be maintained, but in the stand at present upon the land the best that can be obtained is 0.15 inches. The rotation is 40 years in the second rotation and afterwards, but is 54 years for the present stand because of the slow growth rate. In the future it is expected that the stand will be 50% stocked with 21.8 cords having a soil expectation factor of $48.20 and a soil expectation value of $31.20 after expenses. Again taking the 50% figure to the Present Worth Grid for 0.15" current growth and 0.20" future growth and reading on the present stocking of 33% of the normal, the value of present worth of soil and growing stock is placed at $42.40. This figure is easily checked:

$$ {}^{m}Fe = \frac{(Yr + Se) - E(1.0p^{r-m}-1)}{1.0p^{r-m}} \qquad 1.03^{54-27} = 2.221 $$

$$ = \frac{(\$72.60 + \$31.20) - \$8(1.03^{54-27}-1)}{1.03^{54-27}} = \$42.40 $$

For this particular stand we now have the forest expectation value or present worth of $42.40, the soil expectation value of $31.20, the yield in cords of the present stand of 33% of the normal or 14.5 cords, and the estimated volume yield on the second and following rotations of 50% of the normal or 21.8 cords.

Example IV: Another example is a stand of white spruce growing in groups and patches so that the basal area of 150 square feet per acre is maintained. The growth at present is only 0.15 inches per year but it is anticipated that all of the following stands will grow at 0.20 inches annually. Foresters estimate that the second stand will yield 26 cords per acre at 8-inches d.b.h. for a yield of about 60% of the "standard" on the Soil Expectation Factor Chart for 3½% interest. However, the present slow growing stand is only fully stocked on a third of the area. The process of matching a "Discounted Future Yield" of 60% with a "Per Cent of Present

Stocking" of 33% gives the Present Worth of Soil and Growing Stock as \$35.70. The check by formula is:

$$^{m}Fe = \frac{(Yr + Se) - E(1.0p^{r-m}-1)}{1.0p^{r-m}} \qquad 1.035^{54-27} = 2.532$$

$$= \frac{(\$72.60 + \$28.15) - \$6.85(1.035^{27}-1)}{1.035^{54-27}} \qquad = \$35.70$$

As in other examples we have the Fe value; the value of the yield of the present one-third stocked stand of 14.5 cords worth \$72.60; the soil expectation factor of \$44.00 at 60% "standard" less planting cost of \$9 and capital for expenses at \$6.85; and the estimated yield on all following rotations of 26 cords per acre.

CONCLUSION

The problem of aiding managers of forest land in determining the value and classification of their various lands has been met to a certain extent in this work. It has been shown how additional data could be used in the formulas which are back of this presentation. The specific manner of gathering the data has been left to the forester in charge of field parties. No attempt has been made to be all-inclusive in any of this work since it was deemed sufficient merely to sketch the method. The problems of this sort that arise in different forestry organizations are so varied that no purpose would be served by an over-elaborate presentation here. This sketch does not include many of the possible age-groups of reproduction classes that could be found, the combinations of species growing possibly at different rates and selling for different prices, site differences as expressed by height, and the different stockings of the stands. Those details belong properly in the duties of the forester administering the lands. Each organization meets its own problems in its own way with the tools that it has. Here has been presented another tool.

The soil expectation formula was adapted to meet the need of expressing percentages of a "standard" soil expectation value. This was cumbersome as the formula originally stood, but when the variable soil expectation factor, $(Yr/1.0p^r-1)$, was considered separately from the constant planting costs and expenses, (C and E), the Se factor was found to be proportional to the volume of the yield. It might be said that if for any reason a chart of soil expectation values were desired it could be devised by subtraction of the constant factors, (C and E), from the line of the Se factors. The line for each diameter would merely be lowered by that amount. The purposes of this method, though, are served by the use of the soil expectation factor alone since a percentage of the "standard" is all that is really needed.

The forest expectation formula works out in a similar manner so that it may be charted as the Present Worth Grid. This is achieved by separating the variable factors of the expanded Fe formula from the constant factors as is shown in the General Method. Again, a straight line relationship results that may be charted so that any forest expectation value may be found within the limits of the stand and value conditions. This Present Worth Grid is the closest approach to a single colution for present worth of land and growing stock that this paper shows.

Several limitations in this method may have appeared to the reader thus far. One limitation is simply that the method is solely for even-age forest management. It has no application under all-age conditions. This limitation is so common in forest management that nothing further need be said.

The question of stocking has barely been touched upon in this work. The limitation that many conditions change with a change in stocking had to be met by saying that within "groups and patches" the stocking held up when the volume per acre dropped. This solution is rather unsatisfactory although such a condition is admittedly met in the forest. The other problem where stocking drops with a loss in volume due to even distribution of the trees has not been solved or considered in this work.

Two other problems that might have been considered are: the break-even point to which stocking could go before planting became essential to establish each succeeding rotation; and the break-even point of minimum area of ownership that could meet the taxes upon the land.

It is hoped that the presentation of this method will also aid foresters in reevaluating their methods of obtaining field data. Emphasis has been placed upon expected growth rate rather than present growth rate. Both are needed for management purposes but an unconventional scheme will have to be resorted to in order to obtain this expected growth rate. Such information is unlikely to be a product of the ordinary timber cruise.

Additionally, it is hoped that foresters will see the use of the valuation data and try to implement more exact methods of determining stumpage values and rotations. Better methods are on the way already for each of these, but they need to be used by operating companies to become effective.

This method is to be applied only to forest lands that are under even-age management. Consideration of only one species and a limited number of other factors was done for simplicity's sake. This should in no way interfere with such expansion as might be needed for actual use.

It is hoped that in spite of the limitations of this method the reader will see that a simple method of evaluation of forest land has been evolved from more complicated material.

The volume per tree data used in Schedule I for White Spruce was adapted by curve from Technical Bulletin 188 (1944), Michigan State College as follows:

Diameter Breast High Inches	Volume, Unpeeled Standard Cords
6	.04
7	.07
8	.10
9	.14
10	.18
11	.23
12	.28

Column (8) of the various Schedule III's was calculated by formula, using the proper interest rate and rotation, as follows:

$$^{m}Fe = \frac{(Yr + Se) - E(1.0p^{r-m}-1)}{1.0p^{r-m}}$$

Where:

Yr = yield in dollars at maturity, column (7).

