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Measuring and Modeling Tree Taper

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This note touches upon the measurement of tree taper and the modeling of tree taper. Methods incorporated into FBRI's Forest Projection and Planning System (FPS) are compared to approaches used in other growth models.

Girard "Form Class" versus FPS "Taper Class"

The traditional practice for estimating tree form has been to ***select a sample height*** on the tree and then measure an associated upper stem diameter at that height. The most common example of this approach is the Girard 16-foot Form Class measurement. The cruiser determines a point on the tree which appears to be 17.3 feet from ground level (including a 1-foot stump height and a 0.3 ft trim allowance). Then, most commonly, a Spiegel Relaskop is used to estimate the diameter of the tree at that height. Girard Form Class is then computed as the diameter inside bark at 17.3-feet divided by the diameter outside bark at breast height. Resulting values typically range from 0.66 to 0.86 as dib/Dbh ratios.

An alternative approach is to ***select a sample diameter*** on the tree and then measure the associated height to that diameter using the same Spiegel Relaskop identified previously. Since the Relaskop is designed to easily adjust for slope, backing away from the tree until the tree is 'boarder line' at breast height is well understood. Then the cruiser shifts up the tree profile until a height is achieved which is 80 percent of the view bars width at breast height. That height is recorded. Taper Class is then that intermediate height (- 4.5) divided by total tree height (- 4.5). Values typically range from 0.10 to 0.50 as height ratios.

The Spiegel Relaskop is designed to be relatively precise for measurements of height while removing the effects of topographic slope and terrain. It is only precise for tree diameter at fixed edges of black and white horizontal bars. This is not effective for a precise measurement of a tree diameter at a specific height, as is required for Girard Form Class. The cruiser must interpolate within the Relaskop bars visible in the view of the tree bole. However, it is very effective for obtaining a precise measurement of height at a specific relative diameter, as is required for FPS Taper Class.[1]

Silviculturally, we will apply the group selection treatments in a staggered time series. The objective is to not allow the harvest openings to expand in size as each additional year gets invoked. As expressed in the SAF Dictionary, the management unit may be identified as an aggregation of groups. Figure 1 provides a partial view of stands where each stand (unique color) is divided into five groups. The sequence of harvests will be staggered in time within each stand so that 20 percent of each stand is harvested at each entry. For a 60-year rotation, each stand will experience harvest entries at 12, 24, 36, 48 and 60 years. A minimum 12-year green- up period is provided (by design) between each harvest entry and its neighbors.

Tree form changes due to crown recession. At high densities, intermediate and suppressed trees have small crowns and a more cylindrical form than open-grown trees. This is demonstrated in Figure 1 where 5,656 felled and measured Douglas-fir trees were grouped by FPS Taper Class. Diameters and heights along the bole were simply converted to relative

[1]As discussed in the FPS Forester's Guidebook (Arney 2015) and FPS Mathematics of Trees (Arney 2016), quality control and review of field precision should begin before going to the field.

diameters and relative heights as proportions of Dbh and total height, respectively. The trees were then simply grouped into five taper classes based on the relative height values of each tree at the point where the upper diameter is 80 percent of the Dbh. Look closely at Figure 1 and notice that the greatest height differences between curves occur at approximately 80 percent of Dbh. The highest curve represents suppressed tree forms (Taper Class = 50%). The lowest curve represents open-grown tree forms (Taper Class = 10%). Note the vertical reference bar to highlight this index point.

Table 6. *Comparison of measurement precision required to determine "taper" versus "form" classes for 12-inch, 80-foot tall trees.*

Taper Class	ht80 (ft)	ht80 diff.	dob17	dib17	dib diff.	Form Class
10%	12.1		9.2	8.2		.68
		7.5			0.8	
20%	19.6		10.1	9.0		.75
		7.5			0.5	
30%	27.1		10.6	9.5		.79
		7.5			0.4	
40%	34.6		11.0	9.9		.82
		7.5			0.2	
50%	42.1		11.3	10.1		.84

Also notice that an 80-foot tall tree would have a form class measurement at (17.3-4.5)/(80-4.5) = 0.17 height level in Figure 1. This is approximately the greatest horizontal difference between taper class curves anywhere in the Figure. To distinguish between these five taper curves in the field would require the precision in measurements as outlined in Table 6.

As you can readily observe, to distinguish a taper difference in a 12-inch, 80-foot tree using the taper class method requires observing a 7.5-foot difference in height between each class. This is feasible using a standard handheld Spiegel Relaskop. However, to distinguish the same differences using the form class method requires observing a 0.2 to 0.8-inch difference in inside bark diameter at 17.3 feet up the tree bole. Each 0.02 step in Form Class (i.e., 78% to 80%) requires a 0.2-inch precision in diameter inside bark at 17.3 feet in Table 6 (a 12-inch tree which is 80 feet tall).

