Estimating Financial Returns from Mid-Rotation Release in Coastal Plain Loblolly Pine Plantations

Jon P. Caulfield, Barry D. Shiver, and Leon V. Pienaar, *University of Georgia, and* **Harold E. Quicke,** *American Cyanamid.*

ABSTRACT: *Financial rates of return are estimated for mid-rotation release from hardwood competition for Coastal Plain loblolly pine plantations. Economic benefits were measured against the costs required to obtain those benefits. A base case scenario was employed to approximate the average initial stand conditions of an existing release study. Product volumes were projected for released and nonreleased conditions for a maximum rotation length of 30 yr. Three release levels, 95%, 75%, and 50%, were simulated. Annualized rates of return were calculated from age 10 for each 5 yr period up to age 30. Sensitivity tests estimated how changing release age, maximum height response, and timber product prices influenced results. South. J. Appl. For. 23(2):94–99.*

Timberland owners recognize that intensive management of pine stands enhances biological productivity, which can increase financial returns. A management activity of growing importance is the use of silvicultural herbicides for controlling hardwood competition in mid-rotation plantations.

Researchers examining the impact of mid-rotation herbicide release (referred to as "release") report a positive and persistent impact on growth rates of treated plantations (Fortson et al. 1996, Shiver 1994). These studies also suggest release is economically justified because it results in larger trees and a more valuable timber crop at harvest. But several questions remain unanswered.

First, although existing work demonstrates that while release may increase timber volumes and future sale revenues, added benefits are not weighed against costs. Neither does it estimate how different release levels influence financial returns. For example, a release treatment which eliminates 50% of competing hardwoods should be expected to show a lower return than one that removes 95% of competition, given comparable treatment costs.

Existing studies show how release positively affects yields and value of a single product such as pulpwood. But increasing the biological growth rate means trees move more rapidly into more valuable product classes. Following release, larger volumes of chip-and-saw and large sawtimber are produced at younger ages. It is reasonable to anticipate higher financial returns as a result.

This study estimates financial rates of return for mid-rotation release from hardwood competition in Coastal Plain loblolly pine plantations by using a combination of results from existing studies combined with informed judgment to adjust an existing growth and yield model. The analysis includes both economic benefits from increased pine growth rates and treatment costs. The impact of varying levels of release is also estimated. The effect of release on the merchantable volumes of different product classes is included in the calculation of financial return.

The approach used here can be useful, and may be necessary in situations where forest managers are required to make decisions despite a lack of complete long-term response information from experimental plot data. In forestry, such situations are the norm rather than the exception. However, the estimates provided by the study should not be construed as substitutes for more completely developed growth and yield equations which include the impact of release treatments.

The next section describes how financial returns from mid-rotation release are calculated. This is followed by a discussion of how release influences plantation growth, and how growth was modeled for the analysis. The base case set of parameters is described, as are sensitivity tests that were performed. Finally, study results are presented and discussed.

Financial Returns from Mid-Rotation Release

When projections of merchantable product volumes for nonreleased and released stands are available, estimating financial returns from release is straightforward. Assume a landowner is considering treating a 10-yr-old stand of loblolly pine, at a cost of $\$C$/ac, and wishes to measure annual returns

NOTE: Jon Caulfield is the correponding author and he can be reached at (706) 542-6228; Fax: (706) 542-8356; E-mail: caulfiel@smokey.forestry.uga.edu.
Manuscript received January 8, 1998, accepted June 11, 1998.

from time of release to age 20. The released stand is projected to be worth $\$V_r$/ac at age 20, versus $\$V_{nr}$ without release. The annualized rate of return is:

$$Rate\ of\ Return\ (ROR) = \{ ((V_r - V_{nr}) / C)^{1/10} \} - 1$$

If a released stand is projected to be worth \$1000/ac at age 20 versus \$750 without treatment, and release costs \$80/ac, then:

$$ROR = \{ ((\$1000 - \$750) / \$80)^{1/10} \} - 1$$
$$= 0.1207 = 12.07\%$$

The calculation focuses on the return from the release operation itself and weighs the benefits of release—the incremental value gain from the treatment over a nontreated stand—against the cost required to achieve that gain. It ignores factors such as original land cost, and investments in site preparation and planting because these costs are already "sunk" and have no bearing on current decision-making. The appropriate way to think of mid-rotation release is as a potential investment in the stand. If the marginal wealth generated by this investment exceeds the marginal cost, then it is worthwhile.

