A DIAMETER DISTRIBUTION APPROACH TO ESTIMATING AVERAGE STAND DOMINANT HEIGHT IN APPALACHIAN HARDWOODS

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Abstract—A technique for estimating stand average dominant height based solely on field inventory data is investigated. Using only 45.0919 percent of the largest trees per acre in the diameter distribution resulted in estimates of average dominant height that were within 4.3 feet of the actual value, when averaged over stands of very different structure and history. Cubic foot and board foot yields on a per acre basis can be easily obtained based solely on field tally of tree diameters and total height on inventory samples.

INTRODUCTION

In many different cover types, stand volume per acre can be accurately determined as a function of stand basal area and average dominant height (Brooks and Wiant 2004). The determination of average dominant height normally requires the subjective assignment of crown class and the measurement of tree total height. Previous studies have shown that stand average dominant height can be accurately predicted using a percentage of the diameter distribution, when arranged in decreasing size order (Bailey and Brooks 1994, Bailey and Martin 1996, Brooks 2003). This percentile of the diameter distribution in pines has been shown to be very stable and can be used to extract average dominant height from inventory data when crown class assignment has been omitted. The estimation of hardwood stand volume based on these two stand level variables has also been shown to be quite stable (Brooks and Wiant 2004) but this diameter distribution approach has never been reported for the determination of average dominant height in more variable hardwood populations. This study uses permanent sample plot data collected in three very different hardwood stand conditions to test this application for the estimation of stand average dominant height.

METHODS

Three Appalachian hardwood datasets were selected for study based on the precision of measurements and the diversity of stand types. All three locations involve permanent fixed area sample plots where dbh, total height and crown class were recorded for all trees 4.6 inches dbh and larger. Diameters were measured to the nearest 0.1 inch with a diameter tape, while total heights were recorded to the nearest 0.1 foot with an Impulse laser hypsometer. The first dataset represents the initial measurement and some remeasurement data on 40 square 0.2 acre sample plots located on the West Virginia University Research Forest (WVURF) located in north central West Virginia. This forest is approximately 75 years old and is predominately even-aged. The forest is composed of two broad cover types; mesophytic and oak types. In general, the mesophytic types occur on north and east-facing aspects and coves while the oak types occur on south and west aspects and ridges. Descriptive statistics of the forest structure are displayed in table 1. The second dataset represents 67 circular 0.2 acre permanent sample plots located near Daily, West Virginia (Tygart). This forest was originally even-aged prior to a diameter limit selection harvest in the early 1970s. Dominant species include white oak (*Quercus alba* L.), chestnut oak (*Q. prinus* L.), scarlet oak (*Q. coccinea* Muenchh.), yellow-poplar (*Liriodendron tulipifera* L.) and northern red oak (*Q. rubra* L.). Descriptive statistics of the forest structure are displayed in table 1. The third dataset is based on 15 circular 0.1 acre permanent plots located in southeastern Ohio. This forest includes dominant trees of 110 years of age and is dominated by maples (Acer spp.), oaks (Quercus spp.) and American beech (*Fagus grandifolia* Ehrh.). Descriptive statistics of the forest structure are displayed in table 1.

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Table 1—Descriptive forest statistics for the three hardwood datasets

Forest	No. plots	TPA	BAAC	Max DBH	DHT
			ft²		*ft*
WVURF	57	193.3	153.7	35.0	89.4
Tygart	67	228.6	107.7	29.5	73.4
Ohio	15	207.3	83.8	28.1	71.6

TPA = trees per acre; BAAC = basal area per acre; DHT = average dominant height;
WVURF = West Virginia Univeristy Research Forest.

For each dataset, all inventory data were sorted by plot number in decreasing dbh and total height order. For each plot, a percentile of the diameter distribution was identified where the average total height of the current tree and all larger trees was approximately equal to the average height of all dominant and codominant trees, regardless of species type. This percentile was identified for each plot and the mean and variance of this value was determined for each dataset and across all plots and locations. To ascertain whether a single percentile could accurately estimate stand dominant height across these very different stand conditions, the average bias and root mean squared error (RMSE) between actual and estimated average dominant height was determined for each plot in each of the three datasets. In addition, the sensitivity of the mean dominant height estimation error was examined as the percentile of the ranked diameter distribution was varied from 10 to 90 in steps of 10 percent.

RESULTS AND DISCUSSION

The diameter distribution percentile that equates to average dominant height was calculated for each sample plot of the 3 forests examined. These percentiles ranged from 9 to 84 percent, with a mean of 45.0919 percent when averaged across all plots (fig. 1). Although visually quite variable, the variance across all plots is only 0.024918. The average diameter distribution percentile and its associated variance are shown by forest and across all plots (table 2). To determine whether a single percentile could be used to accurately estimate average dominant height, the average height of all trees in the upper 45.0919

