

# Balsam Boughs in Minnesota

A Resource and Market Study



Minnesota Department of Natural Resources  
Division of Forestry



United States Forest Service, North Central Research Station

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Report co-authors:

Keith Jacobson; MNDNR, Division of Forestry

Mark Hansen; USDA Forest Service, North Central Research Station

Ronald McRoberts; USDA Forest Service, North Central Research Station

Report editing and review provided by:

Keith Moser; USDA Forest Service, North Central Research Station

Meg Hanisch and Steve Flackey; MNDNR, Division of Forestry

**For more information contact:**

Keith Jacobson

Wood Product Utilization & Marketing Program Leader

MNDNR, Division of Forestry

500 Lafayette Road

St. Paul, MN 55155-4044

Phone: (651) 259-5270

E-mail: [keith.jacobson@dnr.state.mn.us](mailto:keith.jacobson@dnr.state.mn.us)

## EXECUTIVE SUMMARY

Balsam bough wreaths and decoratives are a \$23 million plus annual industry in Minnesota. The industry employs thousands of people (many on a seasonal basis). However, little is known about sustainability of the resource.

A four-stage study was designed to gather some of the basic information needed to determine sustainability of the balsam bough resource and industry in Minnesota including:

- Current resource amount and condition
- Ongoing measurements of resource condition
- Annual statewide harvest levels.

**Stage 1 (Bough Sampling).** Field crews harvested and weighed balsam boughs from individual sample trees representing a cross section of the site, stand, and tree conditions under which balsam fir grows in Minnesota. For each sample tree, they also collected associated Forest Inventory and Analysis (FIA) plot and tree data.

**Stage 2 (Data Analysis).** The data collected in Stage 1 was used to develop models (prediction equations) that describe the relationship between the potential balsam bough material available from an individual tree in pounds per tree and the attributes commonly observed by FIA on inventory plots throughout the region. These models are then used together with the 1999-2003 FIA inventory data to produce statewide estimates of the total available balsam boughs (total tons) and area in various density classes (tons per acre) with breakdowns of these estimates by attributes of interest to industry and land managers such as county, ownership, and distance to road. **The estimates are presented in tabular and map form in Appendix B.** Results show a total available balsam bough resource in the state of 676,000 tons on forest land that is not reserved from timber harvesting, with 63 percent of this resource on public lands. Among all public owners, the state of Minnesota owns 44 percent of the resource, the U.S. Forest Service owns 33 percent, and counties own 21 percent.

The models and FIA plot data were also used to produce yield tables that will be useful to forest managers in predicting expected yields of balsam boughs from stands they are managing. **The yield tables are presented in tabular form in Appendix C.**

**Stage 3 (Continuous Monitoring of Bough Harvesting Through FIA Plots).** FIA crews began measuring reductions in boughs due to harvesting on all FIA inventory plots starting with the 2004 field season. These measurements, together with the models developed in Stage 2, will be used to provide estimates of the extent and characteristics of bough harvesting across all forest land in the state. Repeat measurements of bough harvesting will begin in 2009. The repeat measurements will provide information on the ability of balsam boughs to regenerate following harvesting.

Preliminary data from the plots measured in the 2004 field season show that most harvesting of boughs takes place on trees 2.0 to 5.9 inches in diameter. Of the 930 live balsam fir trees that were sampled in this diameter range, 60 percent (560) had some boughs that were suitable for harvesting (contained at least one bough that met minimum harvest standards), of which 5.0 percent (28 of 560) showed evidence of past harvesting.

**Stage 4 (Estimates of Bough Harvesting through Survey Samples).** Annual bough harvest levels were determined through industry survey. Annual bough harvest in Minnesota is estimated to be

4,320 tons, slightly less than 1 percent of the total resource found in Stage 2. This annual harvest level is in line with the preliminary harvesting levels observed in Stage 3.

**Study Application.**

Application of the predictive equations developed in Stage 2 to the FIA database has provided the first-ever assessment of the potential balsam bough resource in the state.

Field observations of reductions from potential gathered in Stage 3 will provide estimates of available bough biomass.

Comparisons of available bough biomass to actual harvest levels gathered in Stage 4 will help assess sustainability of the resource.

The study could have application beyond Minnesota, into other states with a balsam fir resource.

A brochure summarizing key study findings entitled “Balsam Boughs – An Important Minnesota Resource” was produced in December of 2005.

