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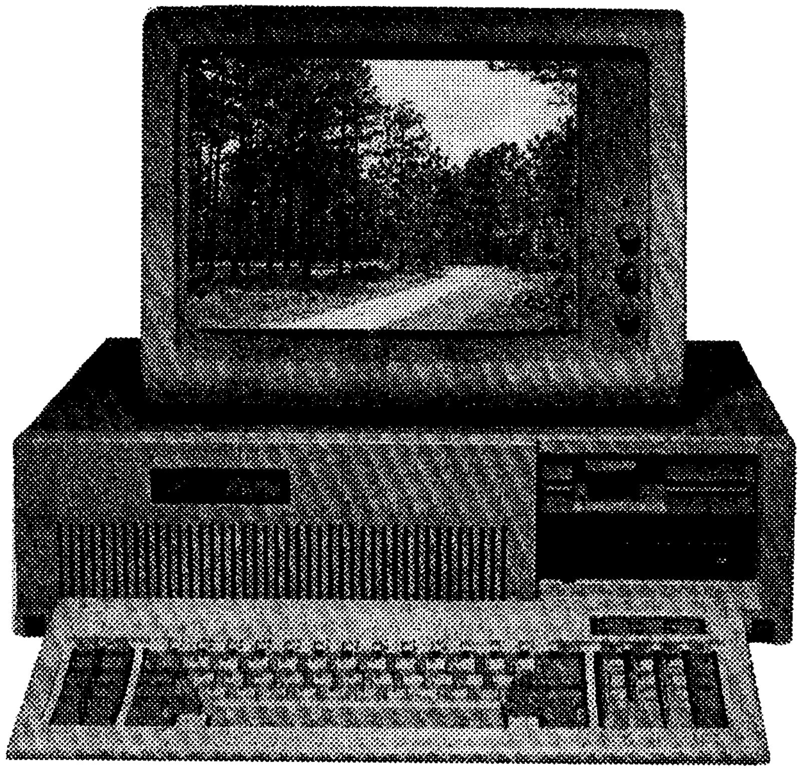
Microcomputer Software for Predicting Growth of Southern Timber Stands

Robert M. Farrar, Jr.



SUMMARY

Sixteen BASIC programs and 21 electronic spreadsheet templates for microcomputers are presented with documentation and examples of use. This software permits simulation of the growth and yield of natural stands of even-aged southern pines, uneven-aged loblolly-shortleaf and shortleaf pines, even-aged yellow-poplar, and of certain planted pine stands for a variety of site indices, thinning regimes, and management schemes. The software employs information from 14 published stand-level prediction systems. Precautions concerning use of the software are also discussed, and software source is presented. Novice knowledge of BASIC or spreadsheet use is required.

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INTRODUCTION

Southern foresters often need to predict the expected response of an existing or hypothetical timber stand to optional thinning regimes for the purpose of choosing a treatment schedule to meet a timber management objective. Stand volume and growth prediction equation systems that allow this are available for pure even-aged natural stands of four major pine species and yellow-poplar, for uneven-aged mixed loblolly-shortleaf and pure shortleaf pine stands, and for certain planted pine stands (Farrar 1986, Farrar and others 1985). All of these systems predict volume or growth values for the entire stand rather than for individual trees or by diameter classes, but most allow predictions for merchantable components: total, merchantable, sawtimber, and/or pulpwood volume and growth. Although these equation systems are relatively straightforward, they are difficult to evaluate without a programmable computer. Reference tables can be produced from these systems, but they are cumbersome to use and, unless very elaborate, often do not contain values for the specific stand conditions and treatment regime in question.

To facilitate the use of these systems, a set of BASIC programs and a set of SuperCalc and Lotus 1-2-3 electronic spreadsheet templates have been written for IBM-PC or compatible microcomputers. These are illustrated herein using test problems and examples of utility. An elementary working knowledge of BASIC or one of these spreadsheets is required. Disks are available that contain the programs or templates along with essential documentation. Within the limits of the sources for the various systems, these programs and templates enable simulation of the volume growth and yield expected for a wide variety of thinning schedules, management periods, and site indices. Site index base age is 50 years unless stated otherwise.

OVERVIEW OF PRESENT PREDICTION SYSTEMS

Several growth and yield prediction systems are available for thinned, natural stands of the major southern pines (table 1). These lump-sum simultaneous volume and growth prediction systems are quite useful, but not as versatile as stand-and-stock table systems employing a stem-profile function to predict multiple products. Nevertheless, the presently available systems permit volume and volume growth estimates for a wide variety of initial ages, growth periods, sites, and initial densities and allow simulation of the response to various thinning regimes over time. The type of thinning assumed is generally improvement-cut—low-thinning in the even-aged systems and essentially "free" thinning (Smith 1962) in the uneven-aged systems (not "selective cutting" or "high-grading"). Although stand-and-stock table predictors are not generally available, recent developments in simultaneous system modeling do allow a useful partitioning of the basal area and volume production into merchantable, sawtimber, and pulpwood components.

At the USDA Forest Service, Southern Forest Experiment Station, we have put 14 prediction systems into the cell contents of SuperCalc electronic spreadsheet software and into BASIC programs for microcomputers. Both are capable of the same tasks, but the BASIC programs enable the prediction of current and future stand volumes for only one growth period at a time, whereas the spreadsheet enables predictions for an entire rotation of thinnings or series of cutting cycles simultaneously.

PREDICTION SYSTEM SOURCES

The literature sources for the equation systems incorporated in the programs are shown in table 1 along

Robert M. Farrar, Jr. is a research forester and project leader (retired), U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, Mississippi State, MS 39762. In cooperation with: Mississippi State University, and the Mississippi Agricultural and Forestry Experiment Station, Mississippi State, MS 39762.

Table 1.—*Preprogrammed timber stand growth and yield systems available as BASIC programs and / or SuperCalc / Lotus 1-2-3 templates*

System	Input*	Output†
Natural thinned even-aged pine		
Loblolly		
(1) Brender and Clutter 1970	A1, A2, BM1, Q	BM2, BS2, M1, M2, I1, I2
(2) Sullivan and Clutter 1972	A1, A2, BT1, BT2, Q	BT2, T1, T2
(3) Murphy 1983	A1, A2, BM1, BM2, Q	BM2, BS2, M1, M2, D1, D2, I1, I2, S1, S2
Longleaf		
(4) Farrar 1979	A1, A2, BT1, Q	BT2, T1, T2, M1, M2, C1, C2, I1, I2
(5) Farrar 1985b	A1, A2, BT1, BS1, Q	BT2, BS2, T1, T2, M1, M2, C1, C2, I1, I2
Shortleaf		
(6) Murphy and Beltz 1981, Murphy 1982	A1, A2, BM1, BS1, Q	BM2, BS2, M1, M2, C1, C2, D1, D2, I1, I2, S1, S2
Slash		
(7) Bennett 1970, 1980	A1, A2, BM1, Q	BM2, M1, M2, I1, I2
Natural unthinned even-aged pine		
Longleaf		
(8) Farrar 1985a	A1, A2, TSO(A1), Q	Stand and stock tables at A1 and A2 showing trees, basal area, and volumes per 1-inch d.b.h. class and stand totals
Natural thinned uneven-aged pine		
Loblolly-shortleaf		
(9) Murphy and Farrar 1982, 1983; Farrar and others 1984	P, BM1, BS1	BM2, BS2, M1, C1, C2, D1, D2, I1, I2, S1, S2
Shortleaf		
(10) Murphy and Farrar 1985	P, BM1, BS1, Q	BM2, BS2, M1, M2, C1, C2, D1, D2, I1, I2, S1, S2
Planted thinned pine		
Loblolly		
(11) Sullivan and Williston 1977	A1, A2, BT1, Q	BT2, M1, M2
(12) Burkhart and Sprinz 1984	A1, A2, BT1, Q	BT2, M1, M2, I1, I2
Longleaf		
(13) Lohrey 1979	A1, A2, BT1, Q	BT2, T1, T2, I1, I2
Natural thinned even-aged hardwood		
Yellow-poplar		
(14) Beck and Della-Bianca 1972, 1975	A1, BM1, Q	A2, BM2, M1, M2, I1, I2

