Growth and Yield In Naturally Regenerated Longleaf Pine Stands

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ABSTRACT

Due to continuing maintenance of a cooperative regional permanent-plot growth study in thinned, even-aged longleaf pine stands of natural origin, information is now available on stand development to age 100 years and eventually will be available to age 150 years. These data are used to develop and periodically improve thinned-stand growth prediction systems applicable to the East Gulf region of the mid-South. For prescription purposes, predictions can be made of the growth and yield expected for nearly any combination of ages from 20 to 100 years, site indices of 50 to 90 feet (at age 50), and stand densities of 30 to 150 square feet of basal area per acre left after thinning at 5- to 10-year intervals. The usefulness of computer software programs employing the systems and precautions concerning their use are illustrated in examples. Also, the early performance of research stands of longleaf pine managed under an uneven-aged, group-selection system employing a 10-year cutting cycle and 3-year prescribed burn cycle is reported. This information makes it possible to estimate the development and production of uneven-aged stands of longleaf pine and to make some qualified comparisons with forests composed of even-aged stands. The current activity and future needs in both even- and uneven-aged longleaf pine stand growth research are discussed.

INTRODUCTION

The Southern Forest Experiment Station conducts research and demonstrations on the development, growth, and yield of both even- and uneven-aged stands of longleaf pine (*Pinus palustris*) to provide an objective basis for management of this species for a variety of purposes. Important among these purposes are the production of valuable utility poles and sawtimber on long rotations and maintenance of suitable habitat for certain rare and endangered species of plants and animals indigenous to longleaf pine forests.

The Southern Station has maintained a cooperative study in the East Gulf region of the mid-South on the production of thinned, even-aged, naturally-regenerated (hereafter called natural) stands since the mid-1960s. The purpose of this comprehensive, long-term, permanent-plot study is to provide data for prediction systems that permit simulation of the development of managed stands and estimates of various product volumes produced for rotations up to 150 years in length. This report gives a brief description of this study, a description of the major products produced, and examples of the uses of these products. In addition, since the mid-1970s the Southern Station has maintained demonstrations of managed and regulated longleaf pine stands under an uneven-aged or selection system on the Escambia Experimental Forest (EEF) in south Alabama. The development and growth results of these demonstrations to date are presented along with a comparison to even-aged conditions and a discussion of possible applicability. Finally, the current activities and future needs in longleaf pine tree and stand development research are discussed. A glossary is appended for those unfamiliar with common forestry terminology (Anon. 1988, Society of American Foresters 1958).

EVEN-AGED PREDICTORS

Regional Longleaf Pine Growth Study

This ongoing study, started in 1964, is maintained by the Southern Station with cooperation from industrial and nonindustrial private owners, Region 8 of the Forest Service and other public owners (see ACKNOWLEDGEMENTS), and with Auburn University and Mississippi State University. The Regional Longleaf Growth Study (RLGS)

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now comprises some 265 permanent plots (Table 1) located on cooperator lands and installed in a comprehensive array of stand ages, site qualities, and residual densities maintained by periodic low thinning. Plots were initially installed and treated during the dormant seasons over a 3-year period. Each study plot is inventoried at 5-year intervals and rethinned at each inventory as needed to maintain its assigned density level. The fifth 5-year inventory, conducted cooperatively by Auburn University, started in the fall of 1989 and will be completed by the spring of 1992. At the start of this 25-year inventory the database contained some 6 megabytes of tree measurement, description, and location information.

The purpose of the RLGS is to monitor the development of thinned even-aged stands over time so that product volumes can be predicted at various ages for virtually any stand on a given site maintained under a certain density regime by periodic low thinning. The best information, particularly for large, valuable products such as sawtimber and poles, ultimately comes from stands that are managed and monitored from a young age through final harvest at rotation age. This approach is the only way such information can be obtained for developing predictors—it cannot be developed from temporary-plot or short-term studies. However, rather than go through a rotation to obtain estimates of production, plots were initially selected to fit into an array of cells formed by all possible combinations of four (now five) 20-year age classes, five 10-foot site-index (SI) classes, and five 30-square-foot basal area classes with about three replications of each combination. Such a design provides preliminary volume and growth predictors, particularly for cubic-foot volume, after one or two remeasurements. All predictors improve with each succeeding inventory, especially those for large products, because the stands have been managed under their prescribed residual density for longer and longer periods and develop tree-size distributions that more and more reflect the prescribed density regime. When the youngest stands have been so managed for a rotation, we will be able to develop the most definitive predictors.

In the array of plot cells, the age classes now range from 20 to 100 years, the SI classes from 50 to 90 feet at age 50, and residual basal area levels from about 30 to 150 square feet per acre (Table 1). Because of increasing interest by the Forest Service in the performance of old stands, the oldest plots currently in the array will be maintained to an age of 120 to 150 years. The plots are located in north and northwest Florida, southwest Georgia, southern and central Alabama, and southern Mississippi, but concentrated in southern Alabama and northwest Florida. In addition to the initial group of 20-year-old plots established in the mid-1960s, the array includes a group of young plots installed in the mid-1970s and another group established in the mid-1980s. Each additional group of plots was 20 years old when established, and each has a complement of site and density combinations similar to the initial group. Plans are to maintain, treat, and monitor each of these three groups to a rotation of at least 80 years and perhaps 150 years. These groups of plots provide three replications in time and will afford the best information on stand and product development over time. The majority of these time-replication plots are of one geographic seed source and at one location on the EEF in south Alabama. Since each local group is similar in initial age, covers a similar range in SI and residual density, and is separated by 10 years in time, these local replications-in-time of the 20-year age class may also allow detection of any changes in growth rate that may occur over time. If possible, a local fourth time replication should be installed in the mid-1990's to continue this monitoring.

Careful and precise records are kept of the plot trees. Plots are circular and consist of a central 1/5-acre net or measurement plot surrounded by a 1/2-chain wide isolation strip, treated the same as the net plot, resulting in a gross plot of about 1/2 acre. As added protection, an additional 1/2-chain untreated buffer strip surrounds the gross plot, bringing the total area of a single plot to about 1 acre. When plots are clustered in a stand, the 1/2-chain buffer strip surrounds the group of gross plots. On each net plot, each tree is uniquely and positively identified (paint numbered) consecutively from magnetic north by progressive azimuth and has the following information recorded for it: tree number, diameter at breast height (dbh), crown class, pole class and length, azimuth and distance from plot center, whether living or dead (if dead, cause of death), whether cut or left, and whether a sample tree or not. Approximately one-fifth of the trees are systematically selected as permanent samples (until cut or dead) on which the following measurements are made: total height, height to base of live crown, and age if dominant or codominant. The isolation-strip trees are not monitored but are thinned to the same density as the net plot.

RLGS Products

The study has led to a number of publications

Table 1.--Expected plots per age, site index, and basal area cell at the beginning of the 1989-91 inventory of the regional longleaf growth study.[1]

		Residual basal area (ft^2 per acre)				
Age	Site index	30	60	90	120	150
(yrs)	(ft)	(number of plots)				
20	50	4	4	4	4	3
	60	4	3	3	4	4
	70	5	5	5	5	4
	80	1	2	2	2	3
	90	-[2]	-	-	-	-
40	50	-	-	-	-	-
	60	2	2	3	2	2
	70	5	3	5	5	4
	80	7	9	7	8	6
	90	2	-	-	-	1
60	50	1	2	2	1	-
	60	1	-	1	2	2
	70	3	3	1	-	3
	80	3	4	6	3	2
	90	-	-	1	-	1
80	50	2	1	1	-	-
	60	2	1	2	1	4
	70	2	4	2	2	-
	80	5	3	3	3	3
	90	-	3	2	3	-
100	50	1	1	2	1	-
	60	1	2	1	1	-
	70	5	4	4	3	4
	80	-	-	-	-	-
	90	-	-	-	-	-

[1] This study was initiated by the Southern Forest Experiment Station in 1964; a cell refers to a combination of age, site index, and basal area.

[2] - indicates no plots are present for this cell.

and computer software programs related to the development, volume, and volume growth of even-aged, natural, thinned longleaf pine stands. First, as initial supporting information for data analyses, a set of compatible equations was developed to predict tree stem cubic-foot volume and surface area (inside- and outside-bark) to various merchantable top specifications and in terms of tree dbh and total height (Farrar 1981a). This set of equations was followed by an illustration of the additional utility of incorporating crown ratio into a tree volume-defining function (Farrar 1985c). Subsequently, an integrated stem-profile function was developed for natural longleaf pine stems in terms of tree dbh, total height, and crown ratio class (Farrar 1987). This function allows the volume in cubic feet or board feet to be estimated between any two diameters or any two heights on a stem. The study also led to a site index function for natural stands (Farrar 1981b) and other publications dealing with information provided by the study on stand volume and volume growth estimation (e.g., Boyer and Farrar 1981, Dennington and Farrar 1983, Farrar et al 1985, Farrar 1990, and Somers and Farrar 1991).

