A System to Derive Optimal Tree Diameter Increment Models from the Eastwide Forest Inventory Data Base (EFIDB)

Don C. Bragg, *USDA Forest Service, Southern Research Station, P.O. Box 3516 UAM, Room 111, Forest Resources Building, Monticello, Arkansas 71656.*

ABSTRACT: *This article is an introduction to the computer software used by the Potential Relative Increment (PRI) approach to optimal tree diameter growth modeling. These DOS programs extract qualified tree and plot data from the Eastwide Forest Inventory Data Base (EFIDB), calculate relative tree increment, sort for the highest relative increments by diameter class, and generate an ASCII file for post-processing in any software package capable of customized ordinary least squares regression. South. J. Appl. For. 26(4):214–221.*

Key Words: Potential Relative Increment (PRI), optimal growth modeling, FIA, Internet.

There are several possible ways to develop tree growth models, depending on the objectives of the user and the desired end product. One popular approach involves designing optimal increment equations, which can then be rescaled with environmental modifier(s) to arrive at predicted "actual" growth. The gap models (Botkin et al. 1972, Shugart and West 1977, Pastor and Post 1986) are classic examples of this strategy. While the gap model optimal increment functions have a number of conceptual problems, the empirically grounded Potential Relative Increment (PRI) approach to optimal growth modeling offers a reasonable solution and avoids the major weaknesses of other designs (Bragg 2001, D.C. Bragg, unpublished manuscript). This article describes the software used to derive PRI growth models from the USDA Forest Service's Eastwide Forest Inventory Data Base (EFIDB).

Accessing the Inventory Information

Forty-eight states have their Forest Inventory and Analysis (FIA) records available for public use (only Alaska and Hawaii are absent). Of those states with inventories, 37 are incorporated in the EFIDB. The EFIDB was a logical choice for this analysis because of the broad extent and species representation found in this inventory [see Hansen et al. (1992) for information on the sampling protocols and data availability]. This database can be retrieved either by ordering a CD-ROM from the FIA program [(865) 862-2000] or by contacting the author [(870) 367-3464, ext. 18]. The most efficient way to download all necessary EFIDB inventory data is to select the self-extracting *.EXE file, save this to a hard drive, and then open the file locally.

Both plot (EFIDB record type 20) and tree (EFIDB record type 30) data are needed for the development of the PRI models. These data are found in separate comma-delimited ASCII files and are denoted by a two-letter state code and file type indicator. For example, the EFIDB plot data for Arkansas (AR) are found in the file ARPLOT.CSV and the individual tree data are found in ARTREE.CSV. For states with multiple inventories, a two-digit inventory date is added (e.g., MIPLOT80.CSV represents the plot data for the 1980 remeasurement of Michigan). Due to slight formatting departures, Maine's EFIDB inventory must be modified to work with the current PRI software. The differences between the EFIDB and the Westwide Forest Inventory Data Base and the newer Forest Inventory and Analysis Data Base are significant enough to require additional software development. While this article assumes the use of EFIDB, any other inventory containing the requisite mensurational information could also be examined if formatted properly.

Program Overviews

Six files are necessary for PRI data extraction using version 2.01 of the PRI software:

- *RGR.EXE* (combines plot and individual tree data files and writes qualified trees to an ASCII file (*.RGR) that is read by the next program)

NOTE: The author can be reached at Phone: (870) 367-3464 ext. 18; Fax: (870) 367-1164, E-mail: dbragg@fs.fed.us. Thanks to the following for making this work possible: Dave Roberts (Utah State University); Tom Crow (USDA Forest Service North Central Research Station); Jim Guldin (USDA Forest Service Southern Research Station); and the USDA Forest Service's Forest Inventory and Analysis Program, North Central Research Station, and Southern Research Station. The comments of Jim Guldin, Boris Zeide (University of Arkansas at Monticello), Dave Larsen (University of Missouri at Columbia), and two reviewers helped improve this article. Article received June 19, 2001, accepted October 10, 2001. This article was written by a U.S. Government employee and is therefore in the public domain.