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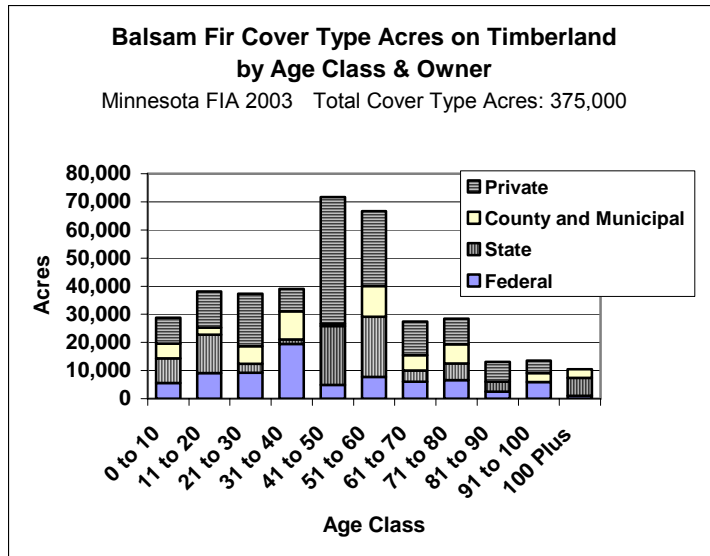
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## INTRODUCTION

### Minnesota Bough Resource and Industry Overview

Resource: Balsam fir is a significant resource in Minnesota, with cover type acreage of approximately 375,000 acres according to 2003 Forest Inventory and Analysis (FIA) figures. Its range covers essentially the northern one half of the state. In addition to that found in the balsam fir cover type, the balsam fir species is also commonly found mixed in as a component in several other cover types. Of the more than 1 billion balsam fir trees one-inch and diameter and larger, 21 percent are in the balsam fir cover type, with 27 percent in other softwood cover types, 28 percent in the aspen cover type, and 24 percent in other hardwood cover types.



Most of the balsam fir cover type is privately owned, followed in decreasing order of ownership acreage by national forests, state, and county. The cover type is dominated by stands at and above 40 years, making it a relatively old resource for a short-lived species.

Balsam fir timber is used largely in the manufacture of high-quality paper, where it is prized for its excellent fiber qualities. Some is also used by the sawmill industry, mostly in making studs. A very small amount of balsam fir is used in making Oriented Strand Board (OSB).

Wreath and Decorative Industry: In addition to timber, balsam fir has the distinction of being the Minnesota species providing the greatest economic return from non-traditional forest products. Balsam fir foliage is collected each autumn by shearing or cutting portions of the branches of live trees (boughs). Many hundreds of harvesters earn seasonal income from bough collection. Boughs are commonly sold by the ton to large and small companies that make decorative wreaths or garlands for sale to consumers as holiday decorations.

Wreath production is handled in several ways:

- A few wreaths are made and sold by harvesters themselves as small businesses.
- About one-half of the wreaths in Minnesota are produced by rural families in their homes, under contract to large wreathmakers. The large wreathmakers then collect, distribute, and market these wreaths.
- About one-half of the wreaths in Minnesota are produced by large wreathmakers in their company facilities, after purchasing raw material from harvesters and transporting it to manufacturing facilities.

The industry gives an economic boost to many rural Minnesota families.

Bough harvest takes place on all land ownerships. The harvest had been somewhat loosely regulated by permit on public ownerships and was largely unregulated on private lands until

approximately 10 years ago. At that time, the Balsam Bough Partnership (Partnership) was formed through the efforts of industry representatives and government land managers. Membership is voluntary. The purpose of the Partnership is to promote sustainable harvest of the bough resource in order to maintain the resource and industry long term. Through educational efforts, this group and its members have promoted the adoption of sustainable harvesting techniques. Through legislative efforts, selling and transport of boughs are now regulated by a license required of bough buyers.

### **Study Purpose**

Balsam bough wreaths are a \$23 million plus annual industry in Minnesota. The Industry employs thousands of people (many on a seasonal basis). Little was known, however, about tons/ per acre of boughs present on sites with differing conditions or about the actual size of the market itself.

This study was designed to find answers to balsam bough resource and market unknowns and to assess sustainability of the resource and industry.

### **Study Objectives**

A four stage study was designed to answer some of the basic questions needed to determine sustainability of the balsam bough resource and industry in Minnesota including:

- Current resource amount and condition
- Ongoing measurements of resource condition
- Annual statewide harvest levels.

### **Study Application**

Application of the predictive equations or models developed in Stage 2 to the FIA database has provided the first-ever assessment of the potential balsam bough resource in the state.

Field observations of reductions from potential gathered in Stage 3 will provide estimates of available bough biomass.

Comparisons of available bough biomass to actual harvest levels gathered in Stage 4 will help assess sustainability of the resource.

The study could have application beyond Minnesota, to other states with a balsam fir resource.

A brochure summarizing key study findings entitled “Balsam Boughs – An Important Minnesota Resource” was produced in December of 2005.



## **Stage 1: Balsam Bough Sampling**

### **Description**

Field measurements of balsam bough weights were conducted during the winter of 2002-2003. DNR crews harvested and weighed balsam boughs from individual sample trees representing a cross section of the site, stand, and tree conditions under which balsam fir grows in Minnesota. For each sample tree they also collected associated Forest Inventory and Analysis (FIA) plot and tree data.