The most useful information has resulted in publications and computer software dealing with predictors of the development, volume, and volume growth of stands constructed using study data (Table 2). The first comprehensive stand-level prediction system used data from the first 5-year growth period (Farrar 1979). It permitted estimates of total, merchantable, and sawlog cubic-foot volumes, as well as International 1/4-inch board-foot volumes and volume growth for a wide variety of stand conditions. By simulating the manipulation of initial and residual density at the start of a growth period, the system permitted estimates of the results of thinning. If desired, it could also provide estimates of the dry weight of wood in the merchantable and sawtimber stands. However, only total basal area manipulation could be simulated, and the effects of thinning on the sawtimber component of a stand could not be directly estimated. Therefore, an updated and improved stand-level prediction system was developed using data from the 5- and 10-year inventories (Farrar 1985b). This is the main system currently suggested for use. It provides all the features of the earlier system; in addition, it allows simulated manipulation of both the total and the sawtimber basal area, within limits, in a stand and thereby permits direct estimates of the effect of thinning on the total, merchantable, and sawtimber components of a stand. Since the sawtimber is a subset of the merchantable component, an estimate of the merchantable sub-sawtimber or pulpwood component can be made by subtracting the sawtimber component from the merchantable component.

The main prediction system (Farrar 1985b) normally starts at age 20 years and uses basal area as the density measure. However, a prediction can be started as early as about age 10 when the stands are composed of seedlings and saplings and when number of trees has more utility than basal area as a density measure. To develop a procedure for making the density translation from trees per acre to basal area over time, the data from an RLGS spacing experiment in young natural longleaf stands on medium sites were used to develop a companion prediction system (Farrar 1985a). Stand density expressed as both trees per acre and basal area per acre was monitored from age 10 to age 20 years, making it possible to predict basal area at age 20, when basal area can be used in the main prediction system.

Table 2.--Preprogrammed natural longleaf pine stand growth and yield systems available in spreadsheet templates and BASIC programs.

System and source	Input[1]	Output[2]
Stand-level		
Farrar 1979b	A1, A2, BT1, Q	BT2, T1, T2, M1, M2, C1, C2, I1, I2
Farrar 1985b	A1, A2, BT1, BS1, Q	BT2, BS2, T1, T2, M1, M2, C1, C2, I1, I2
Dbh distribution		
Farrar 1985a[3]	A1, A2, TS0(A1), Q	Stand-and-stock tables at A1 & A2 showing trees, basal area, and volumes per 1-inch d.b.h. class & stand totals

[1] A1 = initial age; A2 = final age; BT1 = initial total basal area (BA); BS1 = initial sawtimber BA; Q = site index (index age = 50); TS0(A1) = total number of surviving trees at age A1.

[2] BT2 = final total BA; BS2 = final sawt. BA; T1 = initial total ft^3 vol.; T2 = final total ft^3 vol.; M1 = initial merch. ft^3 vol.; M2 = final merch. ft^3 vol.; C1 = initial sawtimber ft^3 vol.; C2 = final sawtimber ft^3 vol.; I1 = initial Int. 1/4- inchfbm; I2 = final Int. 1/4-inch fbm.

[3] BASIC program only (no spreadsheet template available).

In the following section, current volume and volume growth prediction systems for natural longleaf pine stands are examined in more detail to illustrate how and what they predict. Their uses and limitations are also discussed. Those interested in the details of the data base, analysis, function fitting, and precision of the prediction functions should see the specific publications cited above.

Predictor Utility

Two related stand volume and volume growth prediction systems are currently available for managed stands of natural longleaf. One is the comprehensive, main stand-level system (Farrar 1985b), which can normally be entered at age 20 years and is the most versatile. The other is a limited supplemental dbh-distribution system (Farrar 1985a) for unthinned young stands, which permits estimates to start as early as age 10 on medium sites. Other improved systems are being developed and will be briefly discussed later. Basically, these predictors first estimate the current volume of a stand given its age, SI, and density and then project for a period of years to obtain estimates of future stand density and volume. Projections can be made for one period or a sequence of periods comprising a planning horizon or rotation. A schematic of the operation of the main system for one growth period is shown in Fig. 1. Essentially, initial stand age, SI, and density in terms of total and sawtimber basal area are input at the start of a growth period along with age at the end of the growth period. The system predicts the final densities and various volumes at the start and end of the period, from which growth for the period can be calculated. In the main system, at the start of each period, stand density reductions can be simulated to estimate the effects of thinning. The earlier stand-level system (Farrar 1979) can still be used, but it is not recommended because the current main system is more versatile and based on a larger database.

There are several ways these predictors can be used, depending on the computing facilities available. If no programmable computer is available, one can use the tables given in Farrar (1985b) (Fig. 2); however, this is time-consuming, generally requires interpolations that may result in loss of precision, and may require considerable interpolation if the conditions one wishes to evaluate are not given in the tables. Evaluating the systems is much easier if a microcomputer is available because both BASIC programs and electronic spreadsheet templates (Farrar and others 1985) are available for the main stand-level system, and a BASIC program is available for the supplemental dbh-distribution system for unthinned young stands. The BASIC program for the main system allows one to predict certain current wood volumes and dry weights; future densities, volumes, and weights; and to calculate the estimated growth for a given stand (Fig. 3). Obviously, all predictors in the system are not included in this small program, but the program is easily modified to include any desired predictor. Lotus 1-2-3 and SuperCalc spreadsheet templates are available to evaluate a thinning regime over several growth periods (Fig 4). These templates and the BASIC programs mentioned above are currently available from the author.

The BASIC program for the supplemental young stand system (Farrar 1985a) will allow predictions for one set of stand conditions or an array of stand conditions. By itself, this prediction system is limited as to the ages and sites for which it can predict and is probably best used to provide input for the main system. In this capacity, the system will allow predictions to start as early as age 10 years, whereas the main system essentially starts at age 20. Fig. 5 shows typical output from this program.

Both systems provide estimates of total and merchantable cubic-foot volumes, both inside- and outside-bark. The main system further provides estimates of sawtimber volumes and permits simulation of thinnings in both the merchantable and sawtimber stand components. The main system also allows estimates of wood production in dry weight, if desired (Fig 3). Consequently, a wide variety of stand management scenarios can be investigated, including the effect on volumes of age, SI, and varying stand densities through time. The investigation can vary from looking at predictions for one short growth period for a known stand to viewing the predictions for an array of hypothetical thinning regimes on different sites for different rotation lengths. Spreadsheet output for one thinning regime, SI, and rotation are given in Fig. 4, in which the volume predictors are the same as in Fig. 3. This scenario shows thinning from below to leave a total basal area of 80 square feet every 5 years for a 60-year rotation with regeneration cutting starting at age 50. A further condition imposed is that sawtimber cuts of at least 1,500 feet board measure (fbm) International 1/4-inch rule (Int. 1/4) will be made each 5 years, starting as early as practical.

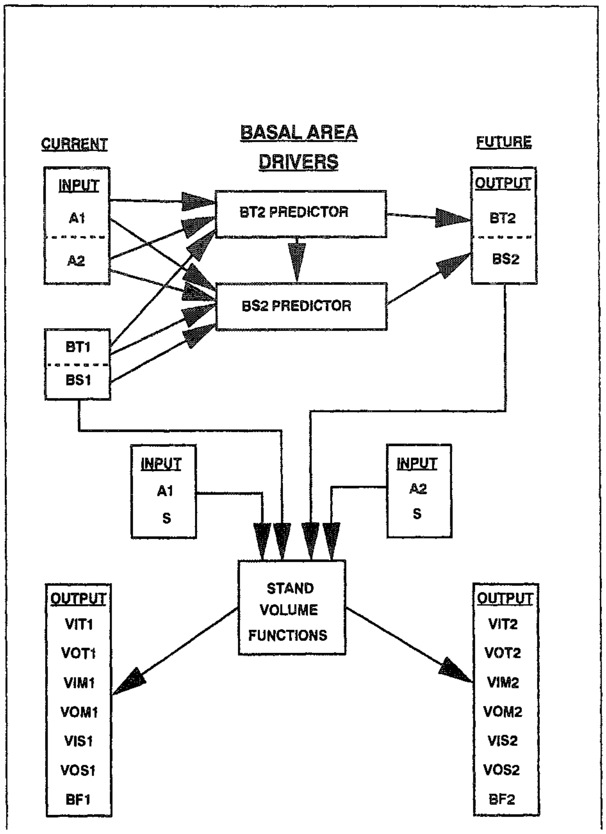

Figure 1.—Schematic of RLGS Main Prediction System Operation.

