Increasing Intensive Management: Does it Necessarily Mean Economic Optimization?

Curtis L. VanderSchaaf
David B. South
Larry Teeter

Abstract

There is a prevailing attitude among plantation managers that increasingly intensive management results in decreases in discounted costs per unit of production thereby maximizing financial returns. It is indeed true in most cases that increasing management intensity will result in more volume production. However, the value of this increase in volume production may not be enough to offset the large amount of investment required to obtain these increases. A manager's perception of how volume (and value) growth will change in response to increases in management intensity (and costs) will determine to a large extent what management prescriptions will be selected. We assume that potential production responses to increases in management intensity can be represented by four model forms where volume production is related to management intensity using total discounted costs as a measure of silvicultural intensity. These four theoretical forms yield dramatic differences in NPV. Depending upon the site and model selected, maximizing volume production does not necessarily maximize economic returns. Resource managers must decide which model form they believe is most consistent with prevailing principles of biological growth and yield. This will help them make decisions about the appropriate level of silvicultural investment when trying to maximize financial returns.

Keywords: forest economics, intensive management, model alternatives
Increasing Intensive Management: Does it Necessarily Mean Economic Optimization?

Introduction

There is a prevailing attitude among many forest managers that more intensive site preparation and cultural treatments result in a decrease in the unit cost of wood production (Allen et. al. 1998, Yin and Sedjo 2001). If this is true, then increased stand management inputs should result in greater economic returns. However, other things being equal, continual increases in silvicultural effort should be subject to the law of diminishing returns. In terms of loblolly pine plantation management, most managers would agree that to increase a soil’s site index (base age 25) from 55’ to 60’ will require less silvicultural effort than increasing the same soil from site index of 60’ to 65’. Since forest management is often conducted with a goal of maximizing economic returns, the question that needs to be asked is, are the increases in productivity obtainable with new technologies worth the silvicultural capital investment required to obtain these increases?

We do not argue with the fact that (with a few exceptions depending on soil types, moisture regimes, and competing vegetation) more intensive forest management of loblolly pine will increase site productivity. Increases in growth related to intensive forest management of loblolly pine (Pinus taeda L.) in the Southeast have been shown in many studies including the following: Haywood and Tiarks 1990, Miller et. al. 1991, NCSFNC 1996, NCSFNC 2000, Borders and Bailey 2001, Yin and Sedjo 2001. Rather, our concern is whether continuously increasing investments in intensive site preparation, fertilizer and herbicide applications, morphologically improved seedlings, genetically improved stock, etc., result in enough additional yield at current and expected prices to maximize profit. For example, in a particular stand intensive site preparation and herbicide treatments for the first two years are planned. In addition to this standard treatment, a manager is considering whether to fertilize the first year after planting, the first two years, or annually until the planned harvest at age 15. The question we are posing is: will the fertilization in year one result in a larger volume response at age 15 than the year two fertilization, the year three fertilization, the years four, five, six, and seven fertilization treatments, etc? Or will each of these separate treatments produce a positive linear response in volume at age 15. If these fertilization treatments produced a positive linear response, the next question that would need to be asked is what is the degree of response. The slope of the linear response would determine whether annual fertilization was economical. What if all the fertilization treatments did not produce a positive linear response, but rather perhaps an increasing but at a decreasing rate response. If this was true, at some point additional fertilization treatments would not result in enough increase in volume at age 15 to produce a profit or to even offset the discounted costs.

A much more complicated matter than merely deciding to practice intensive management is the degree of intensity and the specific treatment regime selected. Theoretically, every plantation has a maximum amount of merchantable volume that can be produced at any rotation age for a particular species. It can be seen from many studies that “traditional management” or the lack of management certainly does not achieve this theoretical maximum volume production (Borders and Bailey 2001, Haywood and Tiarks 1990, Miller et. al. 1991, NCSFNC 1996, NCSFNC 2000,
Yin and Sedjo 2001). In fact, we may never discover the optimal management scenario that allows us to reach that maximum volume production.