*Input legend: A1 = initial age; A2 = final age; P = growth period length; BT1 = initial total basal area (BA); BM1 = initial merch. BA; BS1 = initial sawtimber BA; TSO(A1) = surviving trees/acre (d.b.h. ≥0) at A1; Q = site index

†Output legend: BT2 = final total BA; BM2 = final merch. BA; BS2 = final sawt. BA; T1 = initial total cu. ft. vol.; T2 = final total cu. ft. vol.; M1 = initial merch. cu. ft. vol.; M2 = final merch. cu. ft. vol.; C1 = initial sawt. cu. ft. vol.; C2 = final sawt. cu. ft. vol.; D1 = initial Doyle fbm; D2 = final Doyle fbm; I1 = initial International ¼-inch fbm; I2 = final International ¼-inch fbm; S1 = initial Scribner fbm; S2 = final Scribner fbm

with the input required to exercise a system for one growth period and the output provided by execution of the program for that growth period. Note that the systems vary somewhat in their capability to predict various merchantable components of the stand, but all provide for at least one cubic-foot volume component. Also, the merchantability specifications vary by system. These specifications are sketched for each program in the appendix, but the user should refer to the specific supporting publications for details and unique features and for limitations on stand conditions.

The basic operating features of a typical prediction system for an even-aged stand for one growth period and a given site index are shown in figure 1. Given an initial stand age, a final stand age, a site index, a cur-

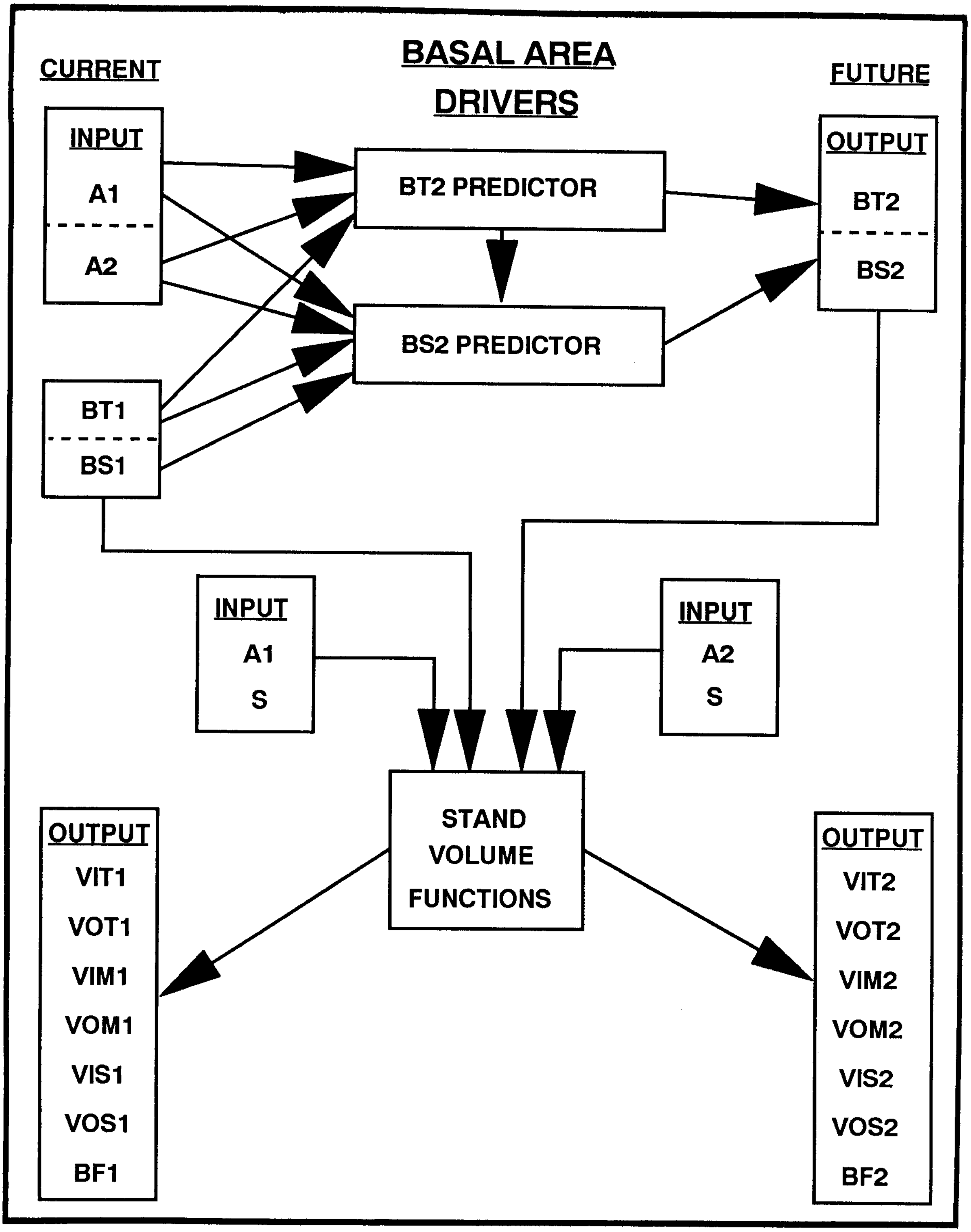

Figure 1. — *Schematic of function of a simultaneous-type prediction system (system 5 in tables 1, 2).*

rent (initial) merchantable basal area, and an initial sawtimber basal area, the system permits: (1) predictions of merchantable and sawtimber cubic-foot volumes and one or more board-foot volumes at initial stand age and (2) predictions of the projected merchantable and sawtimber basal areas and stand volumes at final stand age. Note that the sawtimber basal area is a subset of the merchantable basal area. Net growth is estimated by subtracting an initial value from a final value. For example, net Doyle volume growth would be (D2-D1). Also, an estimate can be made of the cubic-foot volume in subsawtimber or pulpwood as (M1-C1) or (M2-C2), and net pulpwood growth can be estimated as (M2-C2)-(M1-C1). A thinning regime is simulated over a rotation by evaluating a set of specified initial stand conditions for a consecutive series of growth periods. Examples will be used to illustrate this later.

BASIC PROGRAMS

It is assumed that the reader has a working knowledge of BASIC. All programs are written in IBM BASIC version 3.30 but stored as ASCII files so they can be easily modified via a text editor (word processor) in case one wishes to customize a program and/or add or subtract predictors available in the source publications. All programs contain only elementary BASIC statements and should be easily adaptable to run under most BASIC interpreter software. The available programs are shown in table 2.

These programs have been purposely kept simple. They were first developed to run on a TI-59 programmable handheld calculator (now outdated) and later modified for microcomputer use by employing a simple, single-screen BASIC program format that displays information for a single growth period.[1] Note that a program may not contain all of the prediction capability contained in the published source. When a number of predictors were available in a given source, only those thought to be of most interest or utility were usually included in the program. Of course, the user is free to modify the program to include additional prediction functions or to make the program as elaborate as desired, including routing output automatically to a printer.

These BASIC programs allow a prediction system to be exercised for a single specified growth period in a given run of the program. Typically, current stand age, site index, and density and growth period length are input, and output is predicted current, future, and growth values for basal area, cubic feet, and board feet for that period. Thinning regimes for a rotation can be simulated by updating the input and running a program several times. A companion set of SuperCalc/Lotus 1-2-3 templates containing all of these prediction systems, except YOUNGLLA.BAS, is also available. These templates (to be discussed later) allow a prediction system to be exercised for a complete thinning regime over an entire rotation on a single spreadsheet in a single run.

