ECONOMIC RATIONALE FOR PLANTING LESS TREES IN THE FACE OF SEEDLING MORTALITY

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Abstract—Simple economic analyses are used to demonstrate that planting extra trees to compensate for initial seedling mortality can actually reduce the profit expected from a pine plantation. At a 6-percent interest rate, the cost of planting 15 or 25 percent additional seedlings compounded to the end of a 30-year rotation exceeds the revenue lost to these rates of seedling mortality when the initial target density is 700 and 800 seedlings per acre, respectively. At 8 and 10-percent interest rates, the compounded costs of the additional seedlings always exceed the revenue lost to seedling mortality. Comparing the marginal costs and benefits of increments of 50 seedlings indicate that optimal planting density decreases in the face of severe seedling mortality. Seedling mortality represents an inefficiency in a forest production system, and unless establishment efficiency can be improved, planting costs will have to be reduced to maximize profitability.

INTRODUCTION

Planting trees plays an important role in the structural development of a stand and its eventual profitability. Much energy has been expended in conducting spacing trials and economic analyses to determine optimal initial spacing (Bennett 1959, Bowling 1987, Caulfied and others 1992, Land and others 1991, Taylor and Fortson 1991). This initial planting density is typically supplemented to compensate for the number of seedlings that experience has shown to die during the first growing season. This practice can actually undermine the initial planning effort and potential profitability of the rotation.

Planting “extra” trees to compensate for initial seedling mortality undermines the initial planning effort by affecting the initial planting costs and potential revenues at the end of the rotation. Seedling costs should be based on costs per established seedling; planting additional seedlings, regardless of initial mortality, will increase cost. Revenue at the end of rotation is a function of rotation length, site quality, and overall stand density throughout the rotation; additional seedlings change stand density. Studies show that trees grow in relation to proximity and size of neighboring trees (Stiell 1978 and 1982). Consequently, when additional trees are planted, the majority of the plantation is overstocked relative to management objectives. The increased density reduces average diameter growth and the number of trees in the more valuable product classes.

The objective of this paper is to demonstrate that initial planting density should not be changed when only light to moderate seedling mortality is expected and that fewer, not greater, numbers of trees should be planted when severe seedling mortality is expected. These outcomes will be demonstrated for loblolly pine (*Pinus taeda* L.) in the western Gulf region and will be supported by two simple approaches: (1) comparisons of costs and revenues and (2) analysis of marginal costs and marginal benefits of tree planting

METHODS

Seedlings were assumed to cost \$0.05 and \$0.07 to plant (Dubois and others 1999), and seedling and planting costs were compounded at 6 percent per year to the end of a 30-year rotation. Revenue at the end of the rotation was calculated with the program COMPUTE_MERCHLOB (MERCHLOB for short) (Busby and others 1990). This program projects growth and yield for loblolly pine plantations in the western Gulf area and then calculates the product mix that produces the greatest revenue based on product specifications and prices. Products considered in this demonstration include pulpwood, chip and saw, and sawtimber with unit prices of \$26.00/cord, \$90.00/cord, and \$400.00/MBF, respectively (table 1). Growth projections do not include thinning and were conducted with a site index of 65 feet at a base age of 25 years.

Table 2 presents the results of a simple comparisons between the variable costs of planting compounded to the end of the rotation and revenue loss resulting from mild and moderate seedling mortality rates of 15 and 25 percent, respectively. The compounded costs of planting 15 or 25 percent more seedlings are compared with the projected revenue lost with 15 or 25 percent less seedlings than planted at the beginning of the rotation. Gaps are created in the plantation when seedlings die, resulting in trees growing closer together than the overall number of seedlings would indicate. In this comparison no allowance was made in the growth and revenue projections for the variation in spacing caused by seedling mortality. In other

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words, spacing between surviving seedlings was considered uniform for all projections. This probably underestimates the growth lost to seedling mortality because average stand diameter would be larger with uniform spacing and thus, more valuable than trees in a stand with the same number of trees but with closer, overall spacing.