### **Methodology**

- ❑ The population of interest consisted of all balsam fir trees on timberland within the state of Minnesota that could be considered as possessing a harvestable amount of boughs. This excludes trees on lands where timber harvesting is excluded, such as state and national parks and wilderness areas, and areas with trees that are considered nonforest under FIA definitions. In particular, the study does not include boughs from Christmas tree plantations, trees in urban areas, or small areas of forest less than one acre in size.
- ❑ The sampling unit was the tree.
- ❑ The sampling design was developed with the goal of maximizing the number of tree observations across a variety of sites and growth forms, given budget limitations. 102 sites were sampled. Sites were all located on state-owned timberlands, were spread geographically across the balsam fir range in Minnesota, and were a minimum of three miles apart.
- ❑ Sites were selected from 16 cover type and physiographic class combinations that have a ratio of live balsam fir trees over 1" Diameter at Breast Height (DBH) to total cover type acres of greater than .02 as calculated from 1990 FIA data.
- ❑ At each sample site a minimum of six trees 1-inch DBH and larger were measured. No trees below 1-inch DBH were measured.
- ❑ When possible, the sample trees on a given site were selected from a range of diameter classes. All sampled trees were unharvested previously for boughs and showed no signs of insect or disease damage.
- ❑ Use of the Minnesota DNR Continuous Stand Assessment (CSA) database insured that an adequate representation of the full range of balsam fir sites and conditions were sampled.
- ❑ The field measurements were broken into three geographic units, listed by county in tabular form on page 10. The units are FIA designations. Unit 1 is Aspen-Birch, Unit 2 is Northern Pine, and Unit 3 is Central Hardwoods. The purpose of sampling across separate geographic units was to ensure sampling across the entire geographic range of the balsam resource and also so the models could try to account for any regional differences.

<b>Balsam Bough Field Weight Measurement Geographical Survey Units (Counties)</b>		
<b>Unit 1</b>	<b>Unit 2</b>	<b>Unit 3</b>
Carlton	Aitkin	Kanabec
Cook	Becker	Mille Lacs
Koochiching	Beltrami	Otter Tail
Lake	Cass	Pine
St. Louis	Clearwater	Todd
	Crow Wing	Marshall
	Hubbard	Polk
	Itasca	
	Lake of the Woods	
	Mahnomen	
	Roseau	
	Wadena	

**Data Collection and Measurements:** Data collection and measurements included:

**A) Site Level Measurements**

Locational Data: GPS Coordinate	Physiographic Class	Cover Type
Site Index	Stand Size	Slope
Aspect	Basal Area	

*(Existing CSA inventory stand data was used for the above parameters, where possible)*

**B) Tree Level Measurements**

Bough weight---Guideline	Bough weight---Aggressive	Bough weight---Total
Diameter at Breast Height	Crown Class	Compacted Crown Ratio
Uncompacted Crown Ratio	Total Tree Length (Height)	

Three levels of bough weight (Guideline, Aggressive and Total) were measured to simulate three differing harvest scenarios (the subset of trees on which “Aggressive” and “Total” weights were sampled was selected at random):

**1) Guideline Weights:** For all 609 trees sampled, “Guideline” bough weights were measured. Balsam fir bough sustainable harvest guidelines have been published by the Minnesota Balsam Bough Partnership. Field crews were directed to use these guidelines during their measurement of Guideline bough weights on individual trees.

**Balsam Bough Partnership Sustainable Harvest Guidelines:**

- Harvest boughs from bottom half of tree only.
- Large end of harvested branches should be no more than .3 inches in diameter.
- Leave a portion of each branch unpruned.
- Harvest boughs from trees that are at least 7 feet in height.
- Additionally, boughs were measured only as high as crews could reach (7 feet high).

**2) Aggressive Weights:** For a subset of 114 of the 609 total trees, “Aggressive” weights were measured.

- Aggressive weights are in addition to Guideline weights.
- Bough weight for entire branches as high as the crew could reach (7 feet high).

**3) Total Weights:** For a subset of 189 of the total 609 trees, “total” weights were measured.

- Total weights are in addition to guideline plus aggressive weights.
- Field crews cut down trees with handsaws and measured all foliage from bottom to top of tree.
- Limited to trees below 7 inches DBH due to handsaw limitations.

### **Time Frame**

Sampling for Stage 1 began September 15, 2002, after the first hard frost, and was completed by February 20, 2003.

### **Results**

Bough weight measurements were taken for 609 total trees on 102 different sites. For a copy of the dataset, contact the Minnesota DNR Resource Assessment office. Phone 218-327-4449; e-mail: [steve.flackey@dnr.state.mn.us](mailto:steve.flackey@dnr.state.mn.us).