Precautions on Predictor Use

The main and supplemental prediction systems provide the means for simulating a wide variety of thinning schedules and rotation lengths for both existing and hypothetical stand conditions. Their versatility is great but not unlimited. Therefore, certain limitations, conditions, and precautions must be observed so that the systems are not misused. These precautions are treated in detail in other publications (Farrar 1985b, Farrar and others 1985, Farrar 1990), and only the major ones are summarized here.

The limits on initial and final ages, SI, and initial densities given in the publications for the main (Farrar 1985b) and supplemental (Farrar 1985a) systems should not be exceeded. The minimum initial age can actually be as low as 15 years in the main system, but 20 years is preferable because SI estimates are more precise at older ages. Also, ingrowth across merchantability thresholds may have a sudden and highly variable effect at young ages and can severely reduce predictability. It is possible to start predictions as early as age 10 years on medium sites by using information on trees per acre at this age in the supplemental system. But again, such a procedure carries considerable risk of imprecision for the reasons already given. The main system assumes a SI from a function developed from RLGS data (Farrar 1981b), but the supplemental system assumes an SI from curves given in Forest Service publication MP50 (USDA FS 1976). This assumption causes no problem because a site-index function fitted to MP50 data for longleaf (Farrar 1975) can be solved for dominant height if stand age is given, and these data can be input into the RLGS site-index function (Farrar 1985b) to obtain an SI value usable by the main system. The main system also requires that any initial value for sawtimber basal area be greater than zero. If zero is input, a program error will occur.

The prediction equations involved in the main system are based on stands essentially thinned from below for one or two 5-year growth periods. Equations for the supplemental system are based on young stands initially given a precommercial thinning and subsequently observed without further thinning for 10 years. Therefore, it is prudent to restrict projections to short periods--preferably 5 to 10 years but probably no more than 30 years at most. Single, long-term projections are not as reliable as short-term projections, and they exclude long-term mortality effects. Forecasting production to age 80 years from a thinning regime starting at age 30 and employing 5- or 10-year cutting intervals is preferable to forecasting from age 30 years the production of an unthinned stand to age 80.

Since the sawtimber predictions are likely to reflect to some degree the unknown events that occurred before the stands were included in the study, they should be used with caution. Additional inventories and analyses will provide ever-improving sawtimber volume estimates because as time passes, more of the stands will have been managed for longer periods under prescribed density levels. A true picture of treatment-induced diameter distributions and sawtimber-size material will emerge when the original sets of 20-year age-class plots have been managed under the imposed density levels by periodic thinning over rotations of 60 to perhaps 150 years.

One final precaution should be mentioned. Users should recognize that these predictors provide average values that are best used in relative comparisons among stand management options for prescriptive purposes. They are not absolute predictors of actual volumes from a specific stand or stands over a growth period or rotation. The sup-

Table 35-- Current and projected merchantable cubic foot volumes,i b ,(VIM) and projected total basal area (BT2) for natural even-aged s-ands of long leaf pine in the East Gulf,initial basal area (BT1) = 80 square feet

Initial age	Fianal age	Site index 50	60	70	80	90	Projected basal area (sq ft.)
(Years)							
A1	A2	VIM (cubic feet,i. b. ,/acre)					BT2
20	20	312	624	908	1168	1431	80
	25	788	1295	1709	2099	2509	1O8
	30	1360	1985	2495	2999	3548	130
	35	1927	2615	3200	3804	4476	147
	40	2440	3162	3810	4500	5280	160
	45	2885	3629	4331	5096	5968	169
	50	3266	4027	4776	5606	6557	177
25	25	599	972	1276	1564	1869	80
	30	1101	1590	1992	2391	2828	103
	35	1626	2191	2676	3179	3739	122
	40	2123	2738	3295	3890	4563	138
	45	2568	3221	3841	4518	5291	150
	50	2960	3643	4317	5067	5926	160
	55	3300	4008	4732	5544	6479	168
30	30	877	1250	1559	1868	2208	80
	35	1350	1803	2i96	2606	3064	100
	40	1818	2332	280i	3305	3876	116
	45	2253	2816	3354	3944	4617	130
	50	2647	3250	3849	4516	5281	142
	55	2997	3634	4288	5023	5870	152
	60	3305	3974	4676	5472	6391	160
35	35	1108	1464	1777	2107	2476	80
	40	1538	1959	2349	2770	3247	97
	45	1954	2431	2891	3399	3978	112
	50	2341	2866	3392	3978	4651	125
	55	2694	3261	3845	4503	5262	136
	60	3011	3615	4253	4976	5811	145
	65	3295	3933	4617	5398	6302	153
40	40	1290	1630	1950	2297	2692	80
	45	1679	Z078	2468	2899	3393	95
	50	2052	2503	2960	3470	4057	108
	55	2401	2899	3417	4001	4674	120
	60	2721	3262	3835	4486	5239	130
	65	3013	3591	4215	4928	5752	139
	70	3277	38B9	4559	5327	6217	147

Figure 2.--Volume and growth predictions as seen in table 35 of the appendix in Farrar (1985b).

porting data regarding age, site, and density come from very homogenous, small plots and include only the effects of suppression-related mortality. Therefore, the results are the optimum that could be expected and will probably overestimate the results from operable stands in the field, which are much more variable in age, SI, density, and mortality. Also, these are regression-based predictors that perform very well for average conditions but may perform poorly for specific individual stands or conditions that are not typical of the stands included in the study. In the best case, the predictor is likely to overestimate for a given stand because it is based on data from very uniform conditions in which mortality effects have been minimized, whereas operable stands are much more variable and suffer varying amounts of unpredicted mortality. For these reasons, the predictors are best used to choose among alternative treatments or management regimes on a relative basis rather than an absolute basis. For example, they can be used to choose among alternative residual basal area levels for a specific stand but not to predict precisely the growth that would result from leaving any given basal area.

The following section reviews the initial results from an alternative and very different approach to longleaf pine natural stand management.

E-A LONGLEAF STAND PROJECTION - EAST GULF AREA

	per acre		
	SITE INDEX 75		
	CURRENT VALUE	PROJECTED 5 YEARS	5 YEARS' GROWTH
STAND AGE	40	45	5
TOTAL BA	80	95	15
SAWTIMBER BA	16	31	15
MERCH. C.F. VOL.(i.b.)	2119	2677	558
SAWT. C.F. VOL.(i.b.)	381	795	415
INT.-1/4 B.F. VOL.	2311	4914	2603
MERCH. WOOD DRY WT.(lbs)	70071	88528	18456
SAWT. WOOD DRY WT.(lbs)	12832	26804	13973

Figure 3.--Example of output from a BASIC program using portions of the prediction system given in Farrar (1985b).

UNEVEN-AGED DEMONSTRATIONS

Longleaf pine is generally regarded as a species best managed in natural stands using even-aged silvicultural systems and as particularly well suited to a shelterwood system (Croker and Boyer 1975, Boyer and White 1990). Due primarily to seedling intolerance to competition, it is not ordinarily thought of as being suited to an uneven-aged or selection system. However, we have evidence that the species can be managed under a group-selection system that includes cyclic prescribed burning for seedbed preparation and control of unwanted vegetation. The following is a brief description of the first 6- and 10-year results from two stands managed under such a system. An expanded treatment of this subject is presented by Farrar and Boyer (1991).

Demonstration Details

Study Areas

Two tracts of natural longleaf pine forest were surveyed and established as selection management demonstrations on the EEF in southern Alabama. One area of 36 acres, designated the "volume/guiding-dbh-limit" (V/GDL) stand, was inventoried and first cut during 1977-78. The other area of 30 acres, designated the "basal area - maximum dbh - q" (BDq) stand, was inventoried and first cut during 1981-83. Each was chosen because it contained irregular, patchy areas of mature longleaf pine as well as groups and patches of seedlings and saplings. Neither had received significant cutting during the preceding decade, but both had been periodically burned for decades, had been treated once with herbicides for hardwood control, and were relatively free of woody competition. The understory of both stands typically contained scrub oaks (*Quercus incana* and *Q. laevis*) on the scattered xeric upland loamy-sand sites, flowering dogwood (*Cornus florida*) and blackgum (*Nyssa sylvatica*) on the prevalent upland and mid-slope mesic sandy-loam sites, and gallberry (*Ilex glabra*) on the more hydric sandy-loam sites on flats and lower slopes. The ground cover is dominated by bluestems (*Andropogon* spp.) but wiregrass (*Aristida stricta*) is absent.

