ECONOMIC GUIDELINES FOR ESTABLISHING LOBLOLLY PINE PLANTATIONS IN VIRGINIA

by

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INTRODUCTION

Approximately two-thirds of Virginia's land area, 15.8 million acres, is commercial forest land (Knight and McClure, 1967). Within the past decade, there has been a steady annual increase in the number of these acres being artificially reforested. Currently, about 85 thousand acres, or more than .5 per cent of the commercial forest land, are being planted annually. Nearly 40 per cent of this acreage is planted by private individuals, with the remainder done by industrial forest landowners. Loblolly pine (*Pinus taeda* L.) is the principle tree species planted in Virginia, accounting for nearly ninety-five per cent of all stock planted in the state.

Objectives

The primary objective of this study was to develop cost estimates of site preparation and planting loblolly pine in Virginia, and to show how these estimates could be used as economic guidelines in making regeneration decisions.

A secondary objective was to assess the feasibility of a methodology for systematically quantifying expert opinion (*i.e.*, management judgment).

The Need for Economic Guides

With the increasing importance of growing more wood per acre, the forest regeneration decision becomes increasingly important. Establishment costs for loblolly pine plantations can approach forty dollars or more per acre. Thus, when dealing with more than 80 thousand acres, the total annual investment in Virginia may exceed three million dollars. This total is divided among the various landowners currently involved in loblolly pine regeneration. It is generally not possible to plant all those acres needing to be regenerated, since each landowner usually has a limited regeneration budget and since vagaries of the weather cannot be foreseen. Therefore, it is desirable to have economic guidelines to improve the efficiency of regeneration operations. Such guidelines are not currently available to Virginia forest landowners.

The Nature of the Regeneration Decision

A forest regeneration decision is characterized by a time lag between the initial cost outlay, for site preparation and planting, and the financial return, or yield, from timber harvest. From the economic viewpoint, such an investment is desirable when the present value of the returns equals or exceeds the present value of the costs. Accordingly, forest regeneration investments have three basic economic components: financial return, cost, and interest rate.

While financial return and interest rate are very important, they will not be empirically examined in this study. A main objective in artificially regenerating loblolly pine in Virginia appears to be: prepare the site and plant the seedlings at the least cost which will attain an acceptable stand. This means that a minimum number of seedlings must capture the site and be "free-to-grow" within a specific time period.

The use of a cost figure as an economic guideline, either by itself or in conjunction with yield and/or interest rates, is justified only if some measure of its reliability is available. For this study, reliability was expressed by the probability of establishing or achieving an acceptable stand of loblolly pine. With an estimate of the probability of a successful plantation resulting from the establishment cost, an expected regeneration cost can be calculated to indicate, on the average, what a forest landowner should expect to spend to achieve an acceptable stand.

The probability of a specific regeneration technique resulting in an acceptable stand is not precisely known. It would be possible to empirically determine this probability, but the cost, in both time and money, would be very high, if not prohibitive. However, persons who are continuously involved in making regeneration decisions have, through necessity, accumulated considerable information regarding the results of regeneration operations. This information derives from personal experience and secondary sources, such as research findings and discussions with other "experts". For this study, the probabilities of regeneration success were developed from expert opinion (management judgment) rather than empirically collected data.

REVIEW OF LITERATURE

The literature review will be concerned with forest regeneration costs, the use of economic guidelines, and the use of expert opinion. Regarding regeneration costs, few studies have related these to a specific regeneration technique. Concerning economic guidelines, some work done outside the scope of regeneration, but within forestry, will be discussed to indicate that economic guidelines have been developed and used. The review of expert opinion will include literature outside forestry to indicate its development as an analytical tool, as well as some previous uses in forestry research.

Costs of Regeneration

In contrast to the quantities of available yield data, little material on the costs of regeneration has been published. Some of the better work, to date, has been done by Teeguarden (1967), who estimated treatment costs for Douglas-fir reforestation in Oregon. In a recent study, Manthy (1970) developed an investment guide for Pennsylvania's cooperative forest management program. In his research, he used public costs and private costs as components of his total cost figure. The data apply to planting and site preparation as a whole, but are not related to specific techniques.

Stevenson (1966) mentioned an average total cost of site preparation in north Florida of \$30 per acre. This cost excluded the planting cost and was for burning to reduce logging slash, chopping with a drum chopper, and harrowing with an offset harrow. Stevenson did not cite costs of different regeneration techniques. Yoho and Dutrow (1968) cited an average site preparation cost of \$23.52 per acre based on a southwide questionnaire interview (Southern Forest Resource Analysis Committee, 1969).

Hayes (1970) undertook an economic comparison of different site preparation techniques. His major conclusion was that current annual expenditures for new site preparation equipment by large pulp and paper companies, in southeastern United States, approach 10 to 12 dollars per acre treated.

Kalmar (1958) and Anderson (1958) studied the economics of site preparation. Because of the uncertainty involved in forest regeneration decisions, these authors concluded that the economics concerning site preparation can be calculated only within limits. Two major uncertainties they mentioned were the financial value of the timber crop at rotation age, and the availability of land. Kalmar stated that land preparation treatment should not cost more than 10 to 12 dollars per acre, using equipment and facilities that existed at that time.

Somberg, et al., (1963), in a cost study, analyzed total costs of forestry practices in the South according to four detailed components: direct labor costs, supervision costs, equipment costs, and overhead costs. Their study considered many forestry practices, including burning, bulldozing or discing, and planting by machine and by hand, as well as others not directly related to forest regeneration. Somberg (1969) also undertook a study in Alabama to analyze the costs of forestry practices in that state. His format was similar to that of the preceding study.

Economic Guidelines

Although little material is currently available on the subject of economic guidelines for forest regeneration, Teeguarden (1967) did develop economic guidelines for Douglas-fir reforestation in western Oregon. He constructed a ranking of reforestation investment alternatives based on cost-effectiveness criteria as a means of providing a guide to the allocation of reforestation budgets. The criteria used by Teeguarden in his analysis included expected present net worth, expected return per dollar of initial outlay, and expected wood yield per dollar of initial outlay. Later, Teeguarden (1969) expanded upon his initial study and used economic choice criteria and calculated risk factors in discussing regeneration decision making. He concluded that it is usually a fixed budget that limits the actions the land manager can take rather than a shortage of investment opportunities. As a result of Teeguarden's work, the United States Department of Interior (1969) published economic guides for Douglas-fir reforestation in southwestern Oregon. These above three references essentially constitute the literature on economic guidelines for forest regeneration.

Economic guidelines have been developed and used in other areas within the realm of forest management. For example, Flora (1966) developed economic guides dealing with tree disease control. He used return per dollar invested as his allocative criteria. Sackett, et al. (1967), developed guides for allocating fire protection budgets based on a benefit-cost approach.

Expert Opinion

The quantification and use of expert opinion is not common in the forestry literature. Teeguarden (1967) used expert opinion in the form of a regeneration success estimate in developing his guidelines. Davis (1965), studying the economics of wildfire protection in California, used expertise to obtain estimates of the frequency of success at fire-fuel break encounters. He obtained the expert opinion in a decision game. The basis of Davis' game was an earlier (but published later), successful game designed by Schultz (1966) and applied to a wildfire suppression problem. Also, Bentley and Kaiser (1967) used expert opinion to obtain Christmas tree survival rates in a study of sequential decisions.