Se = value of bare soil for R years rotation, planting at $9.00 per acre, annual expenses at $.24 per acre, from Schedule II.

m = present age of reproduction.

r = rotation age.

E = e/0.0p = $.24/0.0p

p = interest rate 3% or 3½%.

SCHEDULE I

Average Yields of White Spruce Pulpwood Based on Stocking of 150 Square Feet of Basal Area per Acre at Maturity.

(1) Average d.b.h. of crop trees inches	(2) Average spacing of crop trees feet	(3) Average number of crop trees per acre	(4) Average volume per tree of crop trees. cords	(5) Average yield per acre. cords	(6) Average value of crop per cord. Dollars	(7) Average value of yield per acre. Dollars
6	7.5	774	.04	31.0	$4.47	$138.00
7	8.75	568	.07	39.8	4.80	191.00
8	10.00	436	.10	43.6	5.00	218.00
9	11.25	345	.14	48.2	5.16	248.00
10	12.50	279	.18	50.2	5.27	264.00
11	13.75	230	.23	52.9	5.35	283.00
12	15.00	193	.28	54.0	5.42	292.00
Average yields of stand where timber is in groups and patches so that it maintains 150 square feet of basal area but contains only 25% of the volume of above yields.						
6	7.5	774	.04	7.75	4.47	34.50
7	8.75	568	.07	9.95	4.80	47.75
8	10.00	436	.10	10.90	5.00	54.50
9	11.25	345	.14	12.05	5.16	62.00
10	12.50	279	.18	12.55	5.27	66.00
11	13.75	230	.23	13.25	5.35	70.50
12	15.00	193	.28	13.50	5.42	73.00

Average Value of Crop per Cord or"Stumpage" Value. (3)
Column (6)

d.b.h. inches	6	7	8	9	10	11	12
Surplus after deducting fixed per cord costs from mill price.	$7.40	7.40	7.40	7.40	7.40	7.40	7.40
Cutting cost per cord, 60% efficiency, $.60 wages.	$2.93	2.60	2.40	2.24	2.13	2.05	1.98
Stumpage	$4.47	4.80	5.00	5.16	5.27	5.35	5.42

SCHEDULE II

Value of Soil per Acre Based on a 3% Interest Rate, Cost of Planting $9.00 and Annual Expense of $.24 per Acre. Calculated by Formula: Soil Expectation Value $= \frac{Yr}{1.0p^r - 1} - \left(\$9 + \frac{0.24}{.03}\right)$

When p = 3%

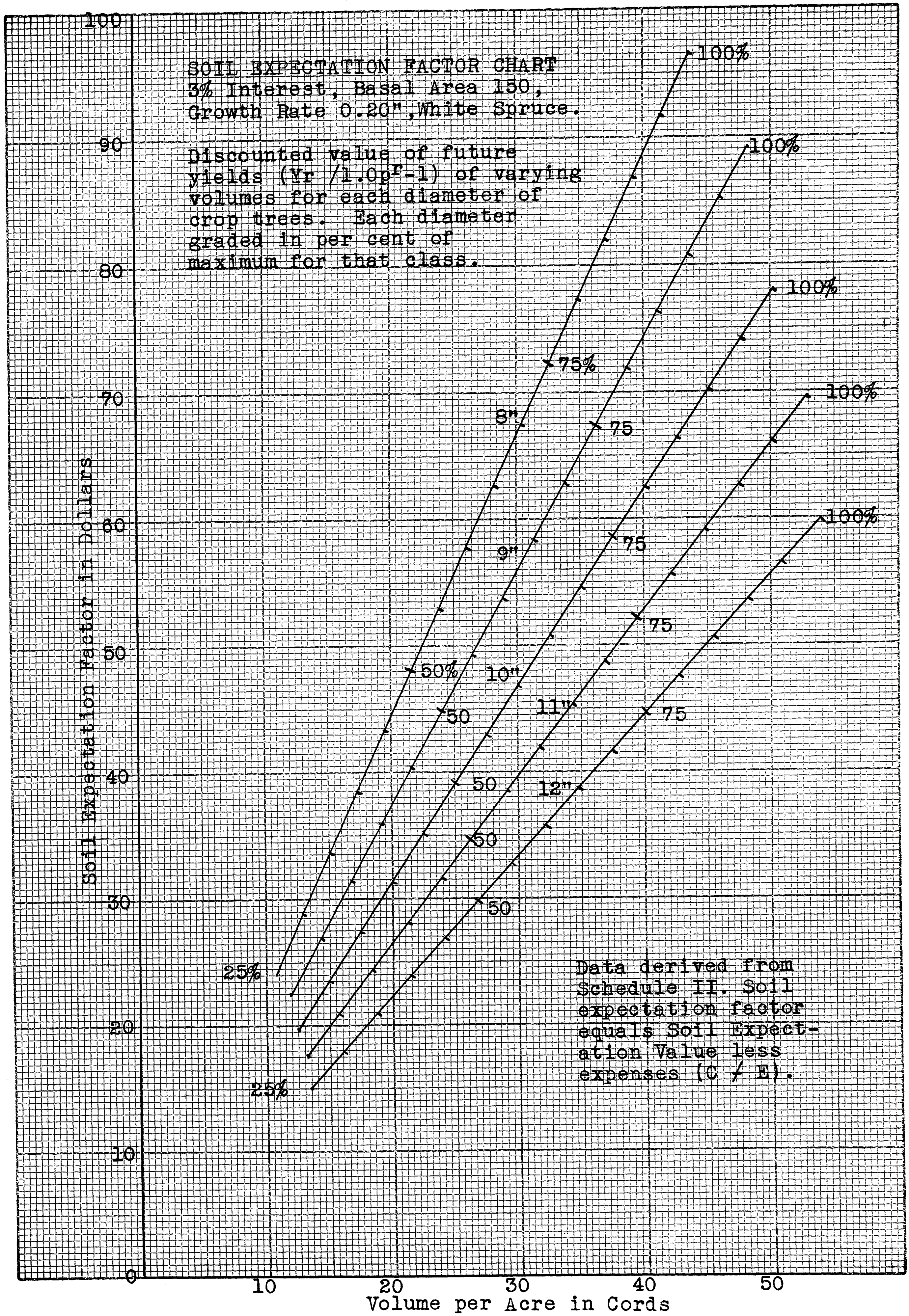
Estimated annual growth rate inches d.b.h.	7 inch Crop Trees: Rotation required, Years	7 inch: Soil value, Dollars 100%	7 inch: Soil value, Dollars 25%	8 inch Crop Trees: Rotation required, Years	8 inch: Soil value, Dollars 100%	8 inch: Soil value, Dollars 25%	9 inch Crop Trees: Rotation required, Years	9 inch: Soil value, Dollars 100%	9 inch: Soil value, Dollars 25%
0.15	50	39.50	neg.	55	36.50	neg.	60	33.80	neg.
0.18	40	67.40	4.10	45	61.50	2.60	50	56.40	1.35
0.20	35	88.00	9.25	40	79.40	7.10	45	72.20	5.30
	10 inch			11 inch			12 inch		
0.15	65	28.30	neg.	75	17.60	neg.	80	13.30	neg.
0.18	55	47.75	neg.	60	40.90	neg.	70	32.50	neg.
0.20	50	61.10	2.50	55	52.50	0.30	60	42.80	neg.

