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# RESPONSE OF LOBLOLLY PINE TO COMPLETE WOODY AND HERBACEOUS CONTROL: PROJECTED YIELDS AND ECONOMIC OUTCOMES—THE COMPROJECT

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ABSTRACT.--Age-8 and -9 data from the 13 study plantations of the Competition Omission Monitoring Project (COMP) were used to project yields and derive economic outcomes for loblolly pine (Pinus taeda L.). COMP treatments were chop-bum, complete woody plant control, complete herbaceous plant control for 4 years, and complete woody and herbaceous (W+H) control. Yields projected with the NCSU Managed Pine Plantation Simulator were greatest for W+H control followed by woody control. Rankings for the other two treatments depended on site index. Profitability increased as site index increased and discount rate and hardwood densities decreased. Woody control was the most profitable on productive sites at discount rates below 5 percent.

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## INTRODUCTION

Vegetation control treatments with herbicides are widely used in Southeastern forests for establishing southern pine plantations, but the rotational growth gains and economic returns are still unknown. Herbicide treatments accelerate pine volume growth, producing greater volumes sooner, resulting in a stand age advance. Early volume advances equivalent to 1 to 6 years have been documented for loblolly pine (*Pinus taeda* L.) after control of woody and herbaceous vegetation on sites across the Southeast (Bacon and Zedaker 1987, Cam and Mann 1980, Colbert and others 1990, Lauer and others 1993, Michael 1985, Nelson and others 1981, Rheney and Pienaar 1992, Zutter and others 1986). Significant growth increases from herbaceous control (ii combination with woody control) have been reported from a network of sites through age 9 (Lauer and others 1993). Growth projections of these data indicate an average 3-year advance in volume for a 25-year rotation. Total volume growth gains from early woody and herbaceous control have been maintained for up to 11 years, with continued gains from herbaceous control in question (Haywood and Tiarks 1990). In the longest term study in the region, woody control responses up to age 27 have been sizable and highly dependent upon control effectiveness (Glover and Zutter 1993). Indications are that herbaceous control enhances early growth (ages l-4) and that woody control is more dynamic, depending on woody species and their relative densities and growth rates (Clason 1978, Miller and others 1991, Perry and others 1993).

The region-wide network of the COMP sites was established to study the long-term influence of woody and herbaceous competition on loblolly pine plantations (Miller and others 1987, 1991). Growth responses through age 8 for the 13 plantations are reported by Zutter and others in these Proceedings. The near-absolute conditions studied by COMP of complete control of woody and herbaceous vegetation, separately and in combination, permits examination of some of the most intensive cultural situations for growing loblolly pine. Since evidence is mounting that significant amounts of growth can be lost by even small amounts of either woody or herbaceous competition (Perry and others 1993, Glover and Zutter 1993), growth gains from complete vegetation control or complete component control should represent near upper limits of pine growth (without fertilizer additions or insect control). Economic returns from the large investments required to achieve these complete control conditions should define upper bounds of investment-return for vegetation management options, indicating the more profitable alternatives. Until long-term data is available, projections of yields and economic outcomes must be relied upon for current decisions and forest planning.

## METHODS

### Growth and yield projections

The four COMP treatments from an operational perspective were: chop-bum, woody plant control only leaving herbaceous competitors, herbaceous plant control only leaving hardwood

and shrub competitors, and woody plus herbaceous control (W+H control). Specific treatment methods are discussed by Zutter and others in these Proceedings (1995), while levels of control achieved were discussed by Miller and others (1991).

Pine and hardwood responses by location and treatment were projected with the North Carolina State University Managed Pine Plantation Growth and Yield Simulator, version 3.2 (Hafley and smith 1991). The inputs for the model were actual age-8 pine and hardwood basal areas, hardwood type (excurrent, decurrent, or mixed), stocking (pine trees per acre, TPA), percent fusiform rust infection and hazard zone (table 1). An advantage of this model is the internal function for hardwood competition, although none exists for herbaceous competition influences. Merchandising criteria for wood output were specified by the following diameters inside bark (d.i.b.) at the small end: pulpwood, 4 to 6 inches; chip-n-saw, 6 to 8 inches; and sawlogs, greater than 8 inches.

Height-age curves were another model input. Height-age curves (base 25 years) for the chop-burn treatment were estimated for each location by equations from Burkhart and others (1987) using age-9 heights of the tallest 300 TPA. An age translation of these height-age curves was used to estimate heights over time that might be realized by the vegetation control treatments (Lauer and others 1993). By substituting the age-9 tree heights for the other treatments into the equation for chop-bum and solving the equation for age, the age advance could be determined for each treatment. This age advance was added to the age variable in the height-age curve for input into the simulator (footnote, table 1). This conservative approach assumes that the shape of the height-age curve does not change with vegetation control treatments, but rather is simply shifted, usually to the left as an advance. Competition control actually tends to make the initial part of the height-age curve more linear, while effects on later stages still are unknown (Miller and others 1991).

