PRELIMINARY EVALUATION OF PRICE PREMIUM REQUIRED FOR GROWING HIGHER QUALITY LOBLOLLY AND SLASH PINES ON EXTENDED ROTATION AGES

Arun Regmi, Donald L. Grebner, Robert K. Grala, and John L. Willis

Abstract—Pine (*Pinus* spp.) plantations in the Southeastern United States are managed intensively following even-aged silviculture. Trees are harvested at young ages resulting in inferior wood quality. We modeled two fast-growing southern pines using the Forest Vegetation Simulator to determine the price premium that forest landowners need to grow higher quality pines on longer rotation ages. Different management regimes were optimized using a land expectation value maximization approach. Results suggested that delaying final harvest by 10 years is financially obtainable, while a 20-year rotation extension depends on demand of higher quality sawtimber. In addition, rotation extension more than 30 years is financially undesirable. This study serves as a basic resource for primary forest product industries interested in purchasing higher quality pine sawtimber.

INTRODUCTION

The Southeastern United States has extensive pine plantations. These plantations are primarily managed with even-aged silviculture through extensive use of clearcutting (Allen and others 2005). Among southern pines, loblolly pine (*Pinus taeda* L.) is the most commercially dominant species, and this forest type has increased over time due to tree planting (South and Harper 2016). Over the past few decades, pine plantations have been harvested at shorter rotation ages—currently, most are generally less than 30 years—to ensure optimal economic returns (Jokela and others 2010, Miller and others 2009). The application of genetically improved seedlings along with advanced silvicultural treatments such as mechanical and chemical site preparation, herbicide treatment, fertilization, competition control, mid-rotation brush control, and thinnings are key reasons for the higher productivity of pine plantations (Allen and others 2005, Fox and others 2007). Higher productivity in short periods (Fox and others 2007, Zhao and others 2016) helps to successfully recover high establishment costs and other initial investments (Guldin 2019). In addition, short rotation harvests can generate large amounts of wood fiber, which is attractive to many forest landowners (Fox and others 2007).

But at what cost has this improved productivity come? Can this improved productivity fulfill the preferences of a diverse group of wood users (e.g., sawmill, veneers mills) who prefer larger, quality sawlogs? Although revenue from intensively managed forests has increased dramatically over time, it has adversely affected sawtimber quality (Zobel 1984), as shown by several past studies which reported the negative consequences of short rotation harvests on wood quality (Barbour and others 2003, Dobner and others 2018, Larson and others 2001, Zobel 1984). Shorter rotations have led to the production of relatively small sawlogs from smaller, younger trees (often 12-16 inches small-end diameter). Trees harvested earlier tend to have a higher proportion of juvenile wood compared to older, mature wood (Larson and others 2001). Larger, older trees can produce larger, higher quality sawlogs with a lower proportion of juvenile wood content (Bendtsen and Senft 2007, Biblis and Carino 2002, MacPeak and others 1990, Zobel and others 1972). Juvenile wood is considered relatively undesirable for manufacturing solid wood products because of lower stiffness and lower strength compared to mature trees (Bendtsen and Senft 2007, Clark and others 2007, Larson and others 2001).

Increasingly shorter harvest rotations have also resulted in shortages of large-diameter pine sawlogs in local solid wood markets. This may prove challenging, given that research shows that recent improvement in the housing sector has positively affected softwood lumber consumption (Howard and others 2017, Wear and others 2016). Since home construction requires higher grades of lumber, increasing construction may raise the demand for high value lumber in the future. In addition, continuous production of relatively small-sized sawlogs for wood fiber and woody biomass has increased overall

Author information: Arun Regmi, Graduate Research Assistant, Pennsylvania State University, State College, PA 16802; Donald L. Grebner, Professor, Mississippi State University, Starkville, MS 39759; Robert K. Grala, Professor, Mississippi State University, Starkville, MS 39759; and John L. Willis, Research Forester, Southern Research Station, U.S. Department of Agriculture, Forest Service, Auburn, AL 36849.

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wood supply, resulting in less demand and decreased prices for pine pulpwood. In this situation, many forest landowners may wait to cut their trees, expecting a higher price for their wood as sawtimber. Furthermore, there are still some landowners who are concerned over forest-derived ecological benefits and are interested in managing their forests for both ecological and economic benefits. Landowners often manage their forests to achieve multiple objectives including wildlife habitat, carbon sequestration, aesthetics, and recreational opportunities (Grebner and others 2015, Kluender and Walkingstick 2000). The increasing focus on timber production from short rotation pine plantations may adversely affect a variety of ecosystem services associated with older forests such as wildlife habitat, carbon sequestration, aesthetics, and water quality.