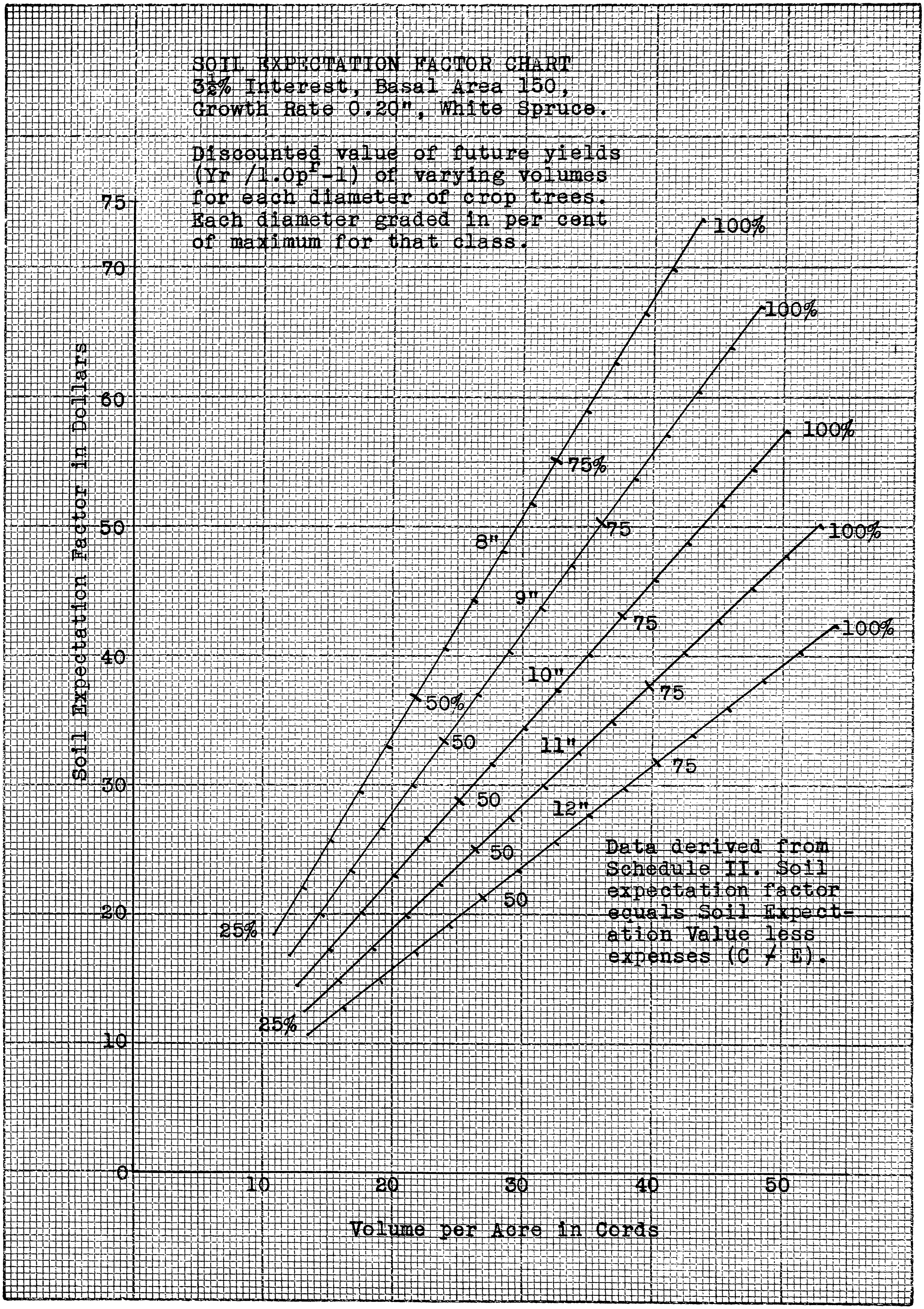
Value of Soil for 8 inch Crop Trees Based on 3.5% Interest.

Growth rate	Rotation	Soil Value 100% Yield	Soil Value 25% Yield
0.15	55	$12.85	negative
0.18	45	42.90	negative
0.20	40	57.75	$2.55

Value of Soil for 8 inch Crop Trees Based on 4% Interest.