- RGR_DEF.CSV (a comma-delimited ASCII file containing *RGR* program defaults)
- FIA_SPP.CSV (a comma-delimited ASCII file containing FIA species codes and common and scientific names)
- *MAXARI.EXE* (selects the highest ARI values from the *.RGR output files, sorts them by size class, and writes the results to an ASCII file)
- ARI_DEF.CSV (a comma-delimited ASCII file containing *MAXARI* program defaults)
- README.TXT (ASCII-based help file)

All of the *.CSV files can be modified as long as their formatting does not change. Altering default values is the only way to customize the *RGR* and *MAXARI* software. These programs are designed to match plot and tree data together, sift through the individual trees to find eligible records, resort to select only the highest performing individuals (by size class), and generate a maximum ARI list for later post-processing and model fitting. Program performance will vary by the capability of the computer, the size of the input files, and how many individuals of a given species are extracted. It usually took less than a minute to sort and merge 2 to 5 MB plot data files with their corresponding 30 to 35 MB tree files and then write an output file of more than 20,000 records on a 500 MHz Pentium III personal computer with 384 MB of RAM.

Receiving and Installing the Necessary Files

A self-extracting file containing the compressed files needed to perform PRI can be downloaded from the Internet at: *www.srs.fs.fed.us/4106/downloads.htm* or by contacting the author. This file (*ZP_PRI.EXE*) can be run from a command prompt, the 'Run' option in the Windows Start Menu, Windows Explorer, or any DOS shell that allows for program execution. When run in Windows, an option window opens to direct the installation (default install directory = C:\PRI2_01e\), with all necessary files except the EFIDB data (downloaded separately) placed into this folder. Those unfamiliar with the operation of *RGR* and *MAXARI* should read the help file (README.TXT) before running the programs.

Using *RGR*

There is a necessary progression to the PRI derivation process, in which a *.RGR file must be produced in *RGR* before *MAXARI* can be run. *RGR* can be executed from a DOS command prompt or in Windows via a DOS shell. Once initiated, *RGR* loads program defaults from RGR_DEF.CSV. The default file must be in the same folder as *RGR*, otherwise the program will not execute. The first line of the RGR_DEF.CSV file are column headers to aid in the interpretation of the output (Table 1), including a date to signify when the last modification of this file occurred. MIN_OLD_DBH is the minimum "old" diameter at breast height (dbh) from the EFIDB. While MIN_OLD_DBH can be set from 1.0 to 1000.0 units, setting this value too high will result in the exclusion of otherwise legitimate records. MIN_RP is the minimum eligible remeasurement period (in years), below which individuals will not be included. Once again, while MIN_RP can be set from 1.0 to 20.0 yr, setting MIN_RP too high may also exclude useful records (most FIA remeasurement intervals are between 5 and 15 yr). A unit conversion factor can be included (UNITS) to produce English or metric results, as shown in Table 1. *RGR* defaults to English units (UNITS = E), so to change to metric units for dbh (cm) and basal area (m^2/ha), set UNITS to 'M'. The next set of parameters permit record classification by environmental characteristics. EFIDB plot files include information on slope, aspect, and physiographic class. Table 1 provides an example in which all possible records are included (see Hansen et al. (1992) for environmental data codes), however, it would be possible to include only those with dry (MIN_PHYSIO = 3, MAX_PHYSIO = 4) southerly aspects (MIN_ASPECT = 90, MAX_ASPECT = 270) ranging in slope from 10 to 20% (MIN_SLOPE = 10, MAX_SLOPE = 20). The final variable in the default file is a time adjustment (in yr) for the fitted models. When PERIOD = 1.0, the models are designed to yield annual optimal growth. If PERIOD = 5.0, then the PRI models predict 5 yr (periodic) optimal increment.

After defaults are loaded, an initial entry screen appears (Figure 1) and the following critical information is requested: plot data filename, tree data filename, and number of species to extract from the inventory. Plot and tree files from non-EFIDB sources must have the same style of headers and

Table 1. Example RGR_DEF.CSV content (in different font), formatting requirements, and variable limitations.

Variable	Example values	Units	Variable type	Minimum	Maximum
MIN_OLD_DBH	1.0	(cm or in.)[a]	Real	1.0	1000.0
MIN_RP	1.0	yr	Real	1.0	20.0
UNITS	M	English/metric[a]	Character	—	—
MIN_SLOPE	0	%	Integer	0	99
MAX_SLOPE	99	%	Integer	0	99
MIN_ASPECT	0	Degrees	Integer	0	360
MAX_ASPECT	360	Degrees	Integer	0	360
MIN_PHYSIO	3	—	Integer	3	7
MAX_PHYSIO	7	—	Integer	3	7
PERIOD	1.0	yr	Real	1.0	20.0

[a] When English units are used, dbh are in inches and basal area is in ft^2/ac, while metric units assume dbh values are in centimeters and basal area is in m^2/ha.