Accurately measuring Girard Form Class on a per tree basis is not feasible using any standard field instrumentation available to the forester unless it includes a ladder and bark gauge.

The observation of relative height, (intermediate height - 4.5ft) / (total height - 4.5ft), where outside bark diameter is eighty percent of the diameter at breast height is the most consistent method for obtaining a third parameter in the field given the limitations of the measuring instruments available to the forester. This is a strong statement since most foresters, who were traditionally estimating taper in the Northwest, have relied on Girard Form Class methods.

No regressions had been attempted on these 5,656 trees prior to display in Figure 1. The point being made here is that the scaling to a relative basis takes away the need to account for large trees versus small trees. Only the difference in taper profile is left to be disclosed. Taper Classes are the relative height values (10%, 20%, 30%, 40% and 50%) at 80% of Dbh (vertical bar).

Taper Equations

Traditional developments of taper equations have relied on the use of a diameter measurement at a fixed height to distinguish differences in taper profiles, such as Girard Form Class. When a large dataset is obtained containing trees across a broad range of Dbh and total height, the traditional least squares regressions tend to default to the trend in average profile from a small tree to a large tree. The variation in observed form is mostly absorbed due to the least squares parametric statistical approach. This shortcoming is evident when overlaying typical taper equations on the Figure 1 display of raw tree averages grouped by Taper Class.

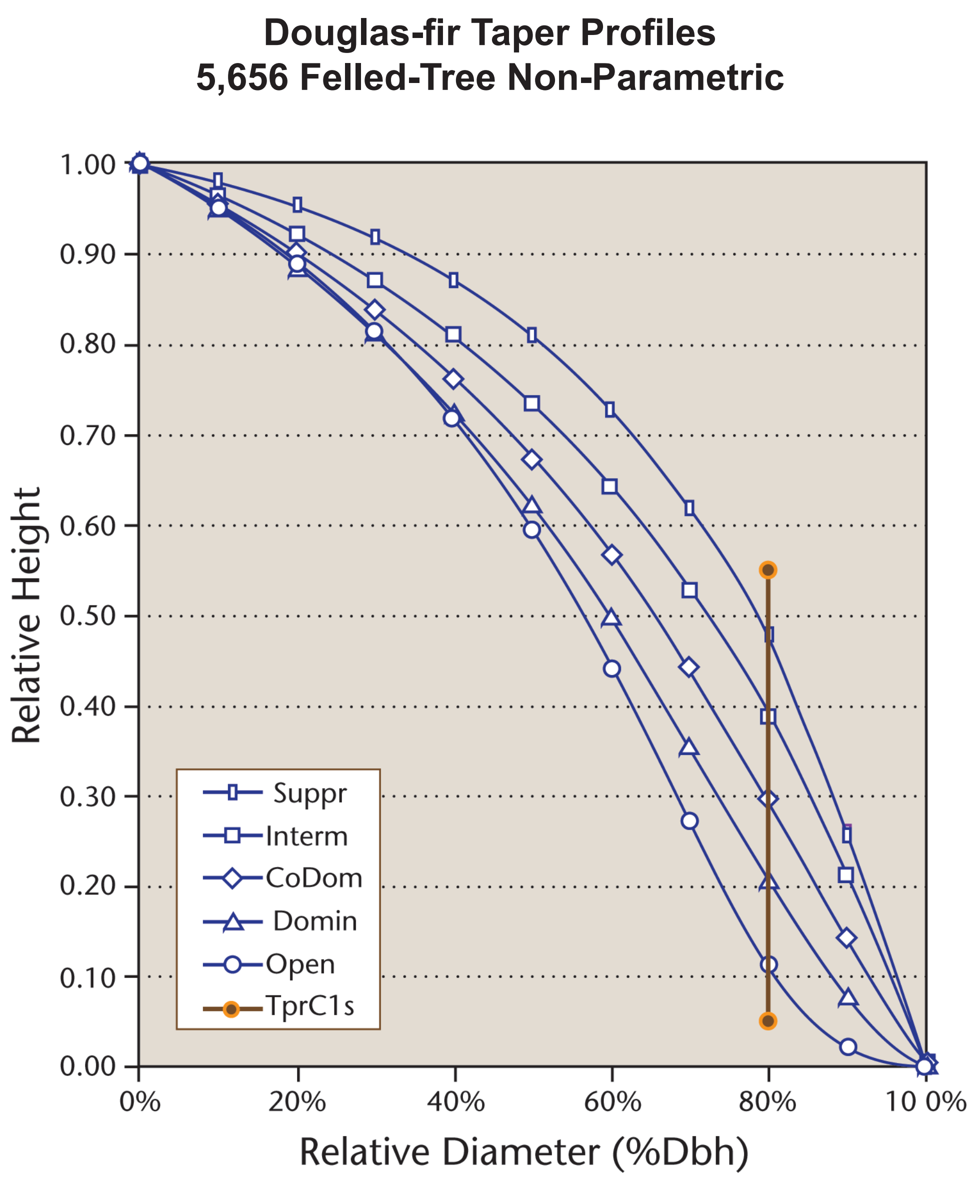

Figure 1. *Raw averages of felled-trees by Taper Class.*

Examples are the tree taper and volume functions used in the FVS and ORGANON growth models. These are based on parametric models and are displayed in Figures 2 and 3, respectively.