Growth rate	Rotation	Soil Value 100% Yield	Soil Value 25% Yield
0.15	55	$13.50	negative
0.18	45	30.00	negative
0.20	40	42.35	negative


SOIL EXPECTATION FACTOR CHART
3% Interest, Basal Area 150,
Growth Rate 0.20",White Spruce.
Discounted value of future yields (Yr /1.0pr-1) of varying volumes for each diameter of crop trees. Each diameter graded in per cent of maximum for that class.
Data derived from Schedule II. Soil expectation factor equals Soil Expectation Value less expenses (C ≠ E).
Soil Expectation Factor in Dollars
Volume per Acre in Cords
0
10
20
30
40
50
60
70
80
90
100
8"
9"
10"
11"
12"
25%
50%
75%
100%
50
75


SOIL EXPECTATION FACTOR CHART
3½% Interest, Basal Area 150,
Growth Rate 0.20", White Spruce.
Discounted value of future yields
(Yr /1.0p^r-1) of varying volumes
for each diameter of crop trees.
Each diameter graded in per cent
of maximum for that class.
Soil Expectation Factor in Dollars
Volume per Acre in Cords
0
10
20
30
40
50
60
70
75
8"
9"
10"
11"
12"
25%
50%
75%
100%
25%
50
75
100%
50
75
100%
50
75
100%
50
75
100%
Data derived from
Schedule II. Soil
expectation factor
equals Soil Expect-
ation Value less
expenses (C ≠ E).

SCHEDULE III

Growing Stock and Soil Value Calculations at 3% Interest.
(All calculations based on crop trees 8 inches in d.b.h. and a growth rate of 0.20" per yr)

(1) Class	(2) Size inches	(3) Age years	(4) Number per acre	(5) Stocking %	(6) Yield when mature. (R-40 years) Cords per acre	(7) Value of Yield when mature. per acre	(8) Present worth of soil and growing stock. per acre
"Standard" or maximum stocking - 100%							
A-1	3-5	20	1200	100	43.6	$218.00	$161.00
A-2	3-5	20	900	75	32.7	163.50	131.00
A-3	3-5	20	700	60	26.2	131.00	113.00
A-4	3-5	20	400	33	14.5	72.60	80.60
A-5	3-5	20	300	25	10.9	54.50	70.60
When yields both on present and future rotations are at 25% of "standard."							
A-1	3-5	20	1200	100	10.9	54.50	30.50
A-2	3-5	20	900	75	8.2	40.85	23.00
A-3	3-5	20	700	60	6.5	32.70	18.50
A-4	3-5	20	400	33	3.6	18.50	10.60
A-5	3-5	20	300	25	2.7	13.60	7.90
"Standard" or maximum stocking - 100%							
B-1	1-3	10	1200	100	43.6	218.00	118.00
B-2	1-3	10	900	75	32.7	163.50	95.40
B-3	1-3	10	700	60	26.2	131.00	82.00
B-4	1-3	10	400	33	14.5	72.60	58.00
When yields both on present and future rotations are at 25% of "standard."							
B-1	1-3	10	1200	100	10.9	54.50	20.70
B-2	1-3	10	900	75	8.2	40.85	15.05
B-3	1-3	10	700	60	6.5	32.70	11.70
B-4	1-3	10	400	33	3.6	18.50	5.85

SCHEDULE III

Growing Stock and Soil Value Calculations at 3% Interest.
(All calculations based on crop trees 8 inches in d.b.h., a present growth rate for balance of rotation of 0.15 inches per year, and a growth rate for all future rotations of 0.20 inches per year.)

(1) Class	(2) Size inches	(3) Age Years	(4) Number per acre	(5) Stocking %	(6) Yield when mature. (R-54 years) Cords per acre	(7) Value of yield when mature. per acre	(8) Present worth of soil and growing stock. per acre
"Standard" or maximum stocking - 100%							
A-1	3-5	27	1200	100	43.6	$218.00	$129.50
A-2	3-5	27	900	75	32.7	163.50	105.00
A-3	3-5	27	700	60	26.2	131.00	90.40
A-4	3-5	27	400	33	14.5	72.60	64.00
A-5	3-5	27	300	25	10.9	54.50	55.90
When yields both on present and future rotations are at 25% of "standard."							
A-1	3-5	27	1200	100	10.9	54.50	23.30
A-2	3-5	27	900	75	8.2	40.85	17.20
A-3	3-5	27	700	60	6.5	32.70	13.50
A-4	3-5	27	400	33	3.6	18.50	7.13
A-5	3-5	27	300	25	2.7	13.60	4.93
"Standard" or maximum stocking - 100%							
B-1	1-3	14	1200	100	43.6	218.00	85.50
B-2	1-3	14	900	75	32.7	163.50	69.00
B-3	1-3	14	700	60	26.2	131.00	59.00
B-4	1-3	14	400	33	14.5	72.60	41.00
When yields both on present and future rotations are at 25% of "standard."							
B-1	1-3	14	1200	100	10.9	54.50	13.35
B-2	1-3	14	900	75	8.2	40.85	9.10
B-3	1-3	14	700	60	6.5	32.70	6.65
B-4	1-3	14	400	33	3.6	18.50	2.30

SCHEDULE III

Growing Stock and Soil Value Calculations at 3.5% Interest.
(All calculations based on crop trees 8 inches d.b.h. and a growth rate of 0.20 inches per year.)

(1) Class	(2) Size inches	(3) Age years	(4) Number per acre	(5) Stocking %	(6) Yield when mature. (R-40 years) Cords per acre	(7) Value of yield when mature. per acre	(8) Present worth of soil and growing stock. per acre
"Standard" or maximum stocking - 100%							
A-1	3-5	20	1200	100	43.6	$218.00	$135.00
A-2	3-5	20	900	75	32.7	163.50	107.75
A-3	3-5	20	700	60	26.2	131.00	91.50
A-4	3-5	20	400	33	14.5	72.60	62.10
A-5	3-5	20	300	25	10.9	54.50	53.00
When yields both on present and future rotations are at 25% of "standard."							
A-1	3-5	20	1200	100	10.9	54.50	25.20
A-2	3-5	20	900	75	8.2	40.85	18.40
A-3	3-5	20	700	60	6.5	32.70	14.30
A-4	3-5	20	400	33	3.6	18.50	7.15
A-5	3-5	20	300	25	2.7	13.60	4.70
"Standard" or maximum stocking - 100%							
B-1	1-3	10	1200	100	43.6	218.00	93.70
B-2	1-3	10	900	75	32.7	163.50	74.50
B-3	1-3	10	700	60	26.2	131.00	62.90
B-4	1-3	10	400	33	14.5	72.60	42.00
When yields both on present and future rotations are at 25% of "standard."							
B-1	1-3	10	1200	100	10.9	54.50	15.90
B-2	1-3	10	900	75	8.2	40.85	11.00
B-3	1-3	10	700	60	6.5	32.70	8.15
B-4	1-3	10	400	33	3.6	18.50	3.10

SCHEDULE III

Growing Stock and Soil Value Calculations at 3.5% Interest.
(All calculations based on crop trees 8 inches in d.b.h., a present growth rate for balance of rotation of 0.15 inches per year, and a growth rate for all future rotations of 0.20 inches per year.)