The Influence of Mid-Rotation Release on Plantation Growth

Existing studies demonstrate that pine growth is modified by release in at least two ways. First, release increases height growth of the treated stand. Second, release increases basal area over time compared to a nonreleased stand. Average stand diameter therefore increases, as does merchantable product volumes. Greater volumes of higher per-unit value products also become available at an earlier age.

A recent study (Fortson et al. 1996) documents the impact of release on loblolly pine stands following silvicultural herbicide treatment at 33 locations in the Piedmont and upper Coastal Plain of Georgia and Alabama. Samples were taken from stands averaging 7 and 14 yr old at the time of treatment. Treated stands were remeasured at 2 yr intervals for an 8 yr period following treatment (ages averaging 15 and 22 yr at the last assessment), and compared to nonreleased check plots.

In treated plots, basal area increased almost 11%, or 14 ft^2/ac, over untreated plots. Height of treated plots increased 1.8 ft over untreated plots. Merchantable wood volume rose an average of 20% (377 ft^3/ac). Responses of this magnitude were achieved even though relatively small amounts of hardwood were present. The percentage of hardwood basal area to total basal area was less than 10% in 26 of 33 installations. Another result of this study was that the differences in basal area, height, and merchantable volumes between treated and untreated plots continued to diverge throughout the measurement periods. The study thus demonstrates that the positive influence of hardwood release on pine growth response is long-term in nature.

A slash pine release study (Oppenheimer et al. 1989) reports similar findings ten growing seasons following release. Merchantable volume increased over 15% on treated plots. Height increased an average of 1.4 ft. The study also demonstrated that differences in merchantable volumes diverged over time. A 14 yr remeasurement of that study (Shiver 1994) showed that volume differences continued to diverge, with treated plots having about 400 ft^3 more merchantable volume—a 30% increase—over untreated plots.

Although the above results are for stands receiving complete vegetation control, one study indicated that hardwood control levels of greater than 90% were achieved by operational aerial applications of 16 oz of Arsenal® herbicide applicators concentrate (Zutter et al. 1987). In the two locations included in that study, hardwood basal areas expressed as a percent of total stand basal area, were 22% and 29%. Stand age at the time of treatment was 14 yr. Two years following application, treated plots had 105 ft^3/ac more volume than untreated plots. These results indicated that growth responses of the magnitude observed in study by Fortson et al. (1996) are achievable from operational treatments and that greater responses are likely at higher initial hardwood competition.

Pienaar and Rheney's (1995) methodology, with some modifications described below, was employed to project growth and yield relationships. The equations and modifications used are described below.

Predicting Growth and Yield for Nonreleased and Released Loblolly Pine

Prediction equations for Coastal Plain loblolly pine stands developed by Harrison and Borders (1996), employing modifications suggested by Pienaar and Rheney (1995) and Shiver (1994), were used in the analysis.

Survival function

$$N2 = 100 + [(N1 - 100)^{-0.74534} + 0.0003425^2\ SI\ (A2^{1.97472} - A1^{1.97472})]^{-1/0.74534}$$

where

$N2, N1$ = Trees/ac at periods 2 and 1, where $N1 > 100$

$A2, A1$ = Age in periods 2 and 1

SI = Site index in feet (base age 25)

Height growth

Nonreleased stands:

$$H = SI\,[\,0.30323 / (1 - e^{-0.01445A})]^{-0.8216}$$

where

H = height at age i

A = stand age

Released stands:

$$H = SI\,[\,0.30323 / (1 - e^{-0.01445A})]^{-0.8216} + \beta_1 YSTe^{-\beta_{2(YST)}}$$

where

YST = years since treatment

β_1 and β_2 = parameters defining magnitude and pattern of the response

(Values used for β_1 and β_2 are described in the following section.)

