A Growth and Yield Model for Predicting Both Forest Stumpage and Mill Side Manufactured Product Yields and Economics

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ABSTRACT

This paper presents and illustrates the application of a growth and yield model that supports both forest and mill side volume and value estimates. Traditional forest stand growth and yield models represent the forest landowner view of yield and economics. Predicted yields are estimates of what one would expect from a procurement cruise, and current stumpage prices are applied to investigate optimum management strategies. Optimum management regimes and rotation ages obtained from the forest side view are unlikely to be economically optimal when viewed from the mill side. The actual distribution of recoverable manufactured product and its value are highly dependent on mill technologies and configurations. Overcoming this limitation of growth and yield computer models necessitates the ability to predict and price the expected manufactured distribution of lumber, lineal meters of veneer, and tonnes of air dried pulp fiber yield. With these embedded models, users of the yield simulator can evaluate the economics of possible/feasible management regimes from both the forest and mill business sides. The simulator is a forest side model that has been modified to produce estimates of manufactured product yields by embedding models for 1) pulpwood chip size class distribution and pulp yield for any kappa number (Schultz and Matney, 2002), 2) a lumber yield and pricing model based on the Best Opening Face model developed by the USDA Forest Service Forest Products Laboratory (Lewis, 1985a and Lewis, 1985b), and 3) a lineal meter veneer model derived from peeler block tests. While the model is strictly applicable to planted loblolly pine (*Pinus taeda* L.) on cutover site-prepared land in the United States (US) Gulf South, the model and computer program are adaptable to any region and forest type.

INTRODUCTION

Growth and yield simulators project standing tree (stumpage) green weights and wood volumes by product category given stand characteristics and merchandizing specifications. They do not provide estimates of final manufactured yields such as dry pulp weight, lineal meters of veneer, and lumber by dimension. These models are highly valuable for forest landowners for determining the economics of various management regimes and land values (maximum price that can be paid based on potential value). However, they do not provide estimates of manufacturing yields and values, and they do not provide a good mechanism to determine the land value for companies who own both land and manufacturing facilities. In the case where a company does not own land, estimates of final product yields for forestlands are useful for determining how much a company can pay for stumpage (the break even point). In the case where a company owns both forestland and manufacturing facilities, final product estimates can be used to value company land or develop management strategies for optimizing profit.

For a growth and yield simulator to predict yields and economic measures for a typical multi-product company, it must include models for predicting dry weight pulp yields, lumber yields by dimension, lineal meters of veneer, and volume or weight of standing timber (stumpage). The objective of this paper is to describe a growth and yield simulator that incorporates models to estimate these final product yields. This growth and yield model also includes an economic analysis package that estimates forest side as well as mill side economics. Example evaluations of forest side and mill side economics for four differing southeastern US loblolly pine (*P. taeda* L.) multi-product management regimes are presented.

COMPONENT MODELS

Growth and Yield-Dry Weight Pulp Yield Simulator

A cutover site-prepared loblolly pine growth and yield simulator (Matney and Farrar, 1992) was integrated with a chip thickness distribution model (Schultz et al., 1999) and a single tree dry weight pulp yield model (Schultz and Matney, in press). This integrated growth and yield model produces realistic estimates of dry weight pulp yields for representative kappa numbers given user selected merchandizing specifications and management regimes. Chip thickness distributions, estimated from tree and stand characteristics (i.e., stand age, dbh class, chip height in the bole) and stumpage weights and volumes are also produced. Component survival and stand level prediction equations are given in Matney and Farrar (1992); tree profile and volume equations are described in Ledbetter et al. (1986); and a neural network chip thickness distribution model is described in (Schultz et al., 1999). A detailed summary of single tree dry weight pulp yield model construction and integration with the profile function of the growth and yield model is presented in Schultz and Matney (in press). The kappa number and pulp prices for mill side economics were obtained from an external Microsoft (MS) Excel file and are derived from industry information (Paperloop Inc., personal communication, Will Mies, May 20, 2005).

Sawmill Simulator

Data to predict lumber final products can be obtained from empirical mill studies or from sawmill simulators such as Best Opening Face Sawing Simulator Analysis (BOFSSA) (Lewis, 1985a) and Optitek (Forintek Canada Corporation, 1994). Mill tally or sawmill simulator models estimate the number of boards by dimension for logs given their scaling diameters and lengths. The BOFSSA sawmill simulator was integrated with the log merchandizing routine of the growth and yield simulator to produce expected lumber yields by dimension. This simulator assumes straight circular logs in even lengths from 1.83 to 9.14 m (6 to 30 feet). A similar program is available for sweepy or eccentric logs (Lewis, 1985b) but, for purposes of this paper, straight circular logs are assumed. BOFSSA parameters consisted of 5.08 cm (2-in) thick lumber using the cast sawing method, a saw kerf of 3.18 mm (0.125 in), dressing allowance of 2.78 mm (0.109379 in), saw setting increment of 0.079 mm (0.03125 in), thickness shrinkage of 4.62 percent, and tangential shrinkage of 7.7 percent.

