BIOMASS OF FIRST AND SECOND ROTATION LOBLOLLY PINE PLANTATIONS IN THE SOUTH CAROLINA COASTAL PLAIN

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Abstract—In the South Carolina Coastal Plain, intensive loblolly pine (*Pinus taeda* L.) plantation management, without fertilization, was sustainable through two rotations as measured by biomass accumulation. Fixed plot tree inventories and destructive tree sampling of first and second rotation sections of the same plantations were used to produce area based estimates of aboveground, oven-dry tree biomass. First rotation plots in two plantations produced 289 and 242 tonnes/ha at 34 and 36 years after establishment respectively. Second rotation plots of these same stands produced 127 to 152 tonnes/ha at 15 years after establishment. Second rotation crown biomass was 67 to 87 percent of the crown biomass of the first rotation plots at 42 to 44 percent of the age of the first rotation trees. Total aboveground biomass of second rotation plots was 44 to 61 percent of the total aboveground biomass of the first at 42 to 44 percent of the age. Biomass accumulation is at least proportional to age from the first to second rotation; thus these management procedures appear to be sustainable.

INTRODUCTION

Sustainable resource management has come to the forefront in the last decade and underlies management decisions of all natural resources. For example, the Ecological Society of America issued an analysis of research needs for resource sustainability for the last decade of the 20th century (Lubchenco and others 1991). Recently, the U.S. Forest Service issued an analysis of the condition of forests in the United States relative to sustainable forest management (Guldin and Kaiser 2004). The July/August and December 2003 issues of the Journal of Forestry were dedicated to sustainable development and certification.

In 1985, Clemson University expanded a site preparation study being established by then-Westvaco Corporation to focus on quantitatively determining the sustainability of intensive loblolly pine (*Pinus taeda* L.) plantation management. For the purposes of the project, sustainability was defined as non-declining biomass accumulation from the first rotation plantation to the second and as preservation of the pools of N and P at the end of the second rotation. Although this definition ignores many aspects of sustainability, such as biodiversity, forest health, water, and socio-economic benefits (Guldin and Kaiser 2004), it does allow reasonably straightforward quantification.

The research reported in this paper is a part of this larger effort and is limited to the accumulation of aboveground tree biomass. The objective of this research was to compare tree biomass in first and second rotation plantations and to compare biomass accumulation by tree component and site preparation method.

SITES

Two loblolly pine plantations were established in South Carolina's Coastal Plain following clearcut harvesting of hardwood flatwood forests. Both stands were site prepared by shearing residual trees and stumps, raking the debris into windrows, and planting improved coastal loblolly pine on beds. At planting, 56 kg elemental P/ha was applied. The Greeleyville plantation was established on a somewhat poorly drained Lynchburg fine sandy loam soil in 1967 and the Snow Mill plantation on a poorly drained Bladen loam soil in 1969. Twenty four 61 m x 61 m treatment plots were established in the first rotation Snow Mill stand in 1985, and most of the stand was clearcut in June 1986, 17 years after establishment. Likewise 16, 61 m x 61 m treatment plots were established in the first rotation Greeleyville stand in 1987, and most of the stand was clearcut harvested later that year, 20 years after establishment. Three treatment plots in each plantation were designated as control plots and were not harvested.

In both stands, the treatment plots were reestablished after harvest and a debris burn. Four site preparation methods were replicated in each of three blocks of plots. Blocks of plots were grouped by average codominant first rotation tree height, and unused plots were not measured. Site preparation methods tested were: (1) three pass shear, rake, and bed; (2) rebed only; (3) herbicide residual trees and plant on old beds; and (4) disk only. Both stands were site prepared and the second rotation planted in 1987. Each treatment plot was split, and the planted seedlings in one half were released from competition by periodic spot herbicide application for the first growing season only.

PROCEDURES

In each second rotation plantation, the following site preparation and release treatment plots were selected for study: (1) three pass site preparation, unreleased half; (2) rebed only site preparation, unreleased half; (3) herbicide site preparation, released and unreleased halves; and (4) the first rotation control plots. In each of these treatment combinations for each of the tree blocks in each stand, we established a 20 m x 20 m measurement plot within the planted area and another measurement plot 20 m long and with a variable width that contained the windrow created during the first rotation plantation establishment.