Basal area

$$BA = e^{-0.90407-33.81182/A} H^{0.98534 + 2.5482/A} N^{0.3213 + 3.38107/A} e^{-0.003689(PHW)}$$

where

BA = basal area at age i

N = number of surviving trees/ac

PHW = percent hardwood expressed as a whole number

Total volume per acre (outside bark)

$$V = H^{0.26855 + 8.9345/A} N^{-7.46686/A} BA^{1.36884 + 3.5534/A}$$

where

$$V = \text{total volume (ft}^3\text{/ac)}$$

Merchantable volume

$$V_{d,t} = Ve^{-0.98265(t/Dbar)^{3.99114} - 0.74826N^{-0.1112}(d/Dbar)^{5.7848}}$$

where

$V_{d,t}$ = total merchantable volume (ft^3/ac) for all trees with minimum dbh ≥ d (in.) to top diameter t

$Dbar$ = quadratic mean stand diameter

Product breakdowns were for pulpwood $V_{5,4} - V_{9,6}$, chip and saw $V_{9,6} - V_{11,9}$, and large sawtimber $V_{11,9}$

Analysis

Base-Level Scenario

The analysis begins with a base-level scenario, which approximates the average initial stand conditions of the loblolly pine release study described by Fortson et al. (1996). A 10-yr-old stand with 600 trees/ac is assumed to be released on site index 60 (base age 25) land. Product volumes are projected for released and nonreleased conditions for a maximum rotation length of 30 yr. Annualized rates of return are calculated from age 10 for each 5 yr period up to age 30 (10–15, 10–20, 10–25, and 10–30 yr).

Release is assumed to be conducted with Arsenal® herbicide applicators concentrate, applied at a rate of 16 oz/ac. Application costs are fixed at $30/ac, and variable costs are set at $3.30/oz of herbicide, for a total cost of $82.80/ac.

Timber prices used to calculate product values for 10-, 15-, 20-, 25-, and 30-yr-old stands in the base-level scenario reflect 1996 average southwide pulpwood, chip-and-saw, and sawtimber prices, as published in *Timber Mart South* (1996). These were $24 and $60/cd for pulpwood and chip-and-saw, respectively, and $237/mbf Scribner for sawtimber. Using southwide prices reflects a conservative bias in the analysis, since the growth and yield relationships described above are for the Coastal Plain region. Coastal Plain timber prices tend on average to be higher than in the Piedmont.

The base-level scenario employs a height response that steadily increases to 3 ft over a 20 yr period. This is a reasonable assumption, and we consider it a conservative one. In the Fortson et al. (1996) study, average tree height increased by 1.8 ft eight growing seasons following treatment. The β_1 and β_2 parameters in the height growth equation for this level of response are 0.4077 and 0.05, respectively.

It was assumed that hardwood constituted 10% of total stand basal area at the time of release. Three different release levels were used in the base case: 95%, 75%, and 50%, to estimate how varying success rates might influence investment returns.

The initial results which used the height growth equation to drive basal area response substantially underestimated the magnitude of the response observed from field study data. Therefore, additional adjustments were required to adequately reflect treatment effects on stand basal area growth. The basal area equation was adjusted upward by 10%, 8%, and 6%, for the 95%, 75%, and 50% release levels, respectively. The 10% adjustment represents an observed response from experimental plots to total control above that predicted by the Pienaar and Rheney (1995) model. This response level, therefore, is consistent with real-world results. The 8% and 6% values have not, however, been observed from experimental plot data. However, they are considered to be reasonable reductions in basal area response resulting from lower levels of release and were included for purposes of comparison. Over time these estimates will be refined as more data become available, but it should be emphasized that these are based on informed judgment rather than hard data.

