Calibrating FVS for the Chattahoochee-Oconee National Forest Planning Effort

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Abstract—The Forest Vegetation Simulator (FVS) is being used to create yield tables for the Chattahoochee-Oconee National Forest plan revision. The FVS Southern variant was calibrated and adjusted to produce reliable yield tables for this region. The large-tree diameter increment model was calibrated using the self-calibration feature of FVS and through FVS-computed mean correction scale factors. Volume estimates were adjusted to the merchantability specifications and defect estimates for the region. Adjustments to the mortality and regeneration models were not done, but may be needed after further analyses are conducted. This paper reports the steps taken to calibrate the large-tree diameter increment model and adjust the volume specifications for the Chattahoochee-Oconee National Forest plan revision.

The Chattahoochee-Oconee National Forest is one of five National Forests undergoing forest plan revision in the Southern Region of the USDA Forest Service. The Chattahoochee-Oconee National Forest covers 865,043 acres in northern and central Georgia, of which 542,240 acres are suitable for timber production (http://www.fs.fed.us/conf/facts1.htm 2001). There are three predominate ecological sections found on the forest: Blue Ridge Mountains, Southern Ridge and Valley, and Southern Appalachian Piedmont.

Forest Plan revision on the Chattahoochee-Oconee National Forest began in the late 1990s. Elements of the plan revision include determining analysis units/strata and allocating National Forest land to these strata, determining administrative layers, developing silvicultural prescriptions, performing growth and yield forecasting, and evaluating the management alternatives. As part of this process, the Forest Vegetation Simulator (FVS) system was chosen to create the yield tables needed for the growth and yield-forecasting element of the forest plan revision. Output from FVS system will be used as input in Spectrum, the analytical tool used to evaluate forest management alternatives (Spectrum Overview 2001).

The FVS system is a suite of software tools designed to translate forest data, simulate forest growth, and process model outputs into usable forms for other analytical tools. At the heart of this system is the FVS model. The FVS model is an individual-tree, distant-independent growth and yield model that has been calibrated to simulate forest growth for most forest types of the United States (Dixon 2001). This paper presents the FVS model calibration and adjustments used to produce accurate yield tables for the forest plan revision on the Chattahoochee-Oconee National Forest.

FVS Variant Selection and Data

There are two FVS variants available for the Chattahoochee-Oconee National Forest: the Southeastern Variant (SE) and the Southern Variant (SN). The Southern Variant was chosen for two reasons. First, it was fit to a larger geographic region, which enabled all National Forests undergoing plan revision in the Southern Region to use the same model. Second, the Southern Variant is more reliable because it was built using FVS growth relationships, while the Southeastern Variant was based on equations in the Southeast TWIGS model (Lilly 1997; Donnelly and others 2001).

The Southern Variant does not have insect or disease extensions. However, the magnitude of possible insect and disease impacts on the forest is being accounted for through the use of FVS addfiles designed specifically to estimate the severity of pests and pathogens, most notably the Southern Pine Beetle addfile (Courter and others this proceedings).

This planning effort used the FVS-ready FIA data for the Southeast available on the FMSC Intranet Web site. Each Forest Inventory Analysis (FIA) plot contained all the input data needed by FVS to make projections. In addition, diameter increment data were included on some tree records.

FVS Calibration and Adjustments

Tree Growth Functions

By default, the FVS large-tree diameter increment model and the small-tree height increment model undergo a process of self-calibration when sufficient growth increment data are supplied with the input tree data. Self-calibration is the process of scaling the predicted growth increments to more accurately match the measured growth rates of trees in the stand (Stage 1973). Wykoff and others (1982), explain this procedure best:

> The scaling procedure (Stage 1973), when stripped of statistical condiments, is really quite simple. The affected models are both linear and logarithmically scaled dependent variables. Therefore, the model

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intercepts are, in effect, growth multipliers. An increment to match each observed increment for a species is predicted, and differences are sorted. The median difference is then added to the model for that species, on the logarithmic scale, as an additional intercept term.