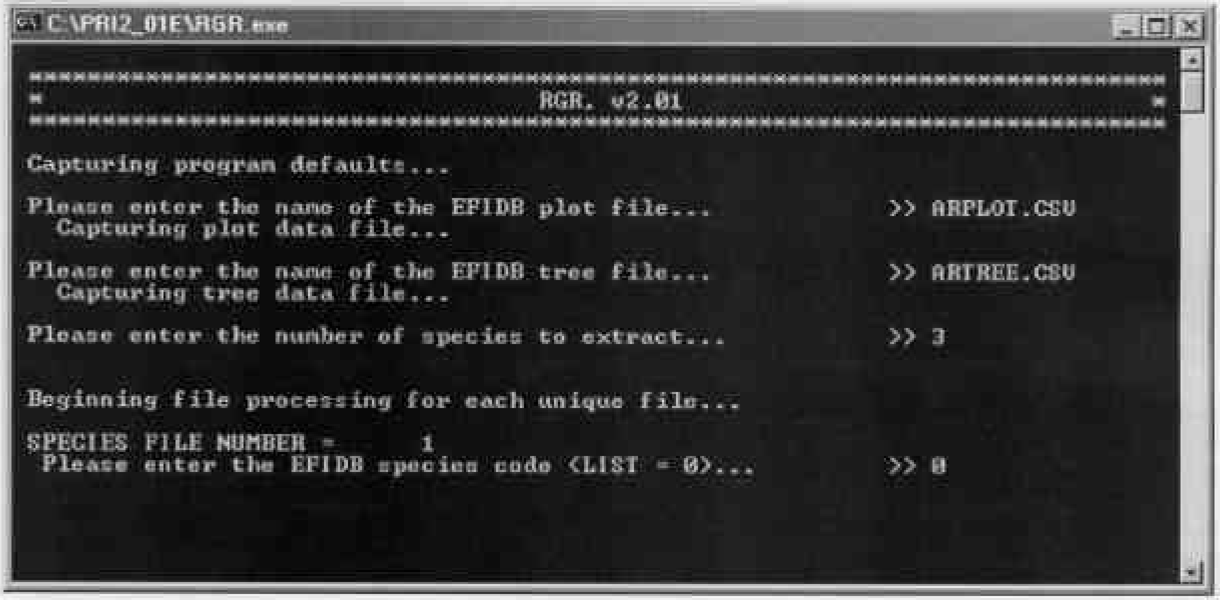

Figure 1. Opening screen of *RGR* (version 2.01). The *RGR* program can be executed from either DOS or Windows, but generates results in ASCII text format only. This example considers three species from the Arkansas EFIDB.

number of columns following the same formatting as found with the EFIDB files [see pages 6 and 19 in Hansen et al. (1992)]. *RGR* allows the user to select the number of species for analysis. At least one species must be chosen, but no more than 999 can be run in any single batch. *RGR* then prompts for the FIA species code [see Appendix 3, Table 6 (pages 44 to 48) in Hansen et al. (1992)]. If you are uncertain as to which species code to use, entering a '0' at this time brings up a listing of codes by common and scientific name (Figure 2). All currently valid EFIDB codes are stored in a comma-delimited file (FIA_SPP.CSV) that can be annotated if new species are added (appropriate formats must be followed). Press the 'ENTER' key to continue scrolling through the species code options, or press 'E' to exit. After the species code has been selected, the user is prompted for an output file name (Figure 3). Up to 8 characters can be entered (no filename extensions are necessary—the program automatically assigns *.RGR). A stand origin filter code to distinguish between stand types (1 = natural stands only; 2 = plantations only; 3 = both