All BASIC programs, except one, are screen-oriented but may be printed by the shift-PrtSc keys on most IBM PC's or compatibles. CAUTION: If the screen displays the BASIC function-key definitions at the bottom, turn this screen display line off by typing KEY OFF before printing the screen. Otherwise, the printer may become disoriented and print garbage when it tries to print this function-key definition line.

One program, YOUNGLLA.BAS, is printer-oriented, and the printer must be turned on before this program is run.

Another program, EAYPG2A.BAS, must be operated using growth periods that are a multiple of 5 years; predictions must be made every 5 years, and thinning intervals must be multiples of 5 years.

Information sources for the programs are as shown in tables 1 and 2 and referenced in the literature cited section. Some limited information about the underlying systems is found in the appendix and in Farrar (1986) and Farrar and others (1985). However, the user is encouraged to obtain a copy of each source publication for reference to details on definitions, study limits and area of application, merchantability specifications and limits, etc.

PROGRAM EXAMPLES

The following examples show how the BASIC programs may be used to predict growth of a timber stand during a given time period. The first program example will duplicate a portion of the first thinning regime simulation via spreadsheet (to be presented later) so that the same results by each means can be verified.

Program Example 1

In the first example (fig. 2), we exercised the system of Murphy (1983) shown as system 3 in tables 1 and 2. In this case, we assume that we have a 30-year-old stand of even-aged natural loblolly pine in the West Gulf (site index 90) with 80 square feet of merchantable basal area that also contains 4 square feet of saw-

[1]The author is indebted to Paul A. Murphy (principal mensurationist, Southern Forest Experiment Station, Monticello, AR) for an initial TI-59 program and to Louis D. Rainey (forester, Deltic Farm and Timber Company, El Dorado, AR) for a prototype BASIC program.

Table 2.—*BASIC programs and/or SuperCalc/Lotus 1-2-3 spreadsheet templates for stand-level southern timber growth prediction systems*

Species	Information source	BASIC program	SuperCalc/Lotus template
Natural thinned even-aged pine			
Loblolly	(1) Brender and Clutter 1970	B&CLOBA.BAS	B&CLobIT.ext*
	(2) Sullivan and Clutter 1972	S&CLOBA.BAS	S&CLobIT.ext
	(3) Murphy 1983-Int. ¼-inch	EALOBG2A.BAS	LobGYITx.ext
	Murphy 1983-Doyle	EALOBG2A.BAS	LobGYDTx.ext
	Murphy 1983-Scribner	EALOBG2A.BAS	LobGYSTx.ext
Longleaf	(4) Farrar 1979	LLSO156A.BAS	L1p156IT.ext
	Farrar 1979 w/dry wt. est.	LL156WTA.BAS	
	(5) Farrar 1985b	EALLGY2A.BAS	L1pGYITx.ext
	Farrar 1985b w/dry wt. est.	LLGYWTA.BAS	
Shortleaf	(6) Murphy and Beltz 1981, Murphy 1982-Int. ¼ inch	EASHGY2A.BAS	Sh1GYPIT.ext
	Murphy and Beltz 1981, Murphy 1982-Doyle	EASHGY2A.BAS	Sh1GYPDT.ext
	Murphy and Beltz 1981, Murphy 1982-Scribner	EASHGY2A.BAS	Sh1GYPST.ext
Slash	(7) Bennett 1970, 1980	EASLAG2A.BAS	NSlashIT.ext
Natural unthinned even-aged pine			
Longleaf	(8) Farrar 1985a	YOUNGLLA.BAS	
Natural thinned uneven-aged pine			
Loblolly/shortleaf	(9) Murphy and Farrar, 1982, 1983, Farrar and others 1984-Int. ¼ inch	UALSGY2A.BAS	SelGYITx.ext
	Murphy and Farrar, 1982, 1983, Farrar and others 1984-Doyle	UALSGY2A.BAS	SelGYDTx.ext
	Murphy and Farrar, 1982, 1983, Farrar and other 1984-Scribner	UALSGY2A.BAS	SelGYSTx.ext
Shortleaf	(10) Murphy and Farrar 1985-Int. ¼ inch	UASHGY2A.BAS	UShlGYIT.ext
	Murphy and Farrar 1985-Doyle	UASHGY2A.BAS	UShlGYDT.ext
	Murphy and Farrar 1985-Scribner	UASHGY2A.BAS	UShlGYST.ext
Planted thinned pine			
Loblolly	(11) Sullivan and Williston 1977	LOBPLTA.BAS	LobPltIT.ext
	(12) Burkhart and Sprinz 1984	B&SLBPLA.BAS	B&SLbPlt.ext
Longleaf	(13) Lohrey 1979	LLPPLTA.BAS	LlPltITx.ext
Natural thinned even-aged hardwood			
Yellow-poplar	(14) Beck and Della-Bianca 1972, 1975	EAYPG2A.BAS	NY-PITx.ext

*.ext = ".cal" for SuperCalc, ".wks" or ".wk1" for Lotus 1-2-3.

```
*****************************************************************************

            E-A LOBLOLLY STAND PROJECTION -  WEST  GULF  AREA  -

                              ------------- per acre -------------

                                        SITE INDEX  90

                              CURRENT       PROJECTED       10 YEARS
                               VALUE         10 YEARS        GROWTH

STAND AGE                     30             40              10
MERCH. BA                     80             107             27
SAWTIMBER BA                  4              52              48
MERCH. C.F. VOL. (i.b.)       1803           2906            1103
SAWT. C.F. VOL. (i.b.)        87             1222            1135
DOYLE B.F. VOL.               500            4958            4457
SCRIB. B.F. VOL.              570            7132            6562
INT.-1/4 B.F. VOL.            623            8299            7676

*****************************************************************************
Ok
```

Figure 2. — *Illustration of output of a BASIC program for the West Gulf loblolly pine predictor (system 3 in tables 1, 2).*

timber basal area. We want to project this stand for 10 years to age 40 and estimate its current volumes, its future basal areas and volumes, and its 10-year growth. These are accomplished by running program EALOBG2A.BAS, entering the above input at the screen prompts, and printing the resulting answer screen (fig. 2). The projection estimates that the stand will grow from 1,803 cubic feet and 623 board feet (International ¼-inch Rule) at age 30 to have, at age 40, 107 square feet of merchantable basal area and 2,906 cubic feet containing 52 square feet of sawtimber basal area and 8,299 board feet. The suggested average annual growth rates are over 110 cubic feet and nearly 768 board feet per acre.

Program Example 2

In the second example, we exercise the program for young unthinned natural stands of even-aged longleaf pine (Farrar 1985a), assuming that we have a stand 10 years old (site index 80) and containing 900 trees per acre (total, including those in and out of the grass stage). We have specified in answering the screen prompts for the program YOUNGLLA.BAS that we want to exercise the program from age 10 to 20 by 5-year intervals, for site index 80 only, and only for 900 initial trees per acre. Figure 3 shows the input and resulting output per acre for stand ages 10, 15, and 20 years. Note that at age 10, there are 900 surviving trees, and 453 are still in the grass stage. By age 15, there are still 899 trees (99.9 percent survival), but only 16 are still in the grass stage, and by age 20 there are 893 surviving trees, and only 1 is still in the grass stage. This rapid stand development is further reflected in the basal area and volume changes. For example, the total cubic-foot volume i.b. (inside bark) escalates from only about 26 cubic feet at age 10 to about 43 at age 15 and to 1,180 cubic feet by age 20. Note that information is also given at each age on the number of trees, basal area, crown ratio (CR), and average height, as well as volumes, for each 1-inch d.b.h. class present. Further, at each age, information is given on the arithmetic and quadratic mean d.b.h., "a," "b," and "c" parameters of the Weibull cumulative density function, and mean crown ratio for the stand. This program does not give board-foot estimates because, generally, within the 20-year maximum age limit of the underlying data, very few sawtimber-size trees were observed.

```
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 3. —*Illustration of output of a BASIC program for the young unthinned longleaf pine system (system 8 in tables 1, 2).*