The selection of management schemes is beyond the scope of this paper, but we would like resource managers to realize that intensive management is much more complicated than a "cookbook" mentality to all sites. A terrific example can be seen in Table 1. Some managers practice intensive management on their highest quality sites using site index to determine quality. Since the Tifton site (Table 1) has a higher site index than the Waycross site (based on dominant height and accounting for the difference in age for the control treatment), a manager would select Tifton to practice intensive management. However, this would not result in an overall economic optimization because the Waycross site has much more response; in fact, not only did the Waycross site respond better, it actually produced more volume than the Tifton site (even when accounting for the differences in age). Therefore, site index is not a fool-proof way to determine which sites to select for intensive management. There are many factors that need to be considered when selecting sites including moisture regimes, nutrient status, nutrient interactions, genetics of the stock, pine-understory vegetation relations, insects and diseases, overstory density, and all potential interactions.

Besides the fact that biological volume maximization is complex, the inclusion of economic optimization into the mix further complicates things. Decisions about whether to invest in stand management treatments are based largely on growth and yield models and other methods to predict future response. What a manager predicts as a response to management treatments depends on the relationship they believe exists between volume production and operational inputs.

**Data and methods**

Four alternative models of loblolly pine volume yield response to increases in management intensity are presented. Discounted costs are used as a proxy for silvicultural effort (Figure 1). The curves were developed using data reported by Borders and Bailey (2001) (Table 1). Two sites were selected from their study based on differences in the response to silvicultural effort: a highly responsive site (the Waycross site) and a less responsive site (the Tifton site). The treatments were: C – a control treatment with no silvicultural activities following intensive mechanical site preparation, F – intensive mechanical site preparation plus annual fertilization, and HF- in addition to treatment F, herbicide treatments to control all herbaceous and woody vegetation the first three years. A common 15-year rotation was used to help simplify the presentation of our models and measure the economic value associated with increasing silvicultural effort. Total cubic foot volumes per acre for each treatment from Borders and Bailey (2001) were adjusted to age 15 by determining mean annual increment at the last measurement age and projecting that growth rate to age 15. These estimated volumes were then plotted over the sum of discounted costs per acre for each treatment at each site. Functions were then created and adjusted consistent with each of the four alternative models proposed (Figure 1) for both of the sites. Total discounted costs for three treatments, (extended to age 15), were calculated using the prices found in Table 2.
The first alternative assumes that yield increases at a decreasing rate as silvicultural effort increases (1a – highly responsive site and 1b – less responsive site). The second alternative assumes that yield increases at an increasing rate with increases in silvicultural effort (2). The third alternative assumes that yield increases at a linear rate as silvicultural effort increases such that discounted cost per unit of volume production increases (3). The fourth alternative assumes that yield increases at a linear rate as silvicultural effort increases such that discounted costs per unit of volume production decreases (4). Graphically, Alternative 4 has a steeper rate of volume growth than Alternative 3 as silvicultural effort becomes greater.

In order to get an idea of the mix of product volumes (pulpwood and chip-n-saw (CNS)) in our modeled loblolly pine stands we used American Cyanamid’s Optimal Rotation Manager (Acorn). This simulator allows the user to obtain an estimate of the wood product distribution at harvest (percentages of pulpwood and CNS). Consistent with biology, as silvicultural effort increases the percent of CNS increases because trees will have greater diameters. We used this information to conduct economic analyses at age 15 for each of the four proposed alternatives. Three different sets of prices were used to see how price would affect NPV. The first set is current prices for pulpwood and CNS based on Timber Mart South (Figure 2). The second set represents historical average prices (Figure 3), and the final series uses very optimistic prices (Figure 4). Since rotation ages are the same in each case, we compared the models using NPV.

Results

For the highly responsive site, NPV continues to increase within our range of silvicultural efforts regardless of model form alternative and price (Figures 2, 3, and 4). However, Alternative 1 is close to reaching an optimal silvicultural effort for all three price ranges. The less responsive site shows much more variation than the highly responsive site. NPV is already decreasing for Alternatives 1 and 3 at a silvicultural effort of $250 per acre. In fact, at our highest silvicultural effort of $1250 per acre a manager would lose money on their investment using Alternative 1. However, similar to the highly responsive site, as silvicultural effort increases NPV becomes greater for Alternatives 2 and 4. The price ranges that we used had little affect on the optimal silvicultural effort. Increases in price only result in steeper NPV curves as silvicultural effort increases.

Discounted costs per unit of volume production are consistent with the theory of each alternative model for both sites (Figure 5). Alternatives 1 and 2 show the most variability.