Expert opinion has been used and studied in disciplines other than forestry. Kaplan, Skogstad, and Grishick (1950) undertook a pilot project in the study of expert opinion. They considered the problems of evaluation, improvement, and appraisal of opinion. They concluded that a serious question raised by the study of prediction is whether the analysis is made on a statistically stable population. Three difficulties they mentioned were that the predictors must be experts in the specific field, the questions must be easily understood by the experts, and the procedure must not be limited by time.

PROCEDURES

Because it is impractical, if not impossible, to develop guidelines for all possible regeneration techniques and opportunities, (see Appendix I for definitions) this study considered only selected techniques and opportunities. Future studies may be able to relax the present restrictions.

Before the study was actually begun, it was assumed that the Virginia Piedmont and the Virginia Coastal Plain were sufficiently different to be considered separately. It was also decided to consider only those regeneration techniques being used by a majority of Virginia's industrial forest landowners; i.e. not every technique currently being used in Virginia is considered. The study data were collected from industrial forest landowners, however, this does not preclude their use by the smaller, individual forest owners. Henceforth, the term forest landowner shall be applicable to both ownership categories.

Preliminary Interview

Before any data could be obtained, it was necessary to define the regeneration techniques and regeneration opportunities that would be studied. It was also necessary to determine the qualifications of the cooperating forest landowners to participate in the study to ensure that they were experts in regenerating loblolly pine in Virginia. Thus, the definition of the techniques and opportunities, and the determination of the cooperators' regeneration qualifications were two primary purposes of a preliminary interview. Definitions of the techniques, opportunities, and technical terms used in the study are contained in Appendix I.

The initial contact with the potential cooperators was made by letter during the early summer of 1970. Upon agreement, an acceptable date for the preliminary interview was established with each cooperating firm.

During the preliminary interview, each cooperator was asked to indicate his and the company's current and past experience with regenerating loblolly pine in Virginia. Then, each cooperator was asked to list the loblolly pine regeneration techniques currently being used by his company; each technique was described to be sure the cooperator and the interviewer were in accord. This description was frequently supplemented by a field demonstration.

Each cooperator was then asked to describe the regeneration opportunities undertaken by his firm. Once the opportunities were defined, the cooperators were asked which of the previously mentioned regeneration techniques are employed on each regeneration opportunity, because not all techniques are used on all opportunities. After each technique was associated with either one or more opportunities, the cooperator was asked to state, in his opinion, the two or three most important factors influencing the regeneration cost on each opportunity. This was necessary in order that the cooperators would later, during data collection, be able to readily associate a technique with an easily identified quality of land.

The cooperators gave information pertinent only to the area of their firm's location. For example, a cooperator who owned land only in the Virginia Piedmont did not supply any information for the Virginia Coastal Plain. However, some of the cooperators whose firm's own land within each area, supplied information for both.

Final Interview

The purpose of the final interview was to obtain the regeneration costs and associated probabilities of achieving an acceptable stand of loblolly pine, as well as to obtain necessary information regarding cost components. However, prior to the interview, forms, indicating the information which would be required, were sent to each cooperator (Appendix II). This gave the cooperators sufficient time to familiarize themselves with the required information, thus ensuring that data collection would be as systematic and efficient as possible. The final interviews were held at each firm's office during early September, 1970. At two of the firms, more than one cooperator participated in the final interview. In these cases, each individual was interviewed independently to ensure that one expert's estimates would not influence those of another.

The data collected during the final interview consisted of estimated 1969 regeneration costs for technique-opportunity combinations, and the cooperator's estimated probability of achieving an acceptable stand of loblolly pine. The cost data were then adjusted for comparability.

Comparable Costs

The components of total regeneration costs were not identical for all firms. Therefore, each cooperator was asked to indicate the components included in his cost estimates. In one case, this information was provided by an accountant.

Specifically, each cooperator was asked whether or not the following items were included in his regeneration cost estimates:

1. Depreciation of equipment used in site preparation and planting and/or in moving between tracts.
2. Interest on equipment (capital) investment.
3. Repairs including labor, materials, and/or maintenance on site preparation and planting equipment.
4. Insurance
5. Supervision and management costs of regeneration operations.

6. Employee fringe benefits.
7. Operating costs.
8. Transportation of men and equipment between tracts, other than equipment depreciation.

Additionally, further information was obtained regarding acreage, equipment, and type of operator. This included, respectively, the average size of site prepared tract, whether or not the equipment was used specifically for regeneration purposes or also for other purposes such as forest road construction, and whether the work was contracted or done using company operators.

If one of the above eight items was not included, the cooperator was asked to estimate, to the best of his ability, what percentage or amount of the total cost each missing factor might contribute. On this basis, it was possible to get all the costs on a generally comparable basis. Then, major differences in costs could be attributed to one or more of the additional items of information obtained, i.e. acreage, equipment, or operator.

RESULTS

Although most data were collected during the final interview, a portion of the study results are attributed to the preliminary interview. It is on the basis of these results that the final interview was accomplished.

Preliminary Results

Appendix III lists the regeneration techniques that are currently associated with regeneration opportunities in Virginia. An indication of the degree of use, or importance, of a particular technique-opportunity combination is the number of cost and probability estimates given for that combination (Appendices III and IV).

More variety exists in the Piedmont regeneration techniques. In that area, the most important artificial methods, classified according to regeneration opportunity, of loblolly pine regeneration include: on those acreas having favorable topography and low brush, burn and hand plant, and on all favorable topographic areas, chop, burn, and hand plant. Other techniques currently being used are: shear, rake, disc, and hand and/or machine plant, hand poison and hand plant, and scalp and plant.

In the Virginia Coastal Plain, during the summer and autumn months under all brush conditions, chop, burn, and hand plant, and during the summer in low brush areas, burn and hand plant are currently the two most used techniques. The only other technique of any significance is the double mechanical treatment and hand plant, mainly during the winter months.

More machine planting is done in the Piedmont than in the Coastal Plain. Only one cooperator gave an estimate for machine planting in the Coastal Plain and one estimate does not justify inclusion in the study results.

Another outcome attributed to the preliminary interview is the status of the cooperators participating in the study. This information is available in Appendix I, number 3. Because the cooperators are highly qualified, the regeneration costs should be the lowest possible for the given techniques. That is, it is doubtful, on the average, if anyone applying the given techniques on the given opportunities can do so at a less cost than the cooperators.

Final Results

The final results of the study include the information extracted during the final interview, as well as the calculation of expected costs and the derived economic guidelines. Initially, the estimated costs had to be adjusted for comparability.

