ECONOMIC ASSESSMENTS OF EVEN-AGED AND UNEVEN-AGED LOBLOLLY-SHORTLEAF PINE STANDS

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Abstract. Present net value (PNV), benefit-cost ratio (B/C), and cost efficiency were determined for conventional and intensive prescriptions for even-aged plantations, even-aged natural stands, and uneven-aged stands, from seven long-term studies having a 36-year management history in loblolly-shortleaf pine (Pinus taeda L.-P. echinata Mill.) stands on the upper West Gulf Coastal Plain. When the existing initial stand was valued as a cost in year 0 of management, the uneven-aged stands had the lowest PNV rank of all systems in the study; when the initial stand was not valued as a cost, the uneven-aged stands had the highest PNV rank. Under the B/C and cost efficiency criteria, the even-aged natural stands exceeded not only the even-aged plantations but also the uneven-aged stands. Reductions in sawtimber stumpage prices, coupled with increases in pulpwood stumpage prices, favored even-aged stands and disfavored uneven-aged stands under the PNV and the B/C criteria; cost efficiency was insensitive to changes in the stumpage price ratio. Most of the trends observed under the research prescriptions held true under synthesized practical prescriptions.

INTRODUCTION

Many notable contributions to our understanding of the economics of uneven-aged stands have been made using growth models derived from forest stands or stochastic approximations thereof (Chang, 1981; Hotvedt et al. 1989; Haight 1987). The advantages of growth models are the ability to compress years of management into milliseconds of computer time, coupled with the ability to instantly assess the merit of stand management alternatives. A fundamental assumption upon which this approach is based is that growth models accurately represent stand development as observed in the woods.

The analysis of empirical data provides an opportunity to validate conclusions about economic efficiency derived from this modeling approach. The long-term forest management research in the loblolly-shortleaf pine (Pinus taeda L.-P. echinata Mill.) type in south Arkansas and north Louisiana exemplify the empirical data base required to conduct such a comparison. The documented record of yields and of the research prescriptions that produced those yields allows for such an economic analysis, if made under appropriate assumptions and conditions.

The goals of this paper are twofold. The first goal is to develop economic comparisons among the silvicultural systems used to manage even-aged plantations, even-aged natural stands, and uneven-aged (natural) stands, based on demonstrated long-term records of production, actual
research-based silvicultural prescriptions, and values for costs and returns applicable to the region. The second goal is to interpret the major observations derived from these empirical economic assessments.

METHODS

Data base

Guldin and Baker (1988) published yield comparisons from even-aged and uneven-aged loblolly-shortleaf pine stands managed for 36 years under three major silvicultural systems - namely, even-aged plantations, even-aged natural stands, and uneven-aged stands. Data for that work were obtained from seven long-term studies originally imposed on similar sites in the West Gulf Upper Coastal Plain of south Arkansas and north Louisiana. A brief description of these seven studies is presented in Table 1.

In each study, all yields were monitored through the 36-year common management interval shared by two of the studies, with yields from the other five studies conservatively extrapolated from ages 34, 35, or 41 to age 36 (Guldin and Baker 1988). All studies had similar merchantability specifications, with slightly more conservative standards used in the uneven-aged stands.

In this current study, the classification of treatments within the seven long-term studies in the data base parallels the previous work (Guldin and Baker 1988). Individual silvicultural systems from each of the seven studies were classified by their relative intensity. Prescriptions for even-aged plantations and even-aged natural stands were classified as conventional or intensive based on intensity and frequency of thinning. Uneven-aged prescriptions were classified as conventional or intensive based on cutting-cycle frequency; intensive treatments had very short (annual) cutting cycles. Intensive uneven-aged treatments

Table 1.-- Description of the long-term research studies included in this economic assessment (Guldin and Baker 1988).