(1) Class	(2) Size inches	(3) Age years	(4) Number per acre	(5) Stocking %	(6) Yield when mature. (R-54 years) Cords per acre	(7) Value of yield when mature. per acre	(8) Present worth of soil and growing stock. per acre
"Standard" or maximum stocking - 100%							
A-1	3-5	27	1200	100	43.6	$218.00	$104.75
A-2	3-5	27	900	75	32.7	163.50	83.25
A-3	3-5	27	700	60	26.2	131.00	70.50
A-4	3-5	27	400	33	14.5	72.60	47.35
A-5	3-5	27	300	25	10.9	54.50	40.25
When yields both on present and future rotations are at 25% of "standard."							
A-1	3-5	27	1200	100	10.9	54.50	18.40
A-2	3-5	27	900	75	8.2	40.85	13.00
A-3	3-5	27	700	60	6.5	32.70	9.80
A-4	3-5	27	400	33	3.6	18.50	4.17
A-5	3-5	27	300	25	2.7	13.60	2.23
"Standard" or maximum stocking - 100%							
B-1	1-3	14	1200	100	43.6	218.00	64.50
B-2	1-3	14	900	75	32.7	163.50	50.75
B-3	1-3	14	700	60	26.2	131.00	42.60
B-4	1-3	14	400	33	14.5	72.60	28.30
When yields both on present and future rotations are at 25% of "standard."							
B-1	1-3	14	1200	100	10.9	54.50	9.33
B-2	1-3	14	900	75	8.2	40.85	5.87
B-3	1-3	14	700	60	6.5	32.70	3.82
B-4	1-3	14	400	33	3.6	18.50	0.23

Sample Calculation of Data for Present Worth Grid for 3% Interest, Current Growth 0.15", Future Growth 0.20", Basal Area 150, White Spruce.

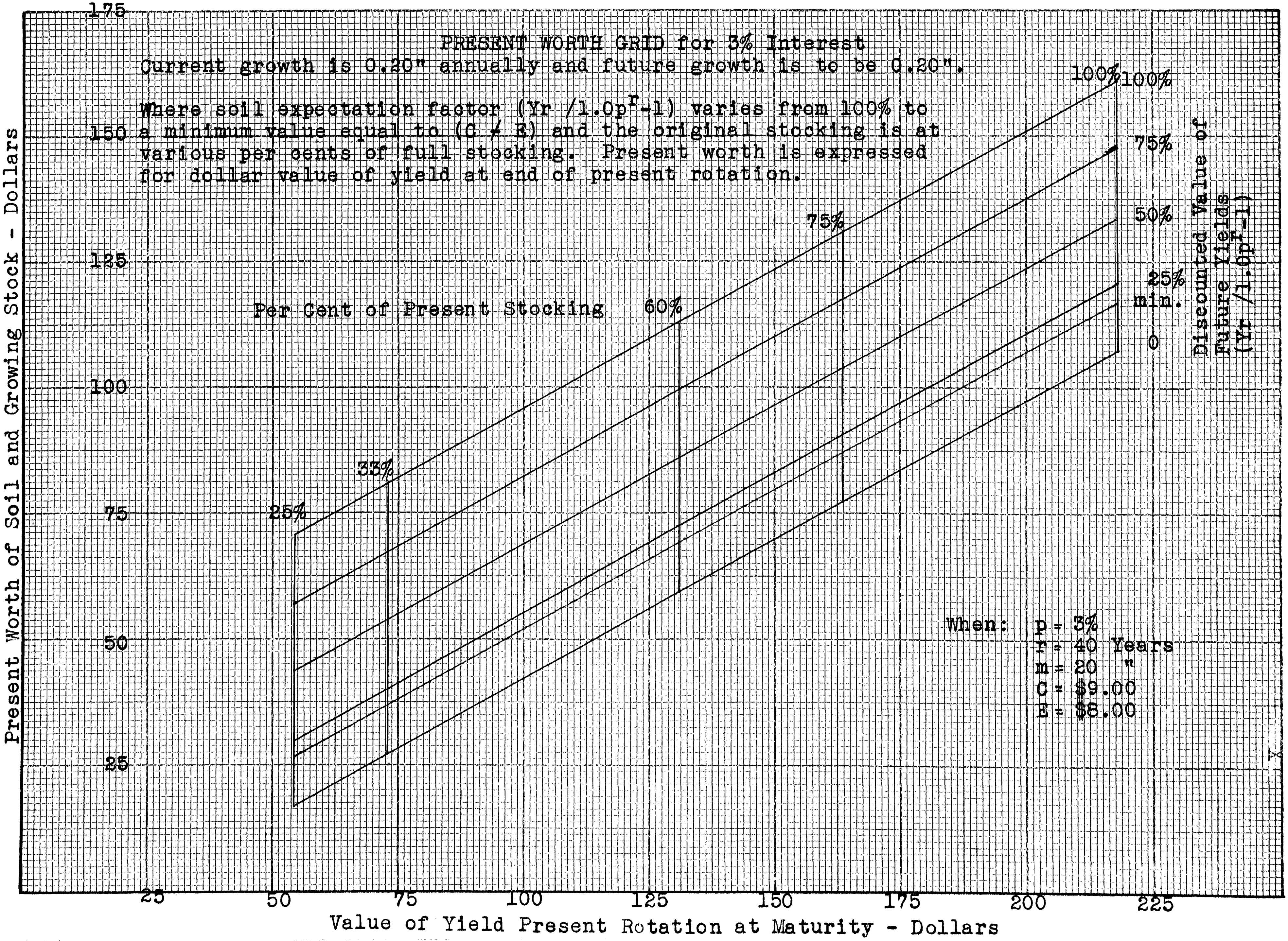
Per Cent of Present Stocking or yield	Yr	Per Cent Discounted Value Future Yields	$\frac{Yr}{1.03^{40}-1}$	Sum of all yields	Discount factor 1.03^{54-27}	Discounted yield	Discounted value all expenses	Forest expectation value
100%	$218.00	100%	$96.40	$314,40	2.221	$141.50	$12.00	$129.45
$218.00	"	75	72.25	290.25	"	130.90	"	118.85
	"	50	48.20	266.20	"	120.00	"	108.00
	"	25	24.10	242.10	"	109.00	"	97.00
	"	minimum	17.00	235.00	"	106.00	"	94.00
	"	0	0	218.00	"	98.25	"	86.25
33%	72.60	100%	96.40	169.00	"	76.10	"	64.10
$72.60	"	75	72.25	144.85	"	65.25	"	53.25
	"	50	48.20	120.80	"	54.40	"	42.40
	"	25	24.10	96.70	"	43.50	"	31.50
	"	minimum	17.00	89.60	"	40.35	"	28.35
	"	0	0	72.60	"	32.70	"	20.70