Economic outcome uroiections

We calculated the economic outcome of the test treatments on land expectation value (LEV) and net present value (NPV). LEV (or bare land value) is the present value of all net cash flows (revenues minus costs) from the management of a tract of land calculated for an infinite time horizon. It is the maximum amount one could pay for a tract of land, manage it for timber by the prescriptions and costs specified, and obtain the rate of return used to discount the cash flows. LEV's are useful for comparing management strategies with unequal rotation periods. NPV is the present value of returns and costs over a single rotation. Taxes were not considered in these analyses.

Product prices were taken from Timber-Mart South. Monthly prices were averaged for 12 Southeastern States from November 1992 to October 1994. Product prices rounded to the nearest dollar were: (1) pine sawtimber, $186/thousand board feet (MBF) Scribner scale; (2) pine chip-n-saw, $47/cord; (3) pine pulpwood, $21/cord, and (4) hardwood pulpwood, $10/cord. For some States, regional average product prices are conservative. A "higher-price" projection used a 12-month average for the State with the highest prices.

Published southwide averages (Belli and others 1993) were used for costing chop-bum site

preparation, at $84/acre, and planting at a 9-by-9-ft spacing (538 TPA), at $57/acre. Since complete control is not achieved by normal operational herbicide applications (Shiver and others 1990, 1991, Michael 1985), regional averages for woody and herbaceous control could not be used. Besides, control comparable to COMP treatments would cost considerably more than published averages. Cost for complete woody-plant control was estimated at $158/acre to pay for a high-rate, aerial application of herbicide and prescribed burning for site preparation ($123/acre) plus a diited spray application in year 2 to eliminate remaining woody plants ($35/a). The cost for complete herbaceous-plant control was estimated at $200/a for a prescribed burn after harvest and three consecutive years of high-rate aerial spray applications ($60/acre/yr). Then the estimated cost of both woody and herbaceous control, at $338/a, combined the costs of both treatment regimes minus $20/acre for improved efficiency when both are applied. All prices and costs were assumed to increase at the inflation rate.

Both LEV and NPV were calculated for real discount rates from 3 to 7 percent. Economic outcome was calculated for both a 25-year rotation without thinning and an economic optimal rotation with two thinnings. The economic optimal rotation age was determined as the maximum LEV using 5-year intervals from 25 to 40 years. The two possible thinnings were made before age 25 when pine basal area exceeded 100 $ft^2$/acre, with thinning back to 70 $ft^2$/acre and a 30 percent reduction of any hardwood basal area.

The relationship between yield and site index by treatment was examined with linear regression.

## RESULTS AND DISCUSSION

### Growth and yield

The input variables for the NCSU Simulator are presented in table 1, grouped by hardwood amounts and listed by increasing site indices (hardwood groupings as discussed by Zutter and others in these Proceedings). These input variables can be used to determine yields for management scenarios not explored here. Averages for these variables are shown at the bottom of table 1 (referred to later as the "average COMP location"). Estimated site indices at age 25 ($SI_{25}$) averaged 65 ft for the 13 sites and ranged from 50 to 88 ft. Compared to the chop-burn treatment the mean advance in the height-age curves was 0.7 years for woody control, 1.6 years for herb control, and 2.9 years for W+H control (table 1).

The following are the mean merchantable pine volumes ($ft^3$/acre) and sawtimber volumes (MBF/acre, Scribner) for the 13 sites projected for each treatment using a 25-year rotation without thinning, showing percent increases over chop-bum:

| | Pine volume | | Sawtimber volume | |
|---|---|---|---|---|
| Chop-bum | 3,652 | - | 2.2 | - |
| Herb control | 3,758 | 3 % increase | 3.0 | 36 % increase |
| Woody control | 4,341 | 19 % increase | 3.6 | 63 % increase |
| W + H control | 4,809 | 32 % increase | 4.9 | 122 % increase |

The mean pine volume yields at 25 years are the simplest indicators of projected biological outcome as far as pines for these treatments. The much larger gains in sawtimber volumes

compared to total pine volumes result from additional stems crossing the minimum size cutoff for sawtimber (8 inches d.i.b., small end). Larger trees were produced sooner, but these trees have a larger core of juvenile wood that may affect value.

Figure 1 shows the linear regressions relating projected pine volume (PV) in cords/acre for a 25 year rotation to $SI_{25}$ for the four treatments. The regression equations, $R^2$'s, and root mean square errors (RMSE) are:

| Treatment | Equation | $R^2$ | RMSE |
|---|---|---|---|
| Chop-burn | PV = -40.5 + 1.4 SI | 0.76 | 8.86 |
| Woody control | PV = -44.9 + 1.4 SI | 0.98 | 2.72 |
| Herb control | PV = -63.8 + 1.8 SI | 0.76 | 11.36 |
| W + H control | PV = -38.4 + 1.6 SI | 0.98 | 2.69 |

For the range of site indices examined, W+H control had the greatest yields followed by woody control. By adding herbaceous control to woody control (W+H control) a constant 6.5 cord increase is suggested across all SI's because of the common slopes. The third most productive treatment was chop-burn below a site index of 61 and herbaceous control above site index of 61.