While managing forests for higher quality pine sawtimber can help achieve a landowner's multiple management objectives, there is a lack of information on the economic trade-off of postponing final harvest to grow higher quality pines. Although past studies have conducted financial analyses on longer rotation management, they were primarily focused on non-timber benefits. Few of these studies looked at economic trade-offs of managing pine plantations on longer rotation ages to produce higher quality wood. Several have focused on economic valuation of different management regimes of southern pines, using a land expectation value (LEV) maximization approach to identify the optimal regime. Research focusing solely on maximizing timber production suggests using shorter rotations for higher financial benefits (Jones and others 2010, Mills and Stiff 2013). Others have considered joint management of pine plantations for timber production and wildlife habitat and evaluated the economic trade-off of alternative management regimes (Barlow and others 2007, Davis and others 2017, Huang 2009). This research concluded that forest landowners need to be incentivized for the forgone timber revenue by adopting alternative management strategies, as wildlife-friendly management lengthened the rotation ages and reduced the LEV. Still others have evaluated economic trade-offs of managing pine forests for carbon sequestration (for example, Foley and Galik 2009, Sohngen and Brown 2008). Several have considered the impact of carbon payments in optimal harvest age or rotation ages (Alavalapati and Stainback 2005, Susaeta and others 2014, van Kooten and others 1995), while others have examined the financial profitability of pine plantations for carbon sequestration (Dwivedi and others 2009, Huang and Kronrad 2006). Their collective work suggests that a longer rotation is economically feasible for the joint management of timber and carbon sequestration, but forest landowners need carbon payments to lengthen the optimal final harvest age.

To address this knowledge gap, the objective of this study is to evaluate the price premium required to grow higher quality southern pines on longer rotation ages across the Lower Coastal Plain and flatwood regions of Southeastern United States.

MATERIALS AND METHODS

We used the Forest Vegetation Simulator (FVS) from the Forest Service, U.S. Department of Agriculture to simulate pine stands. Since the FVS model uses national forests as reference locations, we chose the Desoto National Forest in Mississippi as a study location. Desoto National Forest is in the "232" ecoregion (the Lower Coastal Plain and Coastal Flatwoods) (Bailey 1995). As this ecoregion spreads from South Carolina to eastern Texas, results from this study should be broadly applicable to other Southeastern States covered by the Lower Coastal Plain and Coastal Flatwoods ecoregion.

Management Scenarios

Two fast-growing southern pines, loblolly and slash (*Pinus elliottii* Engelm.), were simulated for different management regimes across a range of site indices and planting densities. Average site index (SI) for a study site was assumed to be 90 feet (base age 50 years). In addition, we used SI 80 and SI 100 to see the impact of site quality on analyses. Simulations were started from a "bareground" condition using initial planting densities (spacings) of 622 (7 feet by 10 feet), 544 (8 feet by 10 feet) and 435 (10 feet by 10 feet) trees per acre (TPA) (Londo and others 2008). We assumed bareroot seedling survival rate to be 90 percent, following chemical and mechanical site preparation and then a banded herbaceous weed control at 1 year post-planting.

All management regimes were thinned from below based on Reineke's Stand Density Index (SDI) target (Reineke 1933), which involved thinning stands to 35 percent of maximum SDI when they reached 55 percent of maximum SDI. This technique was applied to avoid possible density-dependent tree mortality after 55 percent of maximum SDI and maintain full site occupancy to promote the growth of quality trees and reduce unnecessary competition with unwanted species (Dean and Chang 2002). We assumed maximum SDIs of 450 for loblolly pine and 400 for other pines. Upper limits of SDI were set at 247 and 220 (55 percent of maximum SDI) where competition starts, and lower limits were set at 157 and 140 (30 percent of maximum SDI) to ensure full occupancy, for loblolly and slash pines, respectively. A maximum of two thinnings were used and the interval between two successive thinnings and final harvest was at least 5 years. Mid-rotation brush control was carried out 2 years post-thinning to limit competition of unwanted vegetation.

