1986

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RELATIONSHIP BETWEEN DIAMETER BREAST HIGH AND DIAMETER NEAR GROUND LINE FOR HARDWOOD SPECIES IN ARKANSAS

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ABSTRACT

The relationship of diameter breast high (DBH) and diameter near ground line (DNG) was investigated for three groups of Arkansas hardwoods from four physiographic regions in the state. The relationship between DBH and DNG did not vary significantly across species groups or physiographic regions. Equations of both linear and non-linear form were developed to estimate DBH from DNG. The relationships between DBH and DNG is used to estimate timber volume, growth, and value from residual stumps. The relationship is also useful in harvesting system design and cost estimation in operational forestry.

INTRODUCTION

Researchers have explored the relationship between diameter breast high (DBH) and diameter near ground line (DNG) (three to twelve inches, 8-30 cm.) for several reasons. The DBH-DNG relationship was established for seven southwestern species in order to estimate the standing volume of timber from residual stumps following timber theft (Hann, 1976). The same relationship was used to reconstruct growth and yield information for 17 southern species and Douglas Fir (McCulie, 1968; Curtis and Arney, 1977; and Bylin, 1982). Lanford and Cunia (1971) investigated the relationship to provide harvesting engineers with information for the design of three shears. Kluender (1983) used the relationship to estimate total cost to fell trees in a harvesting operation. This relationship has not been established for hardwoods in Arkansas, but is needed.

The objective of the study was to determine the relationship between DBH and DNG for three groups of hardwood species in four physiographic regions in Arkansas.

METHODS

Description of Study Areas

Ozark Highlands — The study area is similar to much of the Ozark Mountains. The soil series is Clarksville-Gepp, a clayey, cherty soil, originating from several horizontally-laid zones of limestones (USDA, 1978). This formation gives rise to the typical North Arkansas benches between the rock layers. In most cases the soil depth and moisture is greater on the benches than on the rock ledge faces. The area extended around the slope on each of three benches (three elevations) on southern, southwestern and western aspects of Waugh Mountain. Most of this mountain is located on the Batesville Livestock and Forestry Experiment Station of the University of Arkansas, eight miles northwest of Batesville.

Coastal Plain — The Coastal Plain data were collected on the Teaching and Research Forest of the University of Arkansas at Monticello. Soils are of the Calloway Series and are somewhat poorly drained. Upper soil layers are silt loams and lower horizons are characterized by a wak frigapan of light brownish-gray mottled silty clay loam (USDA, 1976). Average slope of the area is zero to three percent.

Athens Plateau — The Athens Plateau study area was located eight miles northwest of Arkadelphia, AR, on land owned by The Ross Foundation. Soils in the area are of the Ouachita Mountain major soils group. Typical soil series on the site are Sherwood, Clebit, and Pickens (USDA, 1982). Generally, there is a moderately thick A horizon of topsoil that is well drained. Slopes of ten to fifteen percent are normal.

Ouachita Mountains — This study area is approximately 15 miles northeast of Jessieville. The primary soil type in the Ouachita Mountain study area is of the Goldston-Rockland Association, typified by the Georgeville and Talledaga series (USDA, 1982). Generally, the sites are steeply inclined with deeply fractured rock formations that allow for adequate root penetration and moisture retention. Surface conditions are rough and stony with a relatively shallow topsoil layer.

Figure 1. Physiographic regions of Arkansas showing study sites ( ).

Sampling Techniques

The sites and species group sampled typified the respective physiographic region and forest stands found there (Harlow et al., 1979) (Figure 1). The species within the three assigned species groups (red oak, white oak and mixed hardwoods) varied somewhat by region. For example, the dominant member of the white oak group at Batesville was post oak (Quercus stellata) while the dominant member of the group at Monticello was white oak (Quercus alba). Miscellaneous hardwoods were composed of primarily hickories (Carya spp.) at Batesville, sweet gum (Liquidambar styraciflua) and dogwood (Cornus florida) at Monticello and maples (Acer spp.) and hickories at Jessieville and Arkadelphia.

Samples were taken across contours to obtain a representative sam-
ple within each stand. Also, each of the three species groups were sampled equally with measurements recorded for approximately 30 members each of the red oak, white oak and miscellaneous hardwood groups. Paired measurements for DBH and DNG were recorded for each tree, species group and physiographic region.

Paired observations of DBH and DNG were taken in each DBH class from one inch to the largest class found on the site to insure applicability of the developed equations over a complete range of tree diameters. DBH measurements were taken 4.5 feet (1.37 M) from ground level, DNG measurements were taken not lower than six inches (15 cm.) from the ground, and high enough to be above any fluting or exaggerated butt swell. No DNG measurements were taken above 12 inches (30 cm).