The yields by treatment and product category for stands managed with two thinnings and rotation ages of 25, 30, 35, and 40 years are summarized in table 2. First thinnings (before age 25) were performed sooner after W+H and woody control treatments compared to the other two. Thinnings increased sawtimber yields for all treatments at 25 years. Over rotation ages examined, sawtimber yields were in the order of W +H control > woody control > herb control > chop-burn.

Economic outcome

To illustrate the interaction between the present value of revenues (derived from selling the above predicted yields) and present value of costs, figures 2 a and b show these values projected for rotation. ages up to 45 years using the "average" COMP location (see bottom of table 1). This interaction of revenues and costs results in the NPV shown in figure 2 c, which is similar to the LEV-outcome in figure 2 d. With this example, woody control has the greatest value followed by chop-bum, Herb and W+H control have similar but lower value outcomes, with the optimal rotation age being 6 years earlier for W+H control.

It is evident that the peaks of all four curves are fairly flat with defmable minor optimal peaks. This would indicate that an optimal rotation age occurs within 1 to 2 years but the penalty for missing the optimal is not severe. Figure 2 e shows the LEV when higher prices are used (see methods), which indicates that LEV's (as well as NPV's) are extremely sensitive to prices. Price changes can cause a different ordering of treatment profitability, but optimal rotation ages did

not change. Softwood lumber prices are projected to increase over the next 50 years by about 1 percent per year (Haynes and Adams 1992), which could increase the relative profitabiity of the more intensive treatments.

Optimal rotation age ranged from 25 to 40 years for all sites and treatments, and the optimal age decreased with increasing discount rate (table 3). Linear regression analysis shows that optimal age was not correlated to site index or hardwood abundance. Medii optimal age for the two hardwood groupings only differed from the table 3 values for the 5 percent discount rate and herb control, which was 30 years with low hardwood and 25 years with high hardwood.

The LEV's for each location and treatment are presented in table 4, grouped by hardwood abundance and listed by increasing site index. As discount rate increased, the lower investment treatments were the more profitable on an increasing number of sites. Chop-burn was the most profitable option at 2, 3, 5, 9, and 11 locations as discount rate increased from 3 to 7 percent. Woody control was the most profitable on 7, 6, 7, 4, and 2 sites with increasing discount rates. The most intensive treatment of W+H control was the most profitable on 4, 4, and 1 locations for 3, 4, and 5 percent discount rates. Thus, woody control was the most profitable treatment on more sites when discount rates were below 5 percent.

## SUMMARY

Projections of early stand data indicate that yields can be consistently enhanced by intensive vegetation control treatments, used during establishment, for sites widely ranging in quality. Yields were increased most by controlling both woody and herbaceous competition. On average, control of woody competition increased yields more than control of only herbaceous competition. This may be partly because equations relating herbaceous competition to yields are not part of the NCSU projection model, while integral woody equations subtract increasing yields with increasing woody competition. Competition control increased both total pine volume and sawtimber volume, but increases were proportionally greater for sawtimber.

The profitability of investments in intensive vegetation control depends on discount rate, site index, and hardwood abundance, in addition to costs and prices. Chop-bum was the most profitable treatment when site indices were low and discount rates were high. It also appeared that chop-bum was the more profitable option on low hardwood sites compared to high hardwood sites. In general, investments in woody control were more profitable on more locations than herbaceous control or W+H control. Investments in woody control and W+H control became more attractive on high hardwood sites at discount rates below 5 percent and site indices above 60.

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Tabb 1 .--Input variables for the North Carolina State University Managed Pine Plantation Growth and Yield Simulator age-8 data except dominant pine heiaht which are age-9 data for the tallest 300 trees per acre (TPA)