Financial Analysis

We used price data of pine products from TimberMart-South (2013-2018) (table 1). Table 2 presents costs (Maggard and Barlow 2017) for each management practice used in simulations. We used the LEV maximization method to determine financially optimal management regimes for each species. The structural form of the LEV equation (1) is:

$$LEV = \frac{NFV}{(1+r)^n - 1} \quad (1)$$

where NFV is net future value at rotation age, n is the length of rotation, r is the real discount rate in decimal percent. The LEV difference between the optimal LEV and LEV at extended rotation ages were then calculated from equation (2):

$$\text{LEV Diff} = \text{Optimal LEV} - LEV_n \quad (2)$$

where LEV_n is LEV at 10, 20 or 30 years beyond the optimal LEV. Periodic compensation (PC) was then converted into an annual compensatory rate for respective rotation extension periods (n = 10, 20, and 30 years):

$$\text{Annual compensatory rate} = \frac{PC \times i(1+r)^n}{(1+r)^n - 1} \quad (3)$$

Sawtimber stumpage price (4) required at extended rotation ages (SP_E) to justify the final harvest delay was calculated using an equation further derived from equation (1):

$$SP_E\ (\$) = \frac{LEV[(1+r)^n - 1] + FV_C - FV_{R(pulp+CNS)}}{V_{sawtimber}} \quad (4)$$

where LEV at an optimal rotation age, n is extended rotation ages, FV_C is future value of costs at year n, FV_R is future value of revenues from pulp and chip-n-saw at n, and $V_{sawtimber}$ is sawtimber volume (tons) at year n. Price premiums for growing higher quality pines on extended rotation ages were determined by simply subtracting current market stumpage prices (SP_C) from SP_E (5):

$$\text{Price premium } (\$) = SP_E - SP_C \quad (5)$$

The financially optimal management regimes with maximum LEV were identified for both pine species. LEVs at 10, 20 and 30 years beyond the financially optimal rotation age were then calculated for quantifying compensation rates and price premiums necessary to justify growing higher quality southern pines.

Sensitivity Analysis

A sensitivity analysis to assess the impact of different factors on LEV and price premium evaluation was calculated. We used three discount rates: 3 percent, 5 percent, and 7 percent; three different site indices; and three different planting densities for sensitivity analysis.

RESULTS AND DISCUSSION

To make this analysis simpler to understand, results for the average site at 3 percent discount rates are discussed in detail. Our results (table 3) from the financial analysis of loblolly and slash pine indicated that all combinations of site index and discount rates produced positive LEVs. On an average site of SI 90 with a 3 percent discount rate, the financially optimal rotation age was found at age 34 (LEV of $2133.54 per acre) for loblolly pine and at age 38 (LEV of $1534.52 per acre) for slash pine. Compensatory rates for delaying the final harvest by 10, 20, and 30 years for growing higher quality pines were $26.23 per acre, $39.68 per acre, and $48.16 per acre for loblolly pine, and $22.87 per acre, $30.19 per acre, and $36.69 per acre for slash pine, respectively. Similarly, required price premiums to justify the rotation extension were $2.89 per ton, $9.44 per ton, and $19.56 per ton for loblolly pine, and $3.39 per ton, $9.35 per ton, and $19.50 per ton for slash pine, respectively, for 10-, 20-, and 30-year rotation extensions.

Table 1—Specifications and average stumpage prices ($/ton) of pine products from 2013 through 2018 across the Southeastern United States

Product	d.b.h.	Price
	inches	*U.S.$/ton*
Pulpwood	6-7	9.93
Chip-n-saw	8-11	17.15
Sawtimber	12 & up	24.72

Source: TimberMart-South 2013-2018.

Table 2—Silvicultural practices, timing, and costs for all management scenarios of four pines

Practice	Cash flow (U.S.$/acre)	Year
Mechanical site preparation	140.99	0
Chemical site preparation	78.96	0
Site preparation burning	25.01	0
Per seedling cost	0.12	
Planting labor cost	60.41	0
Banded herbaceous weed control	57.11	1
Mid-rotation release	62.12	2 years post thin

Source: Maggard and Barlow 2017.

Table 3—Financially optimal LEV (U.S. $/acre), compensatory rates (U.S. $/acre/year) and price premiums (U.S. $/ton) for growing higher quality loblolly and slash pines on longer rotation ages on different site index and discount rates at planting density 544 trees per acre