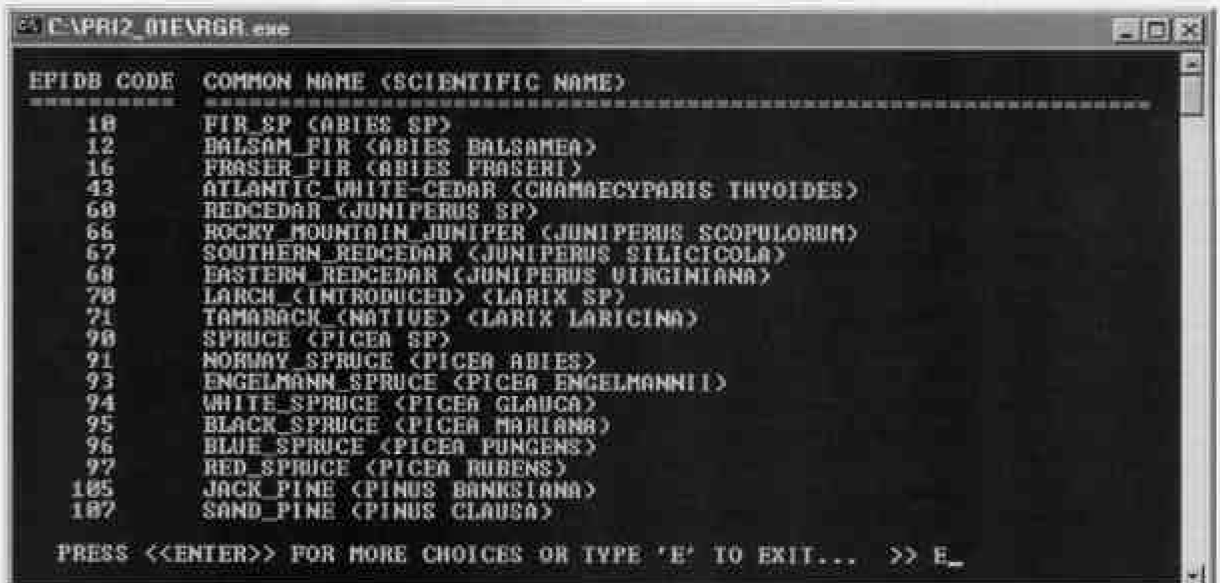

Figure 2. Species code option screen in *RGR*, obtained by entering a '0' in the EFIDB species code query in the appropriate *RGR* prompt.

Figure 3. Species designation screen in *RGR*. Once the species, output file names, and stand origin filter code has been entered, the program will ask for verification of this data.

natural and planted stands) can then be chosen to segregate by the origin of the growing stock.

After the species code, output filename, and stand filter codes have been entered for all species, a screen appears that allows the user to verify their choices before processing (Figure 4). Each species is displayed by its species code, stand filter code, common name, and output file name. If everything is satisfactory, *RGR* then begins sorting the plot and tree data to find eligible records (Figure 5). For an individual record to be considered for inclusion, it must represent a live tree of the correct species and show positive growth. As each species is completed, a message appears indicating how many valid individuals are located. If no individuals of a given species are found, a message indicating this is displayed instead. Each species is written to a unique output file (Table 2) exactly formatted to be the input file for the second analysis program, *MAXARI*.

Some useful summary information can be found in the *RGR* output file. Table 2 provides a partial output file (only 40 of the 6,933 records were included). The header of each

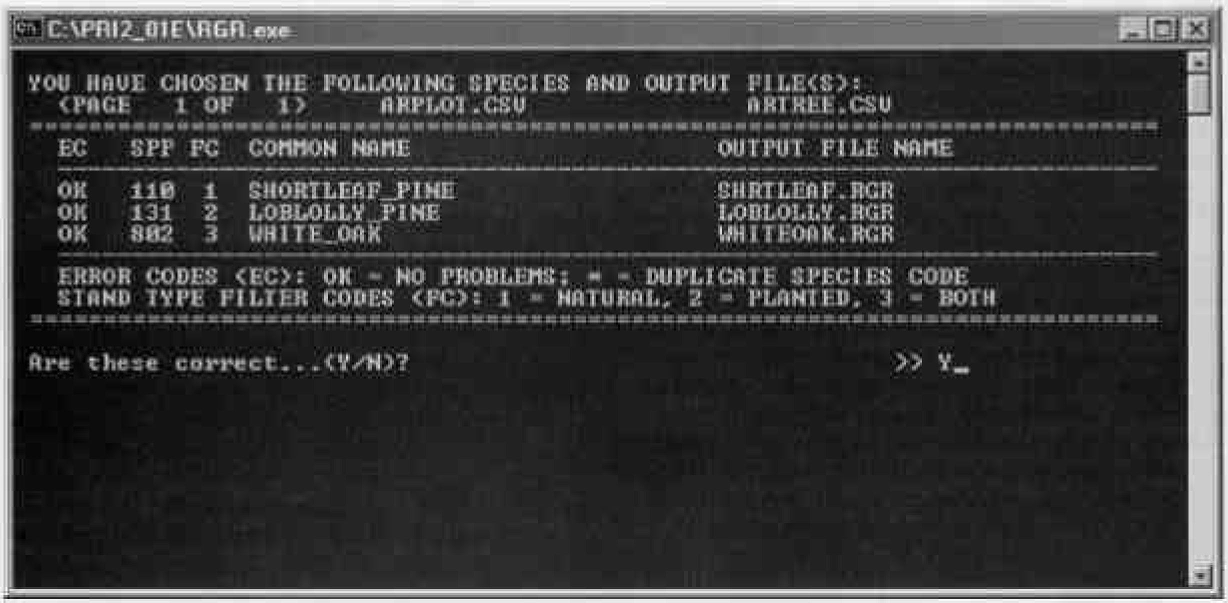

Figure 4. Input confirmation screen in *RGR*. If the information provided in this module is acceptable, *RGR* proceeds in its data extraction.