## Stage 2: Data Analysis

### Description

Model development. The data collected in Stage 1 was used in the selection and fitting of models (prediction equations) that describe the relationship between the potential balsam bough material available from an individual tree in pounds per tree and the attributes commonly observed by FIA on inventory plots throughout the region. The stand variables of basal area and site index, and the tree variables of crown ratio, total height and DBH were found to be important in predicting balsam bough weight of individual trees. Two different models are presented here; both were found to be significantly different across forest types and regions. Although regional differences in the models were found, estimates of the total showed relatively little change when a statewide model was applied.

Statewide estimates. The appropriate regional models were used together with the 1999-2003 FIA inventory data to produce statewide estimates of the total available balsam boughs (total tons) and area in various density classes (tons per acre) with breakdowns of these estimates by attributes of interest to industry such as county, ownership, and distance to road. Tables of these estimates are presented in Appendix B.

Yield table development. The models and FIA plot data were also used to produce yield tables (bough yields per acres by total basal area and basal area of balsam fir) that will be useful to forest managers in predicting expected yields of balsam boughs from stands they are managing. Further analysis of these data and additional measurements from FIA plots will provide more detailed yield estimates.

### Methodology

#### Model development

**Summary of Trees Measured in Stage 1 by classification variables**

COVER TYPE CODE	COVER TYPE DESCRIPTION	PHYS	Number of trees			Number of plots		
			REGION			REGION		
			ne	nw	s	ne	nw	s
1	Ash	4	19	6	12	3	1	2
9	Lowland hardwoods	4	11	12	12	2	2	2
12	Aspen	3	12	12	12	2	2	2
13	Birch	3	12	12	12	2	2	2
14	Balm of Gilead	3	12	12	12	2	2	2
51	White pine	3	12	12	12	2	2	2
52	Norway pine	3	12	12	12	2	2	2
53	Jack pine	3	12	12	12	2	2	2
61	White spruce	3	18	12	12	3	2	2
62	Balsam fir	4	6	12	6	1	2	1
		3	12	12	12	2	2	2
		4	12	12	12	2	2	2
71	Black spruce, lowland	5	12	12	12	2	2	2
		4	18	6	8	3	1	2
73	Northern white cedar	4	30	-	12	5	-	2
		5	12	12	12	2	2	2
total			234	180	194	39	30	33

## Prediction variables considered

### Measured variables

SI	Site index
BA	Basal area
CRCOMPACT	Compacted crown ratio (taken on all P2 [FIA Plot 2] trees)
CRNCLASS	Crown class, only values of 3 or 4 were present. Not considered
CRUNCOMP	Uncompacted crown ratio (taken only on P3 [FIA Plot 3] trees improved the model; however, it could not be used in the final prediction model because it is not available on P2 trees)
DBH	Tree diameter at 4.5 feet (in inches)
HT	Total height (taken on trees 5" DBH and larger on P2 plots, all trees on P3 plots)

The attribute of interest (WTGUIDELI) is the weight of the harvestable boughs under the harvesting guidelines. These are boughs that are within reach from the ground and can be cut under the guidelines. Logical predictors for WTGUIDELI are DBH (larger diameter trees should have more boughs), height to the base of the bottom of the crown (the higher it is to the bottom of the crown, the fewer the boughs that can be harvested), site index (better sites should have more boughs), and basal area (less crowded stands should have more boughs). The recomputed variable  $HT((100 - CRCOMPACT)/100)$  is an observation of the height to the bottom of the crown.

### The nonlinear model:

The model:  $WTGUIDELI = B1*(DBH**(B2))/(HT*((100-CRCOMPACT)/100)) + e$   
 Was selected from many model forms considered.

On standard FIA plots (P2 plots) total height is measured only on trees 5" DBH and larger, thus, a final model that included total height could not be used for prediction. A surrogate was required for height to be used on trees less than 5" in the final prediction model. The following was used as an appropriate surrogate for height:

$$Y = B1*(DBH**(B2))/(HT*((100-CRCOMPACT)/100))$$

and modified for trees < 5 as:

$$Y = B1*(DBH**(B2))/(HT*((100-CRCOMPACT)/100)) \text{ if } DBH \geq 5$$

$$Y = B1*(DBH**(B2))/(B3*DBH*((100-CRCOMPACT)/100)) \text{ if } DBH < 5$$

Fitting this nonlinear model yielded a value of 5.67 for B3, and also a value of approximately 1.5 (3/2) for B2. The B2 value of 1.5 also conforms with the 3/2 power law. The 5.67 value for B3 provides a predicted height for trees < 5" of  $5.67*DBH$ . By substituting  $5.67*DBH$  as an estimate of HT for trees less than 5" and  $DBH**(3/2)$  to develop IND8C, a computed predictor for use in the final linear model is obtained. Here,

$$HTC = \text{Total height if } DBH \geq 5$$

$$HTC = DBH*5.67 \text{ if } DBH < 5$$

and

$$IND8C = (DBH**(3/2))/(HTC*((100-CRCOMPACT)/100)).$$

The graphs in Appendix B plot IND8C vs WTGUIDELI for all the trees, and for trees by region/type group.