Regulation

The V/GDL stand is regulated under the system developed by Reynolds (1959, 1969) and Reynolds and others (1984) for uneven-aged loblolly-shortleaf pine (*P. taeda* and *P. echinata*) stands in southern Arkansas. Simply stated, the stand is regulated under volume control in the sawtimber component using a GDL to help allocate the allowable cut. A desired volume in the sawtimber component at the end of a cutting cycle is adopted as a target, the sawtimber volume growth rate is estimated, a cutting cycle (dependent on the sawtimber growth rate) is adopted, and a sawtimber volume is left after cutting (A-C) that will grow at the determined rate to give the desired stand-

LlpGYITw.CAL Stand: Example Strategy: Lv. 80 RBT & Cut >1500 fbm

			STAND VALUES (per acre)						P.A.I. I M.A.I.			
SI(50)	AGE	STATUS	BT	TotCF	MerCF	BS	SawCF	Int.1/4	TotCF	MerCF	SawCF	Int.114
75	20	b-c	75.0	1173	976	.0	0	0	58.7	48.8	.0	0
		a-c	75.0	1173	976	.0	0	0	58.7	48.8	.0	0
		cut	.0	0	0	.0	0	0				
75	25	b-c	103.3	1996	181	1.0	15	87	164.6	168.3	3.1	17
		a-c	80.0	1556	1420	1.0	15	87	79.9	72.7	.6	3
		cut	23.3	441	398	.0	0	0				
75	30	b-c	1 03.2	2308	2188	4.1	76	445	1 50.4	1 53.8	12.2	72
		a-c	80.0	1800	1711	4.1	76	445	91.6	86.2	2.5	15
		cut	23.2	508	477	.0	0	0				
75	35	b-c	99.6	2475	2396	12.0	258	1 552	134.9	137.0	36.4	221
		a-c	80.0	1998	1938	12.0	258	1552	97.8	93.5	7.4	44
		cut	1 9.6	477	458	.0	0	0				
75	40	b-c	97.0	2607	2554	26.6	632	3886	121.9	123.1	74.9	467
		a-c	80.0	2161	2119	1 6.0	381	2311	100.8	97.2	1 5.8	97
		cut	1 7.0	447	435	10.6	252	1575				
75	45	b-c	95.0	2715	2677	30.9	795	4914	110.9	111.6	82.9	521
		a-c	80.0	2296	2266	21.0	542	3315	101.9	98.8	23.3	144
		cut	1 5.0	419	411	9.9	254	1599				
75	50	b-c	93.4	2804	2776	36.2	993	61 70	1 01.5	1 02.0	90.4	571
		a-c	60.0	1820	1806	27.0	743	4579	101.9	99.1	30.0	187
		cut	33.4	984	970	9.2	251	1 591				
75	55	b-c	71.4	2245	2231	40.9	1184	7383	85.0	85.0	88.2	561
		a-c	30.0	962	960	30.0	870	5385	100.4	97.8	35.3	221
		cut	41.4	1283	1271	10.9	314	1998				
75	60	b-c	37.5	1238	1234	37.5	1136	7079	55.0	54.9	53.3	339
		a-c	.0	0	0	.0	0	0	96.6	94.2	36.8	231
		cut	37.5	1238	1234	37.5	1136	7079				
Yield=			210.3	5795	5655	78.0	2206	13842				
M.A.I. =			3.5	97	94	1.3	37	231				

Figure 4.--Example of output from a SuperCalc template using portions of the prediction system given in Farrar (1985b).

```
YIELDS GIVEN TSO (# OF TREES PER ACRE AT DESIRED INITIAL AGE) WITH TYPICAL
SURVIVAL--

                                                  CU. FT. VOL. ABOVE 0.2 FT. STUMP
                                               ALL TREES  *  4-INCH CLASS AND GREATER
          AV.     STEMS                        ********FOR O.B.  TOPS OF----********
 TSO SI AGE D+C DBH PER BASAL CR    AV.      0 INCHES  *   2 INCHES  *   3 INCHES
          HT.     ACRE AREA         HT.     o.b.    i.b.*o.b.     i.b. *o.b.     i.b.
-------------------------------------------------------------------------------------
 900 80 10 10.4
                    1 273   1.5 58.2  6.1  11.1     5.1
                    2 164   3.6 69.5 11.9  32.4    18.0
                    3  10   0.5 72.6 14.9   4.9     3.0
                      ----  ----         ------  ------  ------  ------  ------  ------
                       447  5.6            48.4    26.2

ARITH. MEAN DBH =1.41        QUADR. MEAN DBH =1.51
WEIBULL PARAM:  A=0.55       B=0.98      C=1.93
SURVIVAL =100.0        MEAN CROWN RATIO = 62.5

-------------------------------------------------------------------------------------
 900 80 15 28.4
                    1 112   0.6 33.0  5.6    4.3     2.0
                    2 284   6.2 63.3 15.8   71.6    40.9
                    3 268  13.2 70.0 22.3  189.5   119.5
                    4 150  13.1 72.8 26.5  210.2   140.3   198.8   132.1   164.0   107.3
                    5  54   7.4 74.4 29.3  125.9    87.3   122.2    84.6   110.4    75.9
                    6  13   2.6 75.4 31.4   45.4    32.4    44.6    31.8    42.0    29.8
                    7   2   0.5 76.1 33.0    9.8     7.1     9.7     7.0     9.3     6.8
                      ----  ----         ------  ------  ------  ------  ------  ------
                       883 43.5           656.7   429.6   375.3   255.5   325.7   219.8

ARITH. MEAN DBH =2.77        QUADR. MEAN DBH =3.00
WEIBULL PARAM:  A=0.55       B=2.51      C=2.05
SURVIVAL = 99.9        MEAN CROWN RATIO = 64.0

-------------------------------------------------------------------------------------
 900 80 20 41.6
                    1  49   0.3 11.7  8.6    2.5     1.2
                    2 167   3.6 38.7 22.9   58.5    34.6
                    3 230  11.3 45.7 31.7  224.6   145.6
                    4 209  18.2 48.9 37.3  402.7   275.5   387.9   264.6   340.7   230.2
                    5 137  18.7 50.7 41.2  437.9   310.6   429.4   304.1   401.5   283.0
                    6  67  13.2 51.9 43.9  320.3   233.2   316.5   230.3   304.4   220.9
                    7  25   6.7 52.8 46.0  166.9   124.0   165.6   123.0   161.5   119.8
                    8   7   2.4 53.4 47.7   62.1    46.9    61.8    46.7    60.8    45.9
                    9   1   0.4 53.8 49.0   11.4     8.7    11.3     8.7    11.2     8.6
                      ----  ----         ------  ------  ------  ------  ------  ------
                       892 74.8          1686.9  1180.3  1372.5   977.4  1280.1   908.4

ARITH. MEAN DBH =3.63        QUADR. MEAN DBH =3.93
WEIBULL PARAM:  A=0.55       B=3.48      C=2.22
SURVIVAL = 99.2        MEAN CROWN RATIO = 44.8
```

Figure 5.--Example of output from a BASIC program using the prediction system given in Farrar (1985a).

ing volume at the end of the cutting cycle. The allowable cut is the difference between the before-cut (B-C) volume and the determined A-C volume. The GDL is the dbh class in the upper portion of the stand table in and above which all the cut could be taken, if desired. However, if this were done, a diameter-limit cut would result and some good, fast-growing trees above the limit might be cut prematurely while some poor, slow-growing trees below the limit might be left. Hence the term "guiding-dbh-limit"—it is a guide that permits leaving good trees above the limit and cutting poor trees below the limit to result in the allowable cut. No such objective provision or guide is provided for controlling the merchantable sub-sawtimber or pulpwood growing stock. It is treated subjectively according to need as suggested by the manager's experience.