Marginal analysis is used to demonstrate the effect of seedling mortality on optimal planting density. Marginal analysis is based on the law of diminishing marginal returns and compares the additional cost of each increment step of input with the resulting incremental change in benefit. The optimum input level occurs when the incremental or marginal cost equals the marginal benefit. Dean and Chang (in press) detail the procedure for using marginal analysis to determine optimum planting density. For this analysis, marginal cost is the cost of additional established seedling lots of 50 compounded at 6 percent for 30 years, and marginal benefit is the change in revenue associated with each increase of 50 additional established seedlings. Seedling mortality transfers their cost to the surviving seedlings; therefore, the cost of seedling mortality is represented in this analysis by increasing the per seedling costs by either 15 or 25 percent. Revenues are calculated with MERCHLOB for rotations of 30 years with no thinning on sites with a site index of 65 ft at a base age of 25 years.

RESULTS

At a 6 percent annual interest rate, the cost of planting additional seedlings compounded to the end of the rotation is less than the projected revenue loss due to seedling mortality for planting densities less than 800 seedlings per acre (table 2). When the target planting density is 800 seedlings per acre, the expected revenues lost with mild and moderate seedling mortality rates are $30.20 and $97.53 per acre, respectively. The costs of planting 15 and 25 percent more than the target number of 800 seedlings per acre compounded at 6 percent to the end of the rotation exceed the respective revenue losses from seedling mortality by $57.40 and $48.47 per acre. At 8 and 10 percent interest rates, the costs for compensating for initial seedling mortality always exceed the expected revenue losses for the target planting densities investigated in this demonstration (table 2).

Marginal analysis of the costs and benefit of each 50 seedling increase in surviving density indicates that with

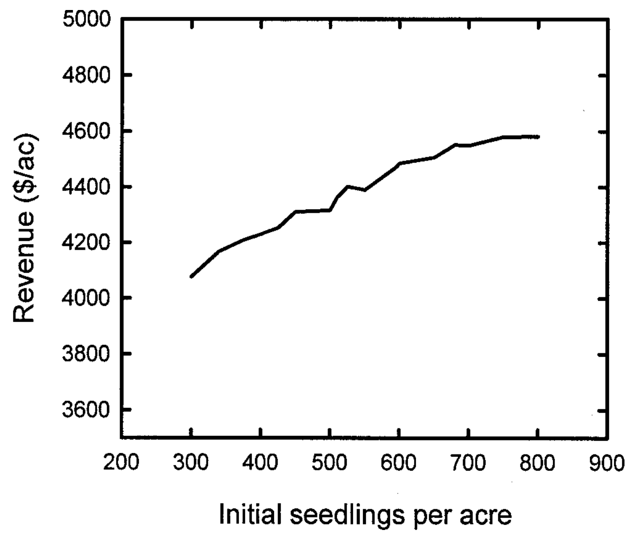

Figure 1—Revenue at the end of a 30-year rotation as projected by the growth-and-revenue simulator COMPUTE_MERCHLOB as a function of initial seedlings per acre for loblolly pine plantations with no thinning.

100 percent seedling survival and a 6 percent interest rate, the optimal number of established seedlings is 700 per acre because the additional revenue gained from having 750 surviving seedlings per acre over having 700 surviving seedlings per acre is $15.37/acre less than the cost of the additional seedlings (table 3). Marginal seedling costs increase $5.40/acre with mild initial seedling mortality, but the increase is not enough to affect the optimum planting density. The increased seedling cost of $9.07 associated with moderate seedling mortality is enough to affect optimum planting density. When 25 percent of the seedlings are expected to die, the marginal cost of each 50-seedling increase in surviving density is $45.37/acre which is greater than marginal benefit of each successive 50-seedling increase in surviving density greater than 600 seedlings per acre.