Finally, three different linear models that included IND8C (as computed above) were found to be good predictors of  $Y = WTGUIDELI$  and are presented here. The SAS nonlinear regression package was used to fit the following models by region and forest-type group and across all regions and forest types.

$$\text{Model 1 } Y = B1*IND8C + e$$

$$\text{Model 2 } Y = B1*(1/BA) + B2*SI + B3*IND8C + e$$

$$\text{Model 3 } Y = B0 + B1*(1/BA) + B2*SI + B3*IND8C + e$$

Y, IND8C, BA, and SI are described above; B0, B1, B2, and B3 are unknown model parameters that are to be estimated; and e is the random error.

**Results of fitting these models to the Stage 1 data are presented below.**

**Model 1  $Y = B1*IND8C$**

Region	Forest Type	RMSE	B1	DF	R <sup>2</sup>
NE-NW	1,9,13,51,52,53,62,73	1.59067	2.158597	269	0.591454
NE-NW	12,14	1.138458	1.342012	47	0.485127
NE-NW	61,71	2.23397	2.81714	95	0.643718
NE-NW	All	1.759057	2.286861	413	0.589749
S	1,9,13,51,52,53,62,73	1.12775	1.440093	131	0.458152
S	12,14	0.560363	0.408644	23	0.228057
S	61,71	0.759496	0.667258	37	0.223558
S	All	1.045578	1.187776	193	0.387226
all	All	1.612806	2.053851	607	0.543585

**Model 2  $Y = B1*(1/BA) + B2*SI + B3*IND8C$**

Region	Forest Type	RMSE	B1	B2	B3	DG	R <sup>2</sup>
NE-NW	1,9,13,51,52,53,62,73	1.528084	-3.20779	-0.01891	3.066598	267	0.625774
NE-NW	12,14	1.000053	28.33495	-0.01665	1.899912	45	0.619612
NE-NW	61,71	2.045353	10.4457	-0.04503	4.361398	93	0.707628
NE-NW	All	1.636534	0.355224	-0.02671	3.493566	411	0.646628
S	1,9,13,51,52,53,62,73	1.06435	-30.7291	-0.01246	2.585269	129	0.524732
S	12,14	0.533819	19.14607	-0.00105	0.108462	21	0.360373
S	61,71	0.747684	5.55796	-0.01539	1.50821	35	0.288195
S	All	1.000731	-1.71283	-0.01311	2.029253	191	0.444482
all	All	1.489894	-0.87023	-0.02474	3.275688	605	0.611785

**Model 3  $Y = B0 + B1*(1/BA) + B2*SI + B3*IND8C$**

Region	Forest Type	RMSE	B0	B1	B2	B3	DF	R <sup>2</sup>
NE-NW	1,9,13,51,52,53,62,73	1.4724	-1.6476	1.5844	0.0113	3.2238	266	0.5136
NE-NW	12,14	0.9769	-1.6443	33.4605	0.0061	2.0791	44	0.5315
NE-NW	61,71	2.0196	-1.3358	13.4363	-0.0192	4.3761	92	0.6127
NE-NW	All	1.5932	-1.4434	5.3311	-0.0023	3.6464	410	0.5460
S	1,9,13,51,52,53,62,73	1.0208	-1.3923	11.0668	0.0057	2.6829	128	0.4554
S	12,14	0.5447	-0.8405	27.3974	0.0110	0.1163	20	0.1507
S	61,71	0.7579	-0.1817	4.9690	-0.0125	1.6159	34	0.1578
S	All	0.9735	-0.9254	0.4504	0.0000	2.3718	190	0.3582
all	All	1.4422	-1.4160	3.7022	-0.0015	3.4907	604	0.5286

In addition to estimates of guideline weights, estimates of bough weights under aggressive harvest and total harvest methods were also desired. The number of trees where these attributes were observed are considerably fewer than the number of trees where guideline weights were taken. Several models were considered for predicting the weight under aggressive harvesting (WTAGGRESSIVE) and under harvesting of all boughs by felling the tree (WTATOTAL) and the simple additive models

$$\text{WTAGGRESSIVE} = B1 \cdot \text{IND8C} + B2 \cdot \text{DBH} + B3 \cdot \text{SI} + \text{WTGUIDELI} + e$$

$$\text{WTATOTAL} = B1 \cdot \text{IND8C} + B2 \cdot \text{DBH} + B3 \cdot \text{SI} + \text{WTGUIDELI} + e$$

were selected. Because of the reduced number of observations and large variability of the observations, fitting these models by region and/or forest type did not significantly improve the model fits. Results of fitting these models to the Stage 1 data are:

Model	RMSE	B1	B2	B3	DG	R <sup>2</sup>
WTAGGRESSIVE	2.04396	0.74356	0.00977	0.01219	111	0.313578
WTATOTAL	7.17503	5.12489	3.30565	-0.0558	199	0.722464