The calculation of financial returns does not include the effects of inflation. All *ROR*s therefore are "real," rather than "nominal" figures. To convert returns into nominal numbers, they are multiplied by the inflation rate. For example, if the real *ROR* is 10% annually and inflation is 3%, the nominal return is (1.10)(1.03) – 1 = 0.1330, or 13.3%.

Sensitivity Tests

Sensitivity tests estimated how changing certain biological and financial assumptions influenced the results. Tests were conducted on three parameters: release age, maximum height response and product prices.

Release Age

There is a question whether release treatments conducted early in a stand's life will result in higher financial returns than treatments performed later in the rotation.

From a biological standpoint, it is not clear whether the same incremental growth would be achieved from later release, assuming the same maximum rotation age. Pienaar and Rheney's (1995) study suggests that the same maximum height response may be achievable for a stand whether it is released at a younger versus an older age (age 7 versus age 14). But for the older stand, the response would require a similar time period following release to be realized.

To address this, an additional scenario is presented where release is conducted at age 15. Returns are calculated for 5 yr periods to age 35. As with release at age 10, this reflects a 20 yr response, at which time maximum height growth response of 3 ft is achieved.

Maximum Height Response

In addition to a 3 ft maximum response 20 yr following treatment, 4 and 5 ft maximum responses were modeled. As already mentioned, a 3 ft maximum response may be conservative when stands have higher levels of competing hardwood than average levels recorded in existing studies (Pienaar and Rheney 1995, Fortson et al. 1996). To account for these possible response levels the values of the β_1 and β_2 parameters in the height growth index equation were modified as follows:

	3 ft	4 ft	5 ft
β_1	0.4077	0.5437	0.6796
β_2	0.0500	0.0500	0.0500

Recall that the height response steadily increases to the maximum response 20 yr following treatment. Height responses for the interim periods used in the *ROR* calculation are less than the maximum and are shown in Table 1.

Product Prices

In addition to the average prices employed in the base level scenario, high and low price scenarios were examined. Low prices were the average pulpwood, chip-and-saw, and sawtimber prices for the three southern states reporting the lowest annual prices for each product to *Timber Mart South* (1996). High prices were calculated as the average for each product for the three southern states reporting the highest prices.

Results

Base Case Scenario

Figure 1 shows basal area projections by release level by 5 yr increment. As expected, basal area increases compared to a nonreleased stand. Differences between basal areas also diverge over time, which is consistent with existing research.

Table 1. Height responses of plantation loblolly pine predicted by the height equation adjustment term. (Source: Pienaar and Rheney 1995, Fortson et al. 1996.)

Maximum height response	Interim height response (yr since treatment)				
after 20 yr (ft)	0	5	10	15	20
3	0	1.6	2.5	2.9	3.0
4	0	2.1	3.3	3.8	4.0
5	0	2.6	4.1	4.8	5.0

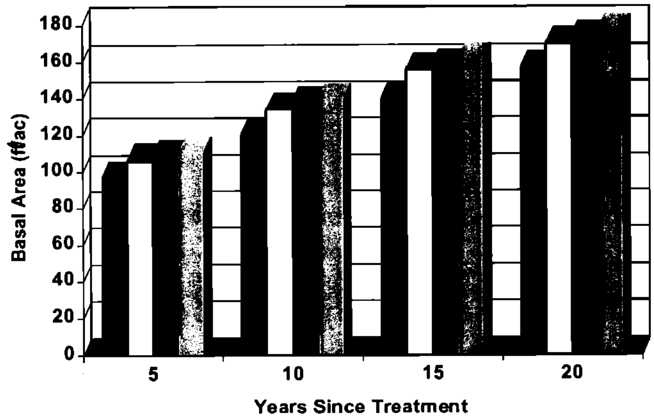

Figure 1. Coastal Plain loblolly pine plantation basal area by years since herbicide release treatment, base case. [600 trees/ac at age 10 release, SI 60 (base 25).]