```
*************************************************************************

                E-A YELLOW-POPLAR STAND PROJECTION - SOUTHEAST  -

                           ------------- per acre -------------

                                      SITE INDEX  90

                             CURRENT      PROJECTED      5 YEARS
                              VALUE        5 YEARS       GROWTH

STAND AGE                    40             45             5
MERCH. BA                    80             89             9
MERCH. C.F. VOL. (o.b.)      2824           3325           501
INT.-1/4 B.F. VOL.           5140           7390           2250

*************************************************************************
Ok
```

Figure 4. —*Illustration of output of the BASIC program for the yellow-poplar system (system 14 in tables 1, 2).*

Program Example 3

The last BASIC example (fig. 4) deals with the prediction system by Beck and Della-Bianca (1972, 1975) for natural even-aged stands of yellow-poplar (system 14 in tables 1, 2). Figure 4 shows the output from exercising the program (EAYPG2A.BAS) for one 5-year growth period for a stand initially 40 years old (site index 90) and containing 80 square feet of merchantable basal area. The suggested annual growth is nearly 2 square feet, over 100 cubic feet containing 450 board feet per acre. Note that this program requires growth periods to be input as the number of 5-year periods and that no independent estimates are possible for sawtimber because they are imbedded in the merchantable stand estimates.

SUPERCALC/LOTUS TEMPLATES

The available spreadsheet templates are shown in table 2. Note that a template may not contain all of the prediction capability contained in the information source. When a number of predictors were available in a given source, only those predictors thought to be of most interest or utility were usually included in the template.

All templates were written for SuperCalc, version 5, and may not operate properly with older versions of SuperCalc. They were stored on disk as both SuperCalc ".cal" files and as Lotus 1-2-3 ".wks" and ".wk1" files under these options in SuperCalc. These templates enable one to exercise a prediction system for a specific thinning regime over an entire rotation on a single spreadsheet with one set of initial manual input. A companion disk of BASIC programs is available, but these programs enable one to simulate for only one growth period at a time and require several runs, each requiring manual input, to simulate a thinning regime for a rotation.

Two new spreadsheets, in addition to the 19 published by FORS in 1985 and 1986 (see Farrar 1986, Farrar and others 1985), are presented: S&CLobIT.cal for natural thinned even-aged loblolly pine in the southeast and B&SLbPIT.cal for planted old-field loblolly pine in the Virginia Piedmont.

All templates have been redesigned to read from top to bottom without any line-wraps (hence the T acronym in each filename.cal). The older FORS versions were designed to be read laterally and were hard to manipulate and follow on the screen (see Farrar 1986, Farrar and others 1985). The modified template format simplifies the information flow and enables one to modify spreadsheet inputs and easily follow the results on the screen without resorting to printing to comprehend the effects.

Note that one template, NY-PITx.cal, must be operated using growth periods that are a multiple of 5 years, predictions must be made every 5 years, and thinning intervals must be multiples of 5 years.

For other pertinent comments about the prediction systems incorporated in the templates, see the Farrar (1986) and Farrar and others (1985) FORS COMPILER articles.

Information sources for the templates are shown in tables 1 and 2. The user is encouraged to obtain a copy of each for reference to details on definitions, study limits and area of application, merchantability specifications and limits, etc.

SPREADSHEET EXAMPLES

The examples that follow illustrate how the templates can be used to predict production for a thinning regime over a rotation, simulate management alternatives for comparison purposes, and emphasize the features of certain systems. These example are the same as those used in the earlier FORS COMPILER article (Farrar and others 1985) except, as noted, where mistakes in the earlier templates have been corrected. The SuperCalc and Lotus templates are set up to operate on an Epson LQ-800 dot-matrix printer. Therefore, if the user's printer does not emulate this printer, the printer setup routines in the spreadsheet program software must be altered by the user to match those for the user's printer.

TWO SIMULATION EXAMPLES

These simulation examples are presented in figures 5 and 6. Note that the underlined values in these figures are the input that can be manipulated by the user. None of the cells in these templates are protected; the user must be certain to alter only those values underlined, otherwise functions or operations may be destroyed, resulting in errors and requiring restoration of cell contents. All cells were left unprotected for the benefit of experienced users who will want to enlarge, reduce, or otherwise alter the size and function of the templates for custom work. The

E-A WG Nat. Lob. LobGYITx.cal			STAND VALUES					P.A.I./M.A.I.				
SI(50)	AGE	STATUS	BM	MerCF	BS	SawCF	Int.1/4	BM	MerCF	BS	SawCF	Int.1/4
90	30	B-C	100.00	2246	4.00	87	623	3.33	74.88	.13	2.91	21
		A-C	80.00	1803	4.00	87	623	3.33	74.88	.13	2.91	21
		CUT	20.00	444	.00	0	0					
90	40	B-C	107.10	2906	52.40	1222	8299	2.71	110.33	4.84	113.47	768
		A-C	80.00	2180	31.00	741	5145	3.18	83.74	1.31	30.55	207
		CUT	27.10	726	21.40	481	3155					
90	50	B-C	100.82	3068	64.33	1663	11592	2.08	88.87	3.33	92.20	645
		A-C	80.00	2443	44.00	1159	8201	2.96	84.77	1.71	42.88	295
		CUT	20.82	626	20.33	505	3390					
90	60	B-C	96.89	3183	68.78	1912	13592	1.69	74.05	2.48	75.31	539
		A-C	80.00	2635	52.00	1465	10534	2.75	82.98	1.84	48.29	336
		CUT	16.89	548	16.78	447	3058					
90	70	B-C	94.20	3269	71.55	2095	15113	1.42	63.33	1.96	62.99	458
		A-C	80.00	2782	58.00	1715	12482	2.56	80.17	1.86	50.39	353
		CUT	14.20	486	13.55	380	2632					
90	75	B-C	86.24	3062	66.21	1988	14482	1.25	55.90	1.64	54.54	400
		A-C	15.00	546	15.00	483	3744	2.47	78.56	1.84	50.66	356
		CUT	71.24	2516	51.21	1504	10738					
90	80	B-C	16.53	612	16.53	540	4192	.31	13.27	.31	11.38	90
		A-C	.00	0	.00	0	0	2.33	74.47	1.75	48.21	340
		CUT	16.53	612	16.53	540	4192					
	YIELD =		186.78	5958	139.80	3857	27164					
	M.A.I. =		2.33	74.47	1.75	48.21	340					

Figure 5. — *Simulated production for a thinned, even-aged natural West Gulf loblolly pine stand (system 3 in tables 1, 2).*

U-A W. GULF	SelGYITx.cal	STAND VALUES					P.A.I./A.A.P.				
t	STATUS	BM	MerCF	BS	SawCF	Int.1/4	BM	MerCF	BS	SawCF	Int.1/4
0	B-C	40.00	1088	20.00	429	3015					
	A-C	30.00	811	13.00	265	1886					
	CUT	10.00	277	7.00	164	1130					
10	B-C	55.35	1516	34.66	794	5490	2.54	70.51	2.17	52.90	360
	A-C	35.00	950	17.00	358	2526	2.54	70.51	2.17	52.90	360
	CUT	20.35	567	17.66	436	2964					
20	B-C	61.93	1701	40.92	956	6579	2.69	75.10	2.39	59.83	405
	A-C	40.00	1088	22.00	477	3345	2.61	72.80	2.28	56.36	383
	CUT	21.93	612	18.92	479	3234					
30	B-C	68.25	1878	47.99	1143	7826	2.82	78.95	2.60	66.52	448
	A-C	46.00	1255	27.00	600	4182	2.68	74.85	2.39	59.75	405
	CUT	22.25	623	20.99	542	3645					
40	B-C	75.53	2083	54.95	1330	9071	2.95	82.74	2.80	72.93	489
	A-C	46.00	1255	32.00	726	5032	2.75	76.82	2.49	63.04	426
	CUT	29.53	827	22.95	604	4039					
50	B-C	75.53	2083	60.37	1477	10050	2.95	82.74	2.84	75.10	502
	A-C	46.00	1255	32.00	726	5032	2.79	78.01	2.56	65.46	441
	CUT	29.53	827	28.37	751	5018					
60	B-C	75.53	2083	60.37	1477	10050	2.95	82.74	2.84	75.10	502