Table 8 (Appendix C) provides predictions of tree guideline weight based on the model 2, all regions-all types fitted values in tabular form across a range of DBH, height, and crown ratio values with basal area set to 80 sq. ft. per acre and site index set at 60. The prediction equations are relatively insensitive to changes in basal area and site index, and this table provides a good means of estimating the total bough yields from inventory data that includes number of balsam fir trees by diameter, height and compacted crown ratio. It should also be noted that the prediction equation is very sensitive to changes in compacted crown ratio. The data used to fit the model did not include any observations with compacted crown ratios greater than 85 percent. Table 8 provides estimates for trees with compacted crown ratios up to 95 percent. These estimates should be considered extrapolations of the model beyond the range of the observations. Compacted crown ratios greater than 85 percent are extremely uncommon and typically only occur on open-grown trees, such as evenly spaced trees in a plantation prior to crown closure. The estimates for trees with compacted crown ratios of 95 percent are high, but do not seem to be unreasonable. Applying the predicted weights for a tree with DBH = 2 in., height = 16 ft. and compacted crown ratio = 95 to a plantation with 500 trees per acre (approximately 8'x10' spacing) produces estimated weights of 2.5 tons/acre (guideline), 3.4 tons/acre (aggressive), and 7.9 tons/acre (total).

### Statewide estimation

Model 2, by creg and ctype (six different fitted models) was applied to the data from all FIA plots measured in the 1999-2003 cycles of the Minnesota inventory to obtain the estimates of totals and breakdowns of these estimates. These estimates are presented in Appendix B in tables 1, 2, 3, 6, and 7. In a few cases the estimated guideline weight in a tree produced by the model yielded a negative value. These were in all cases small trees with very small crown ratios. In those cases the model was modified to produce an estimate of zero for the tree.

Table 4 compares the population estimates based on models 1 and 2, all regions-all types to models 1 and 2 by region and type. The choice of model can change the population estimates by 10 percent to 20 percent; however the degree of prediction error in the models are fairly high and this is not unexpected. For estimates beyond Minnesota, Model 2 as fit to all regions-all types will be used.

Appendix B, Table 5 compares the population estimates of guideline, aggressive and total bough weights, again using the six different regions/forest type versions of Model 2 to estimate guideline



weight. This table shows that aggressive harvesting approximately doubles the estimated weight of boughs and total harvesting increases bough weights by nearly ten times.

Table 5 also addresses some of the concerns that reviewers had with regards to applying the model to trees greater than 8 in. DBH. There were no large-diameter trees in the data used to fit the model. The model predicts very large bough weights for large diameter trees with large crown ratios. Table 5 shows that there are very few large diameter balsam in the population. Over 60 percent of the estimated bough weight is in trees < 4 in. DBH and nearly 87 percent is in trees < 8 in. DBH.

The availability of boughs for harvest is related to the proximity to roads. Tables 6 and 7 give some idea of the proximity of the bough resource to the nearest improved road.

Maps 1 and 2 in Appendix B show the distribution of the observed balsam bough resource. Map 1 is based entirely on the observed plot values of guideline harvest levels on forested plots interpolated between plots. Ancillary sources of nonforest, water, and reserved lands were used to mask out values in those areas. Map 2 included information from high-resolution satellite imagery to improve the interpolation procedure using nearest neighbor methods. Map 2 provides a better representation of the variation in the resource across the landscape; however, it is probably not appropriate for reproduction at a small scale.

### **Yield tables**

Estimates of expected bough yields are useful to forest managers. The FIA plot data provides observations of bough yields from sampled stands across the state. The FIA plot consists of a cluster of four 24-foot radius subplots on which trees 5 in. DBH and larger are measured and four 6.8 ft. radius microplots (located within the subplot) on which trees less than 5 in. DBH are measured. Plots that overlap more than one stand (condition) are mapped so trees and their appropriate estimates are associated with the stand in which they occur.

For the development of the yield tables presented here, only stands that had at least one entire subplot are considered. Stands with less than one subplot were excluded because the observations of bough yields for these stands are based on a small sample and may not include any observation of trees less than 5 in. DBH.

In total, the data set contains 1,545 observations of bough yields from stands where live balsam fir was observed. This data set consists of observations of bough yields (guideline tons per acre) based on the tally trees and the estimation methods presented above, along with observations of all of the stand-level attributes collected by FIA. Figure 1 plots the distribution of these observations bough yields against total stand basal area (TOT\_BA = the basal area of all live trees in the stand) and balsam fir basal area (BF\_BA = the basal area of only the balsam fir trees in the stand). A number of stands BF\_BA = 0 are included in the data set. These are stands where balsam fir seedlings (trees < 1 in. DBH) were tallied; however, no balsam fir trees 1 in. DBH or larger were observed.