| Location | $SI_{25}$ | control treatment | Pine TPA | Pine BA | Hwd' BA | Dom. pine height | Age[b] advance | Fusiform Infect. | Fusiform Haz.[c] |
|---|---|---|---|---|---|---|---|---|---|
| | (ft) | | (no./a) | ($ft^2$/a) | ($ft^2$/a) | (ft) | (yr) | (pct) | |
| Low hardwood sites | | | | | | | | | |
| Counce, TN | 68 | Chop-burn | 635 | 47.6 | 1.6 | 26 | 0.0 | 1 | 0 |
| | | Woody | 632 | 52.3 | 0.0 | 27 | 0.3 | 1 | 0 |
| | | Herb | 613 | 64.7 | 2.9 | 29 | 1.2 | 2 | 0 |
| | | W+H | 616 | 76.2 | 0.0 | 30 | 1.7 | 1 | 0 |
| Warren, AR | 62 | Chop-bum | 527 | 61.4 | 2.2 | 27 | 0.0 | 1 | 10 |
| | | woody | 627 | 66.9 | 0.8 | 30 | 0.8 | 2 | 10 |
| | | Herb | 627 | 93.7 | 3.8 | 34 | 2.6 | 4 | 10 |
| | | W+H | 619 | 101.5 | 0.0 | 35 | 2.7 | 2 | 10 |
| Pembroke, GA | 65 | Chop-bum | 627 | 38.4 | 1.1 | 26 | 0.0 | 6 | 40 |
| | | Woody | 519 | 60.1 | 0.1 | 34 | 2.0 | 9 | 40 |
| | | Herb | 616 | 66.0 | 2.1 | 36 | 2.6 | 13 | 40 |
| | | W+H | 623 | 77.0 | 0.0 | 36 | 3.6 | 22 | 40 |
| Jena, LA | 75 | Chop-bum | 475 | 66.1 | 2.1 | 31 | 0.0 | 0 | 20 |
| | | Woody | 460 | 61.0 | 0.9 | 31 | -0.2 | 1 | 20 |
| | | Herb | 505 | 66.9 | 6.4 | 37 | 1.4 | 1 | 20 |
| | | W+H | 613 | 160.3 | 0.0 | 36 | 1.9 | 0 | 2 0 |
| Monticello, GA | 79 | Chop-bum | 613 | 63.1 | 9.3 | 33 | 0.0 | 9 | 70 |
| | | Woody | 497 | 77.6 | 0.0 | 36 | 0.6 | 12 | 70 |
| | | Herb | 499 | 69.7 | 3.2 | 38 | 1.1 | 21 | 70 |
| | | W+H | 505 | 97.6 | 0.0 | 36 | 1.1 | 27 | 70 |
| High hardwood sites | | | | | | | | | |
| Appomattox, VA | 50 | Chop-burn | 469 | 21.1 | 16.0 | 23 | 0.0 | 0 | 0 |
| | | Woody | 425 | 46.0 | 0.2 | 26 | 2.1 | 0 | 0 |
| | | Herb | 401 | 24.1 | 21.6 | 24 | 0.5 | 1 | 0 |
| | | W+H | 453 | 74.0 | 0.2 | 31 | 3.6 | 0 | 0 |
| Arcadia, IA | 55 | Chop-bum | 517 | 44.1 | 5.0 | 25 | 0.0 | 1 | 10 |
| | | Woody | 517 | 60.1 | 0.1 | 26 | 0.4 | 2 | 10 |
| | | Herb | 497 | 63.3 | 13.2 | 30 | 2.1 | 5 | 10 |
| | | W+H | 525 | 101.0 | 0.0 | 34 | 3.8 | 7 | 10 |
| Tallassee, AL | 66 | Chop-bum | 602 | 33.4 | 19.1 | 25 | 0.0 | 11 | 40 |
| | | woody | 483 | 52.7 | 0.0 | 27 | 0.8 | 10 | 40 |
| | | Herb | 497 | 42.6 | 22.7 | 29 | 1.4 | 13 | 40 |
| | | W+H | 621 | 93.1 | 0.0 | 35 | 4.1 | 23 | 40 |
| Atmore, AL | 69 | Chop-bum | 521 | 34.1 | 6.1 | 26 | 0.0 | 5 | 40 |
| | | Woody | 494 | 52.1 | 0.0 | 30 | 1.2 | 6 | 40 |
| | | Herb | 455 | 44.1 | 15.1 | 30 | 1.4 | 7 | 40 |
| | | W+H | 508 | so.9 | 0.0 | 36 | 3.7 | 24 | 40 |
| Liverpool, LA | 63 | Chop-bum | 527 | 34.6 | 6.5 | 26 | 0.0 | 2 | 50 |
| | | Woody | 530 | 51.4 | 0.0 | 30 | 0.6 | 7 | 50 |
| | | Herb | 510 | 63.9 | 14.6 | 35 | 2.4 | 4 | 50 |
| | | W+H | 513 | 95.1 | 0.0 | 37 | 3.4 | 10 | 50 |
| Camp Hill, AL | 65 | Chop-bum | 502 | 38.1 | 7.0 | 28 | 0.0 | 6 | 50 |
| | | Woody | 491 | 50.3 | 0.0 | 29 | 0.2 | 7 | 50 |
| | | Herb | 499 | 39.4 | 14.4 | 30 | 0.6 | 6 | 50 |
| | | W+H | 497 | 99.6 | 0.0 | 36 | 3.1 | 14 | 50 |
| Liberty, MS | 77 | Chop-bum | 361 | 41.2 | 20.1 | 32 | 0.0 | 12 | 60 |
| | | Woody | 376 | 68.1 | 0.0 | 36 | 0.6 | 11 | 60 |
| | | Herb | 453 | 83.9 | 21.6 | 42 | 2.5 | 13 | 60 |
| | | W+H | 442 | 113.2 | 0.0 | 44 | 3.2 | 21 | 60 |
| Bainbridge, GA | 88 | Chop-bum | 516 | 56.1 | 12.0 | 36 | 0.0 | 18 | 60 |
| | | Woody | 532 | 69.5 | 0.1 | 36 | -0.2 | 25 | 60 |
| | | Herb | 513 | 66.6 | 15.9 | 39 | 0.6 | 34 | 60 |
| | | W+H | 521 | 99.6 | 0.0 | 43 | 1.6 | 48 | 60 |
| Overall average | 65 | Chop-bum | 501 | 43.2 | 6.4 | 28 | 0.0 | 6 | 35 |
| | | Woody | 490 | 58.6 | 0.2 | 31 | 0.7 | 7 | 35 |
| | | Herb | 491 | 63.9 | 12.0 | 33 | 1.6 | 10 | 35 |
| | | W+H | 504 | 93.8 | 0.0 | 37 | 2.9 | 15 | 35 |

