A Model to Estimate Noble Fir Bough Weight

Keith A. Blatner, *Department of Natural Resource Sciences, Washington State University, PO Box 646410, Pullman, WA 99164-6410;* **Roger D. Fight,** *PNW Research Station, 10600 NE 51st Circle, Vancouver, WA 98682;* **Nan Vance,** *Forestry Sciences Laboratory, 3200 SW Jefferson Way, Corvallis, OR 973311;* **Mark Savage,** *Washington Department of Natural Resources, 1111 Washington St, SE, PO Box 47016, Olympia, WA 98504-7016;* *and* **Roger Chapman,** *Department of Natural Resource Sciences, Washington State University, PO Box 646410, Pullman, WA 99164-6410.*

ABSTRACT: *The harvesting of noble fir (*Abies procera*) for the production of Christmas wreaths and related products has been a mainstay of the nontimber forest products industry in the Pacific Northwest (PNW) for decades. Although noble fir is the single most important bough product harvested in the PNW, little or no work has been published concerning the estimation of the weight of harvestable boughs from standing trees. The model presented in this article was designed specifically for use in predicting the weight of harvestable boughs from standing trees. A total of 322 noble fir were selected on the west side of the Cascades of Washington and Oregon. The stands and sites for sampling were chosen to represent a wide range of environmental and stand conditions. Sample trees were selected at fixed distances along systematical located lines at each selected site. Circular plots with a 20-ft radius centered at each sample tree were established to provide data on competition. Regression analysis was used to estimate the final model. Variables included in the final model were total tree height, merchantable bough height, dbh^2, age at dbh, whorl age for each merchantable whorl, and the associated number of boughs for each whorl as well as the total number of trees within a 20-foot radius of the plot tree. In addition, an intercept shifter (0,1) to designate noble fir stands located north and South of the Marion/Clackamas County line in Oregon (South = 0, North = 1) was included in the model. The overall model was significant at the 0.0001 level with an adjusted R^2 of 0.77 West. J. Appl. For. 20(1):44–49.*

Key Words: Noble fir, boughs, weight.

The nontimber forest products (NTFP) industry has been an established sector of the economy of the Pacific Northwest (PNW) since at least the 1920s (Read 1934). Over the past 10 years, NTFP have been the subject of growing research interest in various regions of the United States (Chamberlain et al. 1998) and around the world (Clay 1997). Much of this early research has focused on assessing the size of the markets for these products, the underlying ecology of the species of interest, and various socioeconomic aspects of harvesting and processing of these plant materials.

In the PNW, the harvesting of noble fir (*Abies procera* Rehder) boughs for the production of Christmas wreaths and other seasonal decorations has been at the core of the industry for many years. The exact origins of this aspect of the industry remains unclear, but undoubtedly grew out of the region's long history of harvesting various naturally growing young conifers for use as Christmas trees and the seasonal traditions of early settlers in the region. Schlosser et al. (1991) reported that noble fir boughs were the third most important NTFP harvested in the PNW and the most important bough product harvested in the region in terms of the total value of product at $6.7 million in 1989. In more recent work, Blatner and Alexander (1998) reported that noble fir boughs commanded higher average prices than all other species in the region with the exception of incense cedar (*Calocedrus decurrens*).

Noble fir boughs are the preferred product for the production of Christmas wreaths in the Pacific Northwest and

NOTE: Keith Blatner can be reached at (509) 335-6166; Fax: (509) 335-7862; blatner@wsu.edu. The authors thank Tom Rottman of the Mt. Hood National Forest for cutting the boughs for this study on the Mt. Hood, Willamette, and Gifford Pinchot National Forests. The authors also thank Su Alexander of the Corvallis Forestry Sciences Laboratory for managing the field data collection on the Willamette National Forest.

form the core product for many seasonal arrangements. Boughs from other species of trees and shrubs often are used to accent noble fir wreaths or to serve as the base material for lower quality wreaths. The exception is incense cedar that is used both to accent wreaths and in the production of garland chains (Schlosser et al. 1995).

Public and private forestland owners in the region commonly offer noble fir bough sales in June, July, and early Aug. Depending on the type of sale, contractors bid the sales based on the quantity and quality of bough material available for harvest as well as the difficulty of harvesting the site (e.g., steepness, distance to the nearest road). Sales may be sold on a lump sum or weight scale basis.