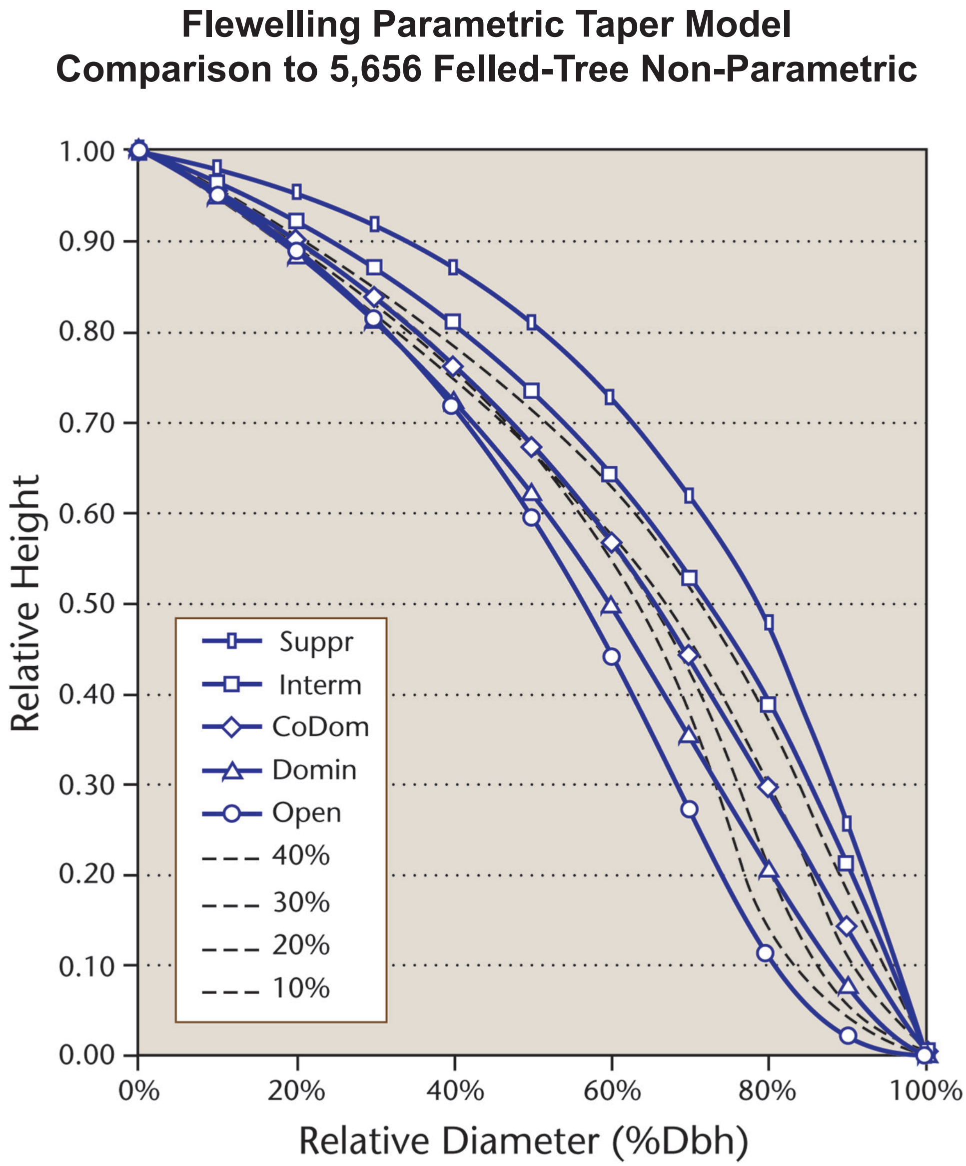

Figure 2. *Douglas-fir taper model (dashed lines) used in FVS relative to actual data.*

Without fault to the author, the range in absolute tree dimensions among trees is far greater than the range in differences due to taper. As a result the regression analysis collapses to the basic equation form selected by the author, rather than discover the underlying taper. The taper regression approach selected by the author tends to be more sensitive to the butt of the tree than the top.