The diameter increment scale factors are attenuated over time. We assume that, on long-term projections, the base model is a more stable estimate of growth potential than is the scale factor. The attenuation is asymptotic to one-half the difference between the initial value of the scale factor and 1. The rate of attenuation is dependent only on time.

Self-calibration of the large-tree diameter increment model occurs in the Southern Variant if, for a given species, there are at least five tree records with backdated dbh greater than 3 inches that contain measured diameter increments (Dixon 2001; Wykoff and others 1982). Likewise, if there are at least five tree records less than 5 inches dbh that contain height increments, the small-tree height increment model is calibrated for that species. If a species is able to undergo self-calibration, a scale factor will be computed for the growth model of that species. Because the plot data for this plan revision do contain a sample of diameter increments, the large-tree diameter increment model will be scaled automatically when the above conditions exist on any plot. No height increment data were available in the data set for the small-tree height increment model to self-calibrate.

For some species, consistent growth function bias may occur within a given geographic area, ecological section, forest type, and so forth. To correct for this bias, mean correction scale factors may be calculated and added to the simulations as multipliers. These multipliers allow the user to simulate regional growth patterns on all plots, not just on plots that self-calibrate. These multipliers remain in effect for the entire simulation and do not attenuate over time.

For species exhibiting growth bias, mean correction scale factors were calculated within each ecological section. The Calibration Summary Statistics Post-Processor was used to render the mean correction scale factors, which were subsequently entered into the simulations using the READCORD keyword. Due to a low number of diameter growth samples, some species had no or few large-tree diameter increment scale factors computed. Therefore, mean correction scale factors were not computed for these species.

The mean correction scale factors were determined for each ecological section using the following six steps (see Section 6.5.3, Dixon 2001):

1. Insert the CALBSTAT keyword into the keyword set for each stand in the area and process the stands. This will generate the auxiliary file.
2. Examine the values in this file and determine the source of any values that seem extremely high or low.
3. For any stands with unresolved sources of error, or with calibration values that you think are not reflective of the area, remove the CALBSTAT keyword.
4. Rerun the set of stands.
5. Run the Calibration Statistics postprocessing program to determine the average large tree diameter growth scale factor and the average small tree height growth scale factor for the area.
6. If these average scale factor values are different from 1.0, enter these values as multipliers using the READCORD, READCORR, and READCORH keyword.

Table 1 lists the resulting species-specific large-tree diameter increment, mean correction scale factors by ecological section. The mean correction scale factors reported are from an updated Calibration Summary Statistics postprocessor. Actual scale factors used in the forest plan are from a previous version and differ slightly. Notice that there is a general trend between ecological sections. For the most part, species had mean correction scale factors less than 1.0 (stands growing slower than model prediction) for the Blue Ridge Mountain and Appalachian Piedmont ecological sections and mean correction scale factors greater than 1.0 (stand growing faster than model prediction) for the Ridge and Valley ecological section.

Volume Specifications and Adjustments

To get estimates of stand volume and volume harvested consistent with the procedures on the Chattahoochee-Oconee National Forest, merchantability limits and percent defect estimates were set to commonly found values on the

Table 1—Mean large-tree diameter increment correction scale factors by species and ecological section.

Species name	Species number	Blue Ridge Mountains	Appalachian Piedmont	Ridge & Valley
shortleaf pine	5	**	**	1.304
longleaf pine	8	*	**	1.087
eastern white pine	12	0.842	*	*
loblolly pine	13	**	0.720	1.065
virginia pine	14	0.675	0.586	0.851
hickory species	27	**	**	1.041
yellow poplar	45	0.992	**	**
scarlet oak	64	0.728	**	**
chestnut oak	74	0.749	0.797	1.056
northern red oak	75	0.808	**	**

* Species does not occur in ecological section
** Insufficient data to create mean scale factor or no bias present.

Chattahoochee-Oconee National Forest (tables 2 and 3). The BFVOLUME keyword was used to set the species merchantability specifications for sawlog portion of cubic feet and board feet volume equations. The VOLUME keyword was used to set the species merchantability specifications for merchantable cubic feet volume. Sawlog defect was specified using the BFDEFECT keyword (VanDyck 2001).

