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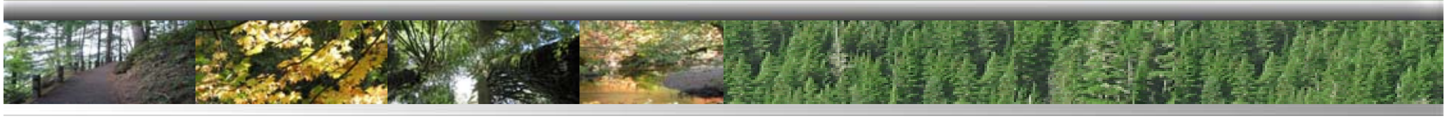

The FORSight Resource

Volume 5, Issue 1 Q3 2008

Upcoming Events...

INFORMS Annual Meeting
October 12-15, 2008
Washington, DC
http://meetings.informs.org/DC08/

Variable Probability Sampling Workshop
October 13-16, 2008
University of Maine, Orono, ME
http://www.umaine.edu/conferences/

Longleaf Alliance Biennial Conference
October 28-November 1, 2008
Sandestin, FL
http://www.longleafalliance.org

SAF National Convention
November 5-9, 2008
Reno-Tahoe, NV
http://www.safnet.org/natcon-08/

15th Biennial Southern Silvicultural Research Conference (BSSRC)
November 17-20, 2008
Hot Springs, AR
http://www.srs.fs.fed.us/bssrc2008/Program.htm

Inside this issue:

Stem Merchandizing in Growth and Yield Models

Growth and yield (GnY) models quantify forest growth, providing a means for estimating future timber volume. An important aspect of GnY modeling is product volume recovery. Rather than reporting total stand-level volume, it is of interest to report volume by product. Products often have markedly different values, meaning product-level volumes may play a role in the economics of management activities. This is particularly true in areas with high value timber, where the price differential between products may be large. Product volumes are recovered by dividing stems into segments and assigning a product to each segment based on its size. Product volumes are summed and expanded to the stand-level. This process is commonly referred to as stem merchandizing.

Little research has been conducted to examine the impacts of merchandizing on GnY volume estimates. There are two basic merchandizing algorithms commonly used in GnY models; fixed length and maximized product length. It is widely believed, however, that these methods produce suboptimal product-level volume estimates. As the value differential between products has widened, planners are increasingly interested in generating optimal or near optimal merchandized yields. Although the implications of optimally merchandized yields on both GnY volume estimates and forest planning decisions are unclear, they provide a baseline to measure other methods against. This article examines merchandizing in GnY models and the impact on volume estimates.

Fixed length merchandizing is the most common and perhaps simplest merchandizing method commonly employed. Figure 1-B illustrates the fixed length technique. The stem is divided into segments of a user-defined fixed length. The segments are then put into the highest-value product 'bin' based on their length, small-end inside-bark diameter (SED) and volume. The Forest Projection and Planning System (FPS) (Arney et al. 2007) and the National Volume Estimator Library (NVEL) (USDA Forest Service 2006) use variations of this method.

The second common method, maximized product length, is outlined in Figure 1-C. This method assigns the longest possible length to each product. In its simplest form, the technique moves through each product from highest to lowest value and calculates the height to reach the minimum SED for that product. The resulting segment, located between the height to SED and the height merchandized thus far, is tested against the product specifications (minimum length and volume). If the piece fails to meet product specifications, it is ignored and the algorithm moves to the next product. This method is sometimes called whole-tree because it avoids the culled top pieces that may occur with the fixed length method. The Forest Vegetation Simulator (FVS) (Dixon 2008) and FPS implement variations on this technique.

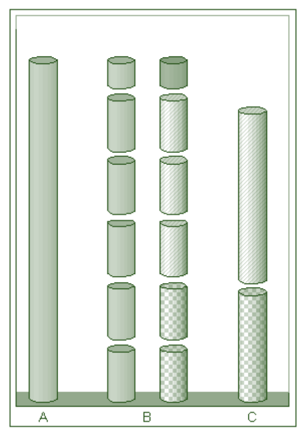

Figure 1. Illustration of fixed length (B) and maximized product length (C) merchandizing methods with two products.

In Figure 1, the products are represented by checkerboard and cross-hatched patterns)

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Stem Merchandizing...

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using a cylinder to represent a tree stem (A).