As would be expected, higher yields appear strongly associated with higher values of both TOT\_BA and BF\_BA. To minimize the effect of extreme values, stands with observed TOT\_BA values greater than 180 ft<sup>2</sup>/acre were set to 180 and stands with observed BF\_BA values greater than 90 ft<sup>2</sup>/acre were set to 90. A number of linear and nonlinear models using various stand attributes were examined, as well as the simple polynomial model,

$$Y_G = b_1 + b_2 * \text{TOT\_BA} + b_3 * \text{TOT\_BA}^2 + b_4 * \text{TOT\_BA}^3 + b_5 * \text{BF\_BA/BF\_TOT} + b_6 * \text{BF\_BA/BF\_TOT}^2 + e,$$

where  $Y_G$  = guideline yield (tons/acre) and  $e$  = random error. Fitting this model to the 1,545 observations produced the following results:

RMSE	0.223908805
b <sub>1</sub>	-0.186019337
b <sub>2</sub>	0.005344057
b <sub>3</sub>	-0.000042885
b <sub>4</sub>	0.000000110
b <sub>5</sub>	0.936316395
b <sub>6</sub>	-0.578385123
DF	1539
R <sup>2</sup>	0.17099

The relatively low R<sup>2</sup> values for this model reflects the high degree of variability within the data. This fitted model was used to produce Table 9 in Appendix B, which provides estimated guideline bough yields by total basal area and balsam fir basal area classes based on using class center values. It should be noted that this table provides a statewide estimate of the average bough yield per acre for stands where live balsam fir was observed to be a component of the stand and should only be applied in cases where balsam fir is present. A number of other stand observations including site index, stand age, physiographic class, total softwood basal area, and forest type were examined for inclusion in the model; however, they did not significantly improve the model.

Users of Table 9 must realize that there is high degree of variability in the resource itself and that there is variability in the ability of an FIA plot to quantify the resource. Thus, a simple model based on total basal area and balsam fir basal cannot predict the yield of a particular stand with a high level of certainty. Two stands with identical total basal area and balsam fir basal area may have greatly different yields due to numerous factors and the estimated yield for an individual stand as observed by a single FIA plot can vary greatly depending on the random location of the plot within the stand. Table 10 , Appendix B demonstrates the level of variability within the FIA data set. This table is based on the same data set of 1545 stands used to fit the yield model and shows the same class of total basal area and balsam fir basal area. The table shows the portion of the stands in each cell where the observed yield was greater than .25 tons per acre. Take the total basal area class 89-90 and balsam fir basal area class 20-30 as an example. The estimated average yield for this class is .25 tons per acre (from Table 9); however, only 25 percent of the measured stands in this class had observed yields of .25 tons per acre or more.

The yield table (Table 9) should not serve as the sole basis when assigning an estimated yield to a particular stand unless the user is willing to accept a relatively high degree of uncertainty. For example, it would be inappropriate to charge individual bough cutters or assign values to boughs on a small area on the basis of this table. The table can be used for the estimation of yields over a large number of stands for planning purposes. Field verification of the quantity and quality of the boughs is necessary for individual stand management.

There was no attempt to estimate bough “quality” during the inventory or modeling procedure, so these figures are estimated raw total harvest levels. Also, the sampling procedures used in collecting the data used to develop the estimation equations excluded previously harvested trees

and trees with insect or disease damage to the boughs. The estimates and yield tables developed here thus reflect estimates based on the absence of harvesting, insects and disease that effect the boughs but do not kill the trees. In areas of known harvesting or damage, estimates must be adjusted.



## **Stage 3: Continuous Monitoring of Bough Harvesting Through FIA Plots**

### **Description**

FIA field crews began measuring three attributes (BOUGHS\_AVAILABLE, BOUGHS\_HRVST, and HRVST\_GUIDELINE) on all balsam fir trees 1 in. diameter and larger tallied on Phase 2 plots. This will be an annual, ongoing effort. It was begun during the 2004 field season (beginning Sept. 1, 2003). The complete procedures section of the North Central FIA field manual for these three attributes is shown in Appendix D. Below is a brief description of the three attributes that are being collected.

**BOUGHS\_AVAILABLE** – Code that identifies trees that contain at least one harvestable bough.

To be considered a harvestable bough it must be in the bottom 7.5 feet of a tree, and at least 18 inches in length with needles present.

**BOUGHS\_HRVST** – Code that identifies trees that have been harvested for balsam boughs.

Harvesting could have taken place at any time in the past. Evidence of bough harvesting can be seen for many years

**HRVST\_GUIDELINE** – Code that identifies whether the Standard Balsam Bough Harvesting Guidelines were followed

### **Results**

Data from the 2004 field season have now been collected. The data from trees on non-reserved forest land are presented Appendix E. Data from the entire North Central Region are presented so that results from Minnesota can be contrasted with those from Wisconsin and Michigan. These data represent only a fifth of the FIA plots being measured under the annual inventory systems. Following completion of the 2008 field season, a complete analysis of the data will provide an improved analysis of the availability and harvesting of balsam boughs. The tables in Appendix D should be considered preliminary results based on a small sample.