Additional Considerations

Regeneration Inputs

While the Southern Variant does simulate stump sprouts from cut trees, it does not automatically simulate other types of natural regeneration. Other than sprouting, users must specify the species and quantity (trees per acre) of trees that regenerate. Regeneration estimates may be obtained outside the FVS framework through the analysis of regeneration surveys and consultation with local experts. In addition, within the FVS framework, users have the option of creating regeneration addfiles based on current stand composition with the REgeneration ImPUTation Extractor (REPUTE) postprocessor (Vandendriesche 2001). Sprouting was turned on in the simulations but no other types of regeneration were input into the simulations.

Mortality Functions

When FVS mortality does not correspond to observed mortality, FVS users may use mortality modifier keywords to correct model outputs. Mortality modifier keywords include FIXMORT, MORTMULT, BAMAX, and SDIMAX (Van Dyck 2001). FIXMORT allows users to replace or add to the FVS calculated species-specific mortality rate for a given diameter range. MORTMULT can be used to increase or decrease the species-specific mortality rate for a given diameter range. BAMAX resets the maximum density of the stand. SDIMAX allows users to reset the maximum stand density index by species. There has not been a need to calibrate the mortality functions in the Chattahoochee-Oconee plan revision yet.

Example

The effects of using the above-mentioned FVS calibration and adjustment techniques are depicted in table 4. In this example, 12 plots from the Blue Ridge Mountains Ecological Section, old growth community type 05, sapling age class (11-40 years old) stratum (B05S) used in this plan revision were selected. Four simulations were performed as follows:

Table 2—Default and adjusted cubic feet and board feet volume merchantability specifications for the Chattehoochee-Oconee plan revision.

Default settings	Keyword	Species	Minimum merchantable dbh	Minimum top diameter*	Stump height
Merchantable Cubic Feet	Volume	all	4.0	4.0	1.0
Merchantable Board Feet	BFVolume	hardwoods	12.0	9.0	1.0
Merchantable Board Feet	BFVolume	softwoods	10.0	7.0	1.0
Adjusted settings	**Keyword**	**Species**	**Minimum merchantable dbh**	**Minimum top diameter**	**Stump height**
Merchantable Cubic Feet	Volume	hardwoods	6.0	4.0	0.5
		redcedar	5.0	4.0	0.5
		shortleaf pine	5.0	4.0	0.5
		slash pine	5.0	4.0	0.5
		longleaf pine	5.0	4.0	0.5
		pitch pine	5.0	4.0	0.5
		eastern white pine	6.0	4.0	0.5
		loblolly pine	5.0	4.0	0.5
		Virginia pine	5.0	4.0	0.5
		hemlock	6.0	4.0	0.5
Merchantable Board Feet	BFVolume	hardwoods	12.0	9.0	1.0
		redcedar	9.0	7.0	1.0
		shortleaf pine	9.0	7.0	1.0
		slash pine	9.0	7.0	1.0
		longleaf pine	9.0	7.0	1.0
		pitch pine	9.0	7.0	1.0
		eastern white pine	10.0	7.0	1.0
		loblolly pine	9.0	7.0	1.0
		Virginia pine	9.0	7.0	1.0
		hemlock	10.0	7.0	1.0

* Minimum top diameter is fixed in this variant and cannot be changed.

Table 3—Percent defect by species and diameter. Linear interpolation between diameters is used to calculate percent defect for a given tree diameter.