Cost Components and Associated Information

For cost data to be comparable, all costs must be composed of the same factors. The total regeneration costs per acre, as given in Appendices III and IV, are composed of the following: depreciation of site preparation and planting equipment, and of equipment used to move labor and materials from tract to tract; repairs on equipment; overhead (supervision) directly attributed to the site preparation and planting work; employee fringe benefits; operating costs such as wages, gas, oil, etc.; transportation, other than equipment depreciation, between areas; cost of fireline construction; and seedlings cost. All costs are 1969 figures. The factor influencing total regeneration costs most significantly from year to year was found [1/] to be the cost of labor, particularly for planting seedlings.

Other pertinent information influencing regeneration costs concerns the acreage regenerated, the equipment used, the operator involved, and the owner's tax structure. Among the firms participating in this project, the average size of site prepared tract in 1969 was about 135 acres, with a range from 75 acres to 200 acres. In all cases except one, the equipment used in site preparation was used only for that purpose. Practically all site preparation work in the Piedmont is contracted, whereas in the Coastal Plain, most of the work is done with company equipment and manpower.

1/ This was determined from personal communication with various cooperators.

Calculation of Expected Costs

Although the estimated costs are considered to be reliable and consistent, they do not fully account for the true cost of regeneration. Undoubtedly, not every tree planted will survive, and in some cases not enough trees will survive on a given tract to meet the requirement of an acceptable stand. Consequently, the tract must be regenerated again. Thus, some measure of the reliability of a particular estimated regeneration cost is needed, and this is the purpose of the probability estimate associated with each cost.

The subjective probability takes into account the uncertainty involved in forest regeneration. Subjective probability offers a possible response to uncertainty which utilizes the reservoir of experience possessed by management (Morris, 1964). In some cases, on very good sites and/or under intensive site preparation, this chance is estimated to be relatively small. However, as site preparation becomes less intensive and/or sites become less receptive, the chance of failure increases. This trend can be seen in Appendix III. For example, consider the Piedmont, favorable topography low brush opportunity. With a highly intensive site preparation technique such as shear, rake, pile, and disc, the average probability of failure is 0.05, whereas a less intensive technique such as chop and burn exhibits a 0.07 average probability of failure. Under the least intensive technique, burning, the average probability of regeneration failure increases to 0.16.

The figure that accounts for both the initial cost and the chance that this cost will have to be repeated one or more times is termed the expected cost. For this study, the expected cost can be defined as the total cost which the landowner can expect to spend, on the average, to achieve successful regeneration.

Mathematically, expected cost is defined as the sum of all possible costs times their associated probability of occurence. To illustrate, let:

c_0 = initial regeneration cost, c_1 = cost of repeating regeneration once, c_2 = cost of repeating regeneration twice, etc.

p_0 = probability of regeneration success on initial attempt, p_1 = probability of regeneration success on the first repeat, etc.

$q_0 = (1-p_0)$ = probability of regeneration failure on initial attempt, $q_1 = (1-p_1)$ = probability of regeneration failure on the first repeat, etc.

i = appropriate discount rate

n = interval between regeneration attempts

EC = expected cost

Then: $$EC = c_0\, p_0 + \left(c_0 + \frac{c_1}{(1 + i)^n}\right) q_0\, p_1 + \left(c_0 + \frac{c_1}{(1 + i)^n} +\right.$$

$$\frac{c_2}{(1 + i)^{2n}}) \quad q_1p_2 + (c_0 + \frac{c_1}{(1 + i)^n} + \frac{c_2}{(1 + i)^{2n}} +$$

$$\frac{c_3}{(1 + i)^{3n}}) \quad q_2p_3 + \ . \ . \ . \qquad (1)$$

If, in the above equation, it can be assumed that:

1. $p_0 = p_1 = p_2 \ . \ . \ . \ p_n$
2. and cost reductions due to discounting are offset by generally rising regeneration costs, the above expression becomes:

$$EC = c(p) + 2c(p)(q) + 3c(p(q)^2 + \ . \ . \ . \ nc(p)(q)^{n-1} + \ . \ . \ . \qquad (2)$$

which reduces to (Hodgman, 1962):

$$EC = \frac{c}{p} \qquad (3)$$

The latter, equation (3), will be used as the estimate of expected cost throughout this study. However, the individual landowner may prefer to use his own data and/or assumptions and calculate expected cost from equation (1).

To illustrate equation (3), if site preparation and planting costs \$80 per acre and the probability of success is 80%, the expected cost (the average cost when the operation is repeated many times) is 80/.8 = \$100 per acre.

Expected regeneration costs, calculated from the data in Appendices III and IV are listed in Appendices V and VI for those technique-opportunity combinations for which four or more estimates were received. Average expected costs are shown in Tables I and II.

Table I. Average expected costs, in dollars per acre, for the most frequent regeneration technique-opportunity combinations in the Piedmont

Technique-opportunity combination	Cost
Favorable topography - low brush	
Scalp and plant	19.63
Burn and machine plant	24.75
Burn and hand plant	25.15
Hand poison and hand plant	30.76
Chop, burn, and hand plant	44.43
Chop, burn, and machine plant	47.68
Shear, rake, disc, hand plant	83.72
Favorable topography - medium brush	
Hand poison and hand plant	41.48
Chop, burn, and hand plant	49.50
Chop, burn, and machine plant	54.26
Shear, rake, disc, hand plant	91.42
Favorable topography - heavy brush	
Chop, burn, and hand plant	61.46
Chop, burn, and machine plant	62.12
Shear, rake, disc, hand plant	98.36

Table II. Average expected costs, in dollars per acre, for the most frequent regeneration technique-opportunity combinations in the Coastal Plain

Technique-opportunity combination	Cost
Low brush - May 15-Oct. 15	
Burn and hand plant	30.51
Chop, burn, and hand plant	42.27
Medium brush - May 15-Oct. 15	
Chop, burn, and hand plant	45.79
Heavy brush - May 15-Oct. 15	
Chop, burn, and hand plant	52.00
Low brush - Mar. 1-May 15; Oct. 15-Jan. 1	
Chop, burn, and hand plant	41.06
Medium brush - Mar. 1-May 15; Oct. 15-Jan. 1	
Chop, burn, and hand plant	54.42
Heavy brush - Mar. 1-May 15; Oct. 15-Jan. 1	
Chop, burn, and hand plant	76.22
Low brush - Jan. 1-Mar. 1	
Double mechanical, hand plant	39.37
Medium brush - Jan. 1-Mar. 1	
Double mechanical, hand plant	43.24
Heavy brush - Jan. 1-Mar. 1	
Double mechanical, hand plant	60.67

Economic Guidelines

Expected regeneration costs, used as economic guidelines, should facilitate Virginia forest landowners in making regeneration decisions. In the absence of any other information, it seems that the minimum expected cost technique should represent the most desirable regeneration investment. However, this may not always be true.

A forest landowner, from Tables I and II, can pick the minimum expected cost technique for a given regeneration opportunity. However, due to technical and biological reasons, actually making the decision of which technique to use may require the assistance of a state or consulting forester.

Other possible reasons for using a non-minimum cost technique are that different degrees of acceptable stands exist, and it is believed by some land managers that more yield is inherently associated with a more intensive site preparation practice. The additional yield could be in the form of more wood per acre, or a shorter rotation. Also, a more intensive site preparation technique may result in a more fully stocked stand than when the site is prepared using a less intensive technique. The 500 tree requirement for an acceptable stand is a minimum, and many industrial forest landowners want more than this minimum.