[a]The hardwood type was specified as "mixed" for all locations.

[b]The height-age curve equation (Burkhart and others 1987) for input is:
HT=EXP(LN((SI$_{25}$ . (25/(A +AGEADV))^(-.02205))* EXP(-2.83285*(1/A + AGEADV)-.04))); AGEADV=Age advance.

[c]Hazard zone for fusiform.

Table P.-Means, standard errors (SE), and range in projected yields for the 13 COMP locations by product categories from two thinnings and harvests at four rotation lengths

| Thinning (yr) and harvest[a] | Sswtimber | | | | Chip-and-saw | | | | Pine Pulpwood | | | | Hardwood Pulpwood | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SE | Low | Hiih | Mean | SE | Low | High | Mean | SE | Low | High | Mean | SE | Low | Hiih |
| | (MBF) | | | | (cords) | | | | | | | | | | | |
| Chop-bum | | | | | | | | | | | | | | | | |
| TIfII-18) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.4 | 0.37 | 2.2 | 6.4 | 0.2 | 0.11 | 0 | 1.0 |
| T2(16-20) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6.4 | 0.58 | 4.6 | 11.2 | 0.1 | 0.09 | 0 | 1.0 |
| H25 | 3.7 | 1.03 | 0 | 11.7 | 4.2 | 1.12 | 0 | 11.1 | 12.2 | 0.74 | 6.4 | 15.5 | 1.0 | 0.30 | 0 | 3.0 |
| H30 | 6.8 | 1.61 | 0 | 17.7 | 2.3 | 0.85 | 0 | 9.7 | 13.9 | 0.78 | 10.0 | 17.3 | 1.2 | 0.43 | 0 | 5.0 |
| H35 | 9.9 | 1.93 | 0 | 23.5 | 1.5 | 0.80 | 0 | 8.0 | 13.9 | 1.15 | 7.2 | 18.7 | 1.4 | 0.40 | 0 | 4.0 |
| H40 | 13.0 | 2.35 | 0 | 29.7 | 1.2 | 0.73 | 0 | 8.1 | 13.2 | 1.39 | 5.4 | 21.0 | 1.5 | 0.45 | 0 | 5.0 |
| Woody control | | | | | | | | | | | | | | | | |
| T1(10-15) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.3 | 0.25 | 2.2 | 5.4 | 0 | 0 | 0 | 0 |
| T2(15-20) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6.7 | 0.69 | 3.6 | 12.6 | 0 | 0 | 0 | 0 |
| H25 | 5.2 | 1.21 | 0.4 | 13.8 | 3.7 | 1.09 | 0 | 10.4 | 11.5 | 0.91 | 5.6 | 16.1 | 0 | 0 | 0 | 0 |
| H30 | 8.9 | 1.63 | 1.9 | 20.3 | 1.5 | 0.62 | 0 | 7.5 | 12.7 | 1.10 | 6.5 | 17.5 | 0 | 0 | 0 | 0 |
| H35 | 12.5 | 2.05 | 3.4 | 27.3 | 0.5 | 0.34 | 0 | 4.5 | 12.4 | 1.35 | 4.5 | 17.0 | 0 | 0 | 0 | 0 |
| H40 | 16.0 | 2.43 | 5.0 | 33.5 | 0.1 | 0.09 | 0 | 1.1 | 11.5 | 1.47 | 3.0 | 16.6 | 0 | 0 | 0 | 0 |
| Herb control[b] | | | | | | | | | | | | | | | | |
| T1(9-18) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.4 | 0.20 | 2.4 | 4.8 | 0.1 | 0.08 | 0 | 1.0 |
| T2(14-20) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6.8 | 0.72 | 4.1 | 11.1 | 0 | 0 | 0 | 0 |
| H25 | 4.7 | 1.21 | 0 | 11.9 | 3.1 | 1.00 | 0 | 9.9 | 12.1 | 1.01 | 2.5 | 16.7 | 0.9 | 0.26 | 0 | 3.0 |
| H30 | 7.9 | 1.72 | 0 | 17.5 | 1.6 | 0.72 | 0 | 9.0 | 13.4 | 1.11 | 4.5 | 17.9 | 1.5 | 0.39 | 0 | 4.0 |
| H35 | 10.9 | 2.08 | 0 | 23.3 | 0.8 | 0.54 | 0 | 7.0 | 14.0 | 1.35 | 6.1 | 18.9 | 1.6 | 0.46 | 0 | 5.0 |
| H40 | 14.1 | 2.57 | 0 | 29.2 | 0.6 | 0.42 | 0 | 5.6 | 12.4 | 1.47 | 5.1 | 20.5 | 2.0 | 0.58 | 0 | 7.0 |
| Woody + herb control | | | | | | | | | | | | | | | | |
| T1(8-12) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2.9 | 0.26 | 1.8 | 4.8 | 0 | 0 | 0 | 0 |
| T2(13-17) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7.0 | 0.69 | 3.5 | 12.5 | 0 | 0 | 0 | 0 |
| H25 | 7.3 | 1.29 | 1.3 | 15.9 | 2.2 | 0.83 | 0 | 9.5 | 12.6 | 0.82 | 7.1 | 17.4 | 0 | 0 | 0 | 0 |
| H30 | 11.0 | 1.72 | 3.0 | 22.9 | 0.7 | 0.38 | 0 | 4.9 | 13.1 | 1.08 | 6.6 | 17.7 | 0 | 0 | 0 | 0 |
| H35 | 14.8 | 2.08 | 4.9 | 29.3 | 0.2 | 0.15 | 0 | 2.0 | 12.2 | 1.28 | 4.6 | 17.7 | 0 | 0 | 0 | 0 |
| H40 | 18.2 | 2.45 | 6.6 | 35.3 | 0.1 | 0.04 | 0 | 0.5 | 11.0 | 1.41 | 3.4 | 17.7 | 0 | 0 | 0 | 0 |