Greater confidence should probably be attached to the nonreleased and 95% release projections. The former were calculated directly from the unmodified growth and yield equations presented above. The latter approximate the conditions in existing studies.

Figure 2 shows merchantable volumes by years since treatment and release level. By age 30, a stand with 95% release at age 10 is projected to grow 5181 ft^3/ac, versus 4095 ft^3/ac for a nonreleased stand, a 26.5% difference. This result is reasonably consistent with previous research for periods up to 8 yr (Shiver 1994, Fortson et al. 1996).

Figure 3 shows rates of return for the base case scenario by period and release level. Higher returns are associated with higher levels of hardwood control. For all release levels, however, annualized returns increase up to 15 yr after treatment (stand age 25). For 95% release, returns reach a maximum of about 11.2%, then drop off to 10.5%, 20 yr after treatment. While the magnitudes of declines differ, the same general relationships apply for 75% and 50% release.

The results suggest that for: (1) typical site quality, survival, and planting density conditions, (2) average regional price conditions and treatment costs, and (3) conservatively estimated response levels, an investment in mid-rotation

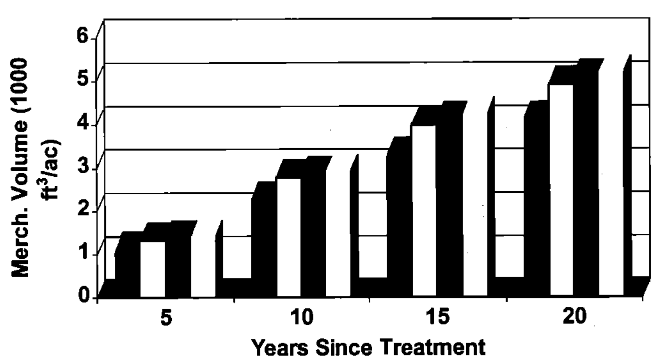

Figure 2. Merchantable timber volume by years since treatment, base case. [600 trees/ac at age 10 release, SI 60 (base 25).]

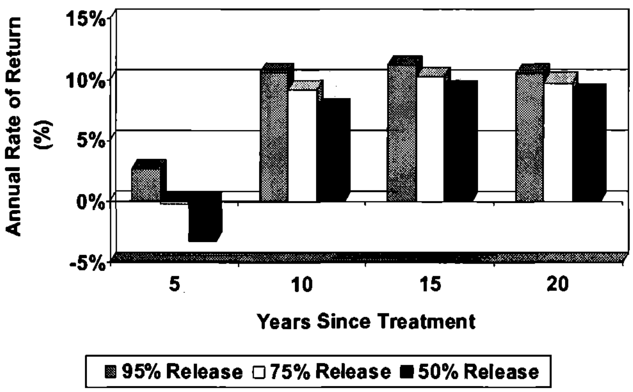

Figure 3. Annual rates of return by years since treatment, base case. [600 trees/ac at age 10 release, SI 60 (base 25).]

release potentially provides a substantial investment return at the margin.

To put these results in a more traditional context, 10 to 11% annual real returns compare very favorably to those received from stock investments during the period from the early 1980s to mid-1990s. Between 1986 and 1996 the S&P 500 had an annual real compound return of 11.08% (after accounting for a 3.8% annual inflation rate). The Russell 2000, a measure of small-capitalization stock performance, returned 8.2%.

Sensitivity Tests

The results reported below examine sensitivity tests relative to the base-case assumptions. The only parameter varied from the base-case in each situation is the one being considered by the sensitivity test itself. However, a full set of tables showing the entire set of possible combinations of results is available from the authors.