Further, the cost of having to repeat regeneration for the industrial forest landowner may be greater than the calculated expected monetary value. That is, there may be disutility in excess of the monetary difference associated with having to repeat regeneration on a given opportunity.

Another possible explanation for using a non-minimum cost method is that many times a more intensive technique is necessary in order to undertake a less intensive technique. An example is the necessity of chopping in order to accumulate the fuel such that it will support a fire.

Also, in many instances, the minimum cost technique can be used only on the most topographically favorable sites. As an example, the scalp and plant technique is technologically restricted to old fields or cut-over, pure pine forest types.

The condition of the opportunity after cutting often dictates the appropriate regeneration technique to use. The minimum expected cost method may or may not be technically feasible.

Given the economic guidelines, in the form of expected regeneration costs, an important question the forest landowner might ask is, "what yield is necessary to achieve a specific rate of return on the regeneration investment?" The following example indicates how the data from this study can help answer this question.

For a specific rate of return, the present value of the regeneration cost must be equal to the present value of the plantation yield. Therefore, the yield necessary to realize a certain rate of return can easily be calculated. But this yield will be expressed on a dollar basis, and conversion to a physical basis (e.g., cords per acre) requires an assumption about future stumpage values and/or volume yields. The before tax dollar value of the necessary yield is calculated as follows:

$$\$Y = EC(1 + p)^n$$

where: $\$Y$ = dollar value of the yield

EC = expected regeneration cost

p = rate of return

n = rotation age

For example, assume a forest landowner in the Virginia Piedmont is contemplating planting loblolly pine on his land, which can be described as having favorable topography with little brush competition. He wishes to know what future return is necessary to justify the initial expense, if he harvests the timber in thirty years.

The first question he might ask is, "what is the best regeneration method to use in the particular situation?" Table I indicates that "scalp and plant" has the lowest expected cost. He sees, from Table I, that, on the average, he can expect regeneration to cost \$19.63 per acre. The financial returns necessary, in thirty years, to realize the indicated rates of return are:

rate of return	necessary return 2/ (dollars per acre)
2%	35.56
3%	47.65
4%	63.67
5%	84.84
6%	112.75
7%	149.43
8%	197.53
9%	260.45
10%	342.53

The necessary return represents the financial return per acre required to justify a regeneration investment for scalping and planting of $19.63 per acre. If the landowner wishes to convert the financial return to physical return, he must assume a future stumpage price. By dividing the necessary financial return by the assumed stumpage price, the landowner can calculate the necessary physical return. For example, suppose he assumes that the future price of stumpage will be $9 per cord. If he can accept a 6% return on his investment, then 12.5 cords per acre are required to justify the regeneration investment.

2/ This is the return in addition to that required to cover non-regeneration costs, such as: land, property tax, administration, protection, and roads. Also, both regeneration cost and return would have to be adjusted to reflect the influence, if any, of federal or state income taxes.

The expected costs can also be used as an aid in computing rate of return, which is an economic guideline. For example, assuming a Piedmont area with site index 80 for loblolly pine, Schumacher and Coile (1960) indicate about 35 cords per acre can be produced in thirty years. If one assumes a stumpage value of $9 per cord and also that the yield is certain, then the maximum possible return based on a regeneration cost of $19.63 per acre is about 9.75%. This calculation is on a pre-tax basis and assumes that the return to all non-regeneration costs is zero.

Thus, the use of an expected cost as an economic guideline is helpful in determining which regeneration technique to use for a given opportunity, as well as in calculating investment rate of return and required financial yield. If regeneration is going to be undertaken, regardless, the study results will indicate the minimum cost route to achieving regeneration. If investment analysis is desired, more information or assumptions regarding interest rates and future yields are required.

DISCUSSION

The discussion will first consider an assessment of using expert opinion as a research methodology. This will be followed by a general discussion and will conclude with recommendations for future studies.

Appraising The Use Of Expert Opinion

One of the objectives of this study was to assess the feasibility of a methodology for quantifying expert opinion. To accurately determine the creditability of results requires experience with similar data, but none are available. As an indication, however, the coefficient of variation was used. Although a measure of variation, it is interpreted in this study to be a measure of reliability for expert's estimates.

This statistic is useful because it is a relative measure, and is weighted by the mean of the distribution of estimates. It is calculated as:

$$CV = \frac{s}{\overline{X}} \cdot 100 \quad \text{(Ostle, 1963)}$$

where: CV = coefficient of variation

s = standard deviation

$\overline{X}$ = mean

Generally, a high coefficient of variation indicates considerable relative variation in estimates, whereas a low coefficient indicates little relative variability of estimates.

Appendices V and VI show the coefficient of variation of expected cost estimates for those technique-opportunity combinations for which at least four estimates were available. These coefficients range from 6% to 67%, but the majority of them are under 30%. In those cases where the coefficient of variation is over 30%, invariably one estimate is largely responsible for the increased magnitude. Further examination of this particular expected cost estimate usually reveals that the reason the estimate is so high is because of the probability estimate, not the cost estimate. Another reason for such a high coefficient of variation in some cases is the number of estimates used. In many instances, only four estimates were available, so any one estimate has a large effect on the coefficient of variation.

Although each estimate is subjective, a generally low coefficient of variation (less than 30%) indicates that some underlying objective basis probably existed during the decision making process. The coefficient of variation is a measure of precision, not accuracy. It measures the tendency of data to cluster about the mean. However, in assessing the methodology used in this study, it appears that the results are creditable, as they generally have a tendency to cluster about the mean. If the results were not precise, it might indicate that the estimators (experts) were guessing more than deliberately thinking and calculating.

General Discussion

Because this was an initial attempt at establishing economic guidelines for regenerating loblolly pine in Virginia, the personal interview method of obtaining data was deemed a desirable beginning. The major reason for this was the desirability of personal contact. Another major advantage of the interview approach is that the most apparent alternative, collecting empirical data, is very expensive in both time and money.

Not all regeneration techniques and regeneration opportunities are included in the study. However, those technique-opportunity combinations most frequently used by a majority of Virginia's industrial forest landowners are included. There are other techniques such as, bedding, being used primarily on an experimental basis.

The data for the study were collected from industrial forest landowners, but this does not preclude their use by the smaller, individual forest landowners in the state. By examining the average expected costs in Tables I and II, the individual landowner can determine the expected investment needed to achieve successful regeneration. These expected costs should provide useful guidelines in making his regeneration investment decision. Also, the individual owner may be able to achieve regeneration at a lower cost. This might be accomplished by substituting labor for capital. For example, he might burn and plant and later conduct a hand release operation instead of originally undertaking a capital intensive operation, such as chop, burn, and plant.[3/]

There are many factors other than topography and season of year which may influence the cost and/or associated probability of achieving successful regeneration. Other factors were not specifically identified in the preliminary interview and, as it turned out, the cooperators thought the opportunities were adequately differentiated and had no trouble associating a cost and probability with a particular technique-opportunity combination. Therefore, further differentiation did not seem warranted, or even practical.

