IMPACT OF SUSTAINABLE FOREST MANAGEMENT ON HARVEST, GROWTH, AND REGENERATION OF SOUTHERN PINE IN THE PIEDMONT AFTER 5 YEARS OF MONITORING

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Abstract—This paper describes a study established to monitor the implications of ecosystem management choices on natural loblolly and shortleaf pine stands on the Oconee National Forests in the Piedmont of Georgia. The impact of partial harvests, group selection cuts, seed tree cuts and no human disturbance on growth, mortality, species composition, and regeneration were monitored from 1994-95 to 1999. In mature stands with no human disturbance growth average 4.7 percent per acre per year and mortality averaged 2.9 percent per acre per year. In stands with partial cuts growth averaged 6.1 percent and mortality averaged 2.4 percent per acre per year. Sweetgum and red maple were the predominant regeneration seedling species in stands with partial cuts and group selection cuts. Loblolly pine was the predominant seedling species in the seed tree cuts. Seed tree cuts appear to be the most successful forest management method for regenerating loblolly pine stands in the Piedmont.

INTRODUCTION

Piedmont National Forest lands have been managed under the multiple-use concept since the 1960's. Under this concept, objectives were to improve the health, quality and volume of pine stands as well as a variety of other benefits. Older pine stands were clear-cut and planted back to pine or harvested using seed tree cuts to establish pine regeneration. Younger stands were thinned to stimulate pine sawtimber growth.

In the early 1990's an ecosystem approach to managing National Forests was introduced to improve the balance among forest values, conserve biodiversity, and achieve sustainable, healthy conditions while retaining the spiritual, historic and esthetic qualities of the land. Under ecosystem management pine and pine/hardwood stands on National Forests in the Piedmont are being converted from evenaged monocultures to unevenaged or two-aged pine and mixed species stands.

This paper reports on a study established to monitor the implications of ecosystem management practices on loblolly (*Pinus teada* L.) and shortleaf (*P. Echinata* Mill) pine natural stands on the Oconee NF in the Piedmont of Georgia. The impact of partial cuts, group selections cuts, seed tree cuts and no human disturbance on harvest volumes; growth; mortality; and seedling density, species composition, richness, diversity, and evenness are reported.

METHODS

Permanent monitoring plots were established in loblolly/shortleaf pine stands on the Oconee NF in the Piedmont to monitor the reponses of these stands to a range of sustainable ecosystem management practices. The monitoring plots were established in 1994-95 and re-measured in 1999. The management practices monitored included: (1) partial cuts, (2) group selection cuts, (3) seed tree cuts and (4) no active management areas. Included in the partial cuts is single-tree selection, salvage cuts, stand improvement cuts and shelterwood cuts. No active management areas are stands in which no human disturbance occurred between stand inventories in 1994-95 and 1999. The group selection openings were 150 to 200 feet in diameter. Each monitoring plot is a cluster group (CG) consisting of three 1/5-acre circular plots and that were randomly located within each stand selected for monitoring. Cluster groups were established in stands representative of four 20-year age classes (20,40,60, and 80 years) (table 1).

On each 1/5-acre plot all trees m 5.0 inches diameter at breast height (d.b.h.) was located by azimuth and distance from plot center. Species, d.b.h., total height, merchantable height, and tree grade were recorded for each live and

Table 1—Number of Natural Stands Monitored by Management Practice and Age Class

Age Class (Yrs)	No Activity	Partial Cut	Group Selection	Seed Tree
	——————No.——————			
20	2	1		
40	2			
60	4	4	2	1
80	2	2		4

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Table 2—Average Proportion of Basal Area by Species Group for Trees = 5.0 inches DBH Measured in 1994-95 and Remeasured in 1999 by Management Practice

Stand Age	1994-95 Species Group				1999 Species Group			
	Pine	Soft Hwds	Oaks	Other Hard Hwds	Pine	Soft Hwds	Oaks	Other Hard Hwds
Yrs	%				%			
No Active Management								
15	87	3	10	0	91	1	8	0
43	88	12	0	0	86	13	1	0
62	75	23	1	1	79	20	1	0
72	80	13	3	4	80	13	2	5
Partial Cuts								
22	97	2	1	0	96	2	2	0
57	92	6	2	0	94	4	2	0
80	83	8	5	4	84	6	6	4
Group Selection Cuts								
60	83	16	0	0	4	91	0	5
Seed Tree cut – No Active cut								
60	91	9	0	0	96	4	0	0
75	83	6	10	1	85	2	12	1
Seed Tree Cut-Active Cut								
70	83	14	1	2	82	14	0	4

