FORESTRY INFORMATION
MICHIGAN
DEPARTMENT OF NATURAL RESOURCES
FOREST MANAGEMENT DIVISION

NUMBER - 1-87

SUBJECT - BARK FACTORS

DATE - 16 Jan. 87

TITLE - BARK FACTOR EQUATION FOR RED PINE

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Background

Bark factor (BF) is the ratio of diameter inside bark (DIB) to diameter outside bark (DOB) at a given tree height. Bark factors vary with age, species, site, and tree height. Even though bark factor does increase with height for many species, a constant bark factor, usually determined at breast height, has been assumed for all tree heights for many species. Thus, the use of a constant breast height bark factor for all tree heights will usually lead to underestimates of most tree and log volumes and overestimates of bark volume.

Purpose

The purpose of this paper is to present a bark factor prediction equation for red pine in Michigan and show how the prediction equation may be used.

Methods and Materials

Felled tree measurements were made on a total of 855 trees from 10 red pine stands in Michigan (2 each in the western, central, and eastern Upper Peninsula, and southern and northern Lower Peninsula) during May-August, 1981-1985. DIB and DOB were measured to the nearest 0.1-in. at stump height (assumed to be 0.5-ft. in this study) and at the top of each 8.3-ft. bolt (100-in. stick) cut out of each tree to an approximate 3.6-in. diameter top limit. Diameter at breast height (DBH) varied from 3.6-23.6 in., and merchantable height varied from 1-9 sticks for the data set of 855 trees.

For each tree height, the bark factor was determined using all of the trees with measurements at that height with the formula

$$B.F. = \frac{\text{sum of diameters inside bark}}{\text{sum of diameters outside bark}}$$

Bark factor was then regressed on tree height using weighted multiple linear regression with weights based on the number of trees with measurements at 11 heights (0.5, 4.5, 8.8, 17.1, 25.4, 33.7, 42.0, 50.3, 58.6, 66.9, and 75.2 ft.).

Sixty felled trees (20 each from 2 stands in the U.P. and one in the L.P.) were used to test the accuracy of the prediction (regression) equation. DBH varied from 5.2-20.9 in., and merchantable height varied from 24 to 64 ft for the data set of 60 trees.

Results

The variation of average bark factor at a given height among stands, regions, and the L.P. and U.P. was relatively small, so all of the data was pooled to construct one prediction equation for Michigan.

The best prediction equation, yielding the smallest standard error of the estimate ($s_{y \cdot x}$) and the largest coefficient of multiple determination (R^2), was

$$\hat{Y} = 0.9405 - 0.01637\left(\frac{1}{X}\right) + 0.009954 \ln X$$

$$R^2 = 0.99, \; s_{y \cdot x} = 0.0625$$

where $\hat{Y}$ is estimated BF and X is tree height in feet. The prediction equation yields the following estimated bark factors for tree height in feet.

Tree Height	Predicted B.F.	Tree Height	Predicted B.F.
0.5	0.901	42.0	0.977
4.5	0.952	50.3	0.979
8.8	0.960	58.6	0.981
17.1	0.968	66.9	0.982
25.4	0.972	75.2	0.983
33.7	0.975		

The prediction equation yielded accurate predictions for the validation data set of 60 trees. The average relative error was less than ±1% for each height class, and the range of relative error was within ±4% for all but 3 predictions. Relative error is the difference between predicted and actual bark factor divided by actual bark factor times 100.

Average bark thicknesses (BT's) at stump and DBH height were 0.55 in. (range: 0.10-1.95) and 0.26 in. (range: 0.15-0.50), respectively. Larger trees had, in general, larger BT's. Average BT's at diameter top limits of 8, 6, and 4 in. were 0.14 in. (range: 0.00-0.50), 0.09 in. (range: 0.00-0.35), and 0.05 in. (range: 0.00-0.30), respectively.

Guidelines for Users

The prediction equation can be used to estimate BF at any tree height. Since BF=DIB/DOB, DIB can be estimated as $\hat{DIB}=\hat{BF} \cdot DOB$ and DOB can be estimated as $\hat{DOB}=DIB/\hat{BF}$. Past DOB and DOB growth can be determined from past DIB growth as follows:

$$\text{Past DOB Growth} = \text{Past DIB Growth}/\hat{BF}$$

and

$$\text{Past DOB} = \text{Present DOB} - \text{Past DOB Growth}$$

where past DIB growth might be obtained using an increment borer.

Specific uses of the prediction equation include: 1) estimation of tree solid wood and bark volume for standing trees, 2) estimation of bark volume, or peeled volume from unpeeled volume, of felled stem sections, 3) growth studies, and 4) estimating tree form (e.g., Girard Form Class).

Bark factors for 2 red pine and 2 white pine stands in southern Lower Michigan were compared. The largest difference in bark factor between species at a given height was 0.004. Thus, the red pine bark factor equation should give adequate results for white pine when DBH is $\leq$16.0 in.

See Husch et al. (1982) for a detailed discussion on bark factors.

Literature Cited

Husch, B., C. I. Miller, and T. W. Beers. 1982. Forest Measurements. John Wiley & Sons, Inc., New York. 402 p.

