THE ECONOMICS OF TREE IMPROVEMENT PROGRAMS IN THE NORTHEAST

Richard L. Porterfield, Associate Professor,
Department of Forestry, Mississippi State
University, Mississippi State, MS and
F. Thomas Ledig, Associate Professor, School
of Forestry and Environmental Studies, Yale
University, New Haven, CT.' Contribution
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State,MS.

ABSTRACT.--A simple break-even, benefit-cost analysis is presented which will provide an initial evaluation of profitability associated with tree improvement programs. White spruce (Picea lauca (Noench) Voss) and black spruce (*Picea mariana* (Mill.) B.S.P.) are used as case studies. Several ideas for increasing the profitability of tree improvement work are discussed in relation to sensitivity analysis of initial assumptions.

The objective of this paper is to discuss analytical techniques for evaluating the economics of tree improvement and to provide some best estimates regarding the profitability of certain tree improvement programs in the Northeast. Only best estimates can be provided because adequate data are simply not available. A final, definitive evaluation cannot be made until improved progeny are harvested. Yet, because tree improvement work is so long-term and expensive the forest geneticist must be concerned about the "Does it pay?" question quite early in a program. The principal difficulty with such early evaluations is that the analyst usually ends up comparing accurately computed costs with minimal benefits (Carlisle and Teich, 1977).

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White Spruce

$$\$2,690 = \frac{(367x)\ (9.8181)}{68.9139}$$

$51 = x = the required value increase per acre of improved plantation in order to return 8 percent to the white spruce program.

No doubt, tree improvement work is much more easily justified with white spruce given the customary grafted seed orchard approach. These results show that the needed value increase is some four times higher for black spruce than for white spruce. At $7.00 per cord stumpage the required volume increase (assuming there were no thinnings or that a similar volume was removed in thinnings from both improved and unimproved plantations) would be 29 and 7 cords for black and white spruce, respectively. The required 7 cord increase for white spruce represents an approximate 13 percent increase over unimproved plantations at an 8 x 8 foot spacing and on site index class 70 lands (Stiell, 1976; p. 184). If the tree improvement efforts increased the amount of sawtimber--sized material and it was valued at $35/MBF, required growth is 5.8/MBF and 1.5/MBF for black and white spruce, respectively. Naturally a combination such as 3.6 cords and 730 board feet for white spruce would also be sufficient,

However, such a simple volume approach does not adequately account for improvement in traits such as specific gravity, straightness, crown characteristics, and others. Nor does it account for factors such as the black spruce's greater resistance to spruce bud worm as compared to white spruce. Recognition of these factors demands a more detailed analysis. Further, stumpage prices used above are current; what will they be 50 years from now? Stumpage prices have been subject to a real price increase in the past (U.S. Forest Service, 1974) and using a conservative 1.5 percent annual real price rise over a 50 year period, stumpage prices will increase to $14.74 per cord and 573.68 per MBF. The required volume increase for white spruce would become a combination such as 1.7 cords and 346 board feet with the higher stumpage prices.

For the new black spruce program

$$\$5{,}457 = \frac{(294x)\quad(11.6546)}{21.7245}$$

$\$35 = x =$ the required value increase per acre of improved plantation in order to return 8 percent to the "new" black spruce program.

The new program being initiated in New Brunswick looks favorable compared to the traditional program. Again using $7.00 per cord, the required volume increase to justify the program (at 8 percent) is only 5 cords. The new program requires only 17 percent as much volume gain as does the traditional program (5 cords versus 29 cords). However, the risks associated with the new program may be higher. Initial costs for the new program are double those for the customary program and most of the advantage of the new program derives from the assumed shorter rotation age of 30 years for improved plantations and the assumption of a higher seed yield. Using a 30 year rotation age in the traditional black spruce program (Table 1) results in x = $45 or only a 6.4 cord requirement to break-even (down from 29 cords). In other words, given the assumptions presented in the two programs (Table 1 versus Table 3), the genetic gain from the "new" program will only have to be 17 percent as much as that required from the traditional program, but assuming a 30 year rotation in both programs, the genetic gain expected from the new approach must be 78 percent of that expected from the traditional program in order for both programs to be equally profitable. The higher seed yields assumed with the new program account for its remaining advantage.

SENSITIVITY ANALYSIS

Such a simple approach as break-even, benefit-cost analysis lends itself well to the "What If" type of question. For example, what if tree improvement results in a shortened rotation age? What if seed production can be increased? A number of such questions are answered for white spruce in Table 4 using $7 per cord and an 8 percent interest rate.

Table 4. Sensitivity Analysis for the White Spruce Tree Improvement Program

Change	Required volume increase per acre of improved plantation (cords)	Percentage change from base volume
1. As calculated in text	7.3	0%
2. Rotation age is shortened to 40 yrs.	5.0	-32
3. Seed yield can be increased by 15 percent	6.4	-12
4. Age to commercial seed production is only 7 yrs.	5.8	-21
5. Required rate of return is 6 percent	2.6	-64
6. Stumpage price increases by 1.5 percent per yr.	3.5	-52
7. Changes 2, 3, and 4 together	3.4	-53
8. Changes 2, 3, 4, and 6 together	1.6	-78

If tree improvement work with white spruce can reduce rotation age to 40 years, the volume response due to tree improvement can be 32 percent less than with a 45 year rotation and still earn an 8 percent return on investment (Table 4). With these relatively long rotations, the influence of interest rate is great (Table 4).