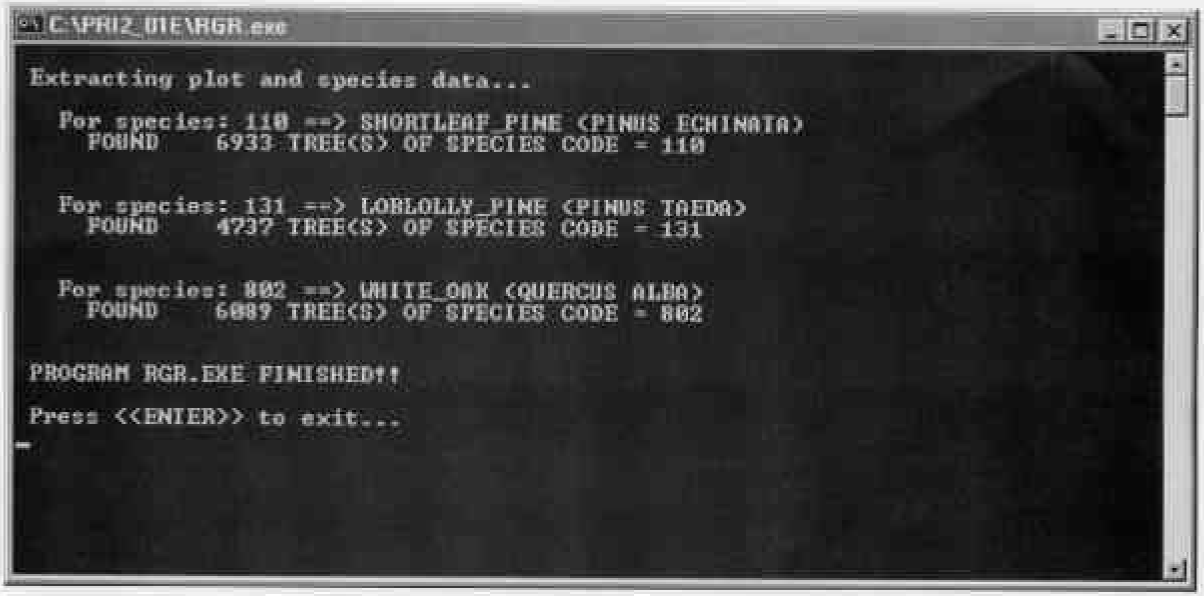

Figure 5. Analysis processing screen of *RGR*. This screen reports the progress and success of *RGR* in analyzing the EFIDB files. The *RGR* program exits once the complete set of designated species has been considered.

*.RGR file contains statistics on the records extracted for each file, including the number of samples taken (N), minimum old dbh (MIN_DBH), average old dbh (AVG_DBH), maximum old dbh (MAX_DBH), and standard deviation of the old dbhs (STDEV), as well as which measurement units are used (metric or English). Every *.RGR file contains columns indicating the species sampled (SPECIES), the EFIDB state code (STATE), unit (UNIT), county (CNTY), and stand origin codes (FC), an arbitrary tree number (NUMBER), dbh at the initial inventory (OLD_DBH), dbh at the current inventory (CUR_DBH), the inventory remeasurement period (REM_PER, in yr), actual relative increment (ARI), EFIDB ownership (OWNER), national forest codes (NATL_FOR), plot basal area (PLOT_BA),

Table 2. Example of a partial *RGR* output file showing only the first 20 records extracted from the Arkansas EFIDB for shortleaf pine (*Pinus echinata*, species code = 110).