Harvesting normally starts in late Sept. or early Oct., after the first few days of frost, and continues until late Nov. or until snowfall precludes access (a few days of frost conditions are critical for maximum needle retention and product life.) (Schlosser et al. 1995). Boughs typically are harvested using a pole cutter, although boughs on taller trees are sometimes harvested by climbing each tree and removing them with a machete. The harvested material is then bundled and transported to the road side by hand, ATV, or helicopter for transport to the buying station.

Noble fir boughs may be harvested four or more times from the lower portion of the tree over a period of years, depending on a variety of factors (e.g., stand density, tree age, presence or absence of competing vegetation). At the present time, noble fir in the PNW is typically harvested once or twice for bough material. The harvesting of boughs for use in Christmas greenery products differs from pruning in the amount of the branch being removed from the tree. The amount of bough material removed ranges in length from 18 to 36 in. depending on the overall size of the bough and whether bough material has been previously removed from a given branch. For the purposes of this article, we will use the term bough to refer to the material harvested from the outer portions of the branches on a noble fir. Although this definition differs from that of any dictionary, this meaning is consistent with the use of the term by the NTFP industry.

Although noble fir is the single most important bough product harvested in the PNW, little or no work has been completed to date concerning the estimation of harvestable bough weights from standing trees for use in estimating crop yields or sale quantities. Various foresters charged with administering bough sales have developed a variety of ad hoc cruise procedures for estimating sale volumes; these procedures, however, typically involve a significant component of professional judgment gained from the administration of previous sales. Similarly, bidders rely heavily on prior experience in determining their bids. Unfortunately, these skills are not easily conveyed to others. This article summarizes the results of recent efforts designed to develop a noble fir bough weight model for use in estimating harvestable quantities of noble fir boughs.

Methodology

This study presented a number of unique problems. Given the lack of previous work in the area, the researchers were required to design an original, cost-effective method for estimating the weight of harvestable boughs. We relied heavily on personal knowledge of bough harvesting developed from a variety of sources as well as ideas drawn from a variety of cruise procedures. The biometrics literature devoted to estimating crown weights also was reviewed.

Stands were located on USDA Forest Service, Washington Department of Natural Resources and Weyerhaeuser lands under a wide variety of stand conditions at regular intervals along the west side of the Cascade Mountains of Washington and Oregon at altitudes ranging from 2,800 to 4,400 ft above sea level. Plot data were collected from as far north as North Bend, WA and to the Cascades East of Salem, OR. Stands were selected systematically across the widest range of age, altitude, aspect and stocking levels possible throughout the range of the species. Summary of key variables is presented in Table 1.

Data for use in model construction were obtained from merchantable noble fir trees which were selected at 150-ft intervals along a line across the longest axis of each of the selected stands. The nearest merchantable noble fir tree to the interval point was selected and became the next plot tree/center. A total of 322 sample trees were established during the normal bough harvest season (late Sept. through early Nov.) of 1997 and 1998.

Tree measurement data were collected for the merchantable tree identified as the plot center. Vegetation data were collected within the 20-ft radius plot centered on each sample tree. On completing the measurements, we returned to the axis line and continued to the next point and again the closest merchantable noble fir was selected as the next sample tree.

Table 1. Noble fir sample data characteristics used in the development of the model.

	Mean	SD	Median	Min	Max
dbh age	15.4	5.9	15.0	5	31
dbh	6.1	2.5	5.9	1.9	13.0
Total height	28.5	11.3	27.0	8.0	65.0
Merchantable height	16.4	8.9	13.0	4.0	45.0
Internodal distance	1.5	0.4	1.5	0.6	2.9
Whorl age	9.5	2.8	9.0	4.0	17.0
Boughs/whorl	4.4	1.4	4.0	2.0	10.0
No. of merchantable whorls	6.2	2.3	6.0	1.0	12.0
No. of trees within a 20-ft circle surrounding the plot tree	7.9	3.7	7	1	24

Tree Variables

Merchantable trees were defined as having at least two merchantable whorls located at or below merchantable height that had not been previously harvested. A merchantable whorl was defined as having marketable boughs on at least two branches. Trees with less than two merchantable whorls were not considered, because harvesters, in general, will not harvest small amounts of bough material unless it is immediately adjacent to another merchantable tree. Because bough harvesters are paid based on the number pounds of material harvested per day, they strongly prefer to concentrate their efforts on trees with more harvestable material.