dead tree. Five 1/300-acre micro-plots were located 30 feet from plot center at 72° intervals within each 1/5-acre plot to tally seedlings and saplings. Seedlings (trees up to 1.0-inch d.b.h.) were tallied by species count. Saplings (trees 1.0 to 4.9 inches d.b.h.) were tallied by species, d.b.h. and total height. Softwoods 5.0 to 8.9 inches d.b.h. and hardwoods 5.0 to 10.9 inch d.b.h. were classified as pole timber. Softwoods m 9.0- and hardwoods m 11.0 inches d.b.h. were classified as sawtimber if they contained one or more 16-foot sawlog. Pine sawtimber trees were classified using a tree classification system for mature pine developed by Clark and McAlister (1998) and hardwood sawtimber trees were classified using USDA Forest Service hardwood tree grades (Hanks, 1976).

Stem green weight of wood and bark to a 4 inch dob top was estimated for trees m 5.0 inches dbh based on DBH and total height using equations developed for natural pine in the Piedmont (Clark and others 1990). Stem weight of soft hardwoods, oaks and other hard hardwoods were estimated using equations developed for hardwoods in the southeast (Clark and others 1986). The equations were applied to the dbh and total height measurements recorded for each live tree in 1994-95 and live and dead trees

Table 3—Average Stem Green Biomass/Acre in 1994-95, Biomass in 1999, Harvest, Mortality and Growth for Stands Monitored

Avg Age Yrs	1994-95 Inventory TNS/A	Harvest TNS/A	1999 Inventory TNS/A	Mortality %	Annual Growth[1/] %
No Active Management					
15	16	0	39	6.3	36.0
43	89	0	109	3.7	5.8
62	69	0	80	3.8	5.1
72	156	0	178	1.3	3.9
Partial Cuts					
22	67	29	61	2.4	12.2
57	103	24	89	2.7	2.8
80	112	33	85	4.8	3.2
Group Selection Cuts					
60	108	105	3	0.4	11.0
Seed Tree Cut – No Activity					
60	31	0	37	0.3	3.6
75	42	0	50	0.6	4.8
Seed Tree Cut – Active Cut					
70	125	79	49	4.2	4.0

1999. Estimated tree weights were expanded to tons per acre. Trees tallied as dead standing and down dead in 1999 but were live in 1994-95 were classified as mortality. Trees cut and hauled were classified as harvest. Average annual mortality was calculated using the following equation:

Mortality = ((dead / intinv) / yrsgrw) * 100
Where: Mortality = average annual mortality in percent
dead = stem weight of dead trees (tons)
intinv = stem weight of live trees in 1994-95 (tons)
yrsgrw = number of years of growth from 1994-95 to 1999

Average annual growth was estimated using the following equation:

Growth = ((99inv-(intinv-dead-harv) / intinv)/ yrsgrw)* 100
Where:
Growth = average annual growth in percent
Harv = stem weight of trees cut and hauled (tons)

Species diversity and evenness were calculated using Shannon's indices of diversity and evenness based on stem counts (Magurran, 1988).

RESULTS

NO ACTIVE MANAGEMENT

The stands that received no active management contained 75 to 88 percent of their basal area (BA) in pine, 3 to 23 percent in soft hardwoods and the remainder in oaks and other hard hardwoods based on the 1994 inventory (table 2). The remeasurement data shows the BA of these stands changed only slightly from 1994 to 1999. The average total green weight of stems per acre ranged from 16 tons on the 15-year stands to 156 tons on the 72-year stand in 1994-95 (table 3). The stand stem biomass/acre increased on all stands with no active management. Average annual growth among sawtimber stands ranged from 5.8 percent for the 43-year stand to 3.9 percent for the 72-year stand. Average mortality ranged from 3.8 percent for the 62-year stand to only 1.3 percent for the 72-year stand. The average mortality of 15-year stands was 6.3 percent per acre per year. However, these young stands were growing at 36 percent per acre per year because of a 40 percent in-growth from saplings to pole timber from 1994 to 1999 and an average increase in quadratic mean DBH from 6.7 to 7.5 inches (table 4).

Average stems per acre for seedlings decreased in all stands that received no active management from 1994 to 1999 by an average of 58 percent and species richness decreased slightly. This decrease in seedling stems per acre was probably a result of the drought conditions in 1998 and 1999 in the Piedmont. On average species diversity and evenness increased slightly (table 5). The most predominant seedling species in 1994-95 were red maple and dogwood, but in 1999 sweetgum and red maple were the most predominant species in the stands receiving no active management (table 6).