A key consideration with both methods is that they are naïve. They divide the stem into segments without considering total stem volume or value. Although they provide a means for recovering product-level volumes, they fail to address optimal merchandized yields. As planners become increasingly interested in generating such volumes, the need for an alternate algorithm becomes apparent.

The tree merchandizing problem discussed thus far represents a simplification of the log bucking problem. Log bucking refers to the conversion of trees into round wood products. After a logger fells a tree, a series of cuts are made to create the logs delivered to processing facilities. Cut locations play a critical role in determining the value recovered from the tree. As a result, the problem of stem-level bucking optimization has received widespread attention. Authors have proposed various algorithms for addressing bucking optimization, including complete enumeration, mathematical programming, and dynamic programming. Variations on the dynamic programming approaches are by far the most widely cited. Dynamic programming appears to be a good candidate for integration into GnY models until solution times are considered. Solutions times of 1-2 seconds per stem, while acceptable for many applications are excessive when considering GnY models. Thousands of stems are merchandized over multiple growth cycles, meaning solution times substantially less than 1sec/stem are required. In response, an algorithm capable of producing near optimal merchandizing with less computational burden was developed. Although a detailed discussion of the proposed algorithm, termed the 3-Piece algorithm, is beyond the scope of this article, results indicate that it exhibits less computational burden while producing near optimal stem-level values.

The impact of merchandizing algorithms on GnY volume estimates was tested by projecting a stand and merchandizing it with each algorithm. A 9-year old Douglas fir plantation with a site index of 140 was projected for twenty 5-year growth cycles using the Stand Management Cooperative (SMC) ORGANON v8.2 variant. Five products were used; No. 1, No. 2, No. 3, No. 4, and utility grade sawlog (see Northwest Log Rules Advisory Group 2006 for product specifications). In all cases a maximum log length of 32 feet was imposed and log lengths were required to be in 2-foot increments.

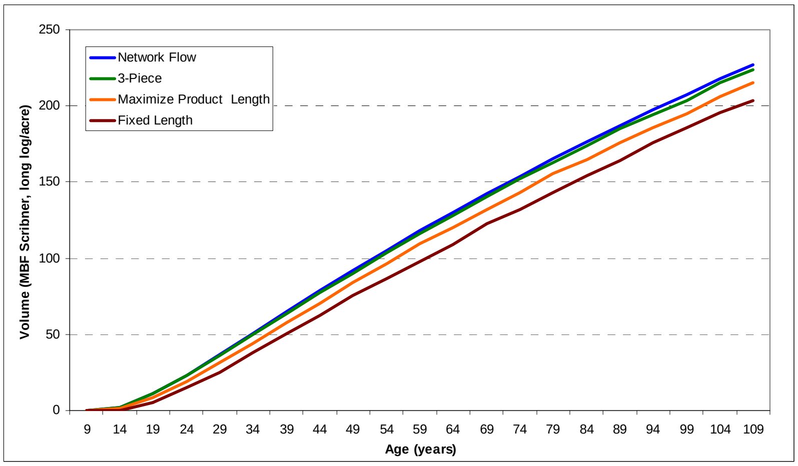

Figure 2. Projected per acre stand volumes using 4 merchandizing algorithms.

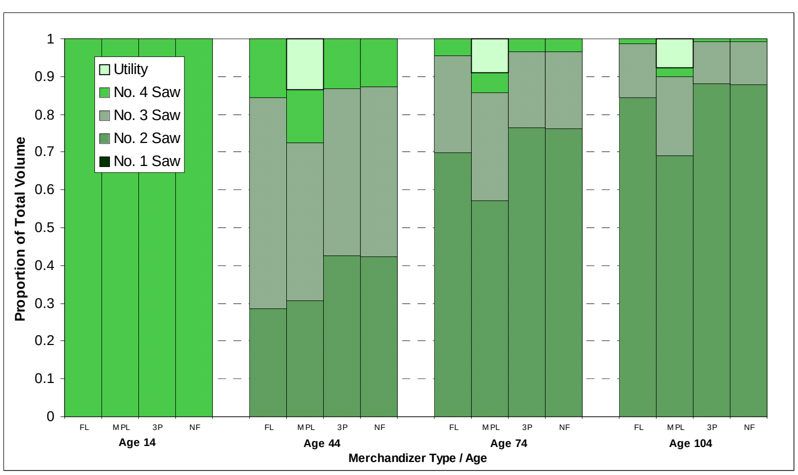

Figure 3. Product proportions at 4 points during projection period with each merchandizing algorithm (FL = Fixed Length, MPL = Maximize Product Length, 3P = 3-Piece, NF = Network Flow).