The same holds true for the definitions of terms used in the study. Slight difficulty did occur with the concept of brush competition. Some of the cooperators noted that it was not only the percentage of the area occupied by brush competition that was important, but also the size and distribution of residual trees on the tract. However, this difficulty was adequately resolved with the relative classification scheme; that is, low, medium, and heavy competition.

The personal interview procedure used in this study is

3/ The more labor intensive operations are becoming less common on industry lands and did not appear as frequently used techniques. It is possible that these techniques are feasible for the smaller landowner who may have surplus labor but little capital.

somewhat analagous to the gaming procedure used by Davis (1965) and Schultz (1966). There are many advantages and uses of this approach in quantifying expert opinion. As Schultz (1966) stated, "gaming is the best available analytical tool which allows the unstructured personal knowledge of experts to be ordered in an analytical framework while also allowing prospective changes ... to be studied with regard to the decision environment." The structured interview used in this study was extremely useful in extracting personal knowledge from the experts, and putting it in such a form so as to be readily employed in the analysis. The success of the procedure depends largely on its ability to synthesize the personal knowledge of several individuals into a consistent framework.

Some researchers and practitioners may question the validity of data collected using the structured interview procedure. The interview results are subjective, for the estimates derive from the opinions and judgments of the experts involved. However, in the absence of any empirical information and assuming that the expert opinion collection is systematic, the resulting data are undoubtedly the best available. Many forestry decisions are obviously made using this type of information.

The value and validity of the expected cost estimates depend on several factors. These include (Davis, 1965) the degree of realism injected into the technique-opportunity descriptions, the ability of the experts to project themselves into the situation, the interest taken by the cooperators in making their estimates, and the basic experience and competence of the cooperators to make the estimates. Davis also maintained that the use of expertise is not completely devoid of objectivity. He stated that if several experts are independently polled on some matter for which actual experience provides the only basis for an answer and the experts substantially agree in their answers, then some underlying objective basis for their answers must exist.

For this study, the majority of cooperators agreed that the regeneration techniques and opportunities were sufficiently described and were representative of actual conditions prevailing in Virginia. The important factor is that the cooperators seemed to be able to associate themselves quite readily with a particular technique-opportunity combination. The interviewer and the cooperators appeared to be in complete accord.

The interest taken by the cooperators in this project was truly rewarding. In practically all cases, the cooperators were sincerely interested in the study and wanted to assist in any way possible. Estimates were not made in any haphazard manner. Rather, the cooperators were deliberate and thoughtful.

The coefficients of variation (Appendices V and VI) seem to indicate general agreement among the experts. As mentioned previously, in those cases where large variation exists, it is generally due to one particular estimate. It should be further noted, that in most cases, the one estimate in question was made by the same cooperator. Although this is not determinable from the data presentation, it was noted during the interview procedure.

Further, for those technique-opportunity combinations most frequently used in Virginia, results tend to be more reliable than for those combinations not in frequent use. For example: The chop, burn, hand plant technique used on the favorable topography, low brush opportunity in the Piedmont. Each cooperator submitted an estimate for this combination, thereby reflecting the amount of use, with a resulting coefficient of variation of only 10%. This may be a result of more data, rather than more reliability, but if more experts are involved with a particular technique, it seems that more information is probably known about that technique than for a less frequently used technique. Also, it seems logical that there should be less variation in expected cost estimates for techniques that have been used for a longer time than in the newer regeneration techniques.

The costs obtained in this study are felt to be realistic and meaningful. All major elements influencing the total regeneration cost are included in each estimate. However, the cost figures for each cooperator do differ slightly. This may be explained to a large extent by the associated information collected at the time; that is, acreage, equipment, and operator.

A cooperator's cost for a particular regeneration method will be less per acre when his average size tract is 200 acres, as opposed to an average size tract of 75 acres. A major reason for this is economy of size, due primarily to the moving or transportation factor. One of the major site preparation costs is the moving of equipment from site to site. With a small average size tract, a landowner will be moving between tracts more often than if his average size tract is larger.

The equipment used is another important factor, although it was not significant in this study. If the equipment used for site preparation is used only for that purpose, then the total equipment cost is charged against that account. But, if the equipment used in site preparation is also used for other purposes such as forest road construction, some of the total equipment cost is written off in the construction account. If, however, equipment is used only for site preparation and site preparation is seasonal, the depreciation may be higher than if the equipment had another use. One of the more significant costs regarding site preparation equipment was found [4/] to be maintenance. This is the major reason for any cost difference between discing and chopping. The maintenance costs of the disc are much higher than those for the chopper.

Whether the regeneration operation is done by company crews or contracted to independent operators, might be expected to influence the cost. For this study, differences due to this

4/ This was determined from personal communication with the cooperators.

factor were trivial. Those cooperators who both contract work and do it themselves indicated that the differences in costs were not great.

Expected Costs

It appears reasonable to assume that site preparation costs should be different under different brush competition conditions. However, this is not always the case. But, the probability of achieving an acceptable stand of loblolly pine under different brush conditions is almost always different. Therefore, the expected regeneration cost will be different.

As an example, consider chop, burn, and hand plant in Piedmont, favorable topography under all three brush conditions. Four cooperators indicated a constant cost, $41.12 per acre, regardless of brush competition (Appendix III). But, the probability of achieving an acceptable stand decreased with increasing brush competition, for each of the cooperators. The result is more readily seen by examining Table I. This reveals that the expected regeneration cost increases in all cases as the degree of brush competition increases. The same relationship holds for Table II.

For the Piedmont, expected costs are different for various topographies. Although not calculated, an examination of Appendix III indicates that practically all regeneration methods undertaken in areas of unfavorable topography have higher costs and associated lower probabilities and therefore higher expected costs, than those areas that are topographically favorable. Because very few areas in the Piedmont characterized by unfavorable topography are being regenerated, it is doubtful that this opportunity differentiation was necessary for this study.

The study results indicate that the time of year differentiation in the Coastal Plain was not as important a factor as the degree of brush competition. The only major difference in expected costs is between autumn and summer, under heavy brush conditions. The principal reason for this is that the site preparation is usually not as effective in the autumn months as in the summer. Under conditions of heavy brush, more sprouting will occur as a result of autumn site preparation, and consequently the probability of achieving an acceptable stand will decrease, thereby causing the expected regeneration cost to increase.

Finally, there are few differences in expected costs between comparable areas in the Piedmont and Coastal Plain regions. The average expected costs of regeneration methods used in both areas are very close, as indicated by Tables I and II. Actual cost estimates are a little lower in the Coastal Plain, but these are offset by slightly lower probabilities than in the Piedmont.

Study Limitations and Future Implications

Although this study is useful in several ways, it also has limitations that might be removed with future research. Some of these are applicable to the procedural format, some to the results, and some to the nature of the study.

The results of this study are limited in their application. This project has identified the major artificial loblolly pine regeneration methods currently used in Virginia. With improvements in technology and more emphasis on a quality environment, these methods are likely to change. Also, the cost figures will soon be archaic. A major recommendation is for future review of the study and possible expansion to new regeneration methods.