Specifically, the V/GDL prescription was to leave a volume of about 4,000 fbm Doyle rule, or 6,500 fbm Int. 1/4, which, with an assumed growth rate of 200 fbm Doyle (300 fbm Int. 1/4), would grow in 5 years to provide about 5,000 fbm Doyle or 8,000 fbm Int. 1/4. All volumes are on a per acre basis unless otherwise stated.

The BDq stand is managed under structure control in which the entire merchantable stand table, not just the sawtimber, is regulated. Thus, management is more complete and more objective. Simply stated, an A-C target structure (stand table) specified by stand basal area, maximum dbh of trees to be left, and a 1-inch q (the fixed ratio of the numbers of trees in succeeding 1-inch dbh classes) is adopted. Then, the before-cut (B-C) inventory stand table is compared with the A-C target, and surplus trees in excess of the target stand table are harvested. If there are deficits between the A-C target and the B-C inventory, enough basal area in trees above the target is left to ensure that the prescribed A-C basal area remains. See Farrar (1981c, 1984) and Farrar and others (1989) for more information and other references on both V/GDL and BDq regulation.

The specific BDq prescription was to leave 50 square feet of merchantable basal area (in trees over 3.5 inches dbh), adopt a residual maximum dbh of 20 inches, and use a 1-inch q of 1.2.

Inventories

The merchantable pine stand in each area is given periodic 100% inventories by 1-inch dbh classes. These inventories include those to determine the B-C stand table, to mark the trees to be cut, and to tally any logging or other damage for salvage. At the time of each B-C inventory, a sketch map is made of the stand to show features such as roads, fences, or streams and concentrations or scarcities of timber sizes (e.g., sawtimber, pulpwood). Volumes are determined by use of local volume functions and custom inventory summary software for the EEF (Farrar 1986).

At the time of the B-C volume inventory, pine reproduction is also sampled, and 100 nested, temporary sample plots are systematically inventoried on each tract. The nested plot consists of a central circular milacre on which seedlings (stems over 0.5 to 4.5 feet in height) are tallied, within a circular 1/100-acre plot on which saplings (1-, 2-, and 3-inch dbh classes) are tallied.

Marking

The marking rules for obtaining the allowable cut for both V/GDL and BDq methods are the same and basically simple. The trees poorer in vigor, stem form, and spatial position are removed in the allowable cut, and the better trees are left. In addition, these group-selection rules are followed, by priority:

1. Enlarge any existing group of reproduction by cutting merchantable border trees that are candidates for removal, but only if reproduction exists beneath these trees.
2. Start a new group of reproduction by removing trees in and above the GDL or maximum dbh class that need to be cut and have reproduction beneath them.
3. Remove the rest of the allowable cut in trees taken singly in thinnings in the closed remainder of the stand.

The main logistical problem is to mark all of the allowable cut lot one pass through the stand. This can be practically achieved by dividing the stand into, say, quarters; allocating about 1/4 of the cut to each quarter; trying to meet the cut quotas in each quarter; and adjusting the cut up or down as required from quarter to quarter to mark the allowable cut. See Marquis (1978) for more details on this operation.

Note that there is no attempt to allocate any certain area to any tree size class, and we do not keep records on the area occupied by any size (age) class. The group-selection marking rules are depended on to create the desired uneven-aged structure eventually. That this will probably occur is intuitively seen in the BDq system but is not so apparent in the V/GDL system.

Since growth on these medium sites was less than anticipated, cutting cycles were lengthened to 10 years to provide an adequate operable cut. Thus, the V/GDL stand was cut initially in 1977 and not again until 1987, and the BDq stand was cut initially in 1982-83 and not in 1987.

Treatments

Both stands have received one herbicide treatment to reduce unwanted woody vegetation that could not be effectively controlled by prescribed fire. All undesirable stems 1-inch dbh and larger were injected with herbicide. The V/GDL stand was treated in 1980 (Tordon 101-R) and the BDq stand in 1965-66 (2,4-D amine).

Once the unwanted woody vegetation is brought under control as described above, continued control is by periodic prescribed fire. Both stands are winter burned on a 3-year cycle. Occasionally, 2-year spring burns may be imposed for a few cycles if the 3-year winter burns do not keep hardwoods small enough to be controlled by winter fires. Because burns are prescribed to give complete coverage of the demonstration areas, they are not necessarily best for all timber sizes. Burns are most effective in the groups of closed timber, from large sapling to mature sawtimber in size, and are somewhat less effective in the groups of reproduction where fuels are principally grasses rather than pine needles. Burns also kill varying amounts of fire-susceptible reproduction beneath parent trees, but since regeneration is cyclically re-established and these fires also prepare seedbeds, the net effect so far is that regeneration is regularly established and much of it retained.

Results and Discussion

Merchantable Stands

The merchantable stand periodic growth for 10 years is shown for the V/GDL stand in table 3 and for 6 years for the BDq stand in table 4. Growth has not been outstanding in either case, amounting to about 30 merchantable cubic feet per acre per year or about 140 fbm Doyle per acre per year, which is considerably less than the 200 fbm expected. At this rate, a 5-year cutting cycle results in about 700 fbm Doyle available for cut, which is not economically feasible, assuming 1,000 fbm Doyle to be a minimally operable cut. With this sawtimber growth rate, a 10-year cutting cycle results in growth of about 1,400 fbm Doyle, which is economical to cut.

The poor growth during the first growth period in each stand resulted from volume loss caused by mortality. In the V/GDL stand the actual causes of the unsalvaged mortality are unknown, but they were most likely lightning strikes and associated bark beetle attacks; possibly some was from logging damage. In the BDq stand the negative volume change is thought to be due to the same reasons plus mortality from a 1983 windstorm. Although the latter was largely salvaged and captured in the cut, it did cause the cut to be about 300 fbm Doyle per acre above the amount marked, and it reduced the base for growth. During the second period in the V/GDL stand, the relatively large positive change in volume suggests minor mortality and a growth rate that is probably more normal for such stands.

Sub-merchantable Stands

Regeneration appears to be adequate and sustainable in both the BDq and V/GDL stands (tables 5 and 6). In each case, during the management period, the numbers of trees in each sapling dbh class has increased. If the number of seedling and sapling trees dictated by the adopted A-C target BDq structure is taken as an absolute minimum (table 5), then the reproduction amount appears to be more than adequate in both cases (table 6). Also, we note in both cases a decrease in seedlings during the management period. However, the seedling numbers are likely to fluctuate due to repeated burning, intermittent seed crops, logging damage, and recruitment into the sapling classes. In both cases, there was no logging during these periods so the change is attributable mostly to burning and recruitment.

We might add that for a 10-year period prior to selection management of the BDq stand, we observed that its irregular stand of mature natural longleaf had similar basal area density, sustained periodic light cutting, and received burns on a 3-year cycle. During this period, sapling frequencies also increased in this stand (table 7). This observation suggested that longleaf could be managed and reproduced under a selection system that included the cyclic prescribed burning required for seedbed preparation and control of hardwood competition.

Qualified Comparisons with Even-aged Stands

The growth of selection stands of longleaf pine is not likely to reach the optimum that may be achieved under an even-aged shelterwood system using large blocks (>40 acres) in each age class. The difference is probably due to the competition exerted by large timber on adjacent smaller trees, particularly seedlings and saplings. The competitive effect of large timber root systems extends for about the height of the large timber (or about 1 chain) into adjacent seedling and sapling stands or groups and retards their development, with the effect decreasing with distance. Thus, a circular opening of about 1/3 acre is entirely under competition from adjacent large timber. The effect is reduced at an exponentially decreasing rate as opening size increases. For example, a 5-acre circular opening has about 2.8 acres or 56% of its central area free of competition from adjacent mature, timber while a 40-acre opening would have about 31 acres or 83% of its central area similarly free.

Table 3.—Ten-year production history - V/GDL selection stand.

	Merchantable stand/acre			Sawtimber stand/acre		
	Trees	Basal area	Volume	Volume	Doyle	Int.1/4"
	(no.)	(ft²)	(ft³)	(ft³)	(fbm)	
B-C inventory 1977	98	62.0	1,576	1,274	4,808	7,988
B-C inventory 1982	72	53.7	1,394	1,177	4,532	7,414
Change 1977-82	-26	-8.3	-182	-97	-276	-574
Cut 1977-78	30	12.3	288	205	846	1,319
Growth 1977-82	4	4.0	106	108	570	745
PAI 1977-82	**1**	**0.8**	**21**	**22**	**114**	**149**
B-C inventory 1982	72	53.7	1,394	1,177	4,532	7,414
B-C inventory 1987	88	62.4	1,613	1,357	5,437	8,637
Change 1982-87	16	8.7	219	180	905	1,223
Cut 1982-83	0	0	0	0	0	0
Growth 1982-87	16	8.7	219	180	905	1,223
PAI 1982-87	**3**	**1.7**	**44**	**36**	**181**	**245**
Cut 1987	13	11.2	297	261	1,126	1,694
A-C inventory 1987	75	51.2	1,316	1,096	4,311	6,943

Table 4.—Six-year production history - BDq selection stand.