Merchantable height was defined as the height of the highest merchantable whorl located at or below a point equal to 50% of total height of the tree if the tree was 30 ft or less in height, or two-thirds of total height if the tree was greater than 30 ft in height. For example, merchantable boughs located from ground level to 14 ft aboveground were sampled from a tree with a total height of 28 ft. For a tree taller than 30 ft—say, 36 ft in total height—merchantable boughs from ground level through 24 ft above ground level were sampled. The definition of merchantable height was derived from bough harvest contract limits commonly in use on private, state and federal lands in Washington and Oregon.

The merchantable height of trees included in this study ranged from 4 to 45 ft (Table 1). The maximum merchantable height was limited by the height that could be reached with a pole cutter working from the ground or by climbing the lower portion of the tree. As a practical matter, the productivity of a harvester working with a pole cutter drops sharply when the cutting height exceeds 30 or 35 ft.

Although it is possible to harvest boughs from a given whorl twice (by first cutting a bough from each branch while leaving one or two actively growing laterals to regrow over a period of years), this is uncommon in noble fir stands managed for timber in the PNW at the present time. For regrowth to produce marketable material, stocking levels have to be controlled to allow adequate light to reach the lower branches of the tree during this period. In practice, because of high stocking levels, we found it extremely difficult to locate previously harvested stands of noble fir where the cut branches had received sufficient light to produce merchantable regrowth. In other cases, prior harvesting had removed all of the actively growing material from the branches, leaving only 1 or 2 ft of branch material. Hence, our analysis was limited to previously unharvested whorls. Trees that had been harvested previously were included in the analysis if the tree had at least two merchantable whorls above the prior harvest level.

Tree variables collected included diameter breast height (dbh), age at breast height, total height, merchantable height, and whether or not bough material had been previously harvested from the tree. In addition, whorl age was collected for all whorls at or below merchantable height. Whorl age was defined as the age of the whorl counting down from the leader. Hence, the first whorl below the actively growing tip of the tree was counted as one; the second whorl was counted as two and so on down the tree until the lowest merchantable whorl on the tree was reached. In this way, whorl age reflects the number of years since growth was initiated.

Data collected included the range of whorl ages for the merchantable whorls and the number of unmerchantable whorls within the range. For example, the top most merchantable whorl below the merchantable height may have been whorl 7 and the lowest merchantable whorl 12, where whorls are numbered by age counting down from the tree apex to the base. The assumption is that each whorl represents one year's growth. Within this range all of the whorls might be deemed merchantable or one or more whorls might be considered unacceptable due to competition with adjacent trees, snow damage, or other factors.

One merchantable whorl was selected at random for harvest from the previously unharvested merchantable whorls on each sample tree using a random number table. The selected whorl then was harvested in accordance with accepted harvest procedures. This involved removing the merchantable bough with clippers or a pole pruner, a bough that included the primary branch tip and lateral branches, leaving one or two actively growing laterals on each branch. Occasionally, two "boughs" were cut from the same branch, where prior snow damage or other factors resulted in a forked branch with two merchantable boughs. The cut boughs were then weighed and the surface moisture condition was recorded. In addition, a subsample of randomly selected cut boughs were also weighed in the field and then sealed in heavy plastic bags for the calculation of weight correction factors.

Other Plot Data

Data collected from the 20-ft-radius plot centered at each sample tree included the number of dominant and codominate noble fir, Pacific silver fir (*Abies amabilis*) and other tree species. Trees less than 10 ft in height were not counted. Data on location, elevation, year of establishment, whether or not the stand had been precommercially thinned or fertilized, slope and aspect were also collected. The presence or absence of beargrass (*Xerophyllum tenax*) within the plot was also recorded, because at least some land managers expressed a belief that the presence of this plant was often associated with lower quality boughs and an increased incidence of needle disease problems even though no published documentation was found to verify this. A summary of plot data used in the model development is presented in Table 1.