All standing stems 2.5 cm d.b.h. and larger were tallied by recording species d.b.h. and status (as alive or dead). Every fourth live tree tallied was tagged with a sequentially numbered punch tag. Total height to terminal bud was measured

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on all tagged trees in the Snow Mill stand. Because the Greeleyville stand had a higher density of volunteer pines and understory hardwoods, total heights were measured on up to 10 tagged, planted pines, up to 10 tagged, volunteer pines, and up to 15 tagged hardwoods per measurement plot. Total height was measured with a telescoping fiberglass measuring rod with the beginning of a 30 m fiberglass tape attached to the tip. The rod was raised against the tree bole until a distant observer indicated that the tip of the rod was adjacent to and level with the terminal bud. The fiberglass tape was then read at groundline.

Twenty-six pine and 12 hardwood trees located in each second rotation plantation were destructively sampled to determine biomass. Likewise, 10 pines and 12 hardwood trees were destructively sampled in each first rotation plantation. For each combination of first and second rotation plantations and pine and hardwood species groups, three to five diameter classes were established such that each class contributed equally to estimated stand biomass. Then equal numbers of trees were destructively sampled in each diameter class with standard methods.

Biomass equations were developed, separately by stand, for seven tree components [bole, foliage, twigs, unfoliated branches, deadwood, crown (as the sum of foliage, twigs, unfoliated branches, and deadwood), and total aboveground biomass (as the sum of crown and bole)] for pines and hardwoods (separately) in the second rotation section and pines and hardwoods (separately) in the first rotation section. All equations used log dbh^2 to predict the log of the biomass component of interest. Biomass equations were used to predict area based aboveground biomass estimates from the live stem inventories. To facilitate data analysis and presentation, inventoried stems were assigned to a product class based on d.b.h. and species. Pine stems < 9.5 cm d.b.h. were considered precommercial as were hardwood stems < 18 cm d.b.h. Pine stems > 9.4 cm d.b.h. and < 17.8 cm d.b.h. were classified as pulpwood as were hardwood stems at least 18 cm d.b.h. Pine chip and saw stems were > 17.7 cm d.b.h. and < 30.5 cm d.b.h. Pine stems > 30.5 cm d.b.h. were considered sawtimber. Bonferroni pairwise mean comparison tests with P=0.05 were used to determine significant differences.

RESULTS AND DISCUSSION

The first rotation portion of the Snow Mill stand had accumulated almost 290 tonnes/ha 34 years after establishment, and the second rotation portion had accumulated 128 to 152 tonnes/ha 15 years after establishment (table 1). For the Greeleyville stand, the first rotation section accumulated 242 tonnes/ha, and the second rotation section accumulated 118 to 148 tonnes/ha. The total biomass of the second rotation was 44 to 53 percent of the total biomass of the first rotation for Snow Mill and 49 to 61 percent for Greeleyville. However, second rotation tree crown biomass was 68 to 86 percent of the crown biomass for first rotation trees for Snow Mill and 67 to 82 percent for Greeleyville. This higher percent of crown biomass compared to total biomass indicates that crown biomass accumulation of the second rotation trees is more rapid than bole biomass accumulation. As indicated in table 1, in both stands the crown biomass for the second rotation treatments are not significantly different for the crown biomass for the first rotation trees. In contrast, total biomass and bole biomass are significantly different between the two rotations.

For both the Snow Mill and Greeleyville stands, the total aboveground tree biomass of the second rotation as a percent of the total aboveground tree tree biomass of the first rotation is > the same percents of their ages. The second rotation trees of the Snow Mill stand are 44 percent of the age of the first rotation trees, but total aboveground biomass is 44 to 53 percent of the first rotation trees. Likewise, the age of the second rotation trees in the Greeleyville stand is 42 percent of the age of the first rotation trees, but the total aboveground biomass is 49 to 61 percent of the first rotation trees. The second rotation trees are accumulating biomass faster than a linear prediction from age alone.