[a] T1 = first thinning: T2 = second thinning with the range of ages when thinningr occurred in parenthesis and H = rotational harvests at 25, 30, 35, and 40 years.

[b] Appomattox, VA, did not have a first or second thinning for this treatment and Tallassee, AL, did not have a second thinning for this treatment. Zeroes for these omitted treatments are not included in the mean.

Table 3.--Optimal rotation age by treatment and discount rate (percent), showing the median value (since rotation age was examined in 5-year intervals) and the range

| Control treatment | Discount rate 3 | 4 | 5 | 6 | 7 | Discount rate 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|---|---|
| | --- (year) --- | | | | | ---------- (year) ---------- | | | | |
| | median | | | | | range | | | | |
| Chop-burn | 35 | 35 | 35 | 30 | 25 | 30-40 | 25-40 | 25-35 | 25-35 | 25-30 |
| Woody (W) | 40 | 35 | 35 | 30 | 25 | 30-40 | 25-40 | 25-35 | 25-35 | 25-30 |
| Herb (H) | 35 | 30 | 30 | 25 | 25 | 30-40 | 25-40 | 25-35 | 25-30 | 25-30 |
| W + H | 35 | 30 | 25 | 25 | 25 | 30-40 | 25-35 | 25-30 | 25-30 | 25-30 |

Table 4.--Land expectation values by discount rate (real) for each COMP location and treatment, calculated using a optimal rotation age