Analysis

Normalization With Respect to Moisture Content

To eliminate error due to variation in the moisture content among the boughs sampled, the biomass model was based on oven-dry weight. In the real world, boughs are harvested, brought to buyers, and priced based on fresh weight. Boughs are harvested in the late fall when weather conditions vary from warm, sunny days and cool nights to periods of heavy precipitation in the form of rain and snow. This affects the fresh weight of boughs, which retain a certain amount of moisture in their foliage depending on the conditions under which they were harvested. In turn, the amount of moisture present on boughs affects the harvest weight of the boughs when sold.

To examine how harvest conditions affect the relationship of oven-dry to fresh weight of boughs, a subsample of 238 boughs from the larger data set were randomly selected from 45 sites for determination of oven-dry/fresh weight ratio. Harvest conditions were separated into three categories: dry, moderately moist, and heavily moist. "Dry" was defined as no visible moisture on freshly harvested boughs. Conditions under which they were harvested were dry. "Moderately moist" was characterized by the presence of some visible moisture on the cut boughs, but not drops of water. "Heavily moist" was defined as harvested under conditions of recent or current precipitation at the time of harvest. Boughs shed snow or droplets of water when shaken. Boughs were placed in plastic bags, transported to the laboratory and weighed. The boughs were then oven dried at 65° C for 48 h for dry weight determination.

Differences in oven-dry weight ratios among the three moisture conditions described above were analyzed by analysis of variance (ANOVA) using Statgraphics statistical software. Mean ratios were compared using Tukey HSD multiple range test. The results are presented in Table 2 and show that the condition of the boughs does have a significant effect on the oven-dry/fresh weight ratio. Furthermore, the results indicate that the three moisture categories are significantly different from one another. The oven-dry fresh weight ratios should be applied to adjust to harvest conditions in any modeling/cruising effort to obtain consistent results. These ratios (Table 2) were used as correction factors in the model for oven-dry weight.

Weight Model Estimation

A regression model was used to estimate oven-dry weight of the cut boughs obtained from each whorl sampled. Various functional forms were tested during the model development phase of the analysis. Due to problems with heteroskedasticity, the logarithm of

$$\frac{Wt_i}{dbh^2 \times MHT}$$

was used to estimate the weight of the boughs harvested from the *i*th whorl of a tree. Dividing the original dependent variable by some dbh^2 × height is a very common technique in the growth and yield literature as a mechanism for collecting problems with heteroskedasticity. We chose to

Table 2. Differences in mean oven-dry/fresh weight ratios of noble fir boughs harvested under different field moisture conditions.

$F = 73.05$	Pr > F <0.0001	SD (n = 238)
0.440_a*	(Dry conditions)	0.022
0.414_b	(Moderately moist)	0.029
0.393_c	(Heavily moist)	0.031

* Different letters denote significant differences detected by Tukey HSD ($P \leq 0.05$).

also use a log transform in this case, because of the positive affect it had on developing a satisfactory model. The final form of the model for individual bough weight is presented in the following equation.

$$\ln\left(\frac{Wt_i}{dbh^2 \times MHT}\right) = \alpha + \beta_1\left(\frac{THT - 4.5}{Age}\right) + \beta_2 WhorlAge$$

$$+ \beta_3 \ln(Age) + \beta_4 NS + \beta_5 \#Cuttings/Whorl + \beta_6 T\#Trees$$

where:

ln	=	the natural logarithm (Log_e)
Wt_i	=	the calculated oven-dry weight of the boughs obtained from whorl age *i*, determined by multiplying the weight of the boughs measured in the field by the appropriate correction factor from Table 1.
dbh^2	=	diameter breast height squared
MHT	=	merchantable height (height to topmost merchantable whorl)
THT	=	total height of the tree
Age	=	age at breast height
Whorl Age	=	the age of whorl *i* counting down from the top of the tree
NS	=	an intercept shifter (0,1) to designate noble fir stands located north and South of the Marion/Clackamas County line in Oregon (South = 0, North = 1).
# Boughs/ Whorl	=	the number of cut boughs per whorl; and
T#Trees	=	total number of trees within a 20-ft radius of the plot tree

The independent variables used reflect an effort to capture those factors influencing the harvestable weight of the boughs. Several of these variables such as dbh^2, age at dbh, total height, and the total number of trees in the plot commonly are used in yield equations and are familiar to practicing professionals.

