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Economic Analysis of Tree Improvement: A Status Report

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Additional keywords: Seed orchards, harvesting, manufacture.

ECONOMIC ANALYSIS OF TREE IMPROVEMENT: A STATUS REPORT

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Rising demands for wood products have caused timber growers to seek methods of increasing per-acre yields. Tree improvement programs have been initiated by public and private landowners anxious to raise production efficiency. Because breeding and planting superior trees alters costs and returns, economists have been asked to analyze the financial efficiency of tree improvement.

Emphasizing methodology, this report summarizes several economic analyses of tree improvement programs. Although the authors discussed here have used various models, economic assumptions, and standards of measurement, all studied the benefits and costs of superior trees, and most concluded that the tree improvement programs they evaluated would expand production.

Since tree improvement is relatively new, data availability largely limited the analyses. Any new analyses should encompass improved methodology and account for additional sources of benefits and costs. To encourage future researchers to develop eclectic models, this report will mention issues requiring further research.

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Softwood Studies

Economic pressures have caused resource managers to emphasize softwood improvement. Swofford and Smith (1972) evaluated the economic advantages of the tree improvement program for the national forests in the South. The program is designed to convert present stocking to superior pine stands in one saw log rotation. Seven species were evaluated.

Swofford and Smith used a standard cost-return model. By directly estimating the added physical amount or dollar value of wood attributable to improved strains of planting stock and expressing the estimates as percentage gains in output or selling price, they provided a direct measure of the worth of superior planting stock. Future incremental value was discounted and compared to incremental costs incurred to achieve the gain. Thus, the authors considered only costs and returns clearly attributable to tree improvement. The costs included development of plans, land clearing for orchard sites, finding and evaluating superior trees, grafting and outplanting, protecting and managing seed orchards, and progeny testing.

Returns accrued from gains in volume or quality. Volume benefits pertained only to wood increases attributable to genetic improvement. Quality gains ascribed to tree improvement were greater total and merchantable height, earlier and more complete pruning, and straighter boles—all of which would bring higher stumpage prices. Price gains were expressed as increases in current market prices for stumpage and ranged from zero for white or sand pine to 20 percent for slash pine.

The study ranked species and geographical sites by internal rates of return for stands converted to superior stock. The rates equate costs and benefits and indicate value increases directly attributable to improved trees. The time period for establishing the rates extended from tree selection and orchard establishment, through stand conversion, to the end of the first saw log rotation. All benefits and costs were calculated for a 10-acre unit. Internal rates ranged from 14 to 19 percent, averaging 15.2 percent.

Swofford and Smith estimated the macroeconomic implications of their results. The 1971 allowable cut of 761.2 million board feet would increase to 943.9 million, and total pine inventory would be raised from 41,569.3 to 51,579.4 million board feet. Improved trees would increase the yield from national forests in the South by 24 percent.

Porterfield (1973) used goal programming to compute gains from public and private genetic improvement programs for loblolly pine. Because goals are substituted for constraints, this analytic technique is a desirable extension of linear programming. Goal programming is especially valuable for forestry and genetic applications where correlations exist as goals rather than constraints. For example, no firm is likely to reject a tree improvement program simply because a 9- rather than a 10 percent increase in specific gravity is attainable.

In measuring the economic benefits of tree improvement programs, Porterfield reduced the traits considered to volume and specific gravity. He used both to project gains in pulpwood production and volume alone to assess sawtimber gains.

A key variable in Porterfield's investigation was selection intensity and its associated costs. Selection intensity is explained as "a standardized statistic defined as the selection differential divided by the phenotypic standard deviation of the total population." As selection intensity mounts, the selected trait must vary increasingly from the stand mean, and thus costs of locating acceptable trees escalate.

Porterfield constructed matrices predicting genetic response from wild-stand selection, roguing, and progeny testing. Given the selection intensity for a trait and desired percentage improvement, the resultant selection-cost constraint interacts with predicted genetic responses to minimize deviation from the genetic goal while satisfying the expenditure restriction. The technique allows sensitivity analyses for changes in seed yields or different degrees of progeny testing.

With Porterfield's model, profit impacts of various roguing intensities and wild-stand selection intensities are calculable. Goals can be changed, absolutely or relatively, in response to market conditions. Underlying economic criteria for profit and market conditions include a minimum rate of return on investments and a benefit-cost ratio exceeding one.