Stumpage prices were Oregon Region 1, Q1 2008 average delivered prices (Oregon Department of Forestry 2008). Stand-level volumes and values for the fixed length (FL), maximized product length (MPL), 3-Piece (3P), and network flow dynamic programming (NF) approaches were compared over the growth period.

Total stand volume results from the GnY projection are shown in Figure 2. The importance of an efficient merchandizing algorithm is illustrated by per-stand GnY runtimes; 0.88 seconds (FL), 0.89 seconds (MPL), 161.03 seconds (NF), and 1.42 seconds (3P). NF took more than 100 times longer than 3P and more than 180 times longer than FL/MPL, indicating the limitations of dynamic programming for GnY modeling. Although 3P took nearly twice as long as FL/MPL, the runtime is not restrictive in terms of practical implementation.

3P merchandized volumes were within 1.4% of the NF values on average, with the worst case volume shortfall only 1.8%. FL produced 23,589 BF/acre (10%) less and MPL produced 11,654 BF/acre (5%) less than NF after 100 projection years. This constitutes values losses of $13,187/acre and $10,970/acre respectively. This is tempered somewhat by considering the entire projection, where average value losses were only $7,908 and $7,413, respectively. Note that it may be possible to lessen the FL volume shortfall by specifying a fixed segment length shorter than the 32 feet used here. Applying the maximum log length as the fixed length increment is, however, common practice.

Figure 3 shows product proportions by volume at 4 points during the projection. None of the algorithms produced No. 1 sawlog volume. This is an artifact of the product specifications rather than the algorithms them-

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Forest Projection & Planning System

	PARTICULARS
Author	James D. Arney (Forest Biometrics Research Institute)
Species	16 Regional Species Libraries (max 96 species per stand)
Region	Western United States and Canada
Silviculture	Site preparation, brush & animal control, thinning and fertilization
Model Type	Tree-level distance-dependent model
Add'l Info	http://www.forestbiometrics.com/software.html

The Forest Projection and Planning System (FPS version 6.51) is an integrated software package for forest inventory, growth projection, silvicultural planning, and long-term harvest scheduling. FPS, originally released in 1995, is marketed through the Forest Biometrics Research Institute (FBRI), a non-profit private research organization. The following review only discusses the FPS growth model.

The FPS growth model has been designed to provide reliable projections for plantations and natural stands, as well as mixed species, multi-age, and varied-structure stands. The growth model architecture includes the following features:

Open-Architecture Database Structure

FPS uses Microsoft ACCESS as a relational database and interface for handing cruise data, growth model run parameters, and projection output. The interface provides the user the ability to readily customize database tables, queries, forms, and reports, and is unique to FPS.

Regional Species Libraries

FBRI currently maintains 16 regional libraries covering Washington, Oregon, California, Idaho, Montana, Hawaii, Alaska, British Columbia, Alberta and Saskatchewan with multiple local regionalizations based on productivity, habitat, climate, and species occurrences. Parameters within the libraries can be locally calibrated to each user's operating area to produce more precise application of survival and height growth estimators. A maximum of 96 species and 20,000 trees may be represented per stand per growth projection period.

Silvicultural Treatment Regimes

Alternative thinning treatments include from below, d/D ratio, from above, via a minimum/maximum range, or group selection to a maximum 2-acre opening. The user can specify site preparation, along with brush and animal control efficacy to the nearest 10% (range: 0-100%). In addition, the user can prescribe nitrogen fertilization to the nearest one pound per acre. Silvicultural treatments are specified as regimes, with a maximum of 12 treatments per regime, and an unlimited number of regimes per stand.

Tree-Level Competition

FPS is a distance-dependent growth model. A clumpiness index, derived from a variation in crown competition factor, is calculated from tree data on each sample plot. This index is used for generating an approximate stem map and a competitive stress index (CSI) for each tree.

Biologically-Based Growth Intervals

FPS growth intervals are based on 6-meter height increments. These growth intervals are meant to be long enough to observe treatment and environmental affects on growth and mortality. FPS generates projections for intermediate ages by interpolating within each growth interval.

Merchandizing

Each species may be compiled to its own merchantability specifications, log

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Stem Merchandizing...