	Merchantable stand/acre			Sawtimber stand/acre		
	Trees	Basal area	Volume	Volume	Doyle	Int.1/4"
	(no.)	(ft²)	(ft³)	(ft³)	(fbm)	
B-C inventory 1981	74	54.3	1,404	1,154	4,404	7,254
B-C inventory 1987	81	49.2	1,244	1,012	3,893	6,375
Change 1981-87	7	-5.1	-160	-142	-511	-879
Cut 1982-83	10	11.9	323	293	1,222	1,888
Growth 1981-87	17	6.8	163	151	711	1,009
PAI 1981-87	**3**	**1.1**	**27**	**25**	**119**	**168**
Cut 1987-88	0	0	0	0	0	0
A-C inventory 1987	81	49.2	1,244	1,012	3,893	6,375

Table 5.--Sub-merchantable Stand Development - BDq.

Dbh Class (in.)	Inventory and Date: A-C Tgt.	A-C 1983	B-C 1987
	(number of trees per acre)		
0	39	590	360
1	32	267	394
2	27	106	174
3	22	24	34
Total	120	987	962

Table 6.--Sub-merchantable Stand Development - V/GDL.

Dbh Class (in.)	Inventory and Date: B-C 1982	A-C 1987
	(number of trees per acre)	
0	320	170
1	80	132
2	28	74
3	34	14
Total	462	390

Table 7.--Sub-merchantable Stand Development - EEF Cpt. 65.

Dbh Class (in.)	Inventory and Date: B-C 1965	B-C 1970	B-C 1975	B-C 1981
	(number of trees per acre)			
0	-	-	-	-
1	16	55	186	264
2	15	16	53	145
3	18	11	9	35
Total	49	82	248	444

Table 8.—Ten-year Production History - Farm 40 Even-aged Stands.

	Merchantable stand/acre			Sawtimber stand/acre		
	Trees	Basal area	Volume	Volume	Doyle	Int.1/4"
	(no.)	(ft²)	(ft³)	(ft³)	(fbm)	
B-C inventory 1977	119	50.8	1,200	857	3,376	5,437
B-C inventory 1982	96	48.0	1,170	844	3,424	5,393
Change 1977-82	-23	-2.8	-30	-13	48	-44
Cut 1977-82	33	8.2	164	90	286	542
Growth 1977-82	10	5.4	134	77	334	498
PAI 1977-82	**2**	**1.1**	**27**	**15**	**67**	**100**
B-C inventory 1982	96	48.0	1,170	844	3,424	5,393
B-C inventory 1987	119	57.8	1,401	1,002	4,106	6,417
Change 1982-87	23	9.8	231	158	682	1,024
Cut 1982-83	0	0	0	0	0	0
Growth 1982-87	23	9.8	231	158	682	1,024
PAI 1982-87	**5**	**2.0**	**46**	**32**	**136**	**205**
Cut 1988	6	5.3	141	121	460	757

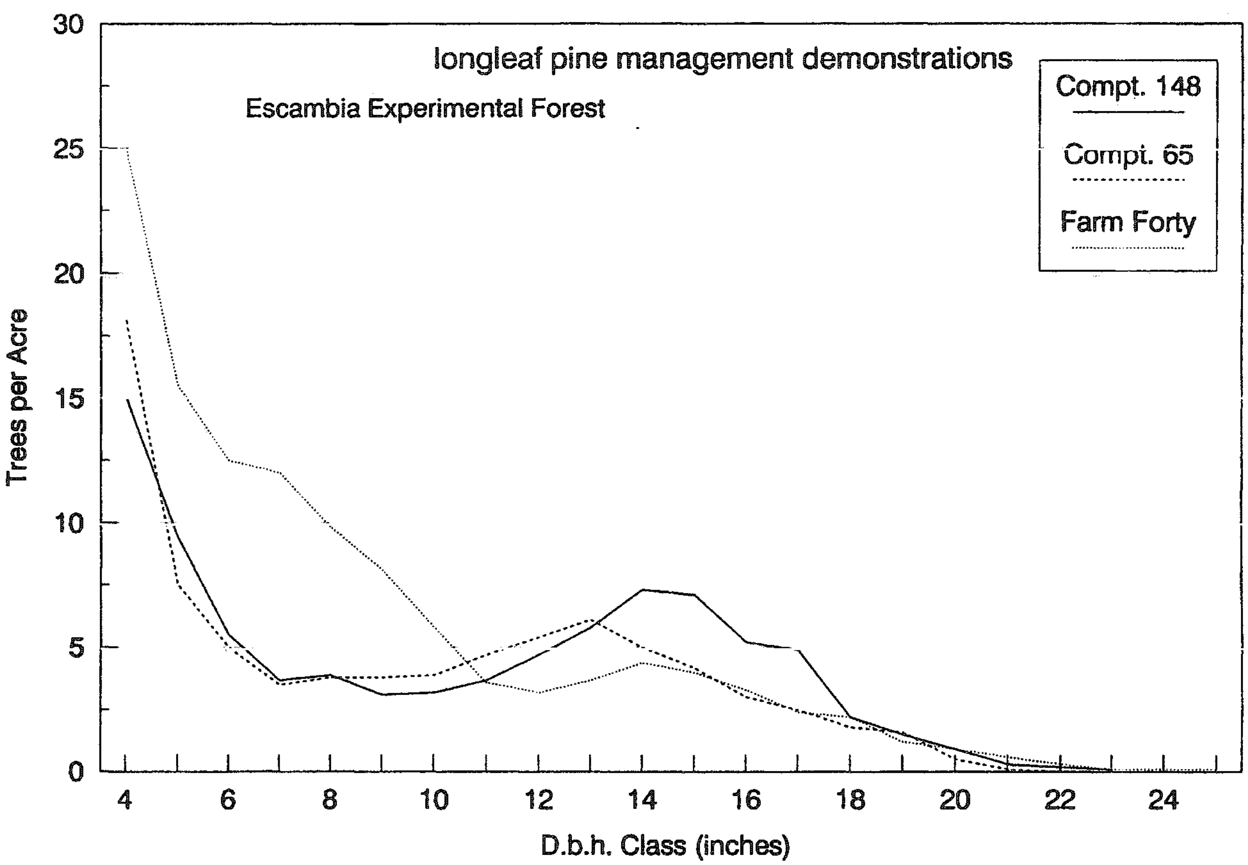

Figure 6.—1988 merchantable 1-inch d.b.h. classes frequencies - V/GDL (compt. 148), BDq (compt. 65), and Farm 40.

How much more efficient in wood production such a system of large even-aged stands will be is unknown, but it appears that a forest of small even-aged stands (about 3 to 5 acres each) grows no better than our group-selection stands so far (table 8). In table 8 the periodic growth for the past 10 years is shown for our longleaf pine Farm 40 demonstration on the EEF. This 40-acre tract has been managed for more than 40 years under an even-aged system of shelterwood in small blocks ranging in size from fractions of an acre to a few acres and with periodic prescribed burning. This tract is being regulated by area control with an 80-year rotation and a 10-year cutting interval, which will result in eight 10-year age classes, each occupying about 5 acres. It is growing at rates comparable to those of our V/GDL and BDq stands. A set of fully regulated, even-aged stands under area control has not yet been achieved in the Farm 40, but their composite is beginning to reflect the classic, reverse-J-shaped dbh distribution expected under regulation (Fig. 6). Thus, it appears that there will be little volume production difference between a longleaf stand managed and regulated under group selection and a similar area managed and regulated under an even-aged system that creates a balanced set of age classes in small stands of a few acres each.