Statistical Analysis

- Regression equations predicting DBH as a function of DNG were constructed in each of two different forms for each physiographic region-species group combination. The null hypothesis was that there was not a significant difference in tree form by species group and by physiographic region. The equation forms were:

\[ DBH = a + b \times DNG \]

And

\[ DBH = a \times DNG^b \]

Where: DBH = diameter breast high
DNG = diameter near ground
a = a constant, and
b = the slope of the regression line.

The precedent for using simple linear regression estimation has been well established (McClure, 1968; Lanford and Cunia, 1971; Henn, 1976; Curtis and Arney, 1977; and Bylin, 1982). In order to have comparable results and to produce a set of equations of maximum utility to foresters, we used this commonly accepted form.

The non-linear form of estimation more closely approximates the true form of a tree. The relationship of DBH and DNG has been reported in this form in several places (McClure, 1968; Kira and Ogawa, 1969). Until the recent advent of calculators that would raise a number to a power, logarithmic conversions had to be used to adequately express a non-linear relationship. This problem greatly reduced the utility of non-linear forms for practitioners whose mathematical skills were rusty. The method we use to obtain the coefficients used a logarithmic transformation but the predictive equations are presented below in their non-linear form.

In order to test the hypothesis of difference in tree form (relationship of DBG and DNG) by species group and physiographic region we constructed a ratio of the estimated DBH (using the 12 developed regression equations) and DNG using a constant ten inch (25.4 cm) value for DNG. The constant DNG value was used to insure that the estimated DBH values were all based on the same level of the independent variable. These tree form ratios (DBH/DNG) were then investigated with an analysis of variance to determine if a significant difference existed by species group or physiographic region.

RESULTS AND DISCUSSION

The results of the analysis of variance tests showed that tree form as indicated by the ratio of estimated DBH and DNG set to ten inches did not vary significantly (p = .05) by species or by physiographic region. We therefore failed to reject the null hypothesis of no differences by species and physiographic region. However, in the means separation, using Duncan's test (p = .05), tree form did vary significantly between the Coastal Plain and the Ozark Highlands. We recognize that having failed to reject the null, the means separation is a relatively weak test. However, we do feel that the means separation test is picking up a slight difference in tree form based on the extremes of our observations. The composition of the species groups and the soil characteristics (primarily depth) differed most noticeably between these two physiographic regions. The results of testing consistency of tree form lead us to pool the data for all species-groups and physiographic regions and rerun the regression analysis. Based on the means separation, we also grouped the data into two additional data sets for upland hardwood stands (Ozark Highlands, Athens Plateau and Ouachita Mountains) and low land hardwoods (Coastal Plain). Results of these rejections for the linear and non-linear forms of the equations are presented in Table 1.

Table 1. Regression equations for prediction of DBH from DNG for hardwoods in Arkansas and for upland and lowland hardwoods.

<table>
<thead>
<tr>
<th>Physiographic Region</th>
<th>Equation Parameters 1</th>
<th>2</th>
<th>R^2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a</td>
<td>b</td>
<td></td>
</tr>
<tr>
<td>Statewide</td>
<td>-0.41</td>
<td>0.86</td>
<td>.980</td>
</tr>
<tr>
<td>Upland</td>
<td>-0.65</td>
<td>0.83</td>
<td>.972</td>
</tr>
<tr>
<td>Coastal Plain</td>
<td>-0.56</td>
<td>0.87</td>
<td>.990</td>
</tr>
</tbody>
</table>

1Table values are in inches, and (centimeters). For the non-linear equations, conversion to metric form only the 'a' coefficient need be altered, since the slope is consistent regardless of units.

2Equations are in the form: DBH = a + b x DNG

3Equations are in the form: DBH = a x DNG

Our results may be applied to estimate individual tree or stand volumes, or the reconstruction of growth and yield data. For example, for timber theft valuation purposes, estimated DBH, from the equations, coupled with an estimate of the height, based on other trees in the area, can be used directed in the estimation of tree volume and hence, value. For rough growth and yield estimation a similar process is used. Stump DNG measurements can be estimated, with an allowance for bark thickness, at previous points in time by direct measurement of the appropriate inner rings. DBH at previous times can then be directly estimated and appropriate heights, as above, used in the estimation of previous tree volumes. With sufficient observations, this information can be extrapolated to stand level data.

Estimation of DNG from DBH can be achieved by recasting the equations with DNG as the dependent variable. This application is some times used in operational forestry when the average DBH of a stand is known but average DNG is needed. DNG, or stump diameter, is used to compute such values as average time to fell a tree or to calculate the force required to mechanically shear a standing tree, or estimate the amount of herbicide needed for tree injection (Yelser and McLemore, 1984).

LITERATURE CITED


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HANN, E. W. 1976. Relationship of stump diameter to diameter at breast height for seven tree species in Arizona and New Mexico, USDA Forest Service Research Note INT-212, Intermountain Forest and Range Experiment Station, Ogden, UT. 16 pp.