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selves. The No. 1 sawlog SED is 30 inches. Trees do not reach adequate size to qualify for this product during the growth projection. Substantial utility grade material is present only with MPL. This illustrates that MPL tends to generate longer segments with the minimum SED relative to the other methods. MPL also results in markedly less No. 2 sawlog and more No. 3 than the other methods. This explains why, despite producing approximately 12 MBF/acre more than FL at 104 years (see Figure 2) the value differential is just over $2,000/acre. Figure 4 confirms that FL and MPL produce nearly identical stand values throughout the growth period despite total volume differences. The strategy of maximizing length assigned to each product tended to favor lower valued products.

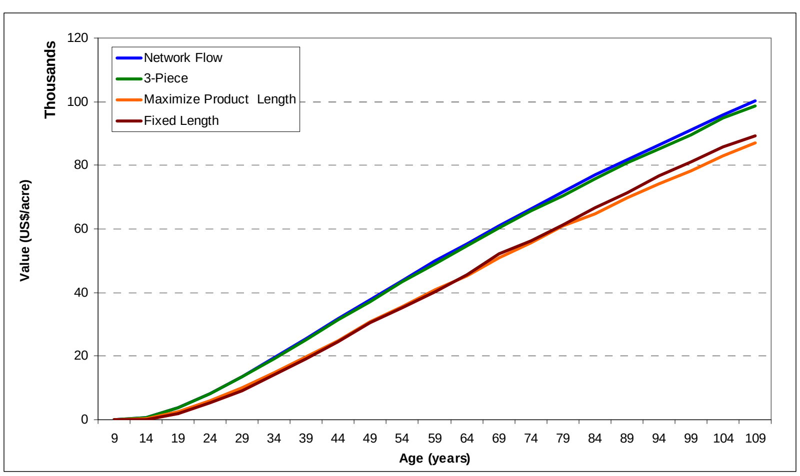

Figure 4. Projected per acre stand values using 4 merchandizing algorithms.

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FPS Review…

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sorts, and value classes. The user can specify top diameters, log lengths, log qualities, and log values by species.

In summary, FPS provides flexibility and functionality that is not commonly available in other growth and yield models. Improvements to the documentation would help users to unlock the capabilities of this powerful tool. In addition, a peer-review of the growth equations would help experienced biometricians to understand the biological basis and the inner workings of the model so that the FPS model can be applied more effectively. Training workshops are offered by FBRI which are described as giving users the opportunity to interact with the model developers and learn more about the inner workings of FPS.

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Stem Merchandizing…

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Results indicate that the 3-Piece algorithm performs well, exhibiting less computational effort than NF while producing similar stand values. It provides a viable alternative for generating near optimal product volumes in the GnY modeling context. FL produced substantially lower volumes than NF. MPL produced total volumes that fell between NF and FL, but favored lower valued products relative to the other methods. The result is that NF and MPL produced similar stand values throughout the projection.

A cautionary note regarding optimally merchandized volume estimates is warranted. In general, GnY models do not produce estimates of stem-level defects such as rot, disease, and sweep. It is widely accepted that these defects result in volume loss. Because the outlined algorithms assume a defect-free stem, volumes will exhibit positive bias over those that could be achieved in practice. This can be alleviated by applying a defect-related volume reduction based on piece size. Although this would reduce total volume, it may not accurately capture changes in product proportions. An alternate approach would be applying a probability matrix relating piece size to the likelihood of its' suitability for a given product. The optimization problem then changes to maximizing the expected stem value. A secondary consideration is that optimal bucking strategies are rarely implemented in the United States. Various authors have demonstrated the stem-level volume shortfalls resulting from suboptimal bucking. As a result, the positive volume bias will be exaggerated when an optimal bucking strategy is not used.

This leads to the question, what merchandizing method should be used in GnY modeling? Although not addressed in this article, it can be reasoned that the best approach may be to mimic the methodology currently implemented on the ground. If cutting a series of fixed length logs is the current practice, then FL may produce the most realistic volumes. Note that in addition to the merchandizing technique, the product specifications should also match those used on the ground. The importance of yields shadowing those that can be generated in practice should not be overlooked. Yield estimates are the primary input in forest planning models. As such, yield bias can have profound effects on model results, including feasibility issues and selection of sub-optimal solutions. Incorrectly estimating merchandized volumes can alter economic rotations which may translate into substantial value loss. These concerns point towards the need for advance merchandizing algorithms such as 3P that are capable of implementing merchandizing strategies more advanced than the naïve FL and MLP approaches.

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