The variable

$$\left(\frac{THT - 4.5}{Age}\right)$$

comes from the crown weight literature and is less commonly seen. Dividing the total height of the tree above breast height by age at breast height provides a measure of average internodal length. The number of boughs per whorl was included to capture the difference among trees with respect to the number of branches per whorl. It also reflects the occasional situation, where as a result of naturally occurring damage, one is able to harvest two "boughs" from a given branch.

NS is a dummy variable designed to capture morphological differences in noble fir within its natural range as they apply to the weight of harvested material. In this case, boughs harvested from the southern portion of the natural range of the species have a somewhat different appearance and weight than those harvested further north. We classified boughs harvested north of the Marion/Clackamas County line in Oregon as "North" and assigned NS a value of "1." Data from the southern portion of the range were classified as "South" and were coded with a value of "0."

Weight Model Results

Individual parameter estimates and other model statistics are presented in Table 3. The overall model was significant at the 0.0001 level with an adjusted R^2 of 0.77. All of the parameter estimates were significant at the 0.05 level except the intercept. The significance level of the intercept was only slightly lower at 0.0592. No evidence of multicollinearity was found in the final model based on variance inflation factor statistics for the independent variables.

The signs of the individual parameters appear logical and remained consistent across various specifications considered. The sign associated with internodal length was negative. These results suggest that boughs cut from trees with a longer internode length are lighter in weight than those harvested from trees with more closely spaced branches. This relationship maybe a reflection of the rapid growth of these trees or other morphological differences between trees.

Similarly, there is a negative relationship between $\ln(Age)$ and the weight of the associated whorl. In this case, increasing tree age while holding all other factors constant reflects the difference in bough weight associated with slower growing, less vigorous trees.

The slightly negative relationship between whorl age and the weight of the boughs from a given whorl was somewhat surprising at first glance. In evaluating this relationship, it is important to remember that the model is designed to estimate merchantable bough weight (typically the outer most 30 in. of bough material) obtained from the lower one-half to two-thirds of the tree depending on total height. It also is important to remember that whorl age increases as one counts down from the top of the tree in this analysis. The slightly negative relationship between whorl age and the weight of an individual whorl may reflect reduced growth associated with the tree's lower branches as a result of the lower light levels reaching these branches and associated physiological changes.

Although the quality of the harvested material was not recorded, based on our experience, it appears that boughs obtained from whorls closer to the ground are of lower quality—as reflected by needle density, length, needle curvature, color, etc. Hence, there appears to be a small, but significant offsetting decrease in whorl weight as one moves down the tree within the merchantable range and probably reflects the relatively high stocking levels of the stands from which our plot data were obtained.

We also found a negative relationship between stocking levels and the weight of harvestable material. This relationship also appears to reflect the critical importance of available light levels in the growth/weight of harvestable noble fir boughs material.

The signs of the remaining independent variables, the number of boughs per whorl and north/south (NS) dummy variable, were both positive. The relationship between the number of boughs and whorl weight reflects the increase in weight associated with trees with more branches per whorl. The positive sign associated with boughs obtained from the more northerly portions of range appear to reflect morphological differences in the boughs and their heavier weight when other factors are held constant.

Using the Model

To estimate the weight of the boughs from a given tree, one needs to obtain the following information for each tree measured as a part of a cruise: total tree height, merchantable bough height, dbh, age at dbh, whorl age for each merchantable whorl, the associated number of boughs for each merchantable whorl as well as the total number of trees within a 20-ft radius of the sampled tree, including the sample tree and the relative location of the stand. The model then is solved for each merchantable whorl and the estimated weights summed to determine the total estimated harvestable oven-dry weight per tree. The estimated oven-dry weight must them be converted to green weight by multiplying by the reciprocal of one of the three conversion factors listed in Table 2 or 2.27 for "dry conditions," 2.42 for "moderately moist," and 2.54 "heavily moist." For example, multiplying the estimated oven-dry weight by 2.27 yields the estimated green weight of a bough harvested

Table 3. Estimated parameters and associated statistics for the noble fir bough yield model.

Dependent Variable: $\ln\left(\frac{Wt}{dbh^2 \times MHT}\right)$

Variable	Estimate	SE	Pr > |t|
Intercept	−0.427110	0.225585	0.0592
(THT–4.5)/age	−0.761681	0.073260	<0.0001
Whorl age	−0.070281	0.010473	<0.0001
ln *(Age)*	−1.639278	0.072880	<0.0001
NS	0.192580	0.066106	0.0038
#boughs/whorl	0.199302	0.020305	<0.0001
T#Trees	−0.014702	0.007204	0.0421
$R^2 = 0.77022$			
$N = 322$			
$F = 175.98$ Pr $>F$ = <0.0001			

under dry conditions. Alternatively, one could use one of the other correction factors to estimate bough weight under moister conditions, if desired.