<table>
<thead>
<tr>
<th>Study area</th>
<th>County/State</th>
<th>Silvicultural Systems</th>
<th>Site Index feet, base 50</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cattle Farm Plantation, Georgia-Pacific Corp.</td>
<td>Ashley Co., AR</td>
<td>Even-aged plantations, old-field</td>
<td>80-85</td>
</tr>
<tr>
<td>2. Sudden Sawlog Study, USDA Forest Service and Georgia Pacific Corp.</td>
<td>Ashley Co., AR</td>
<td>Even-aged plantations, old-field</td>
<td>85</td>
</tr>
<tr>
<td>3. Hill Farm Thinning Study, Louisiana State University</td>
<td>Claiborne Pa., LA</td>
<td>Even-aged plantations, old-field</td>
<td>100</td>
</tr>
<tr>
<td>4. Methods of Thinning Study, USDA Forest Service</td>
<td>Ashley Co., AR</td>
<td>Even-aged natural stands, Clearcutting method</td>
<td>80-85</td>
</tr>
<tr>
<td>5. Methods of Cutting Study, USDA Forest Service</td>
<td>Ashley Co., AR</td>
<td>Even-aged natural stands, Clearcutting and seed tree methods Uneven-aged stands, selection and diameter-limit methods</td>
<td>85-90</td>
</tr>
<tr>
<td>6. Poor Farm Forty Study, USDA Forest Service</td>
<td>Ashley Co., AR</td>
<td>Uneven-aged stands, selection method</td>
<td>84-90</td>
</tr>
<tr>
<td>7. Good Farm Forty Study, USDA Forest Service</td>
<td>Ashley Co., AR</td>
<td>Uneven-aged stands, selection method</td>
<td>84-90</td>
</tr>
</tbody>
</table>
were further classified as poorly-regulated or well-regulated. Poorly-regulated yields include the period of rehabilitation of the stands; well-regulated yields for a 36-year management interval were based on growth that occurred after the stands were well-regulated.

Assumptions

Three economic parameters were selected for inclusion in this study:

1) present net value (PNV), defined as the difference of discounted costs from discounted returns;
2) the ratio of discounted returns to discounted costs, herein analogous to the benefit/cost ratio, B/C; and
3) cost efficiency (CE), defined as the volume produced per dollar of discounted cost; results here are presented for the Doyle log rule in units of BF/Doyle/$.

Within the context of this study, the B/C and cost efficiency indices are interpreted as alternative investment criteria.

Silvicultural prescriptions were developed as both research-based treatments and synthesized practical treatments. Yields from all prescriptions were valued using applicable pulpwood and sawtimber stumpage prices.

Research prescriptions represent the actual imposed treatments during the 36-year management period. Treatments that are now out of date, such as the mistblowing of 2,4,5-T which was conducted in many of these stands, were substituted with contemporary treatments of similar intent and effectiveness. We valued inoperable as well operable volumes for both pulpwood and sawtimber; if a sawtimber or pulpwood volume was reported in the yield flow, a financial return was calculated in the given year using the appropriate stumpage price. Recorded volumes of pulpwood and tops harvested concurrently with sawtimber were assumed to be operable, and returns for that volume were calculated at the prevailing pulpwood stumpage price.

Practical prescriptions were developed to produce similar, though probably more realistic, conditions for stand development. Operable harvests and effective understory control were required. Under the practical prescriptions, operable harvests were specified at 4 cords per ac or 1500 bf Doyle per acre. Hardwood control in even-aged stands was conducted using chemical treatment (injection) every 12 years, coupled with prescribed burning on a three-year cycle from age 12 to age 36. In the uneven-aged stands, hardwood control was conducted using chemical treatment (injection) every six years; prescribed burning was assumed to be infeasible.

Costs in this analysis were obtained from Straka et al. (1989). Cost data were utilized from the Coastal Plain category where reported; data were utilized from the overall average category where Coastal Plain data were absent. If a given treatment was not listed in the tables of Straka et al., an appropriate cost was derived based on analogous time and motion values. For example, the mowing conducted in one study was considered analogous to a one-pass drum chopping treatment in that both require a similar piece of equipment in operation for a similar amount of time on a tract. All prescriptions include annual management cost for fire protection (Straka et al. 1989) and property tax assessment (Hickman 1989). In the even-aged stands, property tax liability was assessed on a high-quality bare-land basis ($1.15 per acre per year). In the uneven-aged stands, property tax liability was assessed on a high-quality sustained-yield basis ($5.72 per acre per year).

Three sets of sawtimber & pulpwood stumpage prices were utilized, to reflect regional variations in market conditions:

1) $180 per mbf Doyle, and $15 per cord. These values are based on Coastal Plain stumpage prices for pine reported by the Arkansas Cooperative Extension Forest Products Marketing Bulletin, derived from Timber Mart-South (Norris, 1990).
2) $150 per mbf Doyle, and $30 per cord; and
3) $120 per mbf Doyle, and $60 per cord.