The distribution of biomass among product classes showed differences among site preparation methods (tables 2 and 3). At Snow Mill, the herbicide and herbicide/release plots had windrows that were not site prepared and thus contained much hardwood biomass. In contrast, the rebed only and shear, rake, and bed plots had site prepared windrows and thus had much less hardwood biomass. In the Greeleyville plantation, there was not as strong a difference in hardwood biomass. Most of the pine biomass in both stands was in the chip and saw product class followed by the pine pulpwood class. Chip

Table 1—Bole, crown, and total aboveground, oven dry tree biomass estimates for the first and second rotation portions of the Snow Mill and Greeleyville plantations. Second rotation estimates are presented by site preparation treatments used to establish the second rotation trees. Values within a column followed by the same letter are not significantly different (P = 0.05)

Site preparation	Snow Mill Plantation			Greeleyville Plantation		
treatment	Bole	Crown	Total	Bole	Crown	Total
	- - - - - - - - - *tonnes/ha* - - - - - - - - -					
Herbicide	113.4b	23.6a	137.1b	98.8b	19.0a	117.8b
Herbicide & release	105.7b	22.2a	127.9b	118.4b	23.2ab	141.6b
Rebed only	125.8b	26.2a	152.0b	124.4b	23.6ab	148.0b
Shear, rake, bed	109.6b	20.7a	130.2b	123.5b	23.0ab	146.5b
First rotation	258.7a	30.3a	289.0a	213.6a	28.3b	241.9a

Table 2—**Total aboveground tree biomass estimates of the first and second rotation sections of the Snow Mill plantation by product classes. Second rotation biomass estimates are presented by site preparation treatment**

Site preparation treatment	Pine sawlogs	Pine chip & saw	Pine pulp wood	Pine precommercial	Hardwood pulpwood	Hardwood precommercial
	tonnes/ha					
Herbicide	10.5	84.0	29.2	2.8	3.3	13.9
Herbicide and release	5.2	90.2	23.3	2.0	1.0	8.3
Rebed only	11.6	108.0	26.0	2.2	1.5	5.3
Shear, rake, bed	0.0	86.2	41.6	2.7	0.0	0.9
First rotation	149.1	75.4	0.0	0.0	11.9	21.9

Table 3—Total aboveground tree biomass estimates of the first and second rotation sections of the Greeleyville plantation by product classes. Second rotation biomass estimates are presented by site preparation treatment

Site preparation treatment	Pine sawlogs	Pine chip & saw	Pine pulpwood	Pine precommercial	Hardwood pulpwood	Hardwood precommercial
	tonnes/ha					
Herbicide	4.6	62.2	39.3	4.0	2.7	9.5
Herbicide and release	2.7	104.5	27.4	3.0	0.8	6.5
Rebed only	0.0	92.4	44.4	2.4	0.0	10.4
Shear, rake, bed	0.0	80.2	53.4	5.7	0.0	8.6
First rotation	147.2	69.2	4.9	0.4	2.8	19.4

and saw differences within treatments between the two stands are not consistent nor are treatment differences in the pulpwood class.

Three conclusions can be drawn from this research. First, the area based crown biomass of the second rotation trees at age 15 was not significantly different from the crown biomass of 34- or 36-year-old first rotation trees. In contrast, the bole biomass of the second rotation trees was much less that that of the first rotation trees. Second, at 15 growing seasons after planting, site preparation methods did not seem to affect aboveground biomass accumulation. The herbicide and release plots in Greeleyville had the most chip and saw biomass, and in the Snow Mill plantation, the rebed only plots had the most chip and saw biomass. In both stands, the shear, rake, and bed plots had the most pine pulpwood biomass. Finally, the total aboveground biomass of the second rotation plots as a percent of the total abovegound biomass of the first rotation plots was greater than the percent of the ages. This means that the second rotation plantation is accreting biomass faster than the linear increase in age. Assuming that both the first and second rotation trees accumulate area-based biomass in a sigmoid curve pattern and that the first rotation trees have a small annual increment, then the second rotation trees would accumulate biomass much less the linear percent of age, because they are younger than the 50 percent break point of a sigmoid curve. Only if the second rotation trees were older than 50 percent of the age of the first would one expect growth faster that the linear percent of age. The fact that the second rotation trees at 40 to 45 percent of the age of the first have 44 to 60 percent of the biomass of the first indicates that there is no sign of a lessening of growth rate from one rotation to another. Thus these data indicated that these management practices on these sites are sustainable as measured by biomass accumulation.

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