Another limitation of this study is that economies of size, which might be realized from grouping tracts together, have not been explicitly examined. Also, one is limited with the application of cost figures. By examining cost, one can determine the least expensive method, and also what return is necessary to justify the cost. However, any more calculations using the cost figure require assumptions or knowledge about future stumpage value, future yields, and interest rates.

An approach which seems to have a good deal of merit involves the relationship between site preparation method and another aspect of the total regeneration decision, the physical yield resulting from particular regeneration techniques. It appears that the procedure used in this study, the interview method, would be an acceptable manner in which to accomplish this. Knowing the yield resulting from a particular regeneration technique would allow the Virginia forest landowner to answer many practical questions.

If a yield estimate for a given regeneration technique-opportunity combination were available, the investment's internal rate of return could easily be calculated. Also, the maximum cost for a specific technique could be derived. Furthermore, the landowner could determine whether or not a more intensive site preparation technique would be economically feasible.

Therefore, it would be highly desirable to obtain yield data to supplement this study. However, there appears to be considerable difficulty in obtaining such an estimate at the present time. The main reason for this is that the techniques have not been used long enough to associate a yield with a specific technique. Another problem is that it is difficult to directly associate a yield with a technique and at the same time, hold other factors constant.

A future study should explore the question: why is the regeneration technique (for a given regeneration opportunity) with the lowest expected cost not adopted to the virtual exclusion of all other techniques? Possible explanations have been given in this study, but research is needed to determine the optimum trade-off of increased cost against decreased chance of regeneration failure.

For example, assume one technique has an estimated regeneration cost of \$50 with an associated probability of success of 50%, and another technique with a \$90 cost and associated probability of success of 80%. Does the 30% increase in probability of regeneration success (reduction in regeneration failure) justify a \$40 cost increase? Answers to this type of question would be most desirable, and should be the topics of future research.

SUMMARY AND CONCLUSIONS

Economic guidelines for regenerating loblolly pine are generally not available to Virginia forest landowners. This study developed guidelines in the form of estimates of expected regeneration costs. The guidelines were derived from expert opinion in the form of estimated regeneration costs and associated probabilities of achieving an acceptable stand of loblolly pine.

The procedure consisted of two interviews. The preliminary interview was used to define the relevant techniques and opportunities. The necessary costs and probabilities were obtained during the final interview. The regeneration costs were calculated on a comparable basis by adjusting the cost estimates according to various components.

The major study results include the expected regeneration costs and the derived economic guidelines. The average expected costs are consistent with the appropriate technique-opportunity combinations. The economic guidelines are useful in determining the minimum cost if regeneration is to be undertaken, as well as in determining the financial yield necessary to justify the regeneration cost.

The methodology employed appeared acceptable upon examination of the variation in estimates. Although acceptable, the study itself is limited in its applicability because only cost data are available. It was concluded that additional data, especially yield estimates, would appreciably increase the application of the regeneration costs derived in this study.

In conclusion, expected regeneration costs appear to be acceptable economic guidelines. The methodology employed in this study appears acceptable and might be easily adapted to a yield study. The acquisition of yield data would greatly facilitate decision making for Virginia forest landowners considering loblolly pine regeneration.

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Appendix I. Definitions of terms used in the study

1. Regeneration opportunities. (Particular qualities of land)
   a. Virginia Piedmont: That area in central Virginia characterized by generally rolling topography, usually good drainage, and shallow subsoil depths.
   b. Virginia Coastal Plain: That area in eastern Virginia characterized by generally level topography, numerous poorly drained areas, and usually deep subsoils.
   c. Favorable topography (Form 1, Piedmont): Land which averages less than 20% slope and has a minimum of rock outcroppings.
   d. Unfavorable topography (Form 1, Piedmont): Land which averages more than 20% slope and/or has several rock outcroppings.
   e. Time of year (Form 2, Coastal Plain): The dates roughly correspond to summer, spring, fall, and winter respectively.
   f. Degree of brush competition (Forms 1 and 2): This is defined as the percentage of the area occupied by species of hardwood brush and/or pine reproduction at the time site preparation is begun. It is a relative classification with low, medium, and heavy degrees of competition. Specifically, low indicates zero to twenty-five per cent of the area occupied, medium has from one quarter to one

half of the area occupied, and heavy indicates more than one half the area is occupied by competing species.

2. Regeneration techniques.

   a. Hand plant: The placing of loblolly pine seedlings in the ground by human labor using a planting bar.

   b. Machine plant: The placement of loblolly seedlings in the ground via the use of a planting machine. Seedlings are guided into the machine by a man riding on it.

   c. Hand poison: The killing of undesirable tree species by girdling with an ax or saw, or injecting a silvicide using a tree injector.

   d. Scalp and plant: This is straight machine planting with a scalping blade, which rolls back the turf or soil, mounted on front of the planting machine.

   e. Chopping: This technique is one of the most popular currently being used in Virginia. A rolling drum, usually filled with water, and having several blades mounted on it, is pulled behind a tractor over the area to be planted. Most vegetation having a diameter up to about five inches is readily mowed down to the ground.

   f. Burn: This technique is usually used in conjunction with the preceding technique. After chopping, which accumulates the fuel, the area is burned to eradicate the remaining brush, as well as to expose the bare mineral soil. Sometimes, however, burning is used alone if there is sufficient fuel to support a fire.

g. Shear, rake (pile), and disc: This is an intensive site preparation technique which is becoming more popular in Virginia. Shearing consists of a special large cutting blade attached to the front of a tractor which is driven over the tract to be planted. This knocks down the vegetation quite successfully. Shearing is followed by raking, or piling. Raking consists of moving the debris on the ground such that it can be piled. This is done using a tractor mounted blade. The debris is usually piled in long rows called windrows. These windrows are sometimes, but not always, burned. Discing follows the raking (piling) procedure. This is accomplished using an off-set harrow that is dragged behind a tractor over the tract that was previously sheared and raked.

h. Double mechanical treatments: This term is defined to include: double chop, chop and disc, or double disc. The double treatment implies two runs over the tract, i.e., the tractor goes over the same area twice.

3. The Cooperators. The individuals who participated in the study are designated as the cooperators. These men were

selected from organizations in Virginia which are currently involved and have had past experience with regenerating loblolly pine in the state. The men are district supervisors on company forests, woodland managers, or land managers for certain districts, but a few held higher administrative positions. All the cooperators have direct contact with the regeneration work being done in their organization. Therefore, these men were highly qualified to participate in the study.

The organizations represented by the cooperators have had considerable experience with loblolly pine regeneration. They are responsible for the regeneration of approximately 400,000 acres of forest land in Virginia during the past decade. Practically each year they have increased the number of acres being planted. Currently, their involvement in forest regeneration in Virginia can be conservatively estimated at 80,000 acres per year.

4. Cost. (Cst) This is the total per acre cost of site preparation and planting.

5. Probability. (Prob; Prb) Probability is defined as the estimated number of times, per 100 attempts, an acceptable stand will be achieved.