Release Age

Figure 4 shows rates of return for stands released at age 15. Five years after 95% release, *ROR* for age 15 release is greater than for age 10 release (6.5% versus 2.6%). An explanation is that trees released at age 15 grow into more valuable product classes sooner than trees released at age 10. This results in larger value differences 5 yr after treatment for trees released at age 15. Ten years after a 95% release treatment, *ROR*s for release at age 10 and 15 are comparable (10.6% and 10.7%, respectively). However, for release at age 15, returns

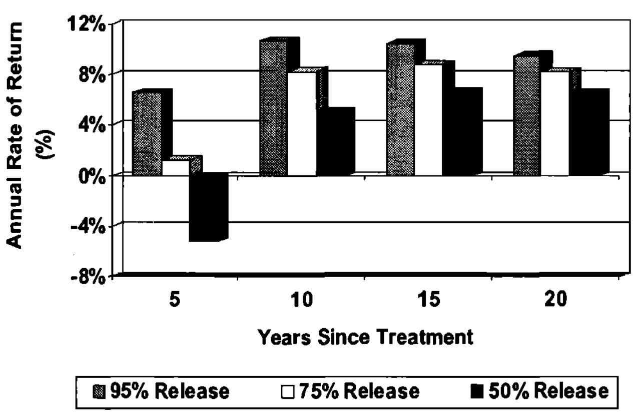

Figure 4. Annual rate of return by years since treatment for age 15 release. [600 trees/ac at age 10 release, SI 60 (base 25).]

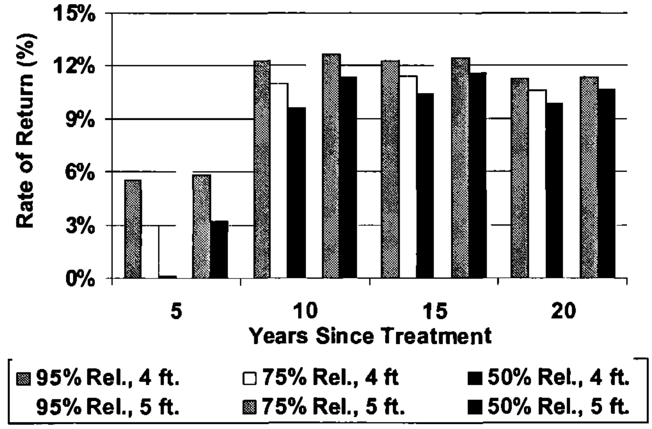

Figure 5. Returns from release with 4 ft and 5 ft. Maximum height responses, by years since treatment. [600 trees/ac at age 10 release, SI 60 (base 25).]

are at a maximum 10 yr after treatment, while returns from release at age 10 increase to a maximum of 11.2% 15 yr after treatment. For 75% and 50% release levels, returns for age 15 release are generally lower than for age 10 release.

Maximum Height Response

Figure 5 shows *ROR*s for situations where the maximum height response was increased to 4 and 5 ft, respectively. As expected, the impact on *ROR* is positive relative to the base case. At 10 yr following release, a 4 ft increase raises the *ROR* to 12.3%, versus 10.6% for a 3 ft response in the base case; a 5 ft increase raises it to 13.8%, which is 3.2% higher than the base case. It should be noted that no additional basal area adjustment was made for these height increases beyond that described earlier for the 3 ft response.

Product Prices

Figure 6 shows the impact of low and high timber product prices on returns, for 95% release levels. Interestingly, while the low price scenario reduced returns as would be expected, the *ROR*s between 15 and 20 yr following release remain above 8% This result suggests that mid-rotation release may be a viable alternative even in relatively low-price timber markets.

For the high price scenario, returns were far greater than for the base case. A *ROR* of 14% was estimated 10 yr after release. In high-price markets, release is apparently not only a viable option, but one that can attain return

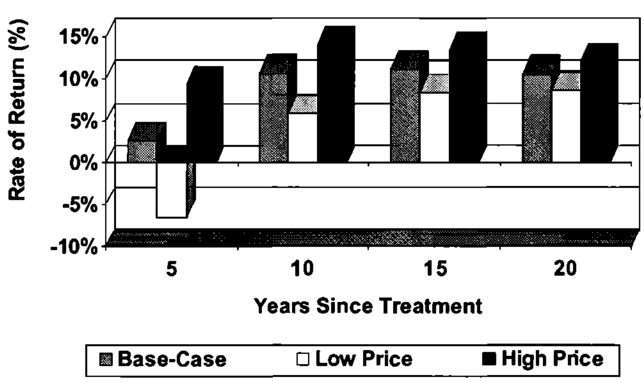

Figure 6. Returns for low and high timber price scenarios versus base case (95% release only). [600 trees/ac at age 10 release, SI 60 (base 25).]

levels in excess of those typically associated with well-diversified stock investments.

