BEFORE AND AFTER COMPARISONS OF TREE HEIGHT IN SUCCESSIVE LOBLOLLY PINE PLANTATIONS WITH INTERVENING MACHINE, WHOLE-TREE HARVESTING

Thomas J. Dean, D. Andrew Scott, and A. Gordon Holley[1]

Abstract—In 1993, several forest industries, the U.S. Forest Service Southern Research Station, Louisiana Tech University, and the School of Renewable Natural Resources in the Louisiana State University Agricultural Center formed a cooperative that came to be called Cooperative Research in Sustainable Silviculture and Soil Productivity. One of the objectives of the cooperative is to determine whether typical, high-production harvesting is detrimental to the growth of newly established plantations. Prior to harvesting, dominant and codominant trees were severed and discs cut from the stems at 0.5-m intervals up to 10 m in height. Annual heights of the trees were determined through stem analysis. Height comparisons were made between trees from the previous plantation with those of the current plantations up to age 12. For the four sites considered, no changes in productivity were evident as a result of harvesting as measured by the height of the tallest trees in the successive generations.

INTRODUCTION

At the beginning of the 1990s, the U.S. Forest Service began establishing a Long-Term Soil Productivity Study (LTSP) on national forests nationwide to identify the growth response of major forest types to extremes in soil compaction and organic matter removal. The study is motivated by a requirement in the National Forest Management Act that management practices must preserve site productivity. Powers (1999) identified these two factors as the principal causes of any potential loss of site productivity due to harvesting. Heavy harvesting equipment can compress the soil, and efficient harvesting usually requires complete removal of the tree.

The LTSP study is providing much interesting information (Powers and others 2005), but it does not directly address the question of whether high-production harvesting reduces site productivity. Between 1995 and 2003 a series of studies were installed as part of the Cooperative Research in Sustainable Silviculture and Site Productivity (CRiSSSP) to address this question in loblolly pine plantations (table 1). The CRiSSSP protocol incorporates two harvesting intensities. The first is high-production harvesting where the tree is cut with a feller buncher and the whole tree yarded with a grapple skidder. The second is minimum disturbance harvesting where only the commercial portion of the bole is removed leaving the associated vegetation and forest floor intact and the underlying soil nearly undisturbed.

The objective of this analysis is to compare, to the extent possible, the before and after effects of these harvesting treatments on site height. Site height is the mean height of some subset of the tallest trees on the site and is most reflective of site and environmental conditions. A conifer’s leader meristem is largely insensitive to crowding (Lanner 1985). It sits in a preferred position with the hydraulic architecture of tree (Zimmerman 1983). Furthermore, site height is the only metric that can be analyzed across rotations since it can be reconstructed from stem analysis.

METHODS

Experimental Design

CRiSSSP installed experiments in six locations across the South to address the question of whether high-production harvesting affects the growth of loblolly pine (*Pinus taeda* L.). Data from four of these installations are used in this particular analysis (table 1). Each location was originally occupied by a stand of loblolly pine that was either artificially or naturally regenerated. The field design is described in detail by Carter and others (2006). To summarize, the two harvesting intensities are crossed with one or two other establishment treatments such as bedding or broadcast burning to create either $2 \times 2 \times 2$ or 2×3 factorial treatments. The eight or six treatments were randomly assigned to eight or six, approximately 0.12-ha plots within three or four blocks. A broadcast application of a mix of herbicides was applied at each location for competition control, especially for competing trees and shrubs. At the two youngest installations, planting was followed by herbicide release from herbaceous competition, based on the widespread positive response of tree growth to this treatment. Each level of establishment treatment included the absence of the treatment so that within each block, two plots represent only the effect of harvesting and competition control. Just these two treatments at four locations are included in this study (table 1).

Plots were planted with 1-year-old, half-sib, loblolly pine seedlings the winter after harvesting and site preparation. Each plot contained 14 rows of 14 seedlings. Rows were generally spaced 3 m apart, and seedlings within rows generally 2 m apart. The outer 2 rows and outer 2 seedlings on each row served as a buffer, leaving 100 potential measurement trees.

Measurements

Height accumulation of the previous stand at annual intervals was reconstructed with stem analysis of a subsample of dominant and codominant trees—the number of trees analyzed

[1]Professor, Louisiana State University Agricultural Center, Baton Rouge, LA; Research Soil Scientist, U.S. Department of Agriculture Forest Service, Southern Research Station, Pineville, LA; and Associate Professor, Louisiana Tech University, Ruston, LA, respectively.

Table 1—Some physical characteristics of the sites used in this study

Location designation	Physical location	Soil subgroup	Mean annual precipitation	Site index	Harvests[a]
			inches	*feet*[b]	*number*
Fred	Fred, TX	Oxyaquic Paleudult	53.54	59	2
Bryceland	Bryceland, LA	Typic Hapludult	53.94	59	2
Black Lake	Campti, LA	Glossaquic Paleudalf	53.94	56	1
Lee Forest	Pine, LA	Typic Fragiudult	64.17	66	2

[a] Including the harvest treatment.