INPUT PLOT FILE NAME	>> ARPLOT.CSV	N	= 6933 UNITS = METRIC
INPUT TREE FILE NAME	>> ARTREE.CSV	MIN_DBH	= 2.79
OUTPUT FILE NAME	>> SHRTLEAF.RGR	AVG_DBH	= 26.42 STDEV = 10.49
SPECIES CODE AND COMMON NAME	>> 110 SHORTLEAF_PINE	MAX_DBH	= 70.1

SPP	STATE	UNIT	CNTY	FC	NUM	ODBH	CDBH	REMP	ARI	OWN	NFOR	PBA	SLOPE	ASP	PHYS
110	5	3	3	1	1	21.6	25.7	6.3	0.02988	20	0	12.4	0	0	5
110	5	3	3	1	2	16.8	18.5	6.2	0.01711	20	0	34.0	3	334	5
110	5	3	3	1	3	34.3	36.8	6.2	0.01195	20	0	29.2	6	219	5
110	5	3	3	1	4	51.3	57.1	6.1	0.01867	70	0	17.9	0	0	5
110	5	3	3	1	5	46.0	49.0	6.1	0.01087	70	0	17.9	0	0	5
110	5	3	3	1	6	38.4	42.7	6.1	0.01846	70	0	17.9	0	0	5
110	5	3	3	1	7	32.3	36.3	6.1	0.02065	70	0	17.9	0	0	5
110	5	3	3	1	8	27.7	31.0	6.0	0.01988	20	0	14.7	20	90	5
110	5	3	3	1	9	21.1	24.1	6.3	0.02295	20	0	24.1	15	120	5
110	5	3	3	1	10	21.3	24.4	6.3	0.02268	20	0	24.1	15	120	5
110	5	3	3	1	11	22.1	22.4	6.3	0.00182	20	0	24.1	15	120	5
110	5	3	3	1	12	46.7	50.5	6.2	0.01315	20	0	7.8	0	0	5
110	5	3	3	1	13	41.1	44.5	6.2	0.01294	20	0	7.8	0	0	5
110	5	3	3	1	14	32.0	35.1	6.0	0.01587	20	0	24.6	0	0	5
110	5	3	3	1	15	25.9	28.2	6.3	0.01401	20	0	17.2	0	0	5
110	5	3	3	1	16	41.9	45.5	6.3	0.01347	20	0	10.3	0	0	5
110	5	3	3	1	17	42.2	43.9	6.3	0.00669	20	0	10.3	0	0	5
110	5	3	3	1	18	52.8	55.4	6.3	0.00763	20	0	10.3	0	0	5
110	5	3	3	1	19	15.0	17.8	6.3	0.02959	20	0	3.0	0	0	5
110	5	3	3	1	20	33.5	37.8	6.3	0.02044	20	0	28.7	0	0	5

Column abbreviations: SPP = tree species; STATE = FIA state code; UNIT = FIA unit code; CNTY = FIA county code; FC = stand origin code; NUM = tree number; ODBH = old dbh (cm, in this case); CDBH = current dbh (cm, in this case); REMP = remeasurement period (yr); ARI = actual relative increment; OWN = FIA ownership codes; NFOR = FIA national forest code; PBA = plot basal area (m^2/ha, in this case); SLOPE = plot slope (degrees); ASP = plot aspect (degrees); and PHYS = FIA physiographic code. See Hansen et al. (1992) for FIA codes.

Figure 6. Introductory and processing screen in *MAXARI* (version 2.01). This program selects the highest actual relative increments in each diameter class and writes them to a separate ASCII file.

slope percent (SLOPE), and aspect (ASPECT, in degrees), and an EFIDB physiographic code (PHYSIO). All that is needed to perform the PRI analysis are the OLD_DBH, CUR_DBH, REM_PER, and ARI columns.

Using *MAXARI*

Once initiated (Figure 6), *MAXARI* requires the number of *.RGR files to examine (three in this example), the input file name (using the *.RGR extension), and the output file name (including extension). *MAXARI* captures the *.RGR data file(s), sorts through the records to find the highest values by dbh class, and then writes a file containing the maximum ARI information (Table 3). In this example the *MAXARI* output file was named SHRTLEAF.ARI, although any legitimate DOS filename and extension could have been used.

In addition to the old dbh, current dbh, actual relative increment, and remeasurement period for the maximum individual tree record by size class, plot basal area, slope, aspect, and physiographic class are also presented for both the subject tree and a size class average, allowing for comparisons. In addition, if a more conservative estimate of PRI is desired, the TOP3DBH and TOP3ARI columns represent the average of (up to) the top three fastest growing individuals (substitute for the OLD_DBH and MAX_ARI columns, respectively). The final two columns indicate how many records were actually used to calculate TOP3DBH and TOP3ARI (as a count and percent of total in that size class).