	A-C	46.00	1255	32.00	726	5032	2.82	78.80	2.60	67.06	451
	CUT	29.53	827	28.37	751	5018					
70	B-C	75.53	2083	60.37	1477	10050	2.95	82.74	2.84	75.10	502
	A-C	46.00	1255	32.00	726	5032	2.84	79.36	2.64	68.21	458
	CUT	29.53	827	28.37	751	5018					
80	B-C	75.53	2083	60.37	1477	10050	2.95	82.74	2.84	75.10	502
							2.85	79.78	2.66	69.07	464
CUT =		192.66	5388	172.62	4478	30064					
CHANGE =		35.53	994	40.37	1048	7035					
YIELD =		228.19	6382	212.99	5526	37099					
A.A.P. =		2.85	79.78	2.66	69.07	464					

Figure 6. — *Simulated production for a thinned selection stand of West Gulf loblolly-shortleaf pine, SI = 90 (system 9 in tables 1, 2).*

recalculate option in the particular spreadsheet program software can be activated to enable quickly viewing the effect of changes in input.

In the first example (fig. 5), we start with a 30-year-old natural loblolly stand (site index 90) with 100 square feet of merchantable basal area (d.b.h. >3.5 inches). We thin this stand from below initially and every 10 years up through age 70 and leave 80 square feet after each cut. The cuts are simulated by manipulating the after-cut basal area inputs at each age. At age 75, we make a seed tree cut to leave 15 square feet, and at age 80, we harvest the seed trees. In the first cut at age 30, we do not remove any sawtimber; in subsequent cuts we try to have at least an operable sawtimber cut (at least 1 Mbf) but remove no more than one-fourth to one-third of the sawtimber in any one cut up to the seed tree cut. The after-cut basal areas are manual inputs but could be programmed to represent the before-cut basal areas minus some fraction of the previous period growth. However, such programmed inputs should always be reviewed to be sure they are logical. We obviously cannot cut more sawtimber than merchantable basal area, because the sawtimber basal area is a subset of the merchantable basal area, but a programmed input might result in such an illogical operation. At each age, the spreadsheet calculates the basal areas and volumes in the before-cut stand and the cut stand and the volumes in the after-cut stand. Using the after-cut and successive before-cut values, the periodic annual increments (p.a.i.'s) are calculated. By summing the cut values, the yield is obtained, and the mean annual increments (m.a.i.) is obtained by dividing the yield by the rotation.

For this even-aged loblolly stand, we note that the p.a.i. for cubic feet and board feet peaked at about age 40. If it is assumed that approximately 80 cubic feet i.b. equals a cord, then the m.a.i. suggests fair production over the rotation of about 0.9 cord per acre per year containing about 340 board feet, International ¼-inch Rule.

Note that the after-cut input and predictions at age 30 and the projected before-cut information at age 40 match the information in figure 2, which illustrated this prediction system as a BASIC program.

In the second example (fig. 6), we assume that we have an uneven-aged stand of loblolly-shortleaf (site index 90) with 40 square feet of initial merchantable basal area (d.b.h. >3.5 inches) and 20 square feet of sawtimber basal area (d.b.h. >9.5 inches). We want to manage this stand on a 10-year cutting cycle and build growing stock to a desired level using selection management techniques (Farrar 1981, 1984, 1989; Reynolds 1959, 1969). We can do this by cutting less than growth, until at the 40th year, a before-cut stand exists containing about 75 square feet of merchantable and 60 square feet of sawtimber basal area. This before-cut stand illustrates the basal area and volume structure generally recommended by Reynolds as desirable at the end of a cutting cycle. We obtained the current volumes and the projected basal areas and volumes using the functions developed by Farrar and others (1984) and Murphy and Farrar (1982, 1983). We see that a residual density of about 46 square feet of merchantable basal area containing about 32 square feet of sawtimber basal area will return to the recommended levels in 10 years. This scenario suggests that, barring catastrophes, the indicated cut at the end of the 50th year and the associated average annual production (a.a.p.) should be obtainable for an infinite series of cycles thereafter. Over the 80-year period, the indicated m.a.i.'s are about 80 cubic feet of merchantable volume containing about 460 fbm (board foot measure, or board feet) International ¼-inch Rule. Note that most of the cubic-foot production (about 87 percent) is in sawtimber.

EXPECTED YIELD OF THINNED NATURAL STANDS ON AVERAGE SITES

To obtain some indication of the growth and yield potentially obtainable on average sites under assumed standard management regimes, an example was calculated for each of the four major southern pines in an even-aged situation (figs. 7 through 10). In each case, we leave 80 square feet of merchantable (or total) basal area at each cut prior to the regeneration period and assume an 80-year rotation using natural regeneration: shelterwood for longleaf and seed tree for the other three species. We generally assume the same additional constraints assumed in the first example in figure 5 for the even-aged loblolly stand. Note that the average site index is assumed for each species, not the same site index. An assumed initial sawtimber basal area of only 4 square feet is rather low for loblolly pine (site index 90), but this value was chosen to give direct comparisons with longleaf and shortleaf pines, which are likely to have such a sawtimber basal area on their average sites. These examples are mainly for information and demonstration of system capabilities and are not really suitable for species comparisons. Such comparisons are legitimate only within a species because we do not usually know, for example, what the site index is for any other species on a given soil area occupied by loblolly pine (site index 90), unless we have information from adjacent and validly comparable stands of the other species growing on that same soil area. Given a sufficiently large area, site-index averages for soil series may be valid, but for specific small areas (stands), the

E-A GA Piedmont B&CLobIT.cal			STAND VALUES					P.A.I./M.A.I.				
SI(50)	AGE	STATUS	BM	MerCF	BS	SawCF	Int.1/4	BM	MerCF	BS	SawCF	Int.1/4
90	30	B-C	100.00	2785	n.a.	n.a.	6694	3.33	92.85	n.a.	n.a.	223
		A-C	80.00	2263			5544	3.33	92.85			223
		CUT	20.00	523			1150					
90	40	B-C	110.29	3434	n.a.	n.a.	11017	3.03	117.14	n.a.	n.a.	547
		A-C	80.00	2547			7590	3.26	98.92			304
		CUT	30.29	888			3427					
90	50	B-C	103.43	3473	n.a.	n.a.	12346	2.34	92.59	n.a.	n.a.	476
		A-C	80.00	2734			9164	3.07	97.65			338
		CUT	23.43	739			3183					
90	60	B-C	99.10	3498	n.a.	n.a.	13320	1.91	76.46	n.a.	n.a.	416
		A-C	80.00	2866			10390	2.88	94.12			351
		CUT	19.10	632			2930					
90	70	B-C	96.11	3517	n.a.	n.a.	14063	1.61	65.08	n.a.	n.a.	367
		A-C	80.00	2965			11366	2.70	89.97			354
		CUT	16.11	552			2697					
90	75	B-C	87.15	3254	n.a.	n.a.	13012	1.43	57.94	n.a.	n.a.	329
		A-C	15.00	632			2865	2.61	87.84			352
		CUT	72.15	2622			10146					
90	80	B-C	18.05	760	n.a.	n.a.	3545	.61	25.54	n.a.	n.a.	136
		A-C	.00	0			0	2.49	83.94			338
		CUT	18.05	760			3545					
	YIELD =		199.14	6715	n.a.	n.a.	27079					
	M.A.I. =		2.49	83.94			338					

Figure 7. — *Simulated production for a thinned, even-aged natural Georgia Piedmont loblolly pine stand (system 1 in tables 1, 2).*

error can be quite large (± two 10-foot site index classes). The best guide is local productivity experience with several species on the soils in question. Further, the various species prediction systems were often developed in different locales and may not be comparable due to differing geographic races and climates.