Summary and Conclusions

This study estimates financial rates of return through time for mid-rotation release of Coastal Plain loblolly pine plantations. The approach taken was to begin with a base case set of assumptions for a 10-yr-old pine stand representative of typical growing conditions and region-wide product pricing. Growth and yield were projected to age 30 and differences compared at different time intervals for released versus nonreleased conditions. Initial stand conditions at time of release were chosen to approximate those of existing release studies.

Economic benefits, measured by the value of increased merchantable product volumes were weighed against the costs required to obtain those benefits. The influence of varying levels of release success were also considered. Sensitivity tests examined how rates of return varied by release age, varying levels of height growth response and product pricing.

For the base case, real RORs from 95% release reached a maximum of 11.2% annually 15 yr after treatment (stand age 25). This compares very favorably to returns from stock investments over the past decade. For the base case under a high price scenario, real returns of 14% were achieved 10 yr after treatment. This indicates that in high price markets, release can attain return levels in excess of those typically associated with well-diversified stock investments. Even under a low price scenario, real returns of over 8% were achieved.

This analysis did not account for anticipated timber price increases over the inflation rate. The USDA Forest Service forecasts that prices for southern pine sawtimber will increase by 38% net of inflation between the years 2000 and 2040 (USDA Forest Service 1994) Any timber price increases net of inflation would increase returns presented in this analysis.

The results presented strongly suggest that mid-rotation release may be a financially attractive investment over a wide range of conditions. It should be emphasized, however, that some of the yield relationships employed to predict the impact of release on plantation growth are still in the developmental stage. As a result, several adjustments to the projection equations rely on anticipated growth responses employing estimates by the researchers. Every effort was made to provide estimates which are reasonable and consistent with currently available knowledge.

Literature Cited

Fortson, J.C., B.D. Shiver, and L. Shackelford. 1996. Removal of competing vegetation from established loblolly pine plantations increases growth on Piedmont and upper Coastal Plain sites. South. J. Appl. For. 20(4):188–193.

Harrison, W.M., and B.E. Borders. 1996. Yield prediction and growth projection for site-prepared loblolly pine plantations in the Carolinas, Georgia, Alabama and Florida. Plantation Manage. Res. Coop., Daniel B. Warnell Sch. of For. Resour., Univ. of Georgia, PMRC Tech. Rep. 1996 -1. 59 p.

Oppenheimer, M.J., B.D. Shiver, and J.W. Rheney. 1989. Ten-year growth response of midrotation slash pine plantations to control of competing vegetation. Can. J. For. Res., 19:329–334.

Pienaar, L.V., and J.W. Rheney. 1995. Modeling stand level growth and yield response to silvicultural treatments. For. Sci. 41(3):629–638.

Shiver, B.D. 1994. Response and economics of mid-rotation competition control in southern pine plantations. P. 85-92 *in* Proc. of the 1994 Southern Weed Sci. Soc., 47.

Timber Mart South. 1996. Yearly Summary, 4th Quarter 1996, 21(4). Daniel B. Warnell Sch. of For. Resour., Univ. of Georgia.

USDA Forest Service. 1994. RPA assessment of the forest and rangeland situation in the United States—1993 update. USDA For. Serv. For. Resour. Rep. No. 27. 75 p.

Zutter, B., J. Britt, P. Minogue, and H. Quicke. 1887. Response of hardwoods and loblolly pines two years after a midrotation aerial application of Arsenal applicators concentrate. American Cyanamid Forestry Tech Service Res. Rep. 97–02. 9 p.