| Location | Control treatment | Discount rate (pct) 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| | | (dollars) | | | | |
| Low hardwood sites | | | | | | |
| Counce, TN | Chop-bum | 666 | 329 | 153 | 80 | 3 |
| SI=58 | Woody (W) | 583 | 245 | 119 | 41 | -12 |
| | Herb (H) | 532 | 237 | 113 | 35 | -17 |
| | W + H | 496 | 199 | 83 | 11 | -38 |
| Warren, AR | Chop-bum | 903 | 497 | 270 | 136 | 54 |
| SI=62 | Woody | 965 | 487 | 240 | 116 | 45 |
| | Herb | 1004 | 520 | 261 | 118 | 44 |
| | W + H | 933 | 439 | 210 | 100 | 28 |
| Pembroke, GA | Chop-bum | 1002 | 639 | 297 | 149 | 81 |
| SI=65 | Woody | 1031 | 542 | 279 | 126 | 41 |
| | Herb | 970 | 497 | 233 | 100 | 31 |
| | W + H | 920 | 428 | 182 | 81 | 15 |
| Jena, LA | Chop-bum | 1767 | 1050 | 668 | 425 | 265 |
| SI=75 | Woody | 1657 | 985 | 586 | 366 | 237 |
| | Herb | 1771 | 1043 | 628 | 380 | 242 |
| | W + H | 1780 | 1011 | 584 | 373 | 234 |
| Monticello, GA | Chop-bum | 1943 | 1158 | 744 | 485 | 313 |
| SI=79 | Woody | 2130 | 1290 | 811 | 511 | 311 |
| | Herb | 2063 | 1235 | 760 | 483 | 300 |
| | W + H | 2087 | 1185 | 697 | 437 | 283 |
| High hardwood sites | | | | | | |
| Appomattox, VA | Chop-bum | 5 | -87 | -107 | -131 | -145 |
| SI=50 | Woody | 205 | 43 | 49 | -108 | -144 |
| | Herb | -433 | -237 | -209 | -195 | -186 |
| | W + H | 115 | -82 | -136 | -158 | -169 |
| Arcadia, LA | Chop-bum | 450 | 216 | 100 | 27 | -23 |
| SI=55 | Woody | 450 | 205 | 66 | 1 | -32 |
| | Herb | 304 | 154 | 57 | -5 | 47 |
| | W + H | 434 | 177 | 61 | -9 | -53 |
| Tallassee, AL | Chop-bum | 298 | 131 | 39 | -20 | -59 |
| SI -56 | Woody | 484 | 193 | 45 | -22 | -54 |
| | Herb | 137 | 58 | -12 | -56 | -86 |
| | W + H | 433 | 125 | 8 | -50 | -86 |
| Atmore, AL | Chop-bum | 502 | 235 | 96 | 21 | -27 |
| SI=59 | Woody | 656 | 299 | 109 | 14 | -34 |
| | Herb | 353 | 125 | 38 | -17 | -55 |
| | W + H | 621 | 225 | 64 | -6 | -54 |
| Liverpool, LA | Chop-bum | 807 | 415 | 207 | 87 | 13 |
| SI=63 | Woody | 906 | 453 | 218 | 81 | -5 |
| | Herb | 748 | 358 | 142 | 36 | -17 |
| | W + H | 989 | 476 | 189 | 44 | -17 |
| Camp Hill, AL | Chop-bum | 915 | 483 | 259 | 130 | 48 |
| SI=65 | Woody | 993 | 519 | 262 | 104 | 20 |
| | Herb | 650 | 277 | 130 | 51 | -3 |
| | W + H | 1108 | 563 | 266 | 83 | 13 |
| Liberty, MS | Chop-bum | 1408 | 615 | 484 | 295 | 169 |
| SI=77 | Woody | 2004 | 1170 | 730 | 454 | 271 |
| | Herb | 1678 | 984 | 588 | 340 | 175 |
| | W + H | 2057 | 1197 | 707 | 399 | 195 |
| Bainbridge, GA | Chop-bum | 2389 | 1456 | 945 | 625 | 429 |
| SI=88 | Woody | 2664 | 1579 | 1000 | 646 | 430 |
| | Herb | 2220 | 1296 | 859 | 587 | 403 |
| | W + H | 2659 | 1579 | 984 | 615 | 414 |