Observations

Thus far we have found no serious problem to suggest that natural stands of longleaf pine on longleaf pine/bluestem (*Andropogon* spp.) sites on the rolling lower Gulf Coastal Plain cannot be managed and sustained under a group-selection system. For longleaf pine, this system requires regular burning for the multiple purposes of seedbed preparation, unwanted vegetation control, and hazard reduction. However, successful management for 10 years or less does not prove the effectiveness of a system; proof will require practice and monitoring for several more decades. The major question concerns sustainability. Can sufficient longleaf reproduction be developed and enough recruitment secured into the merchantable size classes to sustain acceptable and economically operable production through time? Will the marking rules coupled with 3-year rotation burning and, perhaps, occasional limited supplemental hardwood control treatments maintain an adequate reservoir of reproduction and foster its recruitment? Or will this system fail in the long term to meet the regeneration and recruitment requirements, so that large gaps appear in the structure and production cannot adequately be maintained, forcing reversion to an even-aged system?

In addition to the necessary increase in the cutting cycle from 5 to 10 years dictated by the growth rates, we plan further changes in the management of both selection stands. In the V/GDL stand we expect to increase the residual sawtimber volume gradually to 4,500 to 5,000 fbm Doyle (7,000 to 8,000 fbm Int.1/4) to improve the growth base, growth, and allowable cut. For the same reason, we will gradually increase the residual basal area in the BDq stand to 55 to 60 square feet per acre. We think both targets can be sustained as management continues and structure improves.

We obtain good data on stem frequencies in our reproduction inventories but have no information on the competitive or "free-to-grow" status of these seedlings and saplings. In future reproduction inventories we will obtain this information so we can better assess the portion of the reproduction likely to contribute to ingrowth into the larger sizes.

CURRENT RESEARCH AND FUTURE NEEDS

Even-aged Stands

Several activities are underway in data analysis and inventory in the RLGS to improve the natural longleaf pine growth and yield prediction systems. A combination stand-level and dbh-distribution prediction system enabling prediction of multiple-product volumes for thinned stands has been completed and is in publication. This cooperative work with Mississippi State University involves data from the 5- through 20-year inventories and employs a stem-profile function (Farrar 1987) to predict an assortment of tree product volumes both as stand-and-stock tables and/or as stand-level sums.

Individual-tree-based prediction systems are the most versatile and provide the most detail on responses to simulated treatments. However, they can also be very data demanding and time consuming to construct, require large computer programs, and be relatively expensive to exercise, particularly if multiple species and inter-tree distances are involved. If they involve only a single or a very few species and do not involve tree spatial location, they can be kept relatively small and efficient. In order to best accommodate the wide range of real-world stand and treatment situations and provide good response estimates for them, such predictors will undoubtedly be required in the future. Consequently, a deterministic distance-independent system is now under construction in a cooperative effort with Auburn University, using the 5- through 20-year inventory data from the RLGS. Results should be available within a year.

The 25-year inventory of the RLGS will be completed by the spring of 1992. The work is conducted cooperatively by the Southern Forest Experiment Station (Mississippi State, MS), and cooperators, with Auburn University handling the field measurements. During this inventory, in addition to the full agenda of regular measurements, the utility pole class and length of the qualifying trees on the plots will be assessed. The desirability of production information on these valuable products has long been acknowledged but, due to lack of personnel, funds, and expertise, data have not been gathered.

Recently, funds were made available to support the work, and a complete classification of all plot trees qualifying as poles will be made during the 25-year inventory. As a result, very useful information on pole production in thinned longleaf stands under varying conditions is being obtained, and a preliminary report has been made (Shaw et al 1991).

In addition to the current efforts in modeling and maintenance of the RLGS, several other efforts should be initiated to obtain information to guide future management.

Individual-tree-based prediction systems are likely to become and remain the most useful systems. In addition to the ongoing work with Auburn University to develop a first-stage, distance-independent system, work has been initiated to facilitate improvements. Azimuth and distance from plot center to each plot tree were obtained during the 20-year inventory to make inter-tree distance data available for construction of a distance-dependent prediction system. A study of tree stem and crown dimensions and dbh growth rates of open-grown longleaf pine trees has been conducted (Kush et al 1989), and now the upper limits of dbh growth can be estimated to establish upper boundaries for growth estimates in individual-tree systems.

The present systems can largely account for the effect of the main stand variables (age, SI, and density) on stand volume and net growth for essentially pure stands. The remaining sources of error now need to be accounted for to make further improvements. Sources of error include the following:

1. Impact of admixtures of other woody species, including the effects of species mix, density, and vertical and lateral spatial arrangement of other species on growth of longleaf and the entire timber stand.

2. Impact of nonhomogeneous stands, including effects of variations in age, site (soils, etc.), and density within stands.

3. Environmental effects in the short- and long-term, including climatic variations in precipitation and temperature regimes; geographic, physiographic, pyric, and edaphic influences; and pollutants of air, soil, and water.

4. Impact of nonsuppression sources of mortality, including effects of lightning, windstorm, fire, disease, and insect epidemic on long-term production.

There is also a need for additional mensurational support work in the area of tree volume- and weight-defining functions for natural longleaf pines and probably for the major timber associates of longleaf. Comprehensive predictors are needed for the volume, green weight, and dry weight of the wood, bark, and foliage in tree stems, crowns, and, possibly, roots in terms of tree dbh, height, and form. Some information is available in this area, but it needs to be supplemented and expanded. Work is also needed on the functioning of the forest ecosystem, including the forest floor, understory, midstory, and overstory components, with regard to energy accumulation and losses, carbon sequestration, nutrient cycling, and wildlife habitat aspects.

Uneven-aged Stands

Other than the two demonstrations on the EEF there is no current research by the Southern Station on uneven-aged management of longleaf pine. However, silvicultural and management information is needed in several areas, including the following:

1. Studies are needed to define the effects of

different levels of stand density, different structures (q ratios), and different maximum dbh or guiding dbh limits on the growth and sustainability of uneven-aged stands.

2. Silvical studies of the establishment and development of reproduction under uneven-aged conditions are needed.

3. Uneven-aged management and silviculture need to be investigated on poorer and better sites than those currently being monitored.

4. Other methods of uneven-aged management, including single-tree selection and diameter-limit cutting, need investigation.

5. Various burning schedules combined with different seasons of burn need investigation to determine the effect on pine reproduction and recruitment and hardwood control.

CONCLUSION

The RLGS has existed for some 25 years and continues to provide improved information on the growth of thinned natural longleaf pine stands with each 5-year inventory. The study, plots, and data become increasingly important and valuable with the passage of time and as the plot tenure under assigned densities increases. The study provides increasingly useful prediction systems as the database improves and accumulates, as new variables are taken into account, and as improved techniques for analysis and prediction are developed. The study should be maintained as planned until the initial three sets of 20-year-old plots are carried through a rotation under their assigned densities. The permanent plots in this study can also be used for any number of additional or superimposed studies as long as they are non-damaging, do not endanger plot trees, and do not interfere with objectives of the main study.

For example, the first two time replications in the 20-year-old stands have been used to investigate the possibility of a change in growth rate between the mid-1960's and mid-1970's, and this work will be extended to include the third time replication. The plots can also be used for more definitive investigations of the effects of climate, physiography, and soils on tree and stand growth and plans are being drafted for such work. So the usefulness of this long-term study is likely to remain high, and its protection and maintenance will hopefully remain first-priority activities in the future.

Research on uneven-aged silviculture and management in longleaf pine is in its early stages. Much more definitive research and decades of experience will be required before selection management techniques can be recommended in detail and with the assurance currently associated with recommendations for even-aged management.

GLOSSARY

Term	Definition
basal area	Of a tree: the cross-sectional area (in square feet) of the trunk, including bark, at breast height (4.5 feet above the ground). Of an acre of forest: the sum of basal areas of the individual trees.
board foot	A unit of wood equaling 144 cubic inches. The term is commonly used to measure and express the amount of wood in trees, sawlogs, veneer logs, or lumber. Board feet in a rectangular solid piece of wood is determined by: (length in feet x width in inches x thickness in inches)/12.
canopy	The layer of tree crowns in a stand or forest.
crown class	A system of classifying the position and relative vigor of individual trees in an even-aged stand. Dominant = trees having a crown extending above the general level of the canopy. Codominant = trees with medium-sized crowns forming the general level of the canopy. Intermediate = trees shorter than dominant or codominant trees but with crowns extending into the crown cover formed by them. Suppressed = trees with crowns entirely below the general level of the canopy (i. e. , overtopped).
cruise	A survey (inventory) of forestland to locate timber and estimate its quantity by species, products, size, quality, or other traits. Also, the estimate obtained in such a survey.
cubic foot	A wood volume measurement containing 1,728 cubic inches, such as a cube of wood measuring 1 foot on a side. It may or may not include the bark and air also included in stacked stems or logs.
cutting cycle	The planned time interval between major harvesting operations in the same uneven-aged stand. For example, a cutting cycle of 10 years means that harvests occur every 10 years.
cutting interval	The planned time interval between the various intermediate cuts (e. g. , thinnings) imposed during the life (rotation) in an even-aged stand. For example, a cutting interval of 5 years means that thinnings are proposed once every 5 years.
dbh	Abbreviation for tree stem diameter at breast height (4. 5 feet above ground); usually measured in inches.
diameter-limit	A crude method of harvesting under the selection system whereby all merchantable trees above a specified dbh or stump diameter are harvested. It is suitable in few situations and not generally recommended because it is easily prostituted into simply high-grading the stand.
density	The absolute quantity of vegetation per unit area. Stand density is commonly expressed as trees per acre, basal area per acre, or volume per acre.
ecology	The branch of science dealing with the interrelationships of plants and animals and their environment.
even-aged stand	An aggregate of trees which are about the same age (usually within 10 years, or 1/5 of the rotation, of each other).