PARTIAL CUTS

Harvesting had little effect on the proportion of BA that was in pine, soft hardwood, oaks or hard hardwood in the partial cut stands (table 2). Before harvest the stands averaged 83 to 97 percent pine and following harvest the stands averaged 84 to 96 percent pine. Number of trees per acre (TPA) before thinning ranged from 390 in the 22-year stand to 103 TPA in the 57-year stand (table 4). After the thinning TPA ranged from 83 in the 22-year stand to 67 in the 57-year stand. The average stem weight per acre before thinning ranged from 67 tons per acre in the 22-year stand to 112 tons per acre in the 80-year stand in 1994-95 (table 3). In the thinning operation 43 percent of the stem biomass in the

Table 4—Average Stand Basal Area/Acre, Trees per Acre (TPA) and Quadratic Mean DBH (QDBH) for Tree = 5.0 Inches DBH Measured in 1994-95 and Remeasured in 1999 by Management Practice

	1994-95			1999		
Stand Age (Yrs)	Basal Area (Ft^2)	TPA (No.)	QDBH Area (In.)	Basal Area (Ft^2)	TPA (No.)	QDBH Area (In.)
			No Active Management			
15	40	165	6.7	71	231	7.5
43	77	78	13.5	87	80	14.1
62	68	101	11.1	72	100	11.5
72	126	167	11.8	132	169	12.0
			Partial Cuts			
22	117	390	7.4	83	193	8.9
57	86	103	12.4	67	68	13.4
80	105	147	11.4	73	89	12.3
			Group Selection Cuts			
60	98	115	12.5	5	15	7.8
			Seed Tree Cut – No Activity			
60	28	23	14.9	30	22	15.8
75	33	21	16.9	37	23	17.2
			Seed Tree Cut – Active Cut			
70	108	117	13.0	37	12	23.8

Table 5—Average Stem/Acre, Species Richness, Diversity and Evenness for Seedlings for Stands Measured in 1994-95 and Remeasured in 1999 by Management Practice

Stand Age (Yrs)	1994-95 Stems/Acre (No.)	Richness	Diversity	Evenness	1999 Stems/Acre (No.)	Richness	Diversity	Evenness
			No Active Management					
15	7,840	21	2.2	0.7	3,900	16	2.1	0.8
43	10,040	17	1.7	0.6	3,980	13	1.9	0.8
62	9,340	19	2.1	0.7	6,240	18	2.3	0.8
72	45,860	23	1.4	0.5	16,520	21	1.5	0.5
			Partial Cuts					
22	1,820	15	2.2	0.8	4,360	18	1.9	0.7
57	11,300	20	2.0	0.7	9,451	17	2.0	0.7
80	12,140	21	1.8	0.6	10,480	20	2.0	0.7
			Group Selection Cuts					
60								
			Seed Tree cut – No Active cut					
60	5,740	23	1.9	0.6	8,120	17	1.9	0.7
75	12,340	17	1.8	0.6	9,140	19	1.9	0.7
			Seed Tree Cut-Active Cut					
70	16,540	25	1.9	0.6	8,840	16	2.7	0.7

pole and sawtimber class was harvested in the 22-year stand, 23 percent in the 57-year stand and 29 percent harvested in the 80-year stand. Average mortality ranged from 2.4 percent in the 22-year stand to 4.8 percent in the 80-year stand. Average annual growth ranged from 12.2 percent in the 22-year stand to 2.8 percent in the 57-year stand. Seedling stems per acre increased significantly after the thinning in the 22-year stand but decreased only slightly in the 57 and 80-year stands (table 5). Loblolly pine, red maple and sweetgum were the predominant seedling species in the partial cut stands before harvest in 1994-95. Following harvest in 1999 sweetgum was the predominant seedling species in all partial cut stands.

GROUP SELECTION CUTS

The group selection openings contained 83 percent of their BA in pine and 16 percent in soft hardwoods before the openings were cut (table 2). After the openings were harvested they contained only 4 percent of their BA in pine and 91 percent in soft hardwoods. Harvesting in the group openings removed 105 tons per acre or 97 percent of the pole and sawlog biomass in the openings (table 3). On average the openings contained 98 TPA before harvest and 15 TPA after harvest (table 4). The trees remaining in the openings were growing at an annual average rate of 11 percent and averaged 7.8 inches DBH in 1999. Before harvest the predominant seedling species was dogwood

Table 6—Proportion of Seedling Stems per Acre (%) by Species for Stands Measured in 1994-95 and Remeasured in 1999 by Management Practice