Although genetic manipulation that reduces volume loss to rust would increase supplies throughout the South, Porterfield acknowledged that fusiform rust infection levels and subsequent loss in volume are difficult to measure. He accepted an established linear relationship between the percentage of infection and the percentage of trees displaying stem galls. He then ascertained the correlation between infected stems and wood volume lost. By these means he estimated that the total volume lost would be 40 percent of the trees with stem infections. Losses ranged from approximately 3 percent on sites lightly infected to 24 percent where infection was heavy. Costs for orchard establishment, progeny testing, and tree selection varied from $4,400 to $8,500 per acre, and internal rates of return extended from 10 to 14 percent.

Greater wild-stand selection efforts and more intense roguing promised even higher returns. Porterfield found that profitability could be maintained if selection expenditures were doubled or tripled; and genetic and economic gains would climb with higher roguing intensity. Roguing intensities as high as 75 percent were significantly more profitable than minimal roguing, and benefit-cost ratios were three times as great.

Analytical results implied that the greatest profit accrued when many clones were selected, grafts were closely spaced, and orchards were later intensively rogued. A portion of the profit increment was imputed to a decline in rust infection, since roguing permitted volume gains up to 25 percent in medium rust areas.

Hart and Ferrie (1972) used investment requirements and expected returns as a model for evaluating a private tree improvement program in the Piedmont. Their linear program determined the forest management practices required to maximize net profit after taxes, and they concluded that genetically improved stock was optimal.

A decrease in specific gravity by genetic manipulation would reduce milling costs by increasing the bursting strength of linerboard. Moreover, genetically improved stock bred for rust resistance would reduce acreage requirements. The mill required 381,486 acres for its wood supply on rust-free land, and 696,355 where infection was prevalent. Improved planting stock lowered the acreage needs on rust-free lands 14 percent. On infected land, resistant stock cut acreage requirements by 56 percent.

In test cases set up for infected and noninfected areas, alternative rates of return varied from 4 to 8 percent. Genetic improvement would increase present net worth by $6 per acre at an alternative rate of 6 percent. The internal rate of return was 17 percent on lands without rust incidence; where genetic improvement lowered the risk of loss in previously infected areas, the rate of return was 21 percent.

Lundgren and King (1965) viewed accelerated growth rates from superior seeds as an apparent increase in site index. The basis for comparison in their model was the increase in total height at age 50 imputed to improved jack pine and red pine planting stock. For alternative rates of return ranging from 4 to 6 percent, they concluded that the gain in site index necessary to offset costs for tree improvement could be readily attained. For example, returns of approximately 6 to 7.5 percent were projected if site indexes of class 55 land could be increased by 2 units for both species.

Davis (1967) employed a cost model to measure the economic potential of tree improvement. Initial costs were capitalized into the future to provide an estimate of the gains necessary to make the program financially self-sufficient.

All seed-orchard costs, including management, were the variable inputs, and were compared with probable benefits from superior trees. Davis first determined the combination of inputs that minimized seed production costs over time. He then compared this cost to the cost of purchasing seed from external sources to establish a net figure. If the superior seeds increased yields of timber at the end of the rotation and the discounted value of this yield surpassed the net cost of the seed, the investment in a seed-orchard was judged economically sound.

In applying the model, Davis found that with net costs for superior seeds of approximately $10 per pound, an increase of only 1 cord at rotation, or its value equivalent in quality increase, was required. On a 30-year rotation with planted loblolly pine, a 1-cord gain in the crop will provide an increase of 2½ to 4 percent more than from ordinary seed. Davis suggested that such gains were virtual certainties.

Theoretically, the long-run market price of improved seed would cover all costs. Yet, if net costs of producing seeds internally increased, gains needed to justify production would mount. Publicly subsidized or cooperative seed orchards would provide seeds at less than market prices, and net costs of internal production of superior seeds would be significantly higher, as would break-even demands on yield increases. Higher internal seed costs, less expensive external sources, and pressure to increase growth rates on less acreage would generate spiraling future demands for low-cost seed from cooperative and public agencies.

Perry and Wang (1958) found that genetic improvements of yields by a mere 1 or 2 percent could justify seed orchards. Their data indicated that a 2 percent increase in yield with a 25 year rotation would offset seed expenditures of $19 per pound.