The sawmill simulator was used to populate a MS Excel worksheet with expected lumber yields and prices by scaling diameter, nominal log length, board length, and edge dimension. Prices per thousand board feet (MBF) were obtained from Random Lengths (Church, 2006). A separate whole tree bucking table was also created as an MS Excel spreadsheet. The bucking table was obtained from a local sawmill. Bucking table log lengths ran from 2.29 to 27.13 m (7.5 to 89.0 feet) and assumed a trim allowance of 0.15 m (0.5 feet) per log. Table values give the number of bucked logs in 2.13-, 2.40-, 3.05-, 3.66-, 4.27-, and 4.88 m (7-, 8-, 10-, 12-, 14-, and 16-foot) lengths by tree length and scaling diameter.

The growth and yield simulator approximates per hectare diameter distributions for specified management regimes and produces a tree list of the number of trees per hectare represented by each diameter class. Merchantable tree heights for the tree list are calculated using a height prediction equation and specified merchantable top diameter limit. For each tree in the tree list, the simulator finds the closest entries in the log bucking table for the sawlog portion of the tree. The bucking table provides the number of logs by length in each tree length category, and a tree profile function provides the scaling diameter associated with each log in the tree. The nominal length and scaling diameter of each log are used as look-up indices in the BOFSSA lumber yield worksheet. The lumber yields and prices are summed for each tree and multiplied by the number of trees per hectare for that height and diameter. A grand total is summed over all trees in the growth and yield tree list.

Peeler Model

The peeler or veneer production model was derived from empirical proprietary data obtained from a peeler block test at a southeastern US veneer mill. These data were used to develop a regression equation for predicting lineal meters of veneer from peeler scaling diameter. Equation 1 was used to fill a MS Excel spreadsheet with lineal meters of veneer and values per 1000 lineal meters by bolt scaling diameter. Peeler bolt lengths are assumed to be 2.62 m (103 in).

$$LM = -12.14 + 0.05479 * SD^2. \tag{1}$$

$N = 556$, $R^2 = 99.6$, and $S_{y \cdot x} = 3.1$.

LM = lineal meters of veneer, and SD = scaling diameter in cm.

METHODS

Four typical southern US forest industry management regimes (Table 1.; three loblolly pine multi-product and one primarily sawtimber) were selected to demonstrate the integrated growth and yield simulator. Harvested weights and volumes and net present values (NPVs) were used to compare regimes and harvest schedules within regimes for identifying optimum management strategies and evaluating investments. NPVs for stumpage, the forest landowner side view, include revenues for pulpwood, chip and saw, peelers, and sawtimber and costs for establishment. NPVs for final product, the mill side view, include values for pulp, lineal meters of veneer, chip and saw, and sawtimber plus harvesting, manufacturing, and establishment costs. The assumptions for calculating NPVs and volumes were a cutover planting site, dominant site index of 22.2 m (73 ft) at base age 25, and initial planting densities of 1683 trees/ha on a 2.4 m by 2.4 m spacing (8 ft by 8 ft) for the multi-product regimes and 1076 trees/ha

Table 1. Expected stumpage and manufactured product yields and net present values (NPVs) for three multi-product management regimes and one primarily sawtimber management regime for hypothetical loblolly pine plantations in the southern US.