The estimated oven-dry bough weigh of a tree is given by the aggregated corrected model

$$Wt/\text{tree} =$$

$$2.27 \times dbh^2 \times MTH \times \left[e^{\alpha+\beta_1\left(\frac{THT-4.5}{Age}\right)+\beta_3\ln(Age)+\beta_4 NS+\beta_6 T\#Trees} \times e^{1/2\sigma^2} \right] \times \left[\sum_{i=1}^{20} e^{\beta_2 WhorlAge+\beta_5 Boughs/Whorl} \right]$$

where $e^{1/2\hat{\sigma}^2}$ is the logarithmic bias correction factor (LBCT), where $\hat{\sigma}^2$ is the residual variance from the estimated model (Miller 1984).

In this case, a logarithmic transformation was used in estimating the model; however, our real interest lies in the nonlinear relationship among the variables. Simply taking the antilog of the model results in an estimate of the "median" weight, instead of the "mean" weight, desired in this case. Furthermore, the uncorrected "median" estimate is consistently lower than the true value. Hence, simply taking the antilog of the model results in a biased estimate. Fortunately, correcting for the resulting bias is easily accomplished by adding a correction factor to the model. In this case, the LBCT is equal to $e^{1/2\hat{\sigma}^2}$ where $\hat{\sigma}^2 = 0.2176$ (Miller 1984).

The methodology described above is philosophically similar to that associated with the development of traditional individual tree volume equations. It is important to note that although each sample tree includes an independent estimate of the number of merchantable trees in its immediate vicinity, the accumulated average of this data should not be used to estimate the number of merchantable trees per acre or in the total population because it tends to over estimate the total number of merchantable stems. The upward bias in estimated stems per acre associated with sampling single merchantable trees such as used to develop the prediction equations occurs because the sampling method used to collect data for construction of whorl weight precludes the occurrence of a plots with no merchantable trees. Therefore, as in the case of volume equations a sampling design must be used to estimate value per acre or in the stand and the associated statistics.

Conclusions

The model provides a straightforward approach to the estimation of the weight of harvestable boughs from younger stands of noble fir throughout the natural range of the species in the Cascade Mountains of western Washington and Oregon. The model makes it possible to estimate the weight of harvestable noble fir boughs from a given stand in a rigorous manner.

Professionals with little or no prior experience in bough sales can easily use the model to estimate harvestable volumes and to gain important insights into key factors underlying bough management. The model also provides an important tool in evaluating stand management alternatives. Given the ability to inventory stands growing under a wide variety of ecological conditions, resource managers will be able to more fully evaluate the biological feasibility and financial desirability of managing noble fir for the joint production of boughs and timber.

Literature Cited

BLATNER, K.A., AND S. ALEXANDER. 1988. Recent price trends for non-timber forest products in the Pacific Northwest. For. Prod. J. 48(10):28–34.

CHAMBERLAIN, J., R. BUSH, AND A.L. HAMMETT, 1998. Non-timber forest products: The other forest products. For. Prod. J. 48(10):10–19.

CLAY, J.W. 1997. Business and biodiversity: Rainforest marketing and beyond. P. 122–145 *in* Special forest products: Biodiversity meets the market place. USDA For. Serv. Gen. Tech. Rep. GTR-WO-63, Washington, DC.

MILLER, D.M. 1984. Reducing transformation bias in curve fitting. Am. Statistician 38(2):124–126.

READ, A.D. 1934. The profession of forestry. Macmillan, New York. 68 p.

SCHLOSSER, W.E., K.A. BLATNER, AND R.C. CHAPMAN. 1991. Economic and marketing implications of the special forest products harvest in the coastal Pacific Northwest. West. J. Appl. For. 6(3):67–72.

SCHLOSSER, W.E., K.A. BLATNER, E.G. SCHUSTER, AND M.S. CARROLL. 1995. Potential for expansion of the special forest products industry in the Northern Rockies. West. J. Appl. For. 10(4):138–143.