[b] At 25 years.

depended on the size of the trees. Disks were cut at regular intervals along the stem (cf. Carter and others 2006). Height was interpolated within disc interval with the method recommended and described by Dyer and Bailey (1987). Site height for the previous stand is block averages of the height at a given age.

Height of the surviving trees within the measurement plots was measured on a nearly annual basis using a hypsometer. Site height in response to the harvesting treatments is the average height of the tallest half of the trees within a plot. Age of the trees in the experimental plantations is age from germination.

Statistical Analysis

The effects of regeneration practices on height growth of the subsequent plantation were tested within individual installations by age using a randomized, complete-block analysis of site height for the previous stand and the two harvesting treatments combined with the "zero" level of the additional factorial treatment(s). The null hypothesis tested with this analysis is no effect of harvesting intensity on site height. A probability of a greater F statistic <10 percent for three treatments was considered evidence of a harvesting effect on potential productivity. The probability of erroneously rejecting the null hypothesis was set to 10 percent because of the potential consequences of not detecting a change in site productivity. Since the trees sampled from the previous stand were selected to represent the best trees in the stand, the comparison may be biased toward rejecting the hypothesis that harvesting has no effects on height growth.

RESULTS

During the interval height was measured on the current plantations, average height steadily increased with age for trees in the previous stand and trees planted on the low- and high-intensity harvesting treatments. During the early stages of current plantation, average height lagged behind the height of the sampled trees from the previous plantation. However, at each location, the average height of the current plantation eventually matched or exceeded the height of the trees sampled before harvesting (fig. 1). The differences were statistically significant during the first 3 years after planting at the Fred site and the first year after planting at Lee Forest (table 2). There were no detectable differences in average height before and after harvest nor as a result of harvesting intensity at the Black Lake site and for the Fred site with the exception of one age. At both the Fred and the Lee Forest sites, the average height of the trees planted on the mechanically harvested plots was higher than the average height of the trees in the previous stand and trees planted on the plots harvested with chainsaws and lifts. At Lee Forest the difference in mean height was significant at age 5 years.

Harvesting effects on average height at the Bryceland site were more consistent within treatment and somewhat different than those observed at the other three sites. For the first 4 years after planting, average height of the trees planted after low- and high-production harvesting was less than the height of correspondingly aged trees in the previous stand (table 3). Furthermore, the tallest half of the trees planted on the intensively harvested plots was significantly shorter than the tallest half of the trees planted on the plots harvested with hand tools and lifts. By age 9, the average height of the trees planted on the hand-felled plots was significantly taller than the average height of the trees in the previous stand and the trees planted on the intensively harvested plots. Trees on the hand-felled plots remained taller than trees from the other two treatments for the remainder of the study, though the differences were not statistically different after age 10 years.

DISCUSSION

Evaluating harvesting effects on site height is equivalent to evaluating harvesting effects on site index if the growth curves remain unchanged between generations. For the sites included in this study, no lasting harvesting effect on site quality is evident. Where height of the previous stand was significantly taller than the site height of the current stands, the differences occurred early in plantation and were short lived at Fred and Lee Forest (table 2). At Bryceland where the differences lasted longer, by age 6 years, the site height of the trees planted on the hand-felled plots were as tall as the site height of the previous stand (fig. 1).

One of the problems of using a site height as a measure of generational changes in productivity is the possible