Discussion

So what processes or factors determine whether potential increases in volume are worth the investment? These are costs of operations, current prices, and the wood product mix for a given rotation age. For example, if expected stumpage prices for pulpwood are $50 to $60 per cord, extremely intensive management becomes more attractive. However, at current prices of $15 to $30 per cord in the Southeast (Timber Mart South 2001), intensive management for pulpwood alone is not very attractive. Even more discouraging is that pulpwood prices have remained constant for several years (Timber Mart South 2001). Greater amounts of CNS production in
young stands will provide more economic return because of higher prices per cord relative to pulpwood.

The study reported by Borders and Bailey (2001) provides an excellent data set to show that maximizing yield does not necessarily lead to maximum profits. Achieving maximum economic returns is more complicated than simply increasing silvicultural effort. Foresters need to examine many possible management options, and based on current prices, the costs of site preparation and cultural treatments, growth and yield projections, and biological properties of the site, determine the best strategy to maximize profits. Figures 2, 3, and 4 show that for highly responsive sites greater investments will result in larger economic returns across the range of silvicultural efforts. The additional increases in volume production result in enough discounted returns to offset the larger discounted costs. However, it appears that Alternative 1 reached an optimal silvicultural effort about $1250 per acre. Any effort above this would result in a lower NPV. But if a manager believed that volume responded to increases in silvicultural effort consistent with one of the three other alternatives then they would want to continue to increase their silvicultural inputs. Under these assumptions, NPV will never be maximized.

The results are vastly different for the less responsive site. On these sites, if a manager believed that volume responded to increases in silvicultural effort consistent with Alternatives 1 or 3, then they would maximize profits by managing less intensively. Actually, based on our prices, a manager of the Tifton site would only be able to plant and perhaps conduct either a site preparation operation or a herbicide application operation following planting. Conducting both of these operations or any other additional operation such as fertilization would not maximize NPV. However, if a landowner or manager believed that volume responded to increases in silvicultural effort consistent with Alternatives 2 or 4, then similar to the highly responsive site, more intensive management would result in a greater NPV. As seen from Figures 2, 3, and 4, how a manager believes that volume responds to increases in silvicultural effort can have a huge impact on what management scenario will be selected. If a manager believed that volume responded to increases in silvicultural effort consistent with Alternatives 1 or 3 then the use of the same management scenario on each site would not result in economic optimization on both sites. In fact, if the management scenario that maximizes NPV on the highly responsive site was applied to the less responsive site, a loss on investment would result using current stumpage prices. Many growth and yield models allow users to manipulate density by simulating thinnings but very few allow for different intensive management operations and even fewer allow for multiple operations and multiple treatments of the same operation. Growth and yield models, or adjustments in growth rates, that predict response to intensive management must alter growth for the many complex biological interactions that occur on different sites. As seen in Table 1, sites can have drastically different responses to intensive management.

We examined growth and yield data from several studies (Borders and Bailey 2001, Haywood and Tiarks 1990, Miller et. al. 1991, NCSFNC 1996, NCSFNC 2000, Yin and Sedjo 2001) to determine which theoretical model best fits experimental results. The only model that is consistent with these studies is the one that follows the law of diminishing returns. Generally, additional investments in site preparation, cultural treatments, genetically improved stock, etc. will indeed increase volume production. However, as growth response increases, further
increases in growth response require larger amounts of silvicultural investment per unit of increase eventually resulting in zero return for the additional investment.

Sites that are more responsive to increases in silvicultural effort (Figure 5a) will have a comparatively smaller range of total discounted costs per unit of volume production than less responsive sites (Figure 5b). Total discounted costs per unit of volume production for Alternatives 1 and 3 on the less responsive site showed a steep increase as silvicultural effort increased. On the highly responsive site, total discounted costs per unit of volume production decreases for Alternative 1 but then begins to increase. Alternative 2 on the less responsive site showed a less steep decrease compared to the highly responsive site. Naturally, these relationships depend on the growth and yield predictions and costs of the various silvicultural treatments.