Keyword	Species	5 inch dbh	10 inch dbh	15 inch dbh	20 inch dbh	25 inch dbh
		Percent				
BFDefect	white oak	0.0	0.0	0.5	3.5	3.6
	swamp chesnut oak	0.0	0.0	0.5	3.5	3.6
	chinkapin oak	0.0	0.0	0.5	3.5	3.6
	cheerybark oak	0.0	0.0	2.5	2.5	2.5
	northern red oak	0.0	0.0	2.5	2.5	2.5
	Shumard oak	0.0	0.0	2.5	2.5	2.5
	chestnut oak	0.0	0.0	0.5	10.0	6.3
	post oak	0.0	0.0	0.5	10.0	6.3
	scarlet oak	0.0	0.0	2.6	13.0	7.4
	southern red oak	0.0	0.0	2.5	13.1	7.4
	blackjack oak	0.0	0.0	2.6	13.1	20.0
	hickory sp.	0.0	0.0	0.8	10.2	1.6
	sugar maple	0.0	0.0	0.0	0.0	17.7
	red maple	0.0	0.0	0.6	9.3	21.6
	American beech	0.0	0.0	0.0	20.0	20.0
	blackfum	0.0	0.0	5.8	20.0	25.0
	yellow-poplar	0.0	0.0	0.4	0.0	2.1
	black locust	0.0	0.0	24.7	65.7	90.1
	Virginia pine	0.0	0.0	15.2	33.0	50.0
	eastern white pine	0.0	0.0	0.0	0.0	20.0

Table 4—Mean stratum responses for simulations in the example at a mean stand age of 113 years. Standard errors (±1) are reported for Sawlog board feet.

Simulation*	Trees per acre	Ave. dbh (inches)	Merchantable cubic feet	Sawlog cubic feet	Sawlog board feet
1	276	9.5	6560	5334	33582 ± 1869
2	276	9.5	6395	4959	31142 ± 1762
3	278	9.5	6343	4920	30798 ± 1750
4	290	9.4	6309	4859	30313 ± 1771

* 1: Simulation with no volume adjustments, no self-calibraiton, and no mean correction scale factors.
2: Simulation with volume adjustments, no self-calibraiton, and no mean correction scale factors.
3: Simulation with volume adjustments, with self-calibraiton, and no mean correction scale factors.
4: Simulation with volume adjustments, with self-calibraiton, and with mean correction scale factors.

1. A simulation with no volume adjustments, no self-calibration, and no mean correction scale factors.
2. A simulation with volume adjustments, no self-calibration, and no mean correction scale factors.
3. A simulation with volume adjustments, with self-calibration, and no mean correction scale factors.
4. A simulation with volume adjustments, with self-calibration, and with mean correction scale factors.

The stratum was grown for 150 years with no management with the FVSStand postprocessor combining the output by age into age-based yield tables. The plots within the stratum were given equal weight in the analyses. The resulting stratum data, presented in table 4, refer to the output obtained when the average stand age within the stratum was 113 years (up to 100 years of projection). Simulation mean responses for trees per acre, average dbh, merchantable cubic feet volume, sawlog cubic feet volume, and sawlog board feet volume obtained from FVSStand are displayed in table 4. The standard error of the mean sawlog board feet volume is also included.

Discussion

Little difference was seen when self-calibration was employed, presumably due to either the attenuation of scale factors over time or relatively few species having an adequate number of growth sample trees to self-calibrate. The largest relative differences in the example came when volume adjustments and mean correction scale factors were added to the simulations. Using the mean correction scale factors allowed for scaling of species that would not have been scaled due to too few growth samples in a particular stand. The scaling affected diameter growth, which then had secondary impacts on mortality. This is depicted in table 4 where the scale factors slowed down the diameter growth, smaller average dbh, which then impacted the SDI based mortality model, greater trees per acre.

Even though the relative growth differences are small, adjusting and calibrating FVS is still warranted. First, this example used a small sample from only one stratum out of a possible 135. Other strata may in fact have large growth

differences. Also, practicality is of the essence. It makes sense to adjust the volume merchantability specifications to those used on your district or forest. It also makes sense to calibrate the FVS growth functions to reflect past stand growth. Using mean correction scale factors helps to alleviate systematic bias of the growth functions, especially when self-calibration does not occur due to too few growth increments per species on a given plot. After further yield table review, it might be necessary to further calibrate the model by including regeneration estimates and modifications to the mortality model. The authors believe that the FVS adjustments and calibration techniques used in the Chattahoochee-Oconee plan revision are necessary and should be employed in other plan revision efforts.

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