		Harvested volumes per hectare (ha)									NPV (2005 US $/ha)	
		Pulpwood	Pulp (tonnes)		Chip and saw		Peelers		Sawtimber			
Management regime	Management[a] operation year	Green tonnes	Kappa[c] 30	Kappa[c] 100	Green tonnes	Lumber bd ft[d]	Green tonnes	Veneer 1000 lin. m	Green tonnes	Lumber bd ft	Stump-age[e]	Final product[f]
Multi-product regime 1	1st thin at 16	30.894	12.270	13.717	6.919	1428	0.000	0	0.000	0	-297	-74
	2nd thin at 22	34.536	14.146	15.843	21.155	4557	2.536	377	0.000	0	0	541
	Harvest at 28	8.901	6.092	6.765	34.534	7801	45.613	6870	6.677	1717	739	1408
	30	8.078	6.135	6.811	32.821	8172	50.543	7401	11.922	3183	739	1473
	32	7.952	6.169	6.849	28.803	6397	54.219	8427	19.790	5263	731	1404
Multi-product regime 2	1st thin at 17	37.347	15.004	16.780	8.790	1866	0.000	0	0.000	0	-264	47
	2nd thin at 23	30.853	12.655	14.176	22.199	4848	4.191	579	0.000	0	35	633
	Harvest at 29	10.481	6.841	7.608	30.234	7668	48.805	7161	7.722	1890	754	1505
	31	9.636	6.686	7.433	28.734	6346	51.673	7874	14.343	3830	749	1450
	33	9.770	6.681	7.424	26.067	5841	55.191	8519	20.204	5439	731	1418
Multi-product regime 3	1st thin at 18	43.228	16.805	18.803	12.289	2597	1.229	178	0.000	0	-200	-2
	2nd thin at 24	29.010	11.886	13.319	20.777	4571	5.353	819	0.000	0	82	521
	Harvest at 30	10.691	7.045	7.840	30.527	7574	48.584	7135	8.861	2365	771	1374
	32	10.939	7.076	7.871	27.292	6103	52.182	8083	15.175	4023	761	1282
	34	10.948	6.959	7.740	25.851	5794	54.248	8377	20.977	5725	739	1255
Sawtimber regime	20 yrs 7" dbh[b]	34.702	14.389	16.087	26.255	5792	13.774	2054	0.000	0	67	363
	Harvest at 28	12.697	7.169	7.986	25.072	6392	40.735	6096	14.635	3892	791	1275
	30	11.205	6.942	7.730	24.781	6135	42.468	6186	22.410	6170	796	1327
	32	10.864	6.702	7.458	23.742	5308	44.508	6911	29.230	8058	781	1268

[a]Multi-product regimes include two thinnings and three possible harvest ages.

[b]Average stand dbh attained in 20 yrs at which time thinned to 272 trees/ha (110 trees/ac).

[c]Air-dried tonnes.

[d]There is no metric equivalent for board feet.

[e]Includes stumpage revenues for pulpwood, chip and saw, peelers, and sawtimber and establishment costs.

[f]Includes value of pulp, lineal meters of veneer, chip and saw, and sawtimber and costs of harvesting, manufacturing, and establishment.

on a 1.5m by 6.1 m spacing (5 ft by 20 ft) for the sawtimber regime. Multi-product regime 1 at age 16, removed 20 percent of rows in a row thinning and then reduced the basal area to 13.8 m^2/ha (60 ft^2/ac) with a selective thinning. At age 22, the stand was selectively thinned to 9.2 m^2/ha (40 ft^2/ac). Multi-product regime 2 was selectively thinned to 13.8 m^2/ha (60 ft^2/ac) at age 17 and then selectively thinned again at age 23 to 272 crop trees/ha (110 crop trees/ac). Multi-product regime 3 was the same as multi-product regime 2 except the age of the first and second thinnings were each delayed by one year. The first thinning of the sawtimber regime is scheduled at the age when the stand attains an average stand dbh of 17.8 cm (7 in), in this case at age 20. At that time, the stand is selectively thinned to 272 crop trees/ha (110 trees/ac). For all regimes, the initial site preparation and planting establishment cost of $494.21/ha is assumed. These initial costs were obtained by personal communication with A.W.Ezell, Mississippi State University, June 15, 2005. All costs and revenues are expressed in US dollars. Taxes and periodic or non-periodic management costs and revenues were not included in the NPV analysis. The discount rate used in the analysis is the reported June 2005 prime interest rate of 6 percent.

The tonnes of dry pulp were calculated by the integrated growth and yield simulator for each management regime and for kappa numbers 30 and 100, semi-bleached kraft and linerboard (unbleached kraft) grades, respectively. The final product NPV used the Southern softwood semi-bleached kraft pulp price ($630/air dried tonne averaged from June 2004 to May 2005) provided by Paperloop Inc. (personal communication, Will Mies, May 20, 2005). Harvest and manufacturing cost per outside bark green tonne are assumed to be $28 and $222. These costs resulted in a profit margin of about 7.3 percent depending on the size of the pulpwood trees harvested.

Lumber prices were taken from the *Southern Pine, Kiln Dried, Central* table in Random Lengths, Volume 62, Issue 10 (Church, 2006). The table presents prices for framing lumber. These prices were used because most lumber from plantation grown southern pine harvested between the ages of 28 and 32 is sold as framing lumber. The harvesting and manufacturing costs assumed were $28 and $7. All harvesting and manufacturing costs assumed in this paper are from proprietary sources. The assumed price of $213 for 1000 lineal meters of veneer is also from a proprietary source.

The assumed stumpage prices per green tonne outside bark for pulpwood, chip and saw, peeler and sawtimber of $10, $28, $52, and $52 were obtained from Forest2Market(*http://msucares.com/forestry/prices/reports/2005/2.pdf*) for the same June 2004 to May 2005 time period. Stumpage prices are for the forest side economic analysis.