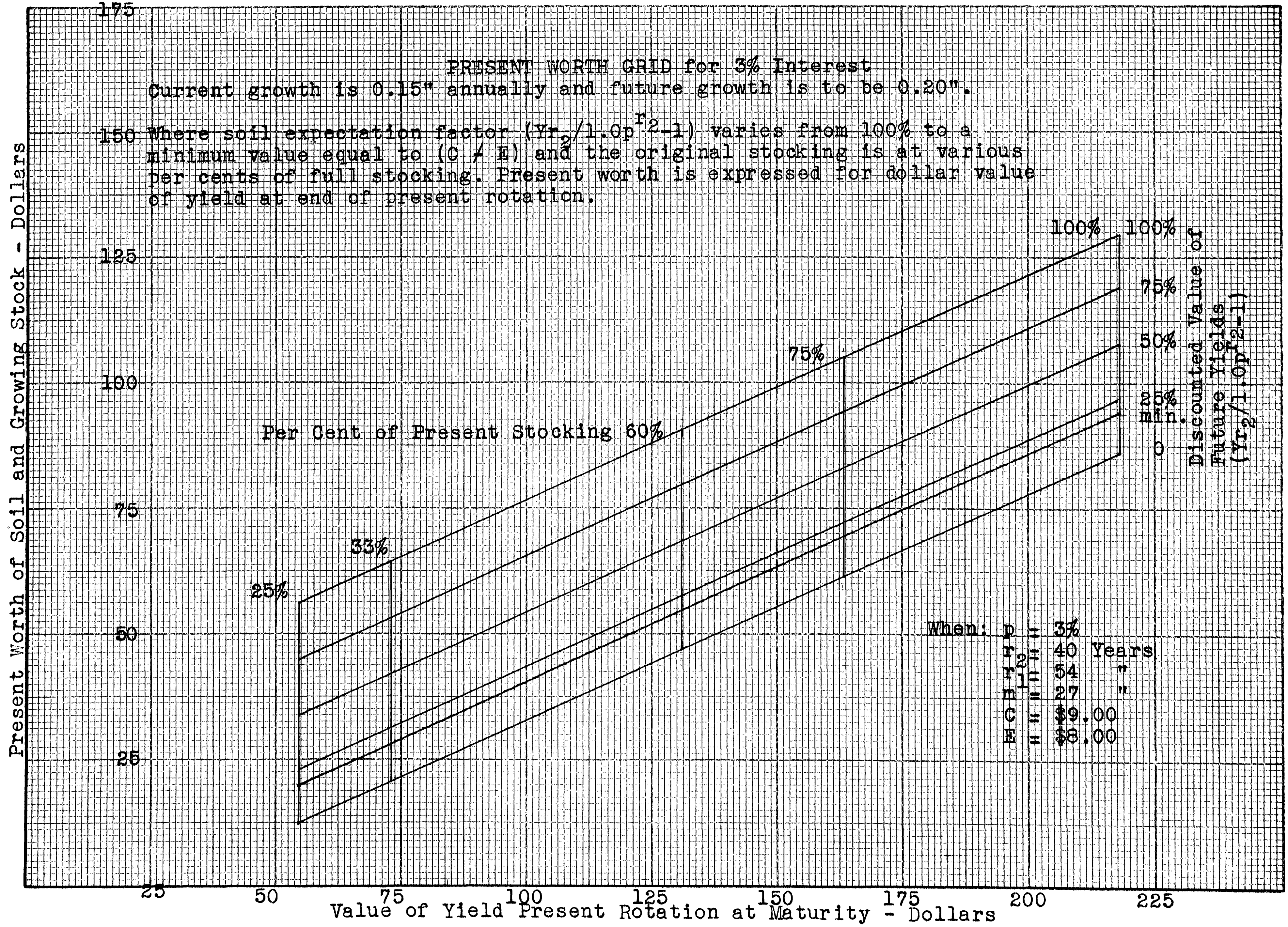
Forest expectation value or present worth of soil and growing stock:

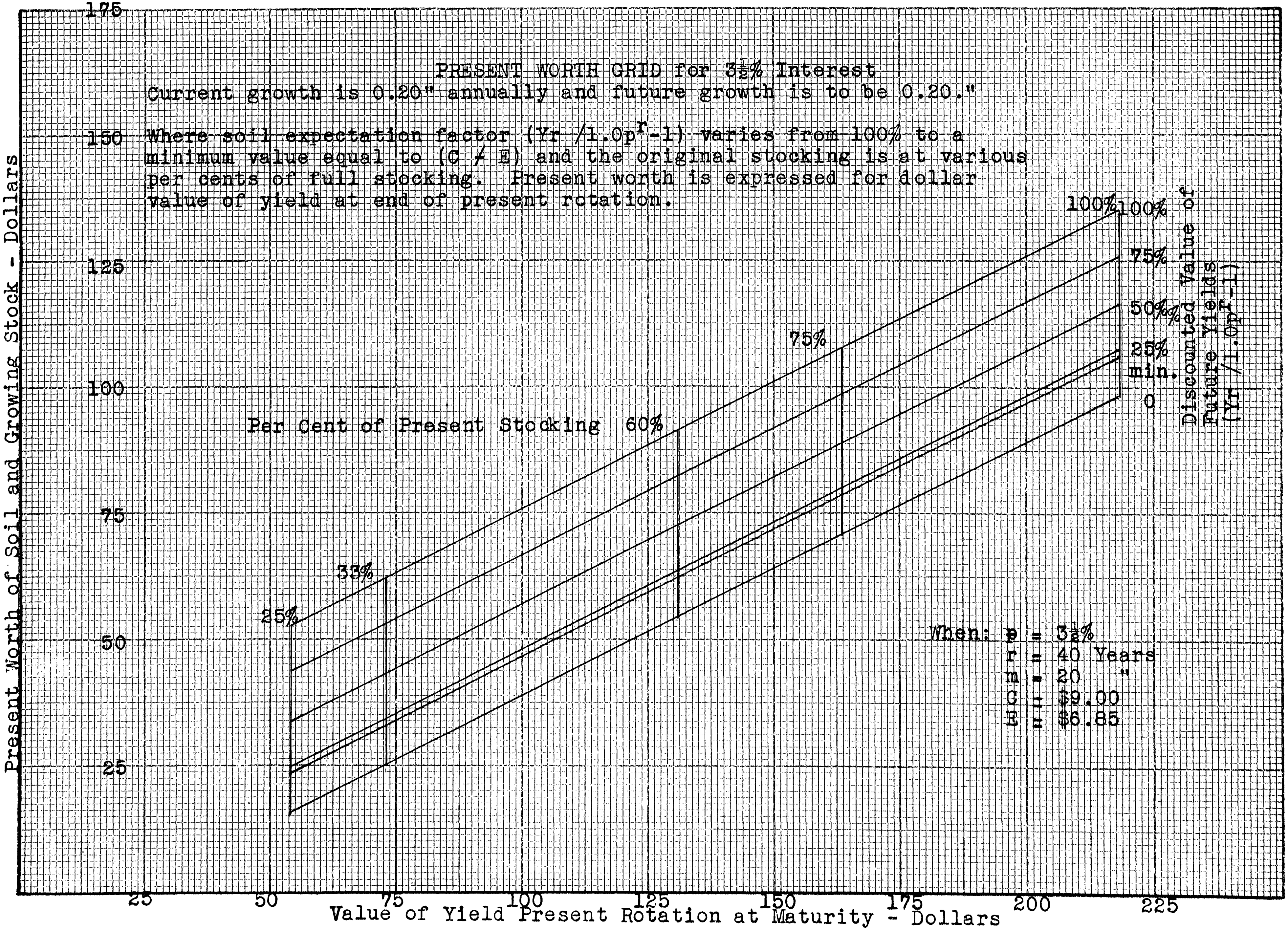
$$^{m}Fe = \left[\frac{Yr_1 + (Yr_2/1.0p^{r_2}-1)}{1.0p^{r_2-m}}\right] - \left[\frac{C + E + E(1.0p^{r_2-m}-1)}{1.0p^{r_2-m}}\right]$$

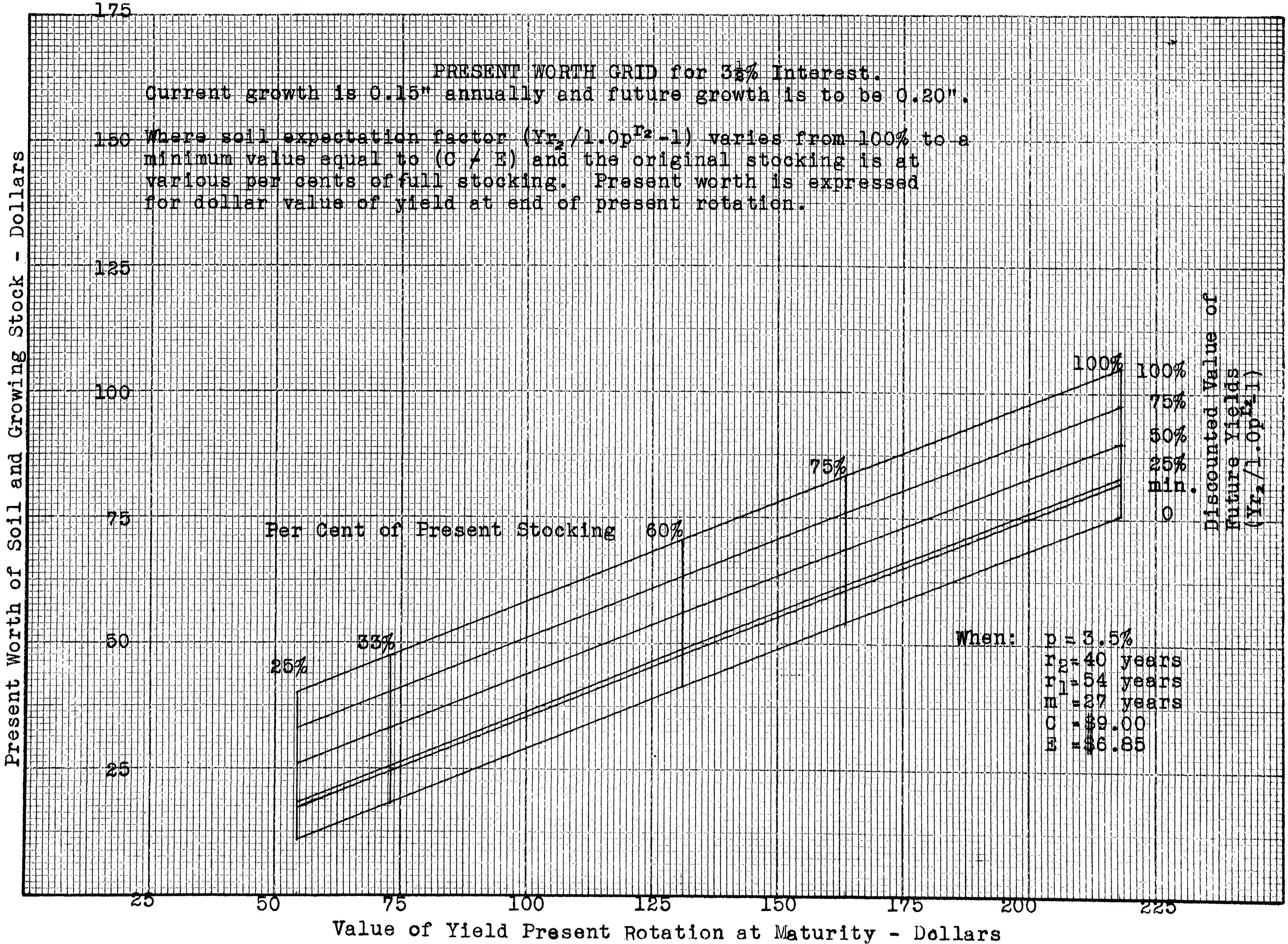
Determination of discounted value all expenses:

$$\left(\frac{C + E + E(1.0p^{r_2-m}-1)}{1.0p^{r_2-m}}\right) = \frac{\$9 + \$8 + \$8(1.03^{54-27}-1)}{1.03^{54-27}} = \$12.00$$


PRESENT WORTH GRID for 3% Interest
Current growth is 0.20" annually and future growth is to be 0.20".
Where soil expectation factor (Yr /1.0p^r-1) varies from 100% to a minimum value equal to (C ≠ E) and the original stocking is at various per cents of full stocking. Present worth is expressed for dollar value of yield at end of present rotation.
Per Cent of Present Stocking
25%
33%
60%
75%
100%
Discounted Value of Future Yields (Yr /1.0p^r-1)
100%
75%
50%
25%
min.
0
When: p = 3%
r = 40 Years
m = 20 "
C = $9.00
E = $8.00
Present Worth of Soil and Growing Stock - Dollars
25
50
75
100
125
150
175
Value of Yield Present Rotation at Maturity - Dollars
25
50
75
100
125
150
175
200
225


PRESENT WORTH GRID for 3% Interest
Current growth is 0.15" annually and future growth is to be 0.20".
Where soil expectation factor ($Yr_2/1.0p^{r_2}-1$) varies from 100% to a minimum value equal to (C + E) and the original stocking is at various per cents of full stocking. Present worth is expressed for dollar value of yield at end of present rotation.
Per Cent of Present Stocking 60%
25%
33%
75%
100%
100%
75%
50%
25%
min.
0
Discounted Value of Future Yields ($Yr_2/1.0p^{r_2}-1$)
When: p = 3%
r_2 = 40 Years
r_1 = 54 "
m = 27 "
C = $9.00
E = $8.00
Present Worth of Soil and Growing Stock - Dollars
175
150
125
100
75
50
25
Value of Yield Present Rotation at Maturity - Dollars
25
50
75
100
125
150
175
200
225


PRESENT WORTH GRID for 3½% Interest
Current growth is 0.20" annually and future growth is to be 0.20."
Where soil expectation factor (Yr /1.0p^r-1) varies from 100% to a minimum value equal to (C ∔ E) and the original stocking is at various per cents of full stocking. Present worth is expressed for dollar value of yield at end of present rotation.
Per Cent of Present Stocking 60%
25%
33%
75%
100%
100%
75%
50%
25%
min.
0
Discounted Value of Future Yields (Yr /1.0p^r-1)
When: p = 3½%
r = 40 Years
m = 20 "
C = $9.00
E = $6.85
Present Worth of Soil and Growing Stock - Dollars
175
150
125
100
75
50
25
Value of Yield Present Rotation at Maturity - Dollars
25
50
75
100
125
150
175
200
225


PRESENT WORTH GRID for 3½% Interest.
Current growth is 0.15" annually and future growth is to be 0.20".
Where soil expectation factor (Yr₂/1.0p^r₂-1) varies from 100% to a minimum value equal to (C ≠ E) and the original stocking is at various per cents of full stocking. Present worth is expressed for dollar value of yield at end of present rotation.
Per Cent of Present Stocking
25%
33%
60%
75%
100%
Discounted Value of Future Yields (Yr₂/1.0p^r₂-1)
100%
75%
50%
25%
min.
0
When: p = 3.5%
r₂ = 40 years
r₁ = 54 years
m = 27 years
C = $9.00
E = $6.85
Present Worth of Soil and Growing Stock - Dollars
175
150
125
100
75
50
25
Value of Yield Present Rotation at Maturity - Dollars
25
50
75
100
125
150
175
200
225

SOURCE MATERIAL

Books

Matthews, D.M.: "Management of American Forests," McGraw-Hill, New York, 1935.

...............: "Cost Control in the Logging Industry," McGraw-Hill, New York, 1942.

Bulletins

Bowman, A.B.: "Growth and Occurrence of Spruce and Fir on Pulpwood Lands in Northern Michigan, " Michigan State College, Agricultural Experiment Station, Technical Bulletin 188, 1944.

Brown, R.M., and Gervorkiantz, S.R.: "Volume, Yield, and Stand Tables for Tree Species in the Lake States," University of Minnesota, Technical Bulletin 39, 1934.

Day, Maurice W.: "Forest Management for the Eastern Part of the Upper Peninsula of Michigan," Michigan State College Agricultural Experiment Station, Circular Bulletin 190.

ACKNOWLEDGMENT

Matthews, Prof. D.M.: for the method embodied in Schedules I, II, and III which he had developed for southern pine, and for much help and advice.