There is an almost direct relationship between seed yield and profitability of tree improvement work (Porterfield, 1974) as shown by the 15 percent increase in seed yield and the 12 percent drop in required volume (Table 4). This fact emphasizes the importance of orchard management techniques such as insect control and fertilization, which are carried out to increase seed yield. Low seed yield is the principal reason for the less favorable position of black spruce.

Briefly considering the traditional black spruce program, a doubling of seedling yield to 184,000 per acre of orchard would lower the required volume (at $7 per cord) from 29 cords to 14.5 cords (a change directly proportional to the change in seed yield). With a doubling of seedling yield plus a 30 year rotation for improved plantations (assumptions nearly identical to those made for the "new" program; see discussion in the last section) the required volume response is only 3 cords. Under these conditions, the new program would actually have to result in higher genetic gains than the traditional program to assure its financial equivalence.

The "new" improvement program for black spruce is very sensitive to the effect of orchard size. If we assume a 10 acre orchard capable of producing 2,000,000 seedlings annually, costs in Table 3 will be halved, except for orchard maintenance which will be unchanged. The required volume response to earn 8 percent for a 10 acre orchard is then 3 cords per acre of improved plantation, identical to that for a traditional grafted orchard with more liberal estimates of seedling yield than those estimated by Morgenstern (1975) and with a shorter rotation. Such a gain seems entirely feasible given current expectations for improving black spruce. Thus, there may be significant "economies of scale" associated with the new approach to black spruce improvement, and interorganizational cooperatives could be investigated to achieve such economies. In the traditional white and black spruce programs, a larger planting program and orchard would reduce per acre costs of selection if the same number of phenotypes were selected. However, increasing scale would result in much less reduction for the traditional programs than for the "new" program.

PROGRAM OPTIMIZATION

Once heritability estimates and genetic correlations are available it becomes possible to compute a sound estimate of the actual rate of return from tree improvement because genetic gains and resultant economic benefits can be estimated with confidence. Seed yields can likewise be more firmly established for on-going programs. Major analytical techniques include linear programming (van Buijtenen and Saitta, 1972), goal programming (Porterfield, Zobel, and Ledig, 1975) and computer simulation (Dutrow and Row, 1977). In the latter study, actual 8-year-old progeny test data were simulated to rotation age and an average 29 percent increase in present net worth was obtained for improved plantations regenerated from unrogued loblolly pine (*Pinus taeda* L.) seed orchards

Analysis of on-going programs has significant implications for new programs but can also serve to guide future generation tree improvement work. Each component part of the improvement program (e. g. roguing, progeny testing, forest selection, and others) can be ranged independently and a plan for total program optimization attained. A summary of recent findings relevant to the Northeast include:

1. The optimum set of selection criteria to be used during forest selection is quite sensitive to the goals of the tree improvement program, therefore establishment of definite tree improvement goals prior to forest selection should be an absolute requirement.

2. Expenditures on forest selection appear too low. Increasing expenditures by a factor of 2 or 3 would greatly increase profits.

3. Given two traits, A and B, with a positive genetic correlation, it can be most cost effective to select for gain in A through its correlation with trait B. For example, bole straightness and desired crown characteristics had a genetic correlation of 0.65 in the study cited above (Porterfield, Zobel, and Ledig, 1975) and greater gain in straightness per dollar spent on wild-stand selection was often obtained by selecting for improved crown characteristics. Thus, if trait A were phenotypically apparent, it could be selected for in order to achieve gain in a highly positively related trait, B, (which might not be phenotypically apparent) with little loss in genetic efficiency and a gain in economic efficiency.

4. Since genetic gain is fixed once a seed orchard is established (prior to roguing it is fixed at one level and after roguing at another) profitability is directly proportional to seed yield from the orchard. Greater seed yield means higher return on investment.

5. Higher roguing intensities for traits such as volume with relatively low heritabilities appear to increase profitability of tree improvement work since progeny testing greatly improves the selection process. A strategy of bringing more clones into the orchard at a closer initial spacing and using a high roguing intensity (such as 1 in 4) has been suggested for loblolly pine. The closer initial spacing would mean less reduction in seed yield after intensive roguing.

6. Recognizing the rising trend in the real price of stumpage greatly increases computed returns from tree improvement. With loblolly pine the benefit-cost ratio for existing programs using 6 percent interest increased from 9.5 to 33.0 simply through recognition of an average annual 3.2 percent real price increase for stumpage. The long time frame for tree improvement increases the importance of taking this factor into consideration.

CONCLUSIONS

Managers of tree improvement programs are often asked to justify tree improvement expenditures. This is a difficult task since little definitive data are available early in a program. Certainly the manager would like to do something more than point out other successful programs. Break-even, benefit-cost analysis offers a means of obtaining a best estimate of profitability specific to a new program. Little time is needed to assemble input data and as long as the required volume (value) gain to assure a benefit-cost ratio of 1.0 is reasonable, further program justification may not be necessary. This technique was demonstrated with both black and white spruce.

As more data become available, a more complete analysis using an optimization technique such as linear programming or computer simulation can provide valuable insights as to the profitability associated with each component of the improvement program. Adjustments can be made to increase returns from the existing program and plans to maximize profits from advanced generation work can be formulated. In general, such analyses of on-going programs have lead to the conclusion that not only are tree improvement efforts profitable but that greater initial investments would have resulted in even higher returns.

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