RESULTS

The sawtimber regime with harvest age 30 (Table 1) has the highest forest side NPV ($796/ha). The multi-product regime 2 at harvest age 29 has the maximum mill side NPV ($1505/ha), approximately double the forest side NPV. The reason the NPVs for the best management regimes are so different on the forest and mill sides is because stumpage prices for large sawlogs are high while lumber prices for the larger dimensions are lower than prices for smaller sized framing lumber. A strong housing market is the probable cause of the escalated price of framing material. Thus, forest landowners would favor management regimes that produce large sawlogs. Companies owning both the mill and land would favor management methods that would produce a high volume of small framing lumber and plywood veneer.

While this analysis is based on the best price and cost information available, it is only a simple representative analysis for a hypothetical company and forest landowner. The analysis, however, does show that the best management regime will most likely be different for the forest and mill viewpoints. A growth and yield program such as the one described gives landowners and organizations the ability to analyze management strategies from a wide variety of viewpoints. Because the computer program (Cloblolly) for the growth and yield model places the lumber and peeler models into external files populated by the user, the user has maximum control over the economic analysis. Future versions of the program will externalize the dry weight pulp yield model to further increase end user control.

CONCLUSIONS

Forest stand growth and yield models have traditionally presented the forest landowner view of yield and economics. The predicted yields and values are those expected from a procurement cruise, and current stumpage prices are applied to investigate optimum management strategies. Optimum management strategies as viewed by the seller of stumpage may not be economically optimal from the view of the mill. The actual distribution of recoverable manufactured product and its value are highly dependent on mill technologies and configurations. To overcome this limitation of not predicting expected manufactured yields, models for estimating tonnes of air-dried pulp yields, lineal meters of veneer, and distribution of lumber production by dimension were integrated in a growth and yield simulator. Options within the simulator allow the selection of scenarios for stumpage sellers and mills that own or do not own forestland. The NPVs produced by the integrated simulator allow a company that owns both manufacturing facilities and forestland to obtain better estimates of the true value of the land base and determine the best management strategies for their required product mix. NPVs for selected management regimes can be used for decisions on harvesting or leaving stands to optimize current or future yields or for basing the purchase price of stumpage on expected product yields. Mississippi State University's integrated loblolly pine growth and yield simulator is downloadable from www.cfr.msstate.edu/fwrc/software.htm by selecting CLoblolly. Examples of the lumber yield, peeler yield, and plywood price MS Excel files are found in the installation subdirectory Template. The names of these files are DefaultLumberModel.xls, Default Peeler Model.xls, and DefaultPulpwood Model.xls. Also installed are the document files used to calculate the forest side and mill side economics for the four management regimes (Table 1). These files are found in the subdirectory Docs. The document files for the example management regimes for the case where a company buys stumpage from itself are installed but this paper does not report these results. The file naming convention for these files is GYif_MP_MR_ECON where MR = 1, 2, 3, or ST are the management regimes in Table 1, and ECON = MILL_FOR for mill side economics, FOR for forest side economics, and MILL for mill side economics when the mill buys stumpage from itself. For example, the document file for the mill side economics for the management regime of sawtimber would have the name GYif_MP_ST_MILL_FOR.

REFERENCES

Church, S. (ed.), Random Lengths 62(10):5-6 (2006).

Forintek Canada Corp., Optitek: User's Guide. Forintek Canada Corp., Sainte-Foy, Quebec, Canada, 185 pp. (1994).

Ledbetter, J.R., T.G. Matney, and A.D. Sullivan, Tree profile and volume ratio equations for loblolly pine trees on cutover site-prepared lands. Southern Journal of Applied Forestry 10(4):241-244 (1986).

Lewis, D.W., Sawmill simulation and the best opening face system: A user's guide. General Technical Report FPL-48. Madison, WI, US Department of Agriculture, Forest Service, Forest Products Laboratory, 29 pp. (1985a).

Lewis, D.W., Best opening face system for sweepy, eccentric logs: A user's guide. General Technical Report FPL-49. Madison, WI, US Department of Agriculture, Forest Service, Forest Products Laboratory, 13 pp. (1985b).

Matney, T.G. and R.M. Farrar, Jr., A thinned/unthinned loblolly pine growth and yield simulator for planted cutover site-prepared land in the mid-gulf South. Southern Journal of Applied Forestry 16(2):70-75 (1992).

Schultz, E.B. and T.G. Matney, An integrated growth and yield simulator for predicting loblolly pine dry weight pulp yields. Wood and Fiber Science (In Press).

Schultz, E.B. and T.G. Matney, Prediction of Pulp Yields from Loblolly Pine Stand and Tree Characteristics. 2002 TAPPI Fall Technical Conference. September 11, 2002. San Diego, CA (2002).

Schultz, E.B., T.G. Matney, and J.L Koger, A neural network model for wood chip thickness distributions. Wood and Fiber Science 31(1):2-14 (1999).