Considering that, inspection of figures 7 through 10 nevertheless reveals some interesting information:

(1) The yield for loblolly is greatest, as might be inferred from its higher site index, and note that slash pine (site index 80) had a lower sawtimber yield than longleaf (site index 70). Longleaf appears to be a better producer during the later stages of the rotation.

(2) For loblolly, shortleaf, and slash, the p.a.i. peaks for both cubic feet and board feet at about age 40, whereas for longleaf (although the cubic-foot peak was near age 40), the sawtimber volume p.a.i. peaks later, at about age 60. This may be due to inherent species differences.

(3) The longleaf and shortleaf systems here allow for separate estimates of sawtimber production (as do the West Gulf loblolly and two uneven-aged pine systems), whereas the loblolly and slash systems do not.

In the latter two systems (and in the yellow-poplar and 1979 longleaf systems), sawtimber predictions

LlpGYITx.CAL   Stand: Example   Strategy: Lv. 80 RBT & Cut 25 to 30 % BS

			STAND VALUES (per acre)						P.A.I. / M.A.I.			
SI(50)	AGE	STATUS	BT	TotCF	MerCF	BS	SawCF	Int.1/4	TotCF	MerCF	SawCF	Int.1/4
70	30	b-c	100.00	2073	1932.59	4.00	69	397	69.11	64.42	2.31	13
		a-c	80.00	1667	1558.87	4.00	69	397	69.11	64.42	2.31	13
		cut	20.00	406	373.72	.00	0	0				
70	40	b-c	116.29	2884	2800.85	26.34	579	3491	121.66	124.20	50.92	309
		a-c	80.00	2001	1950.02	18.00	396	2367	82.25	79.36	14.46	87
		cut	36.29	883	850.83	8.34	183	1124				
70	50	b-c	108.30	3002	2959.83	53.32	1352	8329	100.04	100.98	95.65	596
		a-c	80.00	2233	2205.63	40.00	1016	6212	85.81	83.69	30.70	189
		cut	28.30	769	754.19	13.32	337	2117				
70	60	b-c	103.17	3079	3055.90	73.76	2061	12821	84.64	85.03	104.50	661
		a-c	80.00	2402	2386.08	55.00	1538	9502	85.61	83.91	43.00	268
		cut	23.17	677	669.83	18.76	522	3319				
70	70	b-c	99.59	3134	3120.23	82.05	2457	15352	73.24	73.42	91.89	585
		a-c	60.00	1911	1904.66	60.00	1799	11153	83.85	82.41	49.98	313
		cut	39.59	1224	1215.57	22.05	658	4198				
70	75	b-c	68.20	2211	2204.77	68.20	2102	13079	60.04	60.02	60.54	385
		a-c	30.00	991	990.34	30.00	927	5657	82.26	80.92	50.69	318
		cut	38.20	1220	1214.42	38.20	1174	7423				
70	80	b-c	35.47	1189	1187.94	35.47	1123	6882	39.56	39.52	39.13	245
		a-c	.00	0	.00	.00	0	0	79.59	78.33	49.97	313
		cut	35.47	1189	1187.94	35.47	1123	6882				
Yield =			221.03	6367	6267	136.14	3997	25063				
M.A.I. =			2.76	79.59	78.33	1.70	49.97	313				

Figure 8. — *Simulated production for a thinned, even-aged natural East Gulf longleaf pine stand (system 5 in tables 1, 2).*

are imbedded in the merchantable stand predictions. Artifacts of this imbedding can be seen in these systems in the SuperCalc output. In the slash pine example (fig. 10) at age 30, the after-cut stand has a predicted board-foot volume that is actually 6 board feet more than the before-cut volume—a logical impossibility that is bothersome in simulations of thinning regimes and best handled by ignoring it. This problem is usually minor and disappears as stand age increases. The SuperCalc programs are set up to redefine any such negative differences as zero.

Also note that in the slash system none of the indicated sawtimber cuts that occur before the seed-tree cut meet our minimum merchantable cut of 1,000 board feet. Similarly, this, too, is an artifact of the sawtimber predictions being imbedded in the merchantable stand predictions. In actual practice, these sawtimber removals would be either sold as pulpwood (if any sawtimber trees really needed to be cut), or sawtimber cutting would be delayed until sufficient volume was available in needed removals for a minimum operable sawtimber cut.

For an uneven-aged example, see the second example in figure 6. The suggested m.a.i. for the uneven-aged stand over an 80-year period (site index 90) is about 460 board feet. The predicted m.a.i. for the

E-A W.G. ShlGYPIT.cal Stand: Example Strategy:

			STAND VALUES (per acre)					P.A.I./M.A.I.				
SI(50)	AGE	STATUS	BM	MerCF	BS	SawCF	Int.1/4	BM	MerCF	BS	SawCF	Int.1/4
70	30	b-c	100.00	1794	4.00	65	333	3.33	59.80	.13	2.18	11
		a-c	80.00	1398	4.00	65	333	3.33	59.80	.13	2.18	11
		cut	20.00	396	.00	0	0					
70	40	b-c	99.11	2202	41.87	866	4718	1.91	80.48	3.79	80.03	438
		a-c	80.00	1733	31.00	634	3439	2.98	64.97	1.05	21.64	118
		cut	19.11	469	10.87	232	1279					
70	50	b-c	94.95	2389	55.90	1277	7130	1.50	65.55	2.49	64.33	369
		a-c	80.00	1972	42.00	950	5279	2.68	65.09	1.34	30.18	168
		cut	14.95	417	13.90	327	1851					
70	60	b-c	92.28	2521	60.83	1480	8381	1.23	54.95	1.88	53.01	310
		a-c	80.00	2149	49.00	1183	6677	2.44	63.40	1.43	33.99	192
		cut	12.28	372	11.83	297	1704					
70	70	b-c	90.42	2621	64.05	1629	9322	1.04	47.17	1.51	44.66	265
		a-c	80.00	2285	54.00	1365	7790	2.24	61.08	1.44	35.51	202
		cut	10.42	335	10.05	264	1532					
70	75	b-c	84.70	2497	60.60	1565	8979	.94	42.29	1.32	39.93	238
		a-c	15.00	360	15.00	368	2069	2.15	59.83	1.43	35.80	205
		cut	69.70	2137	45.60	1197	6910					
70	80	b-c	16.70	415	16.70	418	2359	.34	10.95	.34	9.90	58
		a-c	.00	0	.00	0	0	2.04	56.77	1.36	34.19	195
		cut	16.70	415	16.70	418	2359					
	YIELD =		163.16	4542	108.95	2735	15634					
	M.A.I. =		2.04	56.77	1.36	34.19	195					

Figure 9. — *Simulated production for a thinned, even-aged natural West Gulf shortleaf pine stand (system 6 in tables 1, 2).*

even-aged loblolly stand on a similar site over an 80-year rotation (fig. 5) is about 340 board feet. Why is there a difference? There are several possible reasons. Apparently, the uneven-aged stand grows better because it continuously maintains a higher average residual sawtimber basal area; this is the major probable cause. But the differences may also be due to differences in merchantability thresholds and specifications, differences in height-growth patterns due to locale and, hence, differences in tree height at the same ages (except index age) for the same site index. The differences may also be due to different study tenure and design (the uneven-aged system is based on up to 40 years of records on permanent fixed-area research plots, whereas the even-aged system is based on about a 10-year period on remeasured inventory point samples).

PRECAUTIONS

When using the programs presented here, several precautions should be observed. In general, the user should obtain a copy of the supporting publications and become familiar with their details, particularly the limits of the underlying data and the merchan-

E-A SE CP		NSlashIT.cal	STAND VALUES					P.A.I./M.A.I.				
SI(50)	AGE	STATUS	BM	MerCF	BS	SawCF	Int.1/4	BM	MerCF	BS	SawCF	Int.1/4
80	30	B-C	100.00	2802	n.a.	n.a.	3116	3.33	93.41	n.a.	n.a.	104
		A-C	80.00	2294			3122	3.33	93.41			104
		CUT	20.00	508			0					
80	40	B-C	97.29	3223	n.a.	n.a.	6700	1.73	92.95	n.a.	n.a.	358
		A-C	80.00	2705			6125	2.93	93.29			168
		CUT	17.29	519			576					
80	50	B-C	93.56	3435	n.a.	n.a.	8946	1.36	73.09	n.a.	n.a.	282
		A-C	80.00	2985			8179	2.62	89.25			190
		CUT	13.56	450			768					
80	60	B-C	91.15	3584	n.a.	n.a.	10484	1.11	59.91	n.a.	n.a.	231
		A-C	80.00	3189			9665	2.37	84.36			197
		CUT	11.15	396			819					
80	70	B-C	89.47	3695	n.a.	n.a.	11605	.95	50.62	n.a.	n.a.	194
		A-C	80.00	3342			10788	2.16	79.54			197
		CUT	9.47	353			817					
80	75	B-C	84.29	3569	n.a.	n.a.	11648	.86	45.34	n.a.	n.a.	172
		A-C	15.00	759			3995	2.08	77.26			195
		CUT	69.29	2810			7654					
80	80	B-C	17.49	885	n.a.	n.a.	4457	.50	25.30	n.a.	n.a.	92
		A-C	.00	0			0	1.98	74.01			189
		CUT	17.49	885			4457					
	YIELD =		158.25	5921	n.a.	n.a.	15090					
	M.A.I. =		1.98	74.01			189					

Figure 10. — *Simulated production for a thinned, even-aged natural Southeast slash pine stand (system 7 in tables 1, 2).*

tability specifications. Comments on other specific precautions follow.

Projection Period Length