Pine species	Site Index 100				Site Index 90				Site Index 80			
Discount rate	Optimal	10-year	20-year	30-year	Optimal	10-year	20-year	30-year	Optimal	10-year	20-year	30-year
Loblolly pine												
3%												
Harvest years	15, 22, 34	44	54	64	16, 24, 34	44	54	64	17, 25, 40	50	60	70
LEV	2585.91	2214.86	1806.95	1354.23	2133.54	1909.78	1543.22	1189.67	1604.34	1363.86	1099.64	797.96
LEV difference		371.05	778.96	1231.69		223.76	590.32	943.87		240.48	504.70	806.38
Compensatory rates		43.50	52.36	62.84		26.23	39.68	48.16		28.19	33.92	41.14
Price premium		4.24	10.95	23.27		2.89	9.44	19.56		4.05	10.42	22.38
5%												
Harvest years	15, 22, 32	42	52	62	16, 24, 33	43	53	63	17, 25, 35	45	55	65
LEV	912.37	693.84	459.25	265.52	672.85	531.10	327.53	175.89	434.48	336.92	184.92	57.27
LEV difference		218.54	453.12	646.85		141.74	345.32	496.95		97.57	249.56	377.21
Compensatory rates		28.30	36.36	42.08		18.36	27.71	32.33		12.64	20.03	24.54
Price premium		6.66	19.64	42.87		5.06	17.77	37.92		4.32	15.46	35.12
Slash pine												
3%												
Harvest years	15, 23, 35	45	55	65	17, 25, 38	48	58	68	19, 27, 41	51	61	71
LEV	2049.07	1728.99	1392.35	1056.15	1534.52	1339.40	1085.33	815.38	1109.32	978.11	773.88	566.10
LEV difference		320.09	656.72	992.92		195.12	449.18	719.14		131.21	335.44	543.23
Compensatory rates		37.52	44.14	50.66		22.87	30.19	36.69		15.38	22.55	27.72
Price premium		4.45	11.30	22.37		3.39	9.35	19.50		2.79	8.57	17.90
5%												
Harvest years	15, 23, 33	43	53	63	17, 25, 36	46	56	66	19, 27, 38	48	58	68
LEV	662.31	484.48	289.86	143.46	404.22	296.56	156.50	40.05	214.80	136.51	25.40	-61.38
LEV difference		177.83	372.45	518.85		107.66	247.72	364.17		78.29	189.40	276.18
Compensatory rates		23.03	29.89	33.75		13.94	19.88	23.69		10.14	15.20	17.97
Price premium		6.69	20.04	41.66		5.34	16.73	36.90		4.90	16.16	34.13

LEV = land expectation value.

As expected, LEV and compensatory rates increased as site index increased, which has been reported in previous studies (Barlow and others 2007, Carley and Grado 2000, Davis and others 2017). This trend holds true because higher productivity sites yield more wood than lower productivity sites. Therefore, the highest compensatory rates were found on high quality sites while lowest were found on lower quality sites. Consistent with previous studies, our results also indicated that the discount rate was another influential factor, as LEV and compensatory rates decreased as the discount rate increased (due to the time value of money). The effect of discount rates was higher on yield received in later years as it was discounted heavily compared to yield received earlier in rotation ages, and this effect increased with discount rates. Among three planting density levels, medium planting density (544 TPA) was financially optimal for all possible management regimes of both pine species.

Conversely, we found that price premium increased with an increase in discount rates. This could be due to the proportion of sawtimber volume, as we calculated the premium for sawtimber only. An increase in the discount rate led to a decrease in rotation age which resulted in production of lower sawtimber volume and higher chip-n-saw volume. Therefore, more premium was needed to justify the revenue loss. This implies that forest landowners could receive higher price premiums at higher discount rates with less revenue loss.

Our results indicated that, both loblolly and slash pines had nearly similar compensatory and price premium values for all site index and discount rates. For both species, price premium for a 10-year rotation extension ranged from $2.79 per ton to $6.69 per ton while it ranged from $8.57 per ton to $20.04 per ton for 20-year rotation extension. This shows that delaying the harvest age by 10 years is obtainable while more than 10 years may depend on buyers' interest. However, at lower interest rates, the price premium for delaying final harvest by 10 and 20 years was below $11 per ton, which may attract buyers. Given the discount rates and site index, a 30-year rotation extension might not be preferred by buyers because price premium rates are almost 100 percent and more than the existing market price for southern pine sawtimber.

CONCLUSIONS

Overall, the objective of this study was to evaluate the price premium that forest landowners required for growing higher quality loblolly and slash pines on longer rotation ages. The LEV maximization approach was used to conduct a comparative analysis of different management regimes. Our results suggested that growing higher quality pines by extending the harvest age is economically feasible; however, forest landowners would probably need to be incentivized to do so. Price premiums varied according to discount rates and rotation extension periods. Delaying the final harvest by 10 years required a considerably lower price premium, with significant increases realized by extending the rotation by another 10 or 20 years. Indeed, the price premium for 30-year rotation extension was 100 percent (or more) of the existing sawtimber stumpage price, suggesting a 30-year rotation extension may be financially undesirable for most. This study serves as a basic resource for primary forest product industries interested in acquiring higher quality pine sawtimber and forest landowners interested in the economic impacts of applying alternative management practices to their forests.

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