6. Acceptable stand. For the purposes of this study, an

acceptable stand is one which supports five hundred or more "free-to-grow" loblolly pine stems per acre two years after planting. "Free-to-grow" indicates that the seedling has ample light, space, and nutrients to survive.

Appendix II. The forms used during the final interview

Form 1. Estimated regeneration costs and associated probability of achieving an acceptable stand of loblolly pine in the Virginia Piedmont

Regeneration Technique		Favorable Topography						Unfavorable Topography					
		Degree of Brush Competition											
		Low		Medium		Heavy		Low		Medium		Heavy	
		Cost	Prob	Cost	Prob	Cost	Prob	Cost	Prob	Cost	Prob	Cost	Prob
Hand Poison and Plant	hand												
	mach												
Scalp and Plant	mach												
Burn and Plant	hand												
	mach												
Chop, Burn, and Plant	hand												
	mach												
Shear, Rake Pile, Disc, and Plant	hand												
	mach												

Form 2. Estimated regeneration cost and associated probability of achieving an acceptable stand of loblolly pine in the Virginia Coastal Plain

	Time of Year																	
	May 15-Oct 15						Mar 1-May 15; Oct 15-Jan 1						Jan 1-Mar 1					
	Degree of Brush Competition																	
Regeneration	Low		Medium		Heavy		Low		Medium		Heavy		Low		Medium		Heavy	
Technique	Cst	Prb	Cst	Prb	Cst	Prb	Cst	Prb	Cst	Prb	Cst	Prb	Cst	Prb	Cst	Prb	Cst	Prb
Burn and Plant hand																		
Burn and Plant mach																		
Chop, Burn, and Plant hand																		
Chop, Burn, and Plant mach																		
Double Chop and Plant hand																		
Double Chop and Plant mach																		
Chop, Disc and Plant hand																		
Chop, Disc and Plant mach																		
Double Disc and Plant hand																		
Double Disc and Plant mach																		

Appendix III. Estimated 1969 regeneration cost and associated probability of achieving an acceptable stand of loblolly pine in the Piedmont

Technique-Opportunity	Estimates	
Burn and Hand Plant	Cost	Probability
Favorable topography-low brush	16.62	95
"	16.62	65
"	16.62	90
"	16.62	60
"	30.00	75
"	19.91	100
"	20.00	60
"	25.75	100
"	20.50	90
"	20.50	100
Favorable topography-medium brush	22.00	50
Favorable topography-heavy brush	23.00	40
Unfavorable topography-low brush	22.00	60
Unfavorable topography-medium brush	24.00	50
Unfavorable topography-heavy brush	25.00	40
"	37.30	30
Burn and Machine Plant		
	Cost	Probability
Favorable topography-low brush	22.50	95
"	22.50	100

Appendix III. (continued)

Technique-Opportunity	Estimates	
	Cost	Probability
Favorable topography-low brush	29.31	100
"	22.00	70
"	16.83	100
Favorable topography-medium brush	24.00	60
Favorable topography-heavy brush	26.00	50
Scalp and Plant		
	Cost	Probability
Favorable topography-low brush	18.00	90
"	18.00	90
"	18.00	80
"	16.00	100
Favorable topography-medium brush	19.00	85
Hand Poison and Hand Plant		
	Cost	Probability
Favorable topography-low brush	28.00	50
"	20.00	95
"	20.00	85
"	22.44	100
Favorable topography-medium brush	32.00	40
"	27.00	80
"	27.00	70
"	13.61	100

Appendix III. (continued)

Technique-Opportunity	Estimates	
	Cost	Probability
Unfavorable topography-low brush	29.00	50
Unfavorable topography-medium brush	33.00	40
Unfavorable topography-heavy brush	39.00	40
Chop, Burn, and Hand Plant		
	Cost	Probability
Favorable topography-low brush	41.12	95
"	41.12	99
"	41.12	95
"	41.12	100
"	53.38	100
"	43.35	98
"	40.00	80
"	42.15	100
"	35.28	97
"	37.33	80
"	37.33	80
Favorable topography-medium brush	40.00	75
"	43.84	80
"	43.84	75
"	44.45	95
"	53.38	75
"	35.28	97
"	41.12	90

Appendix III. (continued)

Technique-Opportunity	Estimates Cost	Probability
Favorable topography-medium brush	41.12	90
"	41.12	99
"	41.12	100
Favorable topography-heavy brush	42.00	70
"	52.50	80
"	52.50	70
"	46.25	90
"	53.38	50
"	41.12	70
"	41.12	85
"	41.12	99
"	41.12	90
"	35.28	97
Unfavorable topography-low brush	43.00	80
Unfavorable topography-medium brush	44.00	75
"	40.00	77
Unfavorable topography-heavy brush	48.00	70

Chop, Burn, and Machine Plant

	Cost	Probability
Favorable topography-low brush	39.33	80
"	39.33	80
"	45.71	100

Appendix III. (continued)

Technique-Opportunity	Estimates	
	Cost	Probability
Favorable topography-low brush	42.00	90
Favorable topography-medium brush	43.00	85
"	45.84	80
"	45.84	75
"	48.01	100
Favorable topography-heavy brush	46.00	80
"	52.50	80
"	52.50	70
"	49.81	95

Shear, Rake, Disc, and Hand Plant

	Cost	Probability
Favorable topography-low brush	100.00	100
"	65.00	90
"	77.26	95
"	77.26	95
Favorable topography-medium brush	70.00	90
"	88.77	95
"	88.77	95
"	100.00	100
Favorable topography-heavy brush	75.00	85
"	97.43	95
"	97.43	95

Appendix III. (continued)

Technique-Opportunity	Estimates	
	Cost	Probability
Favorable topography-heavy brush	100.00	100
Unfavorable topography-low brush	68.00	90
Unfavorable topography-medium brush	74.00	90
Unfavorable topography-heavy brush	80.00	85
Shear, Rake, Disc, and Machine Plant		
	Cost	Probability
Favorable topography-low brush	63.00	95
"	79.26	95
"	79.26	95
Favorable topography-medium brush	68.00	95
"	90.77	95
"	90.77	95
Favorable topography-heavy brush	73.00	90
"	97.43	95
"	97.43	95

Appendix IV. Estimated 1969 regeneration cost and associated probability of achieving an acceptable stand of loblolly pine in the Coastal Plain

Technique-Opportunity	Estimates	
Burn and Hand Plant		
	Cost	Probability
Winter-heavy brush	20.50	70
"	20.50	70
Winter-Medium brush	20.50	80
"	20.50	80
Winter-low brush	20.50	90
"	20.50	90
Autumn-low brush	20.50	66
"	20.50	60
Summer-low brush	20.50	95
"	20.50	95
"	47.50	100
"	17.90	95
"	17.90	95
"	17.90	70
"	17.90	30
Burn and Machine Plant		
	Cost	Probability
Summer-low brush	22.50	95
"	22.50	95
"	47.50	100

Appendix IV. (continued)