Most of the results are presented using the $180/$15 ratio of stumpage prices, in that these prices reflect the existing market structure in the region where the stands are located. The application of the threefold set of sawtimber/pulpwood stumpage prices reflects the changing price structure across the southern region of loblolly pine, from south Arkansas (high ratio) to the southeastern Coastal Plain of Georgia (low ratio).

Three interest rates (i) - 4%, 7%, and 10% - were used for discounting purposes, to reflect low, medium, and high values of i. The lowest rate is commonly used to value forestry investments; the highest rate is used by the government’s Office of Management and Budget to value investments. We also assumed a 1% real rate of increase in costs and returns across the 36-year management period.

Prescriptions were constructed using computer spreadsheet software (Borland, 1989). A spreadsheet was developed with the capability for sensitivity analyses under changing discount rates, stumpage prices, and a constant rate of change for costs and returns. Each spreadsheet was specific to each prescription. Spreadsheets for the entire set of prescriptions under a given set of conditions (such as those that assess the initial standing volume of a stand as a cost in the first year of management) were nested to facilitate sensitivity testing and graphical analysis.
Analyses are based on two sets of comparisons. General comparisons among silvicultural systems were made by evaluating the conventional and intensive applications of:

1) even-aged plantations (EAP,c and EAP,i),
2) even-aged natural stands (EAN,c and EAN,i), and
3) uneven-aged stands (UEA,c and UEA,i).

Specific comparisons were also made among the uneven-aged stands in the data base:

1) the diameter-limit method in the Methods of Cutting study (MOC,d);
2) the selection method in the Methods of Cutting study (MOC,s);
3) the Poor Farm Forestry Forty, including the interval during which the stand was poorly-regulated (P40,pr);
4) the Good Farm Forestry Forty, including the interval during which the stand was poorly-regulated (G40,pr);
5) the Poor Forty during the well-regulated interval (P40,wr); and
6) the Good Farm Forty during the well-regulated period (G40,wr).

RESULTS

A complete analysis of all parameters in the study resulted in an excessive number of tables and graphs having varying degrees of theoretical and practical importance. Therefore, in this paper, we assumed the liberty of reporting on the four major trends that we interpret from our analyses.

Value of the initial stand

The factor that resulted in the greatest variation in present net value was whether the value of any existing initial stand is expressed as a cost in year 0 of stand management. If the initial volume of the stand is not expressed as a cost in year 0, the uneven-aged stands in this study compare very favorably to the even-aged stands under the PNV criterion; conversely, if the initial volume is expressed as a cost in year 0, the uneven-aged stands (especially those under intensive management) are poor compared to the even-aged stands (fig. 1a).

The initial volume of an uneven-aged stand is essential to develop and maintain stand structure, and to perpetuate uneven-aged conditions. However, that initial volume also has a value that could be harvested, in some cases at great profit. The modest initial volume of the even-aged natural stands under the seed tree method is less critical economically because the seed trees can be harvested soon after the new stand is established.

When the initial volume is valued as a cost in year 0, increasing the discount rate from 4% to 10% results in a larger reduction of PNV for the uneven-aged stands than for the even-aged stands (fig. 1b). At 4%, the PNVs are comparable for the different systems; the 10% discount rate favors conventionally-managed plantations and intensively-managed even-aged natural stands.

Conversely, if the initial volume is not valued as a cost in year 0, ranking by PNV favors uneven-aged management at 4%, 7%, and 10% (fig. 1c). The intensive uneven-aged stands rank higher than the conventional uneven-aged stands at all three discount rates, and both rank higher at each discount rate than any of the even-aged stands.

These trends also apply to the individual uneven-aged stands in the study. When the initial volume is valued as a cost in year 0, the uneven-aged stands with high initial volumes are less attractive under PNV than stands with low initial volumes (fig. 2a). The volume of the initial stand of the poorly-regulated Good Forty, for example, was 5100 bf Doyle, worth over $900 per acre at current stumpage prices; assessing that value as a cost in year 0 results in a highly unprofitable PNV. Conversely, the diameter-limit stand in the Methods of Cutting study had an initial volume of only pulpwood; assessing its value as a cost results in virtually no change in PNV relative to the no-cost alternative.