fbm	A contraction of feet, board measure (i. e. , board feet).
forest	A plant community dominated by trees and other woody plants. From a forestry standpoint, a forest is a collection of stands administered as a unit and may be composed of even- aged or uneven-aged stands or both.
forest management	Applying forestry principles and practices and business techniques in the care of a forest so that it provides the products, services, and values desired by the owner. This may be very narrow as in management solely for pulpwood or very broad as in management to maximize enviromental benefits.
forester	A person professionally educated in forestry or one who possesses qualifications essentially equivalent to those held by one graduated from a recognized school of forestry. A trained applied ecologist.
forestry	The science, art, and practice of managing and using trees, forests, and their associated resources for human and environmental benefit. Forestry is applied ecology.
growing stock	The desirable merchantable portion of a stand; usually expressed in trees or volume per acre.
hardwood	An imprecise term describing broadleaf, usually deciduous, trees such as oaks, maples, elms, ashes, etc. The term does not necessarily refer to the hardness of the wood and some hardwoods are evergreen (holly, magnolia).
high grading	The practice of removing only the largest and best trees from a stand during a harvest operation and leaving only the poorest, lowest quality culls to occupy the site. It is an economic expedient, not a legitimate forestry practice.
improvement cut	A type of intermediate cut with the primary objective of improving the quality and species composition of the remaining stand.
inside bark	Bark is excluded.
intermediate cut	Removing immature trees from an even-aged stand sometime between reproduction and maturity (regeneration cut; final harvest) to improve the quality of the remaining stand. An intermediate cut may or may not generate income or a profit. Thinnings are typical intermediate cuts.
log	A piece of the woody stem (trunk or limb) of a tree. In the eastern U. S. , the standard log is 16 feet long (16. 3 feet, including a trim allowance).
logging	The practice of harvesting timber.
log rule	A table that gives the board-foot contents for logs of various diameters and lengths. Examples are the Doyle, International-1/4", and Scribner log rules. The Doyle rule is the legal rule in several states in the southern U. S.
Mbf	A abbreviation for thousand board feet. A unit of measure of tree volume per acre or sawed lumber.
merchantable	Trees which are of sufficient size and volume, individually or in aggregate, to provide a commercial cut.
mortality	The number of or volume of trees, usually merchantable, dying from natural causes during a certain period of time.

natural stand	A stand of trees resulting from natural seed fall or sprouting.
net growth	The net increase in volume of timber for a certain area of land for a certain period time. It includes the gross increase in the volume of the initially merchantable trees which survived, plus the volume of trees whch became merchantable during the period, minus the merchantable mortality.
outside bark	Bark is included.
plantation	An artificially regenerated stand established by planting seedlings or cuttings or by direct seeding.
prescribed burn	The controlled use of fire to achieve forest management objectives.
pulpwood	Wood cut primarily to be converted into wood pulp for the manufacture of paper, fiberboard, or other wood fiber products. Also, it is commonly taken to be the merchantable sub-sawtimber portion of a stand; trees generally 4 or 5 inches dbh to those 10 or 12 inches dbh.
q	The constant ratio of the number of trees in the succeeding pairs of dbh classes in a classic uneven-aged stand; q is an acronym for quotient .
regeneration	Young trees (seedlings and saplings) which will grow to become the older trees of the future forest (i. e. , reproduction). Also, the process of forest replacement or renewal which may be done artificially by planting or seeding or naturally by natural seeding or sprouting.
regulation	The procedures whereby the stands in a forest are organized, cut, and regenerated to eventually provide a more or less constant periodic flow of goods or services (sustained yield). The two main methods are (1) area control in which the areas occupied by stands are manipulated and (2) volume control in which the stand volumes are manipulated. Forests of even-aged stands can be regulated by both methods or a combination of the two. Uneven-aged stands and forests of uneven-aged stands are usually regulated by some variant of volume control.
rotation	The number of years required to establish and grow the trees in an even-aged stand to a specified size, product, or condition at maturity.
salvage cut	Harvesting dead or dying trees or those in danger of being killed to save their economic value.
sanitation cut	Harvesting or killing trees infected by or highly susceptible to insects or diseases to protect the rest of the stand.
sapling	A non-merchantable small tree usually between 1 and 4 inches dbh.
sawlog	A log large enough to be sawed into lumber or converted into veneer; usually at least 10 to 12 inches in diameter.
sawtimber	A group of trees (stand) with many or most individual trees large enough to contain sawlogs.
seedling	A juvenile tree, usually less than breast height or less than 1 inch dbh, which has grown from seed. Also, a nursery tree grown from seed which has not been transplanted.

selection	The program of forestry practices by which uneven-aged system stands are created and maintained. Individual trees or small groups are harvested at periodic intervals (cutting cycles) of 5 to 15 years based on their species, physical condition, and degree of maturity.
shelterwood	A program of forestry practices by which an even-aged stand is created and maintained. At final harvest the parent stand is removed in two or more cuttings over several years so that new seedlings can become established beneath the cover (shelter) of the parents before their removal.
silviculture	The art, science, and practice of establishing, tending, and reproducing forest stands having desired traits. It is based upon ecological principles.
site index	A measure of forest site quality (productivity) of even-aged stands based on the total height of the dominant and codiminant trees at a specified index age (usually 50 years for natural stands and 25 years for planted stands in the South).
softwood	An imprecise term referring to trees belonging to the order Coniferales, usually evergreen, cone-bearing, and with needle or scale-like leaves such as pines, spruces, firs, cedars, etc. Baldcypress and larch are deciduous softwoods (conifers).
stand table	A tabulation of the number of trees in a stand by dbh classes. It may also contain basal areas.
stocking	Relative density expressed as a proportion of some norm. It is not synonymous with density. Examples are milacre stocking and normal stocking which are referenced, respectively, to 1000 trees per acre and the density shown for stands in normal yield tables.
stock table	A tabulation of the volume in a stand by dbh classes. It and the stand table are often combined to obtain a stand- and-stock table.
stumpage	The value or volume of a tree or group of trees as they stand in the woods uncut (on-the-stump).
sustained yield	Management of forestland to produce a relatively constant flow of timber, other goods, services, or other benefits *ad infinitum*.
timber marking	The process of designating trees to be cut or trees not to be cut.
TSI	Abbreviation for timber stand improvement. An imprecise term dealing with the improvement of a stand by removing cull trees and unwanted woody species, leaving a stand of desired species and stems of good quality. It may be accomplished by cutting, girdling, chemicals, fire, etc.
thinning	Intermediate cuts made in immature even-aged stands to reduce the number of residual stems per acre and improve their growth and quality. Several types of thinning are recognized. One is low thinning and several degrees are commonly applied in which the lower crown classes (suppressed and intermediate, and sometimes codominant) are removed and dominants and codominants are left. In uneven- aged stands, all of the types of cuts commonly applied during the life of an even-aged stand may be applied in a given selection cut and this type of thinning is best termed "free" thinning.
tree	A woody plant having a well-defined stem, a more or less definitely formed crown, and usually a total height of at least 10 feet.

uneven-aged stand — A stand containing more than two age classes of trees. Practically, age is not considered but if a plot of the number of trees by dbh class reveals a reverse-J shaped distribution, the stand is considered uneven-aged. In contrast, a similar plotting for an even-aged stand will reveal a bell- or mound-shaped distribution.

yield table — A tabulation of number of trees, basal area, volumes, etc. expected in stands of specified age, site quality, and density. Yield tables vary greatly in detail and predictive ability. Most current ones are in the form of sophisticated programs executable on personal computers.

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