With most systems, it is prudent to simulate a thinning to leave a reduced basal area at intervals (growth periods) no longer than 5 to 10 years because the underlying studies generally used a 5- or 10-year thinning and remeasurement cycle on the permanent plots involved and thereby exclude long-term mortality. The net growth observed during these short periods may not reflect the mortality that might occur during longer periods. Thus, some of the basal area drivers will predict final basal areas and, hence, volumes that are obviously too high if an unthinned condition is simulated for too long a period. In other words, it is safer to simulate a regime from age 20 to 50 by thinning every 5 or 10 years to leave after-cut basal areas lower than before-cut basal areas at each thinning than it is to simulate from age 20 to 50 with no thinning at all.

Sawtimber Volumes and Growth

Most of the systems are based on the results of one or two relatively short growth periods, and although they may predict total or merchantable cubic-foot volume and growth very well, they probably do not predict International ¼-inch volumes and growth quite as well. They also probably give even poorer estimates of Scribner and Doyle volumes and growth. This is suspected because the underlying stands generally have not been maintained at specific residual densities by periodic cutting for sufficient time to develop d.b.h. distributions characteristic of their residual density regime. To illustrate, consider a 40-year-old stand with 120 square feet of BM (merchantable basal area) that is cut to leave 60 square feet and then remeasured at age 45. In contrast, consider a 45-year-old stand that was repeatedly cut every 5 years from age 15 through age 40 to leave 60 square feet at each cut. Both stands would probably have similar merchantable cubic-foot volumes at ages 40 and 45, and their 5-year cubic-foot growth from age 40 to 45 probably would be similar. But it is doubtful that they would have the same Doyle volumes or 5-year Doyle growth. International ¼-inch volumes and growth are probably the best board-foot estimates because this log rule, similar to cubic-feet estimators, is not as sensitive to tree size as are the Doyle and Scribner log rules.

A possible exception is the system for uneven-aged loblolly-shortleaf stands. This system was developed from 59 stands that were under continuous selection management for time periods of 25 to 40 years. Therefore, this system probably does a good job of predicting all volumes and growth for long-term selection management on average sites. Conversely, it is not expected to do a good job in the initial 5 to 10 years of management of very irregular, poorly stocked stands.

Negative Sawtimber Volumes

An annoying but minor interpretation problem sometimes arises when sawtimber growth and yield are simulated at young ages under thinning regimes in some systems. The predicted volume for a relatively high basal area before cutting can be less than the stand volume predicted for a lower basal area after cutting. The problem is associated with some systems where sawtimber predictors use only total or merchantable basal area estimates, and separate estimates of sawtimber basal areas are not provided. This apparently occurs because sawtimber volume predictions reflect the effect of sudden ingrowth in young stands. This ingrowth effect seems related to total or merchantable basal area such that sawtimber volume peaks at medium densities in young stands and at increasingly higher densities as age increases. In a thinning simulation, the effect can be that at a given early age, less sawtimber volume is predicted for an initial basal area than is predicted for a lower residual basal area, resulting in a logical impossibility.

This problem is illustrated in figure 10 where Bennett's (1970, 1980) system is employed to simulate a thinning regime in natural slash pine where the site index is 80. Here, we see that in the initial thinning at age 30, 3,116 board feet are predicted to be present before cut, but 3,122 board feet are predicted after cut, with a predicted cut of –6 board feet. This problem can also occur in the system by Farrar (1979) for thinned natural longleaf pine stands. However, as above, the effect is typically minor, and the problem disappears as stand age increases. The problem can be ignored when it occurs by assuming that the stand has the same sawtimber volume before and after cutting at a given age and that the sawtimber cut is zero.

Total or Merchantable Basal Area Versus Sawtimber Basal Area

When using systems that allow manipulation of the total or merchantable basal area and the sawtimber basal area, it must be remembered that the sawtimber basal area is a subset of the total or merchantable basal area. Therefore, it is logically impossible to remove more sawtimber than total or merchantable basal area in a simulated cut. However, the user must be careful in making after-cut basal area inputs to avoid specifying such resulting unreasonable cut basal areas because the template structure does not prevent such errors. There are three such mistakes in figure 6, which illustrates use of system 3, in the FORS COMPILER article (Farrar and others 1985). The illogical cut specifications were corrected in the system 3 templates, and the corrected output is illustrated in figure 5.

Alternatives Versus Forecasts

Stand volume and growth prediction systems such as those presented are most properly used as a means for choosing among alternatives for the purpose of prescribing a stand treatment schedule. For example, they can be used to compare thinning schedule "A" with schedule "B" to see which one predicts the greatest volume yield, highest growth rates for certain volume components during specified periods, earliest sawtimber cuts, etc. In other words, they are suited to answering "what if" questions. They are not well suited to forecasting the actual production obtainable from a specific forest property due to the high variability usually present in such a property in terms of stand age, site index, and density. Such forecasters are better based on periodic timber inventories on the property and cutting records. If this information is not available, predictions can be used for forecasts, but the user should be aware that they may not be accurate. The best accuracy will be obtained if stands are stratified into classes as narrow as feasible using stand age, site index, and density criteria of the prediction system and if projections are restricted to short periods. Even after these precautions, the systems may overestimate observed production in individual operational stands by 10 to 50 percent.

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APPENDIX

Program/Template Notes

The 16 BASIC programs for the prediction systems shown in table 2 are available from the Southern Forest Experiment Station as a set of ASCII files on floppy disk. They were written in IBM BASIC 3.30 but should run under most BASIC interpreters (e.g., MicroSoft, GWBASIC, etc.) with little or no modification.

All of the 21 spreadsheet templates for the prediction systems shown in table 2 are also available as either SuperCalc ".cal" or Lotus 1-2-3 ".wks" (or ".wk1") files, or both, from the Southern Forest Experiment Station as sets on floppy disks. The particular version of SuperCalc used to develop both sets of templates was version 5.0, and it was run on an IBM PS2/M60 microcomputer under IBM PC-DOS 3.30. Therefore, it is possible that these templates may not function properly with older versions of SuperCalc. However, the cell contents of each program could be inserted into any other electronic spreadsheet that has equal or better computation and function programming capabilities. A printed listing of any template is available upon request. The procedure for obtaining sets of programs or templates is given at the end of this section.