Post-Processing *MAXARI* output

Unless the plot and tree files are combined before they are processed through *MAXARI*, only one subset at a time can be considered (which is not recommended). For multiple sets to be merged, run *RGR* as needed for each state inventory, then use a text editor or spreadsheet to combine the respective *.RGR files (leaving the column header information for only the first file). When *MAXARI* is then used to process the merged *.RGR file, it will compare individuals within all states for the maximum ARI values. For small states or those with limited tree records, pooling inventories from neighboring states (or adding supplemental inventories from different projects) may be inevitable. If there are not drastic differences in environmental quality, I recommend regionally fitting the PRI equations to boost sample sizes and site conditions because the quality of the results depends on the number and environmental extent of observations (Bragg 2001, D.C. Bragg, unpublished manuscript).

As mentioned earlier, these programs do not produce the actual PRI models, but rather generate a space-delimited ASCII file containing the requisite information. Any software capable of nonlinear ordinary least squares regression for a customized equation form could be used to fit the equations to the following form:

$$PRI = b_1 D_{MAX}^{b_2} b_3^{D_{MAX}} \qquad (1)$$

where the dependent variable (*PRI*) depends on the regression coefficients (b_1 to b_3) and the maximum ARI values by size class (D_{MAX}). Since not all maximal ARI points reported in the *.ARI file will prove useful, I would recommend using post-processing software that allows for easy deletion of points.

To predict optimal increment, simply multiply PRI by current dbh. Equation (1) can produce a skewed modal or declining curve, with a maximum value at small diameters and a minimum at large diameters. As long as b_3 is not larger than 1, this model performs well under most circumstances.

Table 3. A *MAXARI* output file for shortleaf pine in Arkansas listing the highest actual relative increment scores (MAX_ARI) by their diameters, the remeasurement period, and an number of environmental variables.

*.RGR (INPUT) FILE NAME >> SHRTLEAF.RGR UNITS = METRIC
MAXARI (OUTPUT) FILE NAME >> SHRTLEAF.ARI
SPECIES CODE AND COMMON NAME >> 110 SHORTLEAF_PINE

SPP	STATE	UNIT	CNTY	FC	CLASS	ODBH	CDBH	MAXARI	REMP	PBA	AVGBA
110	5	4	105	1	2	3.6	15.0	0.41744	7.7	19.7	28.7
110	5	4	105	1	3	4.8	16.5	0.31442	7.7	19.7	26.1
110	5	4	105	1	4	6.1	21.3	0.32895	7.6	8.0	26.8
110	5	4	149	1	5	9.4	18.8	0.12821	7.8	21.8	24.6
110	5	4	131	1	6	10.7	21.8	0.13431	7.8	12.9	23.6
110	5	3	109	1	7	12.7	20.8	0.08767	7.3	27.3	23.2
110	5	4	149	1	8	14.5	24.1	0.09009	7.4	35.8	24.1
110	5	4	119	1	9	16.8	30.0	0.10232	7.7	20.7	25.0
110	5	5	71	1	10	18.3	27.4	0.05682	8.8	24.6	24.9
110	5	4	83	1	11	21.1	31.8	0.06658	7.6	9.4	25.1
110	5	3	103	1	12	22.4	30.7	0.05952	6.3	10.6	25.8
110	5	4	149	1	13	24.1	36.1	0.06262	7.9	13.3	25.5
110	5	5	47	1	14	27.2	40.6	0.05629	8.8	18.6	25.5
110	5	4	113	1	15	29.7	37.8	0.03647	7.5	28.7	25.4
110	5	3	103	1	16	31.0	38.1	0.03643	6.3	10.6	25.0
110	5	3	53	1	17	32.0	38.9	0.03061	7.0	22.0	26.2
110	5	3	53	1	18	34.5	41.7	0.02859	7.2	19.7	25.6
110	5	4	83	1	19	37.3	46.7	0.03312	7.6	17.7	25.5
110	5	1	69	1	20	38.4	45.2	0.02518	7.1	16.5	25.3
110	5	4	149	1	21	40.1	52.8	0.04164	7.6	23.6	24.4

Table 3. (continued).