When the initial stand is valued as a cost in year 0, the uneven-aged stands with high initial volumes show the largest decrease in PNV under increasing discount rates (fig. 2b). This is illustrated by both Good Forty systems, where an increase in discount rate from 4% to 10% results in a PNV change exceeding $1000, producing an extremely negative PNV at 10%. The well-regulated Poor Forty also exhibits a decrease of similar magnitude, but because of the configuration of cash flows within its prescription, the PNV at 10% is only slightly negative and actually ranks second-best among the uneven-aged stands. It is not surprising that the stand least sensitive to the changing discount rate is the diameter limit stand, whose initial volume contains no sawtimber and only a modest amount of pulpwood.

Conversely, if the initial volume is not valued as a cost in year 0, each uneven-aged stand has a positive PNV at each of the three discount rates (fig. 2c). The well-regulated Good and Poor Forties rank higher than the other uneven-aged stands at all three discount rates. The silvicultural merit of the large initial volume in an uneven-aged stand is that the forester can immediately begin to harvest growth, as there is no need to harvest only a portion of growth so as to build the standing volume. The net result is the relatively prompt production of sawtimber in the first cutting cycles after the initiation of management, which is fundamental to the development of a favorable PNV. The positive PNV of these uneven-aged stands, especially the well-regulated stands at the 4% discount rate, are an unexpectedly intriguing result.
Figure 1a.—PNV by silvicultural system, for initial volume as a cost (IV $) versus initial volume as no cost (IV 0). Research prescriptions, discount rate 7%, stumpage ratio $180/$15.

Figure 1b.—PNV by silvicultural system under discount rates of 4%, 7%, and 10%. Initial volume is a cost in year 0; stumpage ratio $180/$15.

Figure 1c.—PNV by silvicultural system under discount rates of 4%, 7%, and 10%. Initial volume not a cost in year 0; stumpage ratio $180/$15.

Figure 2a.—PNV for individual uneven-aged stands comparing initial volume as a cost (IV $) versus initial volume as no cost (IV 0). Research prescriptions, discount rate 7%, stumpage ratio $180/$15.

Figure 2b.—PNV for individual uneven-aged stands under discount rates of 4%, 7%, and 10%. Initial volume is a cost in year 0; stumpage ratio $180/$15.

Figure 2c.—PNV for individual uneven-aged stands under discount rates of 4%, 7%, and 10%. Initial volume not a cost in year 0; stumpage ratio $180/$15.
Alternative investment criteria

For the benefit-cost and the cost-efficiency investment criteria, even-aged natural stands are excellent alternatives, generally exceeding not only the even-aged plantations but also the uneven-aged stands.

Ranking under the benefit-cost criterion is somewhat dependent on whether the initial stand volume is valued as a cost in year 0. When the initial volume is not valued as a cost, ranking by B/C favors the even-aged natural stands at discount rates of 4% and 7%, but favors the uneven-aged stands slightly at the 10% discount rates (fig. 3a). The largest decline in PNV under the changing discount rates is found in the even-aged natural stands; the lowest decline is in the intensively-managed uneven-aged stands. However, at all discount rates under this initial stand valuation condition, the even-aged plantations are poorer alternatives than the natural stands.

If the initial volume is valued as a cost in year zero, ranking by B/C favors even-aged natural stand management at all discount rates (fig. 3b). The conventional plantations rank slightly higher than the conventional uneven-aged stands, especially at the discount rates of 4% and 7%. Similarly, the intensive plantations rank slightly better than the intensive uneven-aged stands, especially at the lower discount rates.

High discount rates value investments and returns early in the management period at a higher rate than those that occur later in the management period. The lengthy deferral of returns under the even-aged natural stands in this study is strongly influenced by changes in the discount rate, which explains the decreasing advantage of the even-aged natural stands at increasingly high discount rates. The high B/C ratio at low discount rates for the even-aged natural stands reflects not only an enhanced value of future returns, but also the relatively low cost of stand establishment.