Stand Age (Yrs)	1994-95 Species			1999 Species		
			No Active Management			
15	R. Maple (20)	Sweetgum(15)	Water Oak(11)	Sweetgum(16)	Dogwood(14)	R. Maple(12)
43	Dogwood(27)	Lob. Pine(26)	Sweetgum(13)	Sweetgum(23)	Lob. Pine(18)	Dogwood(16)
62	Dogwood(19)	Lob. Pine(19)	Sweetgum(12)	R. Maple(13)	Lob. Pine(12)	Dogwood(11)
72	R. Maple(6)	Dogwood(17)	Elm(3)	R. Maple(65)	Dogwood(11)	Elm(18)
			Partial Cuts			
22	Sweetgum(37	S. Red Oak(9)	Dogwood(9)	Sweetgum(34)	Lob. Pine(32)	B. Cherry(5)
57	Lob. Pine(35)	Sweetgum(15)	R. Maple(7)	Sweetgum(27)	Lob. Pine(21)	Elm(6)
80	R. Maple(31)	Sweetgum(17)	Lob. Pine(13)	Sweetgum(26)	R. Maple(12)	Lob. Pine(4)
			Group Selection Cuts			
60	Dogwood(24)	Lob. Pine(21)	Sweetgum(20)	Sweetgum(40)	Water Oak(18)	Dogwood(16)
			Seed Tree Cut – No Active Cut			
60	Lob. Pine(45)	Sweetgum(24)	Water Oak(4)	Hawthorn(31)	Lob. Pine(25)	Sweetgum(15)
75	Lob. Pine(50)	R. Maple(11)	Sweetgum(7)	Lob. Pine(36)	R. Maple(7)	Sweetgum(7)
			Seed Tree Cut – Active Cut			
70	Lob. Pine(37)	R. Maple(17)	Dogwood(15)	Lob. Pine(37)	Sweetgum(20)	Elm(9)

followed by loblolly pine. Four years after harvesting the openings sweetgum followed by water oak was the predominant seedling species.

SEED TREE CUT- NO ACTIVE CUT

The proportion of BA per acre in pine increased slightly (2 to 5 percent) and proportion in soft hardwoods decreased slightly (4 to 5 percent) from 1994-95 to 1999 on the stands that were seed tree stands prior to 1994 (table 2). The seed tree stands with on active cut averaged 21 to 23 TPA m 5.0 inches DBH and contained 30 to 37 tons of stem biomass per acre in 1999. The stands were growing at an annual rate of 3.6 to 4.8 percent and had an average mortality of 0.3 to 0.6 percent per year (table 3). Average quadratic mean DBH of the seed trees was 15.8 in the 60-year stand and 17.2 in the 75-year stand (table 4). Stems per acre in seedlings increased from 1994-95 to 1999 on the 60-year stand by 41 percent but decreased on the 75 year stand by 47 percent. In 1994-95 the predominant regeneration seedling species was loblolly pine in the seed tree stands with no active cut. Five years after the initial measurements hawthorn was the predominant seedling species in the 60-year stand but loblolly pine was still the predominant species in the 75-year stands. However, over time the loblolly pine seedlings in the 60-year stand should gain dominance over the hawthorn.

SEED TREE CUT – ACTIVE CUT

Prior to harvest the stand that received the seed tree cut contained 108 TPA m 5.0 inches DBH and 83 percent of its BA per acre was in pine, and 14 percent was in soft hardwoods (table 2). Following the seed tree cut the stand contained only 12 TPA but the proportion of BA per acre in pine and hardwoods was about the same as that prior to harvest. Harvesting removed 79 tons per acre or 63 percent of the stem biomass in the stand (table 3). Following the harvest the remaining seed trees were growing at an average rate of 4.0 percent per year and had an average mortality of 4.2 percent per year. The number of seedling per acre decreased from over 16, 540 per acre prior to the harvest to 8,840 in 1999 or by 47 percent. This decrease was probably a direct result the 1998 and 1999 droughts. In 1994-95 loblolly pine was the predominant seedling species and in 1999, four year after the seed tree cut, loblolly pine was still the predominant species.

SUMMARY

The impact of partial harvests, group selections cuts, seed tree cuts and no human disturbance on growth, mortality, species composition and regeneration were monitored for natural pine stands on the Oconee National Forest in the Piedmont of Georgia from 1994-95 to 1999. The stands monitored contained 75 to 92 percent of their basal area in pine, 3-23 percent in soft hardwoods and 0 to 10 percent in hard hardwoods. The stands monitored ranged in age from 15 to 80 years old. In stands over 20 years old, with no human disturbance, the average annual growth was 4.7 percent and annual mortality averaged 2.9 percent. In stands with partial cuts growth averaged 6.1 percent and mortality averaged 2.4 percent. In stands with no human disturbance sweetgum and red maple were the predominant seedling species. In stands with partial cuts and group selection cuts sweetgum was the most predominant regeneration species. Loblolly pine was the predominant seedling species in the seed tree cuts. Seed tree cuts appear to be the most successful method for regenerating loblolly pine stands in the Piedmont.

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