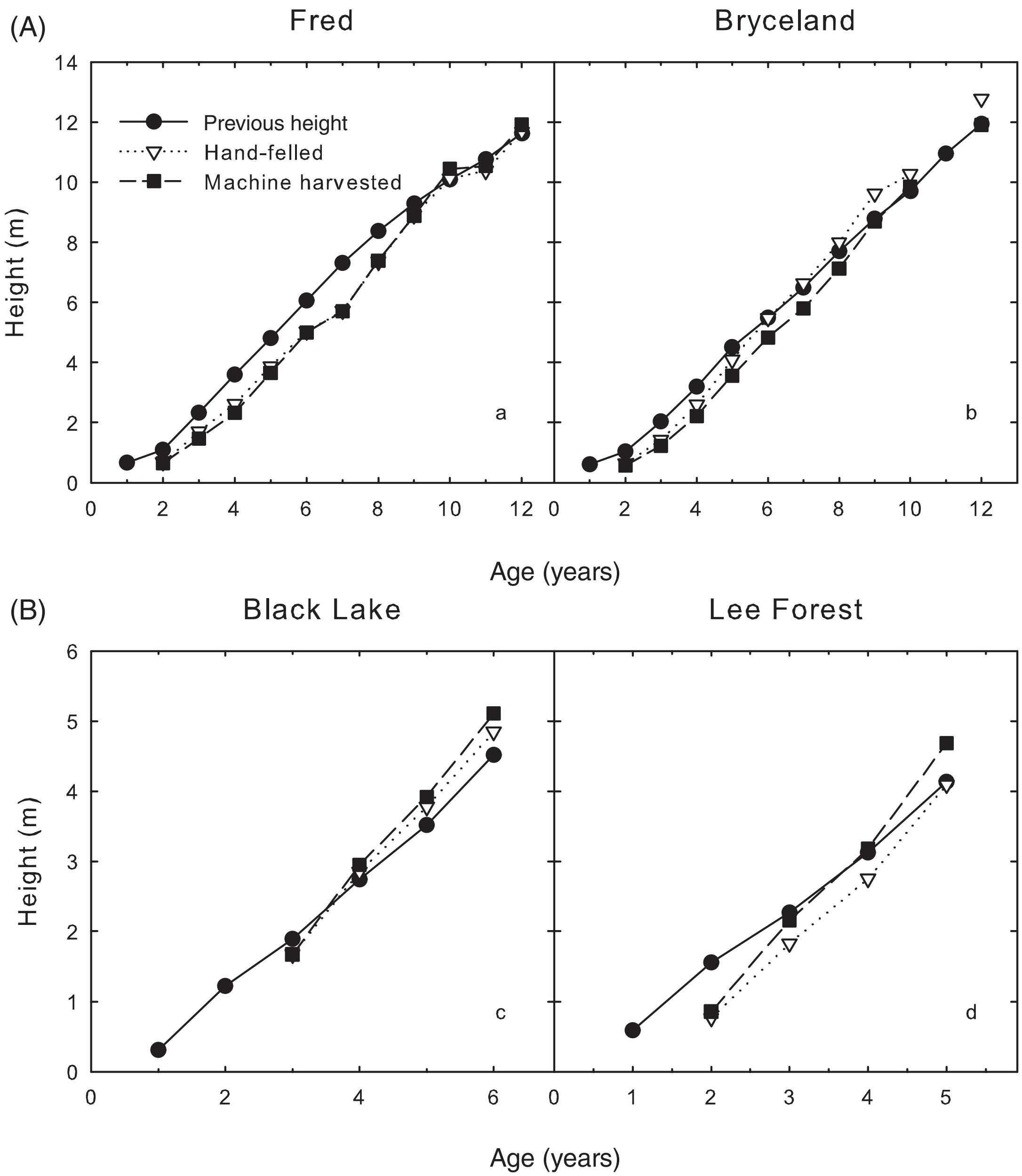

Figure 1—Site height as a function of tree age for loblolly pine at the four sites used in this study.

confounding influence of weather. In a study with slash pine (*P. elliottii* Engelm.) where the second rotation on a site duplicated the site preparation, seed source, planting style, and spacing of the first, Rose and Shiver (2002) observed significant reduction in the average height of the dominants and codominants between the first and second rotations. Since the study was replicated across a range of soil types, they attributed the difference to drought events and high temperatures that occurred during the first two growing seasons of the second rotation. Insufficient data were collected on the four sites used in this study to compare temperature and rainfall patterns between the generations; however, a regionwide, severe drought occurred during the year 2000 and the first half of 2001. At the Fred site, the drought caused only a temporary reduction in height increment at age 7 years; height growth appeared to accelerate after cessation of the drought (fig. 1A). The drought occurred during the 6th growing season at the Bryceland site: no lasting effects were evident (fig. 1B). Black Lake and Lee Forest were established after the drought. Height growth at these sites appears to be resilient against temporary reductions in rainfall.

CONCLUSIONS

While high-production harvesting causes a significant perturbation with regards to the amount of organic matter

Table 2—Probabilities for a greater value of F for the null hypothesis: no harvesting effect on site height

	Site			
Age	Fred	Bryceland	Black Lake	Lee Forest
1				
2	0.005	<0.001		0.024
3	0.051	<0.001	0.854	0.163
4	0.046	0.001	0.753	0.046
5	0.128	0.009	0.822	0.066
6	0.195	0.004	0.415	
7	0.076	0.057		
8	0.375	0.085		
9	0.787	0.076		
10	0.823	0.341		
11	0.868			
12	0.847	0.169		

Table 3—Comparisons of site height by age at the Bryceland site using the Fisher's protected least significant difference procedure with alpha = 0.10

	Treatment		
Age	Previous	H0	H1
2	A	B	B
3	A	B	C
4	A	B	C
5	A	B	C
6	A	A	B
7	A	A	B
8	A	AB	B
9	B	A	B
10	A	A	A
12	A	A	A

H0 = hand-felled, bole-only harvest; H1 = high-production, whole-tree harvest.

Different letters within a row indicate significant differences. Significantly lower means indicated with higher letters in the alphabet.

displaced and compaction of the soil surface, for three-quarters of the sites used in this study, this was only the second tree harvest from these sites. Soil processes appear to recover quite quickly (Carter and others 2002). Furthermore, tree growth appears to be quite resilient to changes in soil properties (Powers 1999). The results of this analysis add further evidence that commercial harvesting of forests is largely benign to the long-term productivity of loblolly pine plantations.

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