Under the cost efficiency criterion, when the initial volume is not a cost in year 0, even-aged natural stand management is favored at all discount rates (fig. 3c). We attribute the increases in cost efficiency with increasing discount rate to the reduced value of future discounted costs at the higher discount rates. The extremely low costs incurred in the establishment of these even-aged natural stands results in an extremely favorable discounted cost value, which in turn produces a high cost efficiency ranking even though the yields of the even-aged natural stands are rather low (Guldm and Baker 1988). The cost efficiency ranking of even-aged plantations relative to uneven-aged stands depends upon the valuation of the initial stand. With no cost ascribed to the initial volume (fig. 3c), the uneven-aged stands rank higher under CE than the even-aged plantations. However, the uneven-aged stands rank lower than the plantations when the initial stand volume is valued as a year 0 cost, similar to findings under the B/C criterion.
Changes in sawtimber/pulplwood stumpage price ratios

Reductions in sawtimber stumpage price, coupled with increases in pulplwood stumpage price, favor even-aged stands and disfavor uneven-aged stands under the PNV and B/C criteria. For example, when initial volume is not a year 0 cost, the PNV of even-aged plantations and the intensive uneven-aged stands increases as the stumpage ratio increases from $180/$15 to $120/$60; the PNV of the uneven-aged stands decreases under the same progression of stumpage (fig. 4a). However, when the initial stand is valued as a cost, both the magnitude and the absolute value of the PNV decrease are accentuated for the uneven-aged stands (fig. 4b), with both the conventionally-managed and intensively-managed uneven-aged stands having a negative PNV under the $120/$60 stumpage ratio.

Among the uneven-aged stands, under the assumption that the initial stand is a cost in year 0, the pattern of increasingly negative PNV's under decreasing stumpage price ratio is apparent in each stand (fig. 4c). The only stands that show a positive PNV under the $120/$60 stumpage ratio are the diameter-limit stand and the well-regulated poor 40, in the first case because of the low initial volume and in the second because more pulplwood was produced than in the other uneven-aged stands.

This stumpage price trend in the even-aged stands versus the uneven-aged stands was also observed under B/C (fig. 4d). Assuming the initial stand volume is a year 0 cost, the conventional plantations and the intensive even-aged natural stands show the largest increase in B/C ratio to changes in stumpage price ratio; the other even-aged stands show only slight increases in B/C ratio. The uneven-aged stands have the lowest B/C rank compared to the even-aged stands under these assumptions, but the magnitude of their decrease in B/C ratio is less than that observed for PNV.
However, these trends in PNV and BC under changing stumpage ratios do not apply to the cost efficiency assessment. Under the assumption where the initial stand is a year 0 cost, the even-aged stands exhibit no change in cost efficiency with changes in the stumpage ratio, and the uneven-aged stands show a slight decrease in CE with increasing stumpage ratio (fig. 5a); under the no-cost assumption, neither the even-aged or the uneven-aged stands show any change in CE with changes in stumpage ratio (fig. 5b).

This result is to be expected, in that the cost schedules that comprise the silvicultural prescriptions are independent of stumpage, and cost efficiency evaluates production in board feet Doyle per discounted dollar cost. Therefore, there is no effect of stumpage price in determining the cost efficiency of these stands. When considering either the assumption of initial volume as a cost or the converse assumption of no cost, the most cost efficient research prescriptions are those of the even-aged natural stands. Subsequent ranking depends on the cost assumption of the initial stand. In the assumption of initial stand volume as a cost, the even-aged plantations are more cost-efficient than the uneven-aged stands. Under the converse no-cost assumption, uneven-aged stands rank more favorably than the plantations.

When comparing the individual uneven-aged stands, considering the initial volume as a year 0 cost, the cost efficiency shows varying degrees of minor change under changing stumpage prices (fig. 5c). The exception is the large variation in the diameter-limit stand, whose initial volume is entirely pulpwood and thus is most sensitive to the increase in pulpwood stumpage price.

Research versus practical prescriptions

Most of the major trends observed under research prescriptions also observed in synthesized practical prescriptions. By and large, there was not much variation between actual research prescriptions and synthetic practical prescriptions. For example, under the PNV criterion, at stumpage of $180/$15 with a 7% discount rate, and where the initial stand volume is not a cost in year 0, the research prescriptions and practical prescriptions were largely comparable (fig. 6a). Valuation of the initial volume as a cost does produce changes in the PNV, especially by reducing the PNV of the natural stands that have a prominent initial volume (fig. 6b).
A major exception to the comparability of results observed under the research versus practical treatments is the prominent reduction in the high ranking of the even-aged natural stands under the B/C criterion (fig. 6c); a similar change in ranking was observed for the CE criterion. Under these scenarios, the major difference between research and practical prescriptions is that the practical prescriptions generally incurred greater cost through the course of the rotation, particularly through the imposition of a regular program of prescribed fire in the even-aged stands and through greater intensity of hardwood control through regularly-scheduled chemical treatments.