Technique-Opportunity	Estimates	
Chop, Burn, and Hand Plant		
	Cost	Probability
Summer-low brush	37.40	95
"	37.40	90
"	37.40	99
"	37.40	100
"	37.33	97
"	37.33	98
"	65.50	95
"	35.28	97
Summer-medium brush	37.40	90
"	37.40	85
"	37.40	99
"	37.40	100
"	43.84	97
"	43.84	98
"	66.50	85
"	35.28	97
Summer-heavy brush	37.40	70
"	37.40	95
"	37.40	80
"	37.40	80
"	52.50	97

Appendix IV. (continued)

Technique-Opportunity	Estimates	
	Cost	Probability
Summer-heavy brush	52.50	98
"	68.50	80
"	35.28	97
Autumn-low brush	37.40	95
"	37.40	75
"	37.40	85
"	37.40	60
"	37.33	95
"	37.33	90
Autumn-medium brush	43.84	95
"	43.84	90
"	37.40	90
"	37.40	80
"	37.40	75
"	37.40	40
Autumn-heavy brush	52.50	95
"	52.50	90
"	37.40	70
"	37.40	70
"	37.40	75
"	37.40	20

Appendix IV. (continued)

Technique-Opportunity	Estimates	
Double Mechanical and Hand Plant		
	Cost	Probability
Autumn-low brush	35.40	90
"	45.40	97
"	50.40	87
Winter-low brush	28.00	90
"	28.00	90
"	28.00	50
"	28.00	85
Winter-medium brush	28.00	80
"	28.00	80
"	28.00	85
"	28.00	40
Winter-heavy brush	28.00	50
"	28.00	75
"	28.00	75
"	28.00	25

Appendix V. Expected regeneration costs in dollars per acre and associated coefficients of variation for the Piedmont

Burn and Hand Plant - favorable topography-low brush

Expected Costs: 17.49, 25.57, 18.47, 27.70, 40.00, 19.91, 33.33, 25.75, 22.77, 20.50

Coefficient of Variation: 28%

Burn and Machine Plant - favorable topography-low brush

Expected Costs: 23.69, 22.50, 29.31, 31.43, 16.83

Coefficient of Variation: 23%

Scalp and Plant - favorable topography-low brush

Expected Costs: 20.00, 20.00, 22.50, 16.00

Coefficient of Variation: 14%

Hand Poison and Hand Plant - favorable topography-low brush

Expected Costs: 56.00, 21.05, 23.53, 22.44

Coefficient of Variation: 61%

Hand Poison and Hand Plant - favorable topography-medium brush

Expected Costs: 80.00, 33.75, 38.57, 13.61

Coefficient of Variation: 67%

Appendix V. (continued)

Chop, Burn, and Hand Plant - favorable topography-low brush

Expected Costs: 43.28, 41.55, 43.28, 41.12, 53.38, 44.24, 50.00, 42.15, 36.37, 46.66, 46.66

Coefficient of Variation: 10%

Chop, Burn, and Hand Plant - favorable topography-medium brush

Expected Costs: 53.33, 54.80, 58.45, 46.79, 71.17, 36.37, 45.69, 45.69, 41.55, 41.12

Coefficient of Variation: 20%

Chop, Burn, and Hand Plant - favorable topography-heavy brush

Expected Costs: 60.00, 65.63, 75.00, 51.39, 106.76, 58.74, 48.38, 41.55, 45.69

Coefficient of Variation: 32%

Chop, Burn, and Machine Plant - favorable topography-low brush

Expected Costs: 49.16, 49.16, 45.71, 46.67

Coefficient of Variation: 6%

Chop, Burn, and Machine Plant - favorable topography-medium brush

Expected Costs: 50.59, 57.30, 61.12, 48.01

Coefficient of Variation: 11%

Chop, Burn, and Machine Plant - favorable topography-heavy brush

Expected Costs: 57.50, 65.63, 75.00, 50.33

Coefficient of Variation: 17%

Appendix V. (continued)

Shear, Rake, Disc, Hand Plant - favorable topography-low brush

Expected Costs: 100.00, 72.22, 81.32, 81.32

Coefficient of Variation: 14%

Shear, Rake, Disc, Hand Plant - favorable topography-medium brush

Expected Costs: 77.77, 93.96, 93.96, 100.00

Coefficient of Variation: 10%

Shear, Rake, Disc, Hand Plant - favorable topography-heavy brush

Expected Costs: 88.33, 102.55, 102.55, 100.00

Coefficient of Variation: 7%

Appendix VI. Expected regeneration costs in dollars per acre and associated coefficients of variation for the Coastal Plain

Burn and Hand Plant - summer-low brush

Expected Costs: 18.84, 18.84, 25.57, 59.67, 21.58, 21.58, 47.50

Coefficient of Variation: 53%

Chop, Burn, and Hand Plant - summer-low brush

Expected Costs: 39.36, 41.55, 37.76, 37.40, 38.45, 38.31, 68.95, 36.37

Coefficient of Variation: 26%

Chop, Burn and Hand Plant - summer-medium brush

Expected Costs: 41.55, 44.00, 37.76, 37.40, 45.20, 45.76, 78.24, 36.37

Coefficient of Variation: 30%

Chop, Burn, and Hand Plant - summer-heavy brush

Expected Costs: 53.43, 39.36, 46.75, 46.75, 54.12, 53.57, 85.63, 36.37

Coefficient of Variation: 29%

Chop, Burn, and Hand Plant - autumn-low brush

Expected Costs: 39.36, 49.87, 44.00, 62.33, 39.30, 41.48

Coefficient of Variation: 19%

Appendix VI. (continued)

Chop, Burn, and Hand Plant - autumn-medium brush

Expected Costs: 46.14, 48.71, 41.55, 46.75, 49.87, 93.50

Coefficient of Variation: 36%

Chop, Burn, and Hand Plant - autumn-heavy brush

Expected Costs: 55.26, 58.33, 53.43, 53.43, 49.87, 187.00

Coefficient of Variation: 41%

Double Mechanical and Hand Plant - winter-low brush

Expected Costs: 31.11, 31.11, 56.00, 32.94

Coefficient of Variation: 32%

Double Mechanical and Hand Plant - winter-medium brush

Expected Costs: 35.00, 35.00, 32.94, 70.00

Coefficient of Variation: 41%

Double Mechanical and Hand Plant - winter-heavy brush

Expected Costs: 37.33, 37.33, 56.00, 112.00

Coefficient of Variation: 58%

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ECONOMIC GUIDELINES FOR ESTABLISHING
LOBLOLLY PINE PLANTATIONS IN VIRGINIA

by

Michael Elwood Shores

ABSTRACT

Economic guidelines for regenerating loblolly pine were developed for Virginia forest landowners. The general procedure used was the structured personal interview.

The basic economic guidelines are expected regeneration costs calculated using the actual total regeneration cost and an associated probability of achieving an acceptable stand of loblolly pine. Average expected costs are calculated for the most frequently used regeneration technique-opportunity combinations in Virginia.

Results indicate the use of expert opinion is an acceptable procedure for developing economic guidelines. The guidelines appear to be useful in determining which regeneration method to use, as well as aids in determining the future financial yield necessary to justify the initial expected regeneration cost and in computing rate of return on the regeneration investment.