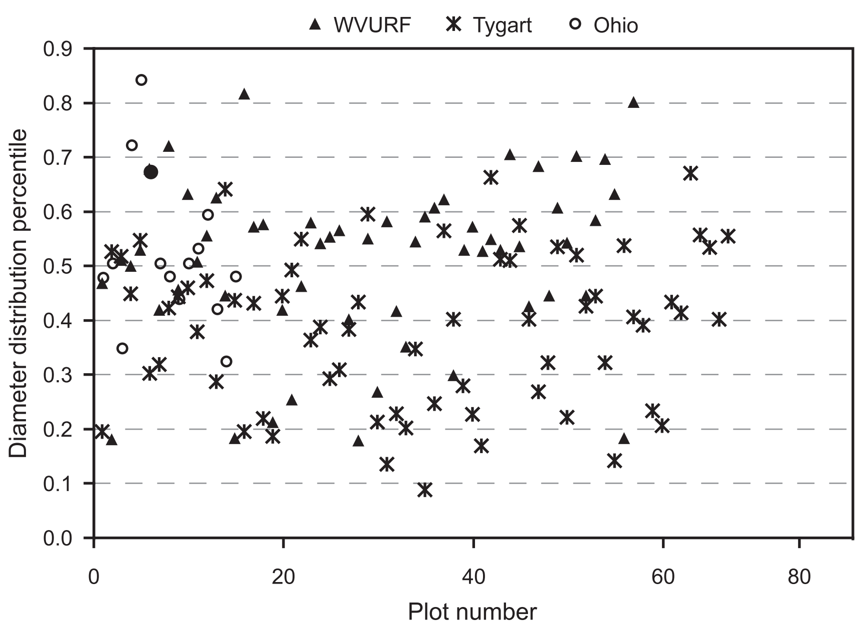

Figure 1—Distribution of average dominant height percentiles by plot and location.

percent of the diameter distribution was calculated for each plot and compared to the known average dominant height based on total height and crown class assignment. Both average bias and RMSE of this height difference was evaluated. Average bias ranged from -8.7 feet (Ohio) to 1.3 feet (WVURF) with a mean across all plots of -1.5 feet (table 3). Based on average bias, the percentage of plots within 10 feet of the actual dominant height ranged from 96 (WVURF) to 60 percent (Ohio). Across all the datasets tested, 88 percent of the individual plots were estimated within 10 feet of the actual value. Similar results were obtained when the RMSE of the prediction error was evaluated. RMSE ranged from 2.5 (WVURF) to 8.7 feet (Ohio). The average error across all plots was 4.3 feet. The percentage of plots within 10 feet of actual dominant height was identical to that expressed for average bias.

To evaluate the sensitivity of the percentile value, the diameter distribution percentile was varied from 10 to 90 percent of the ranked distribution and average dominant height error was calculated at each step. Average error was within 10 feet of the actual dominant height value for an extended range, the smallest of which was with the Ohio dataset where a 10 foot error was obtained within a range from 10 to 50 percent of the ranked diameter distribution (fig. 2).

Prediction of average dominant height in central hardwoods without the field assignment of crown class appears feasible given the stability of the diameter distribution percentile. The plot data selected for study was chosen due to large differences in stand history and structure. The WVURF plots are the

Table 2—Mean and variance of the average dominant height percentile by location and across all locations

	Dominant height percentile	
Forest	Mean	Variance
WVURF	0.4492	0.0231
Tygart	0.3858	0.0202
Ohio	0.5233	0.0188
All	0.4295	0.0249

WVURF = West Virginia Univeristy Research Forest.

Table 3—The average bias, RMSE prediction error and percentage of plots having an average bias within 10 feet of the actual dominant height

Forest	Average bias	RMSE	Percent within 10 feet
	- - - - - - *feet* - - - - - -		
WVURF	1.3	2.5	96.5
Tygart	-2.4	4.9	88.1
Ohio	-8.7	8.7	60.0
All	-1.5	4.3	88.5

WVURF = West Virginia Univeristy Research Forest.; RMSE = root mean squared error.

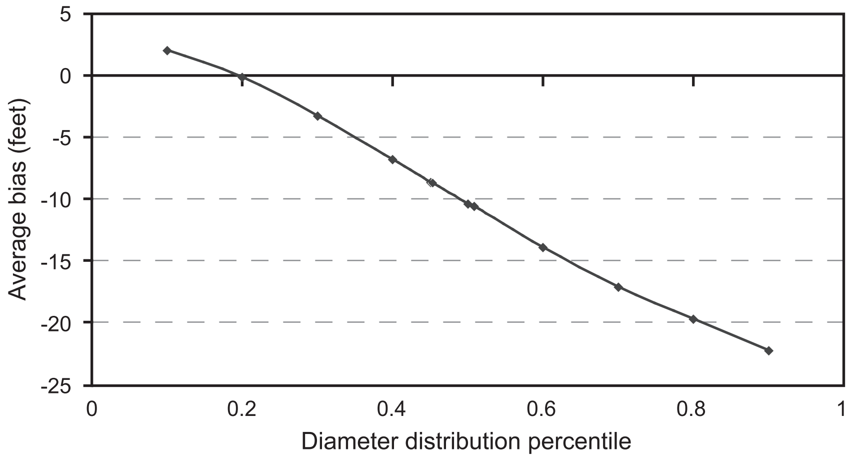

Figure 2—Average dominant height bias in feet by diameter distribution percentile for all sample plots in the Ohio location.

most uniform providing a dominant height RMSE of only 2.5 feet over 57 permanent plots. This error is arguably less than traditional measurement error. In the Tygart dataset, some of the overstory was removed in the early 1970s. The average diameter distribution percentile was smaller in this forest, reflecting the need to only include a portion of the largest trees. In the Ohio dataset, the forest has a much more developed stand structure with many sugar maples developing into the codominant crown class from existing gaps in the canopy. In this situation, much more of the diameter distribution is needed to quantify the average dominant height. Based on field measurements of diameter and total height, both basal area per acre (total and sawtimber only) and average dominant height can be quickly determined and whole stand volume (ft^3 and bf) can be estimated using equations published by Brooks and Wiant (2004, in press). Their results indicate that over 90 percent of the variation in volume yield can be explained by these two stand level variables.

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