DISCUSSION AND CONCLUSION

According to MERCHLOB, projected revenue at the end of a 30-year rotation steadily (though not monotonically) increases as initial planting density increases from 300 to 800 seedlings per acre (figure 1). At the lower part of this range, planting additional seedlings to compensate for initial mortality actually increases revenue at a faster rate

Table 1—Product specifications and prices used in COMPUTE_MERCHLOB to calculate revenues (Dubois and others 1999)

Product Category	Price per unit	Minimum diameter	Maximum diameter
	$	inches	
Pulp wood	26.00/cord	3.5	12.0
Chip-and-saw	90.00/cord	6.0	12.0
Saw timber	400.00/MBF[a]	9.5	18.0

[a]MBF = 1,000 board feet Doyle scale

Table 2—Projected revenue lost in a loblolly plantation across a range of initial seedlings per acre (SPA) due to two rates of seedling mortality compared with the cost of planting additional seedlings to compensate for the mortality rate compounded for a 30-year rotation with various annual interest rates. Values are dollars per acre, and revenue projected with the growth-and-revenue generator COMPUTE_MERCHLOB.

	Seedling mortality rate							
	15 pct				25 pct			
	Revenue loss	Cost of additional seedlings			Revenue loss	Cost of additional seedlings		
SPA		6 pct	8 pct	10 pct		6 pct	8 pct	10 pct
	$/ac							
400	61.93	43.80	102.00	144.60	153.88	73.00	170.00	241.00
500	62.42	54.75	127.50	180.75	107.88	91.25	212.50	301.25
600	121.84	65.70	153.00	216.90	173.62	109.50	255.00	361.50
700	77.33	76.55	178.50	253.05	146.77	127.75	297.50	421.75
800	30.20	87.60	204.00	289.20	97.53	146.00	340.00	482.00

than costs escalate with a 6 percent interest rate. At the upper end of this range (and at the uppermost of the range for the moderate mortality rate), however, the associated costs of additional seedlings equal or exceed the additional revenue gained with the extra seedlings; the best outcome with a 6 percent interest rate is a wash. With 8 and 10 percent interest rates, the additional seedlings always cost more than the recovered revenue.

The simple comparisons of the cost of planting additional seedlings and the revenue that the additional is intended to recover at the end of the rotation is actually a form of marginal analysis. The main difference is that the simple comparisons are evaluating revenue recovered with the cost of compensating for seedling mortality, whereas, with comparison marginal analysis, the cost of an additional surviving seedling is compared with the additional revenue it produces. Since the costs of seedlings that die are assigned to the surviving seedlings, seedling mortality acts to increase marginal planting costs, which for moderate and worse mortality rates, results in lower planting densities. Increasing interest rates also result in lower planting densities that optimize profit.

Table 3—Marginal analysis of costs and benefits for planting additional seedling lots of 50 loblolly pine seedlings per acres (SPA). All values are dollars per acre. Revenue projected with COMPUTE_MERCHLOB with no thinning. Marginal costs calculated with an interest rate of 6 percent. Optimal planting density for each mortality rate designated with a (*).

SPA	Revenue	Marginal benefit	Marginal costs		
			0 pct mortality	15 pct mortality	25 pct mortality
	$/ac				
550	4390.06				
		95.19	36.30	41.70	45.37
600	4485.25				(*)
		20.93	36.30	41.70	45.37
650	4506.18				
		42.94	36.30	41.70	45.37
700	4549.02		(*)	(*)	
		31.60	36.30	41.70	45.37
750	4580.62				
		2.16	36.30	41.70	45.37
800	4582.78				

Seedling mortality can be treated as a measure of inefficiency, and inefficiencies always increase costs relative to revenues, especially in an enterprise that requires decades to produce its product. This analysis demonstrates that in many cases, attempting to overcome establishment inefficiency with increased numbers of seedlings will reduce profitability. Until the establishment efficiency can be improved, input or planting costs need to be reduced to maximize profitability. Focusing on establishment efficiency, i.e., seedling survival, will probably be more beneficial to the enterprise than overplanting to compensate for seedling mortality. Many factors are known to increase initial seedling survival. These factors include prudent site preparation, correctly matching species with site, and following the recommended procedures for storing, transporting, handling, and planting seedlings. According to these analyses, the most profitable operation will be obtained by following the establishment prescription and maximizing establishment efficiency by properly executing each element of the plan.

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