DISCUSSION

The question of whether the initial volume should represent a cost in year zero for uneven-aged stand management is fundamental to the economic valuation of these stands by the PNV criterion. Throughout these analyses, the economic success or failure of uneven-aged silvicultural prescriptions turned on this single factor. When the value of the initial volume was not assessed as a year zero cost, the uneven-aged stands in this study generally exceeded both even-aged plantations and even-aged natural stands; in several cases, the PNV of the uneven-aged stands exceeded $1000 per acre. On the other hand, when the initial stand was assessed as a year 0 cost, the uneven-aged stands were very poor in comparison to the even-aged stands; in several cases, the PNV of the uneven-aged stands was as low as -$400 per acre.

This pattern was also consistent within UEA systems having different initial volumes. The PNV of stands with low initial volumes, such as the MOC diameter-limit stand, was largely unaffected by the valuation of the initial stand as a cost. Conversely, stands with high initial volumes, such as the intensively-managed uneven-aged stands, showed a tremendous decrease in PNV when the initial stand volume was valued as a year 0 cost. However, after accounting for this effect, the rankings of silvicultural systems by PNV were generally consistent across all discount rates under given conditions of initial stand valuation and stumpsage ratio for the stands in this study.

The significance of the investment value of the initial stand has been reported previously. Chang (1981) was first to provide a theoretical justification for the exclusion of initial stand volume as a cost in year 0. The silvicultural importance of the initial stand is such that uneven-aged silviculture is impossible without that initial stand as a point of departure for achieving the desired stand structure. Results from this study suggest that if the Chang theory is correct, an economic framework can easily be constructed to illustrate that the uneven-aged stands in this study have higher PNV than the even-aged stands in this study.
If humans are less rational economic beasts than Adam Smith would expect, an interpretation of this finding will depend on the individual investment environment of each landowner. Under conditions where the landowner purchases land and timber, or views timber strictly as an investment, one could make a case for the consideration of initial volume as a cost in year 0. However, under conditions that place a constraint on total removal of the stand, or where a preference for some continuous standing forest is of major importance in addition to timber yield, one might justify the exclusion of the initial volume as a cost in year 0.

Under the B/C and CE assessments in the research prescriptions, the highest rankings were achieved by the even-aged natural stands. This observation has been reported elsewhere (Baker 1985). However, this trend was not supported by the assessment of practical prescriptions in this study. It is likely that imposing such prescriptions would result in improved yields that are not reflected in the current analysis. This would probably result in a general improvement in the PNV of the practical prescriptions across the board relative to the research prescriptions.

In this study, we observed that increases in PNV and B/C of even-aged systems, and decreases in the PNV and B/C of uneven-aged systems, occurred under increasing stumpage ratios. The stumpage ratios were developed to reflect a shift in market structure for sawtimber versus pulpwood, with the lowest ratio reflecting conditions in the mid-south, and the highest ratio reflecting conditions in the southeastern Coastal Plain. In this study, the low stumpage ratios characteristic of the southeastern states favor even-aged plantation silviculture. Conversely, the high stumpage ratios characteristic of the West Gulf Coastal Plain favor uneven-aged silviculture. Thus, the market-driven structure of stumpage prices may contribute not only to the favorable practice and general optimism of applying uneven-aged silviculture in the West Gulf region, but also to constrained opportunities and perhaps even to a general reluctance to apply uneven-aged silviculture in the southeastern states.

However, this study also indicates an exception to this trend, in that the cost efficiency assessment for the stands in this study were insensitive to variations in the stumpage ratio. This is simply because cost efficiency is driven by volume produced per discounted dollar cost, and stumpage only figures in the calculation in the valuation of initial volume as a cost. Because of this, the relative cost efficiency of the different silvicultural systems is likely to be unaffected by regional variations in stumpage. A more precise assessment of this would include regional differences in cost. However, such differences are not great (Straka et al. 1989), and the general insensitivity of cost efficiency to stumpage ratio would, we hypothesize, hold true.

The best values for cost efficiency in this study were found in the even-aged natural stands under the research prescriptions. This finding contradicts work by Baker (1985), who reported that uneven-aged stands were the most cost efficient. The advantage of cost efficiency for the even-aged natural stands reported here may be due to their relatively low intensity of management. We suspect that further research will be required to establish the criteria under which any single method of management can be described as having the greatest advantage of cost efficiency.

LITERATURE CITED