FORESTRY INFORMATION LEAFLET
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DEPARTMENT OF NATURAL RESOURCES
FOREST MANAGEMENT DIVISION

NUMBER - 2-87

SUBJECT - BARK FACTORS

DATE - 30 Jan. 87

TITLE - BARK FACTOR EQUATION FOR ASPEN

AUTHORS - Gary W. Fowler, Professor of Biometrics, School of Natural Resources, University of Michigan, and Nemah G. Hussain, Timber Sales Specialist, Forest Management Division, Michigan Department of Natural Resources

Background

Bark factor (BF) is the ratio of diameter inside bark (DIB) to diameter outside bark (DOB) at a given tree height. Even though bark factor does increase with height for many species, a constant bark factor, usually determined at breast height, has been assumed for all tree heights for many species. Thus, the use of a constant breast height bark factor for all tree heights will usually lead to underestimates of most tree and log volumes and overestimates of bark volume. Fowler and Hussain (1987) developed a bark factor equation for red pine where bark factor was regressed on tree height.

Purpose

The purpose of this paper is to present a bark factor prediction equation for aspen in Michigan and show how the prediction equation may be used.

Methods and Materials

Felled tree measurements were made on a total of 302 aspen (181 trembling and 121 bigtooth) trees from 5 aspen stands in Michigan (2 stands in each of the Pere Marquette and Mackinaw state forests and 1 in the Escanaba River State Forest) during May-August, 1986. DIB and DOB were measured to the nearest 0.1-in. at stump height (assumed to be 4" in this study) and at the top of each 8.3-ft. bolt (100-in. stick) cut out of each tree to an approximate 3.6-in. diameter top limit. Diameter at breast height varied from 4.6-16.2 in., and merchantable height varied from 1-8 sticks for the data set of 302 trees.

For each tree height, the bark factor was determined using all of the trees with measurements at that height with the formula

$$B.F. = \frac{\text{sum of diameters inside bark}}{\text{sum of diameters outside bark}}$$

Bark factor was then regressed on tree height using weighted multiple linear regression with weights based on the number of trees with measurements at 10 heights (0.33, 4.5, 8.8, 17.1, 25.4, 33.7, 42.0, 50.3, 58.6, and 66.9 ft.).

The accuracy of the prediction equation was tested using 127 aspen (72 trembling and 55 bigtooth) trees from 3 aspen stands in Michigan (one each in the Au Sable, Lake Superior, and Mackinaw State Forests). DBH varied from 6.6-16.6 in., and merchantable height varied from 25.2-73.5 ft. for the data set of 127 trees.

Results

The variation of average bark factor at a given height among stands and between species was relatively small, so all of the data was pooled to construct one prediction equation for Michigan.

The best prediction equation, yielding the smallest standard error of the estimate ($s_{y \cdot x}$) and the largest coefficient of determination (R^2), was

$$\hat{Y} = 0.9217 - 0.0007694\ X + 0.007706\ \ln X$$

$$R^2 = 0.97,\ s_{y \cdot x} = 0.001537$$

where $\hat{Y}$ is estimated BF and X is tree height in feet. The prediction equation yields the following estimated bark factors for tree height in feet.

Tree Height	Predicted B.F.	Tree Height	Predicted B.F.
0.33	0.913	33.7	0.923
4.5	0.930	42.0	0.918
8.8	0.932	50.3	0.913
17.1	0.930	58.6	0.908
25.4	0.927	66.9	0.903

The prediction equation yielded accurate predictions for the validation data set of 127 trees. The average relative error was less than ±2.6, ±2.3, and ±1.2% for each height for the 72 trembling aspen, 55 bigtooth aspen, and all 127 trees pooled, respectively. All predictions but two were within ±8%. Relative error is the difference between predicted and actual bark factor divided by actual bark factor times 100.

Average bark thicknesses (BT's) at stump and DBH height were 0.45 in. (range: 0.15-0.90) and 0.30 in. (range: 0.12-0.65), respectively. Larger trees had, in general, larger BT's. Average BT's at the top of the 1st, 2nd, 3rd, 4th, 5th, 6th, 7th, and 8th sticks were 0.28, 0.25, 0.24, 0.23, 0.22, 0.21, 0.22, and 0.21 in., respectively. Average BT's at diameter top limits of 8, 6, and 4 in. were 0.29 in. (range: 0.20-0.45), 0.24 in. (range: 0.10-0.50), and 0.19 in. (range: 0.10-0.40), respectively. Bark thicknesses at these diameter top limits for red pine are considerably smaller (Fowler and Hussain 1987).

Note that the BF equation for aspen has a different form than the BF equation for red pine. Whereas the BF for aspen increases with height to a maximum at about 8.8' and then decreases with further height increases, the BF for red pine increases with height (Fowler and Hussain 1987).

Guidelines for Users

The prediction equation can be used to estimate BF at any tree height. Since BF=DIB/DOB, DIB can be estimated as $\hat{DIB}=\hat{BF}\cdot DOB$ and DOB can be estimated as $\hat{DOB}=DIB/\hat{BF}$. Past DOB and DOB growth can be determined from past DIB growth as follows:

$$\text{Past DOB Growth} = \text{Past DIB Growth}/\hat{BF}$$

and

$$\text{Past DOB} = \text{Present DOB} - \text{Past DOB Growth}$$

where past DIB growth might be obtained using an increment borer.

Specific uses of the prediction equation include: 1) estimation of tree solid wood and bark volume for standing trees, 2) estimation of bark volume, or peeled volume from unpeeled volume, of felled stem sections, 3) growth studies, and 4) estimating tree form (e.g., Girard Form Class).

See Husch et al. (1982) for a detailed discussion on bark factors.

Literature Cited

Fowler, G. W. and N. G. Hussain. 1987. Bark Factor Equation for Red Pine. Michigan DNR Forestry Information Leaflet 1-87. 2 p.

Husch, B., C. I. Miller, and T. W. Beers. 1982. Forest Measurements. John Wiley & Sons, Inc., New York. 402 p.