Again, without fault to the author, the range in absolute tree dimensions among trees is far greater than the range in differences due to taper. As a result the taper regression analysis collapses to the basic equation form selected by the author. In this case this equation form is more sensitive to upper stem profiles than lower stem profiles.

Results from these **parametric** taper approaches – Two parametric equation forms, one species, are creating two very different results in two different growth models even if the growth dynamics were modeled identically. Even the starting

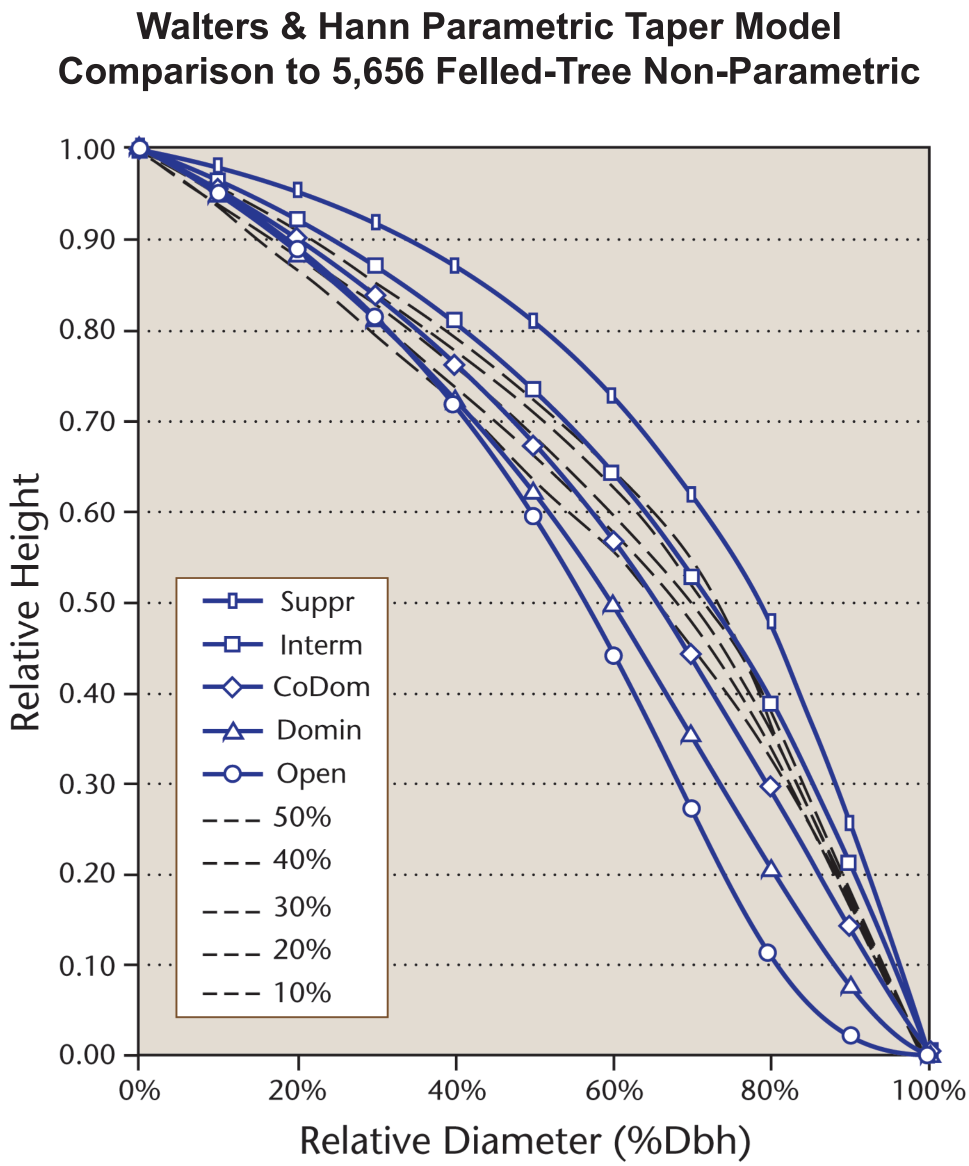

Figure 3. *Douglas-fir taper model (dashed lines) used in ORGANON relative to actual data.*

cruise compilation results in different volumes! ***A better solution is the nonparametric FPS Taper Class approach. It can capture the range of the variation commonly found in tree taper profile data, and it provides a clear separation of tree profile differences regardless of tree size.***

Literature Cited

Arney, J. D. 2015. Biometric Methods for Forest Inventory, Forest Growth and Forest Planning — The Forester's Guidebook. Forest Biometrics Research Institute. Portland, Oregon. 328 pages.

Arney, J. D. 2016. Mathematics of Trees — Analysis of the FPS Universal Library. Forest Biometrics Research Institute. Portland, Oregon. 152 pages.