Carlisle and Teich (1971), working with white spruce in Canada, asserted that gains of 2 to 5 percent in timber volume would readily offset the costs of furnishing genetically superior seed. Their inputs included several site index classes, five tree spacings, growth increments to the standing crop, an interest and inflation rate, a pulpwood stumpage value, establishment and management costs, and a range of improved yields resulting from superior genotypes. Economic outputs included estimates of rotation age, of profits-or-losses at rotation, and of changes in present net worth from tree improvement, in addition to internal rates of return.

The economic rotation was the age where the cost of waiting another year equalled the expected value growth. Rotation age ranged from 38 to 42 years for pulpwood. Profits rose from $8.42 per acre to $21.17 according to spacing and site index. With spacing fixed, profit increased with site index. Conversely, with site class fixed, profits increased with closer spacing. A 15 percent gain in yield would increase present net worth to a high of $11.91 per acre with additional seed costs of only $0.43 per acre. On the best sites, internal rates of return varied from 6.3 to 6.9 percent.

Similar profitability was sustained when per-acre figures were expanded to an annual planting program of 100,000 acres. An initial investment of $1,500,000 in tree improvement, including 6 percent interest, and an annual expenditure of $23,000 for seed production and collection would generate potential economic benefits of $832,000 per year over a 15-year period.

Hardwood Studies

Hardwood tree improvement efforts have lagged behind softwood programs. Until recently, the demand for hardwoods was easily met with existing supplies, and landowners lacked incentives for undertaking tree improvement programs. Supplies of quality timber are diminishing, however, and forest managers are now expressing interest in growing genetically superior hardwoods.

Marquis (1973) used a cost model in one of the few analyses of hardwood tree improvement. He discussed only species that produce many seeds, grow rapidly, and have high value. Since hardwoods are most frequently regenerated by natural means, a hardwood tree improvement program would not only have to absorb the costs of providing superior stock but would also have to bear the cost of converting to artificial regeneration. The slight demand for quality hardwoods limits the feasible size of seed orchards, and small orchards lack economies of scale. All of these factors limit the size of hardwood tree improvement programs. Marquis assumed that the number of acres seeded or planted each year would not exceed the number required to produce one-third of the annual cut of desirable species. Orchard acreage requirements were 6 acres for paper birch, 8 for black cherry, and 240 for red oak. Development costs were virtually independent of orchard size and thereby imposed a heavy burden on small orchards.

Marquis estimated yields required to justify improvement expenditures. He included all costs up to the time superior seeds were available. In addition, he treated the orchard as a capital asset depreciated over a 25-year period. Depreciation, operating, and harvesting costs determined gross cost per pound of seed. Direct seeding or planting costs for a total program ranged from $25 to $66 per acre, depending on species, orchard size, and seeding requirements.

Hardwood profitability was sensitive to species and intensity of management. In terms of quality or growth rate, black cherry and paper birch required genetic improvements of only about 10 percent. Red oak, on the other hand, would require significantly greater genetic gains to justify the costs of a tree improvement program.

Marquis emphasized the need for intensive management of genetically improved hardwood forests. Planting improved stock without thinning incurs financial loss, and highest profits are realized only when tree improvement and intensive management are combined.

A slightly different approach is Smith's (1973) study of the economics of hardwood plantations. Here the units of analysis were trees cultivated under the superior growing conditions of plantations. Smith collected data from more than 70 sycamore, yellow poplar, and sweetgum plantations and constructed yield equations. He determined that pulpwood prices from $9 to $12 per cord would justify establishment of plantations. Average costs of $100 per acre and rotation lengths between 12 and 16 years were assumed. Smith considered his conclusions unduly conservative because sampled plantations had low quality seedlings and poor cultivation. Both increased yields and reduced costs would lower the prices needed to justify planting hardwoods.

Discussion

The authors surveyed thus far consistently predicted favorable results from tree improvement, and some pointed to advantages accruing from phases other than timber production. Uniformity of tree size and growth rate from improved trees would increase harvesting efficiency. Mill processing operations would derive advantages from uniform tree size, wood fiber lengths, and springwood-summerwood ratios. Thus in vertically integrated firms, improved trees could produce savings in harvesting, transportation, conversion to lumber or pulp, and manufacture of consumer goods. These profits could offset any losses incurred in the tree improvement phase of production (Carlisle and Teich 1971).