SLOPE	AVGSLP	ASP	AVGASP	PHYS	AVGPHYS	TOP3DBH	TOP3ARI	#USED	TOTAL#	%USED
15	20.6	345	193.8	5	4.9	3.5	0.29877	3	97	3.093
15	19.2	345	176.0	5	4.9	5.0	0.21558	3	121	2.479
0	17.4	0	170.4	5	4.9	6.8	0.24913	2	86	2.326
0	16.0	0	163.9	5	4.9	9.2	0.10178	3	65	4.615
15	14.2	352	154.6	5	4.9	11.1	0.10322	3	188	1.596
28	15.5	139	175.7	5	4.9	12.9	0.07629	3	227	1.322
0	15.0	0	167.1	5	4.9	14.6	0.08126	3	312	0.962
5	15.6	208	171.2	5	4.9	16.4	0.07954	3	380	0.789
15	15.2	153	164.4	5	4.9	18.5	0.05201	3	420	0.714
4	15.2	210	168.2	5	4.9	21.2	0.05600	3	456	0.658
0	16.1	0	166.2	5	4.9	22.8	0.04832	3	534	0.562
0	16.7	0	171.3	5	4.9	25.1	0.04880	3	508	0.591
3	16.3	215	177.3	5	4.9	27.1	0.03873	3	537	0.559
3	15.4	40	173.1	5	4.9	29.6	0.03123	3	482	0.622
0	15.3	0	165.7	5	4.9	31.1	0.03124	3	480	0.625
0	14.9	0	164.7	5	4.9	32.6	0.02699	3	437	0.686
3	14.5	310	174.6	5	4.9	35.0	0.02598	3	378	0.794
5	13.6	286	164.4	5	4.9	37.1	0.02806	3	346	0.867
0	14.1	0	159.9	5	4.9	38.9	0.02263	3	226	1.327
0	12.4	0	150.3	5	4.8	40.7	0.03213	3	165	1.818

Column abbreviations: SPP = tree species; STATE = FIA state code; UNIT = FIA unit code; CNTY = FIA county code; FC = stand origin code; CLASS = tree dbh class; ODBH = old dbh (cm, in this case); CDBH = current dbh (cm, in this case); MAXARI = maximum ARI by dbh class; REMP = remeasurement period (yr); PBA = plot basal area (m^2/ha, in this case); AVGBA = average plot basal area by size class; SLOPE = plot slope (degrees); AVGSLP = average plot slope by size class; ASP = plot aspect (degrees); AVGASP = average plot aspect by size class; PHYS = FIA physiographic code; AVGPHYS = average FIA physiographic code by size class; TOP3DBH = average of up to 3 maximum dbh in size class; TOP3ARI = average of up to 3 maximum ARI values; #USED = number of trees used to calculate TOP3; TOTAL# = total number of valid trees in size class; and %USED percent of valid trees used to calculate TOP3 values. See Hansen et al. (1992) for FIA codes.

Other formulations based on PRI principles could also be used, given that they share the same assumptions (Bragg 2001, D.C. Bragg, unpublished manuscript).

Existing Products

The PRI methodology has been used to produce optimal growth curves for tree species in the northern Lake States (Michigan, Minnesota, and Wisconsin) (Bragg 2001) and the Midsouth (Arkansas, Louisiana, Missouri, Oklahoma, and Texas) (Bragg 2002a, Bragg 2002b). These regional models should be applied with caution if used outside of their development areas and may not perform as well on fine scales as models fit to more localized data. Because of the flexibility built into the analysis process, it should be possible (given adequate sample sizes) for more precise or more general models to be constructed. For example, it is possible to design an optimal growth equation for all loblolly pine (*Pinus taeda*) in the United States or only those in Arkansas plantations.

Literature Cited

Botkin, D.B., J.F. Janak, and J.R. Wallis. 1972. Some ecological consequences of a computer model of forest growth. J. Ecol. 60:849–872.

Bragg, D.C. 2001. Potential relative increment (PRI): A new method to empirically derive optimal tree diameter growth. Ecol. Model. 137:77–92.

Bragg, D.C. 2002a. Optimal tree diameter growth equations for major tree species of the Midsouth. South. J. Appl. For. (in press).
Bragg, D.C. 2002b. Empirically derived optimal growth equations for hardwoods and softwoods in Arkansas. *In* Proc. 11th Bienn. South. Silv. Res. Conf. USDA For. Serv. Gen. Tech. Rep. SRS-48.
Hansen, M.H., T. Frieswyk, J.F. Glover, and J.F. Kelly. 1992. The Eastwide Forest Inventory Data Base: Users manual. USDA For. Serv. Gen. Tech. Rep. NC-151. 48 p.
Pastor, J., and W.M. Post. 1986. Influence of climate, soil moisture, and succession on forest carbon and nitrogen cycles. Biogeochem. 2:3–27.
Shugart, H.H., and D.C. West. 1977. Development of an Appalachian deciduous forest succession model and its application to the impact of chestnut blight. J. Environ. Manage. 5:161–179.