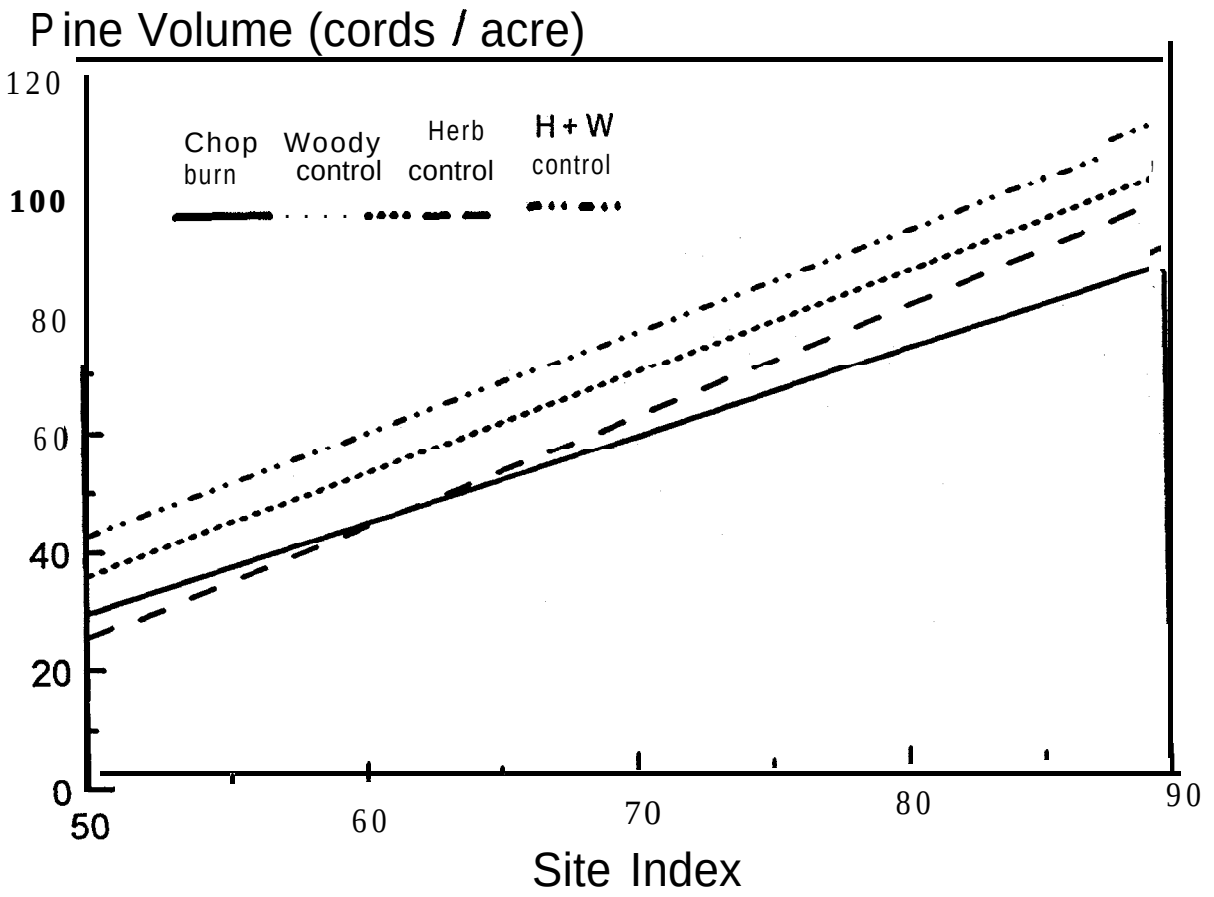


Figure 1. the relationship of site index (base 25 years) and projected pine volume yields at age 25 for the four COMP treatments across the 13 COMP sites.

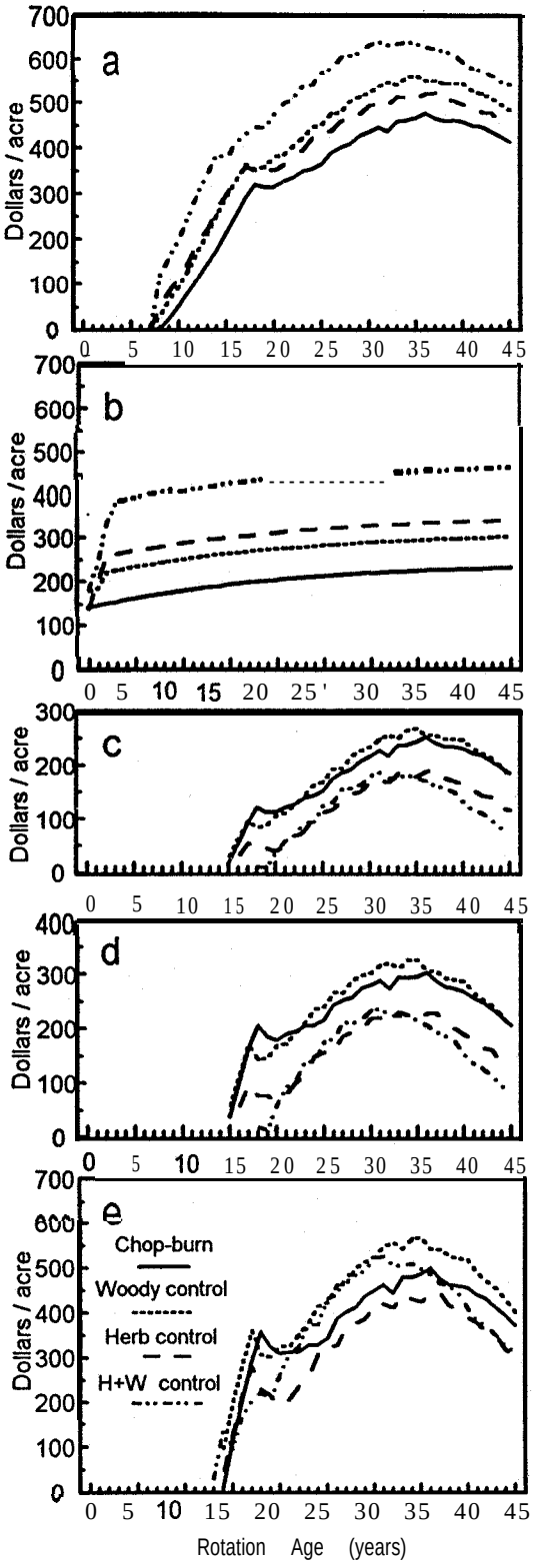


Figure 2-The economic variables and outcomes for modeling four treatments for the average COMP site ($SI_{25}$ =65) by rotation age (with two thinings) using a 5% real discount rate: a. present value of revenues, b. present value of costs, c. net present value, d. land expectation value, and e. land expectation value with higher prices.