Conclusion

It is a great credit to advances in silviculture that we can now produce large amounts of volume on sites that would normally produce about one cord/acre/year (Wallinger 1993). Despite this ability, it must be understood that, at current prices, certain sites will not result in enough additional volume production to warrant large capital investments. Our paper does not present specific models to estimate growth response to intensive management or actual NPVs following intensive management, rather we are trying to make managers aware of the many complexities that can occur when intensively managing pines. Our paper takes a simplistic view of “real-world” forest management in the Southeast. We assumed that specific silvicultural treatments can be generically thought of as silvicultural effort, an input to the production process. So, for example, in our analysis $60 worth of fertilizer or $60 worth of herbicide produce the same volume growth response. In the real world, different site preparation and cultural treatments and different combinations of these operations can produce quite different growth responses. Regardless of the actual growth response our four assumed production functions should encompass the range of growth responses that are possible. Hopefully, this paper has offered managers a different view of how volume responds to continuous silvicultural effort and how vastly different projected NPVs can result from an individual’s view of how growth and yield responds to silvicultural treatments.

Literature cited


Table 1. Cubic foot-volume yields for a less responsive site (Tifton, GA) and a highly responsive site (Waycross, GA) to cultural treatments from Borders and Bailey (2001). Where C – a control treatment with no silvicultural activities following intensive mechanical site preparation, F – intensive mechanical site preparation plus annual fertilization, and HF – in addition to treatment F, herbicide treatments to control all herbaceous and woody vegetation the first three years.

<table>
<thead>
<tr>
<th>Site</th>
<th>Treatment</th>
<th>Volume (ft³/acre)</th>
<th>Age (years)</th>
<th>Dominant height (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tifton, GA</td>
<td>C</td>
<td>2722</td>
<td>11</td>
<td>47.5</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>2773</td>
<td>11</td>
<td>47.8</td>
</tr>
<tr>
<td></td>
<td>HF</td>
<td>3696</td>
<td>11</td>
<td>53.1</td>
</tr>
<tr>
<td>Waycross, GA</td>
<td>C</td>
<td>1562</td>
<td>12</td>
<td>47.5</td>
</tr>
<tr>
<td>&quot;wet site&quot;</td>
<td>F</td>
<td>5284</td>
<td>12</td>
<td>62.7</td>
</tr>
<tr>
<td></td>
<td>HF</td>
<td>5886</td>
<td>12</td>
<td>67.3</td>
</tr>
</tbody>
</table>

Table 2. Prices used for the economic analyses.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Cost ($/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of Intensive Site Preparation:</td>
<td>150</td>
</tr>
<tr>
<td>Planting costs:</td>
<td>70</td>
</tr>
<tr>
<td>Cost of fertilizer/acre:</td>
<td>60</td>
</tr>
<tr>
<td>Cost of herbicide/acre:</td>
<td>60</td>
</tr>
</tbody>
</table>
Figure 1. Four theoretical alternative models (1-4) of increases in cubic foot volume as management intensity increases for both a highly responsive site (a) and a less responsive site (b) to increases in intensive management. Silvicultural effort is measured by total discounted costs.
Estimated yields are based on several growth and yield studies (Borders and Bailey 2001, Haywood and Tiarks 1990, Miller et. al. 1991, NCSFNC 1996, NCSFNC 2000, Yin and Sedjo 2001). The bold solid line is total cubic foot volume production, the lighter solid line is pulpwood volume production, and the dashed line is chip-n-saw volume production.

Figure 2. Net present value for the four alternatives (for both a highly (a) and less (b) responsive site to increases in intensive management) over discounted costs at age 15. Where the price per cord for chip-n-saw is $75.00 and the price per cord for pulpwood is $15.00. Numbers on the lines denote the theoretical alternative model.

Figure 3. Net present value for the four alternatives (for both a highly (a) and less (b) responsive site to increases in intensive management) over discounted costs at age 15. Where the price per cord for chip-n-saw is $85.00 and the price per cord for pulpwood is $25.00. Numbers on the lines denote the theoretical alternative model.
Figure 4. Net present value for the four alternatives (for both a highly (a) and less (b) responsive site to increases in intensive management) over discounted costs at age 15. Where the price per cord for chip-n-saw is $85.00 and the price per cord for pulpwood is $42.50. Numbers on the lines denote the theoretical alternative model.

Figure 5. Discounted costs per unit of cubic foot volume produced for the four alternatives (for both a highly (a) and less (b) responsive site to increases in intensive management) over discounted costs at age 15. Where the price per cord for chip-n-saw is $75.00 and the price per cord for pulpwood is $15.00. Numbers on the lines denote the theoretical alternative model.