Specific program/template notes follow. The system numbers are listed and referenced in tables 1 and 2. Site-index base age is 50 years unless otherwise stated. Illustrative BASIC program outputs for systems 3, 8, and 14 are given in figures 2, 3, and 4, respectively. Illustrative SuperCalc spreadsheet outputs for systems 3, 9, 1, 5, 6, and 7 are given in figures 5, 6, 7, 8, 9, and 10, respectively. These latter are the same examples as those given in the Farrar (1986) and Farrar and others (1985) FORS COMPILER articles. The rest of the templates mentioned in those two articles are duplicated again in the new format in the new templates.

1. *Georgia Piedmont even-aged loblolly* (Brender and Clutter 1970)—Age, site index, and merchantable basal area can be independently manipulated within limits. Volume output in merchantable cubic feet (o.b.) and board feet, International ¼-inch Rule. Sawtimber basal area is imbedded and cannot be independently manipulated in the merchantable basal area.

2. *Southeast even-aged loblolly* (Sullivan and Clutter 1972)—Age, site index, and total basal area can be independently manipulated within limits. Volume output in total cubic feet (i.b.) only.

3. *West Gulf even-aged loblolly* (Murphy 1983)—Age, site index, merchantable basal area, and sawtimber basal area can be independently manipulated within limits. Volume output in merchantable and sawtimber cubic feet (i.b.) and in board by Doyle, International ¼-inch, and Scribner Rules.

4. *East Gulf even-aged longleaf* (Farrar 1979)—Age, site index, and total basal area can be independently manipulated within limits. Volume output in total, merchantable, and sawtimber cubic feet (i.b.) and in board feet, International ¼-inch Rule. Merchantable and sawtimber basal areas are imbedded in the total basal area and cannot be independently manipulated. This system predates the Farrar (1985b) system. One BASIC program also permits estimates of merchantable and sawtimber wood dry weight.

5. *East Gulf even-aged longleaf* (Farrar 1985b)—Age, site index, total basal area, and sawtimber basal area can be independently manipulated within limits. Volume output in total, merchantable, and sawtimber cubic feet (i.b.) and in board feet, International ¼-inch Rule. One BASIC program also permits estimates of merchantable and sawtimber wood dry weight.

6. *West Gulf even-aged shortleaf* (Murphy 1982, Murphy and Beltz 1981)—Age, site index, merchantable basal area, and sawtimber basal area can be independently manipulated within limits. Volume output in merchantable and sawtimber cubic feet (i.b.)

and in board feet by Doyle, International 1/4-inch, and Scribner Rules.

7. *Southeast even-aged slash* (Bennett 1970, 1980)—Age, site index, and merchantable basal area can be independently manipulated within limits. Volume output in merchantable cubic feet (o.b.) and in board feet, International 1/4-inch Rule. Sawtimber basal area is imbedded in the merchantable basal area and cannot be independently manipulated.

8. *East Gulf young unthinned even-aged longleaf* (Farrar 1985a)—No SuperCalc or Lotus 1-2-3 template is available for this diameter-distribution system. A BASIC program (YOUNGLLA.BAS) is available. Age, site index, and total number of trees can be independently manipulated within limits. Volume output in total and various merchantable cubic feet (i.b. and o.b.) by 1-inch d.b.h. classes.

9. *West Gulf selection loblolly-shortleaf* (Farrar and others 1984; Murphy and Farrar 1982, 1983)—Cutting cycle (elapsed time), merchantable basal area, and sawtimber basal area can be independently manipulated within limits. Volume output in merchantable and sawtimber cubic feet (i.b.) and in board feet by Doyle, International 1/4-inch, and Scribner Rules. Site index is fixed at 90 feet.

10. *West Gulf selection shortleaf* (Murphy and Farrar 1985)—Cutting cycle, site index, merchantable basal area, and sawtimber basal area can be independently manipulated within limits. Volume output in merchantable and sawtimber cubic feet (i.b.) and in board feet by Doyle, International 1/4-inch, and Scribner Rules.

11. *Midsouth loessial-soil loblolly plantations* (Sullivan and Williston 1977)—Age, site index, and total basal area can be independently manipulated within limits. Volume output in merchantable cubic feet (i.b.) only.

12. *Virginia Piedmont old-field loblolly plantations* (Burkhart and Sprinz 1984)—Age, site index (base age 25), and total basal area can be independently manipulated within limits. Volume output in merchantable cubic feet (o.b.) and board feet, International 1/4-inch Rule. Sawtimber basal area is imbedded in the merchantable basal area and cannot be independently manipulated.

13. *West Gulf cutover-site longleaf plantations* (Lohrey 1979)—Age, site index (base age 25), and total basal area can be independently manipulated within limits. Volume output in total cubic feet (o.b.) and board feet, International 1/4-inch Rule. Sawtimber basal area is imbedded in the merchantable basal area and cannot be independently manipulated.

14. *Southeast even-aged yellow-poplar* (Beck and Della-Bianca 1972, 1975)—Age, site index, and merchantable basal area can be independently manipulated within limits. Volume output in merchantable cubic feet (o.b.) and board feet, International 1/4-inch Rule. Sawtimber basal area is imbedded in the merchantable basal area and cannot be independently manipulated. Note that growth periods must be a multiple of 5 years, predictions must be made every 5 years, and thinning intervals must be multiples of 5 years.

Software Source

The following information will enable potential users to obtain a copy of any or all of the software mentioned in this report. Send a disk of the desired size for each set of programs requested, specify the program sets desired, and the sets will be copied onto the disks and returned (or precopied sets on similar disks will be returned instead).

Media: 3.5-inch 720 Kb or 1.44 Mb IBM-PC format micro-floppy disk or 5.25-inch 360 Kb or 1.2 Mb IBM-PC format floppy disk

File Sets:

1. 16 BASIC program files in ASCII format plus a READ-BAS.DOC information file (52 Kb total).
2. 21 SuperCalc-5 ".cal" template files plus a READ-CAL.DOC information file (183 Kb total).
3. 21 Lotus 1-2-3 ".wks" template files (created under SuperCalc-5) plus a READ-WKS.DOC information file (275 Kb total).
4. 21 Lotus 1-2-3 ".wk1" template files (created under SuperCalc-5) plus a READ-WK1.DOC information file (285 KB total).

Cost: A blank disk of the desired size and format per set of programs or templates must be supplied by the requestor; otherwise, there is no charge for the software.

Source: Specify the set(s) of programs and/or templates desired and send blank disk(s) to:

R. M. Farrar, Jr.
Southern Forest Experiment Station
Department of Forestry, MSU
P. O. Drawer FR
Mississippi State, MS 39762

Farrar, Robert M., Jr. 1992. Microcomputer software for predicting growth of southern timber stands. Gen. Tech. Rep. SO-89. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 19 p.

Microcomputer software as electronic spreadsheet templates and as BASIC programs for 14 growth and yield prediction systems available in the literature for southern timber stands is discussed. All, except one BASIC program, are based on simultaneous-type stand volume and volume growth predictors. Examples of use and information on how the software may be obtained are included.

Keywords: Growth, production, software, southern pine, yellow-poplar, yield.