Another spillover benefit from improved trees would be the single-expense, multiple-benefit characteristic. Actual costs of establishing a tree improvement program were condensed to a short time span relative to the extension of benefits to a number of future generations. Improved trees also permitted shorter rotations which allowed for reduced capital carrying costs, quicker application of research results, and more frequent opportunities to change land use (Bentley 1973).

Some authors pointed out disadvantages of genetic improvement programs, and others suggested alternative means of increasing production. Bentley (1973) presented negative factors to consider in large scale tree improvement efforts. Any narrowing of gene pools, such as manipulation for superior yields, might increase the susceptibility of trees to pathogen or insect attack. The costs of treating these conditions might not be initially discernible, but could become substantial or even prohibitive. Another possible disadvantage might result from conversion to monoculture. Widespread use of fertilizers or chemical control agents to establish and maintain plantations might create ecological imbalances that would later demand a high corrective price. Another consideration —somewhat difficult to measure—was public opinion, since many people may prefer natural forests to intensively managed ones. Bentley suggested that medium-intensity silviculture might produce forests with desired positive externalities rather than negative ones. Such a forest would minimize the probability of future ecological disaster.

Dawson and Pitcher (1970) suggested techniques that can reinforce genetic improvement programs. They recommended timber-stand improvement as the most promising method of upgrading production in the immediate future and suggested that improvements in protection, utilization, and technology would also increase yields. They predicted high potential gains from matching species to site and cited a study that showed gains as high as 60 percent. These alternatives would not exclude or supplant tree improvement but would increase timber supplies.

Research Goals

Data available to the authors limited their methodologies and restricted the analyses. New analyses should adopt progressively more eclectic models.

Economic analysis of tree improvement must provide inclusive lists of costs and benefits. For example, cost accountability must include future expenditures such as pollution abatement efforts as well as initial expenditure for basic research and development of superior trees. For high-valued hardwoods, data may be required to alter the basis of analysis from the acre to the tree. Future models should include benefits such as decreased costs in harvesting, transportation, and processing.

Methodology will continue to be affected by such controversial items as investment criteria and how to price future goods. Literature in the field of capital theory offers numerous investment criteria. While many authorities agree to the maximum present net worth criterion, strong disagreement persists over the choice of prices, interest rates, and selection of alternatives.

Row (1973) advocated equivalent annual income, a variant of present net worth. This method is especially applicable where investments in tree improvement and forestry must be compared to alternatives that bring annual returns. Equivalent annual income combined with more accurate estimates of uncertainty would clarify managerial decisions. If economic models would include comprehensive estimates of costs and benefits, the chances that management would channel resources into optimal land-use patterns would improve.

Buongiorno and Teeguarden (1973) stressed the benefits of using present net worth as an allocative tool. This measure would allow decision makers to focus on one representative commodity rather than attempt to elaborate the effects of innumerable relative prices. The commodity can be labeled forest consumption and its price—the interest rate. In the analysis, society's propensity to substitute future for current consumption was regarded as an interest rate. Theoretically, this interest rate implied maximum social satisfaction with consumption of forest products, in the present and the future. However, this interest rate must correspond with maximized present net worth. Present net worth is the net value of all current and future costs and revenues. Theoretically the public-agency decision maker would compare present net worths, derived at society's preferred interest rate, and select the maximum values. In practice, no decision-maker can pinpoint this interest rate, but he can use prevailing interest rates or a range of rates

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around them to maximize present net worth and pinpoint the optimum alternative.

The economic concept of projected demand, for land use as well as for wood production, can aid in the establishment of research priorities. Once demands are specified, research dollars can be invested where the likelihood of payoff is greatest. Ideally, genetically improved trees, advantageous silvicultural practices, and sites for planting would be available simultaneously. Research should accommodate both genetic and cultural advances.

It seems certain that tree improvement research will be intensified. As land and labor available to forestry become scarce and prices rise, increased per-acre yields will be more profitable. The gap between wood-fiber demands and acreage available to supply those demands can be partially closed by genetically superior trees. Research programs designed to develop improved trees must be oriented to production goals, yet be flexible enough to accommodate changing needs. Most important, research programs must be supported long enough to obtain benefits.

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