The preliminary results show that trees with diameters between 2.0 and 5.9 inches are the primary sources of boughs. Larger diameter trees typically do not have many harvestable branches within reach. Trees smaller than 2.0 in. are too small to have many boughs, and the guidelines specify that boughs can only be cut in the lower half of the tree. In Minnesota, 60 percent (560 of 930) of the trees tallied in 2.0 to 5.9 in. diameter range contained boughs suitable for harvesting. Harvesting has taken place on 5 percent (28 of 560) of the trees with available boughs in that diameter range. Harvesting rates in Wisconsin and Michigan were lower (1.7 percent in both states).

Evidence of harvesting can be observed for many years after harvest, especially if the guidelines are not followed. Of the 51 total trees in Minnesota where harvesting was observed, only 13 (25 percent) were classified as being harvested within the guidelines. Similar results were also observed in Wisconsin and Michigan; however, in both states the guidelines were followed more often. The number of trees with harvesting that have been tallied is relatively small (104 total in all three states) observed on only 28 plots. A large sample of harvested trees is needed before any definite conclusions can be reached; however, this preliminary data indicates that harvesting guidelines are not being followed on both public and private lands, suggesting better education or enforcement may be necessary.



## Stage 4 Estimates of Bough Harvesting through Survey Sample

### **Description and Methodology**

A survey of 2003 production of the following two segments of the Minnesota balsam bough decorative industry was conducted in the spring of 2004:

- 1) Medium and large wreath manufacturers (identified through personal knowledge and interviews of bough harvesters and sellers) that use boughs from Minnesota
- 2) Balsam bough buyers.

The purpose of the survey was to determine bough harvest levels in Minnesota by county in order to assist with sustainable management of the bough resource, and also to more closely determine industry economic impact. A copy of the survey form is found in Appendix A.

A contractor familiar with the industry and resource was used to do the survey work, which was funded by a grant from the US Forest Service State & Private Forestry's "Rural Development Through Forestry" Program. The survey was conducted largely during March of 2004. Surveys were completed for 20 large and small wreath manufacturers (most of whom are also licensed bough buyers) and for 15 licensed bough buyers who produce no wreaths themselves. 122 total surveys were sent to licensees. "Double-counting" of harvested boughs was avoided by using interviews with bough buyers and wreath manufacturers to determine which wreathmaker the individual bough buyers sold to.

Licensees were identified by DNR license bureau records. Wreath manufacturers were identified through personal knowledge of the contractor and DNR staff, and through interviews with bough license holders.

### **Results**

The survey resulted in the following information about the balsam bough decorative industry in Minnesota.

**Much of the information gathered in the survey is proprietary, so only statewide summary information is given here.**

- Approximately 4,320 tons of balsam boughs are harvested and used annually in Minnesota by the decorative industry.
- Industry economic impact is over \$23 million at the retail level.

*The \$23 million economic impact figure was derived as follows:*

**Wreaths:** A conversion factor of 400 wreaths/ton of boughs (estimate by survey contractor based on personal knowledge) was used for an average 25"-size wreath. It was estimated that 90 percent of boughs are used for wreaths (estimate by survey contractor based on personal knowledge), or approximately 3,890 tons statewide. At approximately \$15/wreath at the retail level (estimate), this amounts to:  $1,555,000 \text{ wreaths} \times \$15 = \$23,325,000$ .

**Garland:** It was estimated that 10 percent of boughs are used for garland (estimate by survey contractor based on personal knowledge) or approximately 432 tons statewide. No attempt was made to estimate worth of garland at the retail level.

- Some wreathmakers were unwilling or unable to provide county-level harvest information, so it turned out to be impossible to determine precise bough harvest levels by county. The statewide harvest estimate above is thought to be reliable, however.
- Regarding county-level harvest, it was possible to determine that that the majority of harvest takes place in St. Louis, Itasca, Cass and Aitkin counties. It was also learned that there is at least some bough harvest in many counties in northern Minnesota.



## Study Conclusions

The bough and wreath industry does have a significant economic impact in Minnesota.

The balsam bough resource in Minnesota is sustainable at current or even increased harvest levels. There may currently be a few small “pockets” of harvesting at unsustainable levels in areas with excellent access and many harvesters competing for the available resource. At a statewide level, annual harvesting is about 2 percent of the available resource on forest land containing at least 1,000 pounds per acre of potential bough material at Guideline harvest rates.

St. Louis, Aitkin, Itasca, and Cass counties support the largest amount of harvesting, however several other counties (Cook, Koochiching, and Lake, especially) have large areas of bough resources.

Estimates presented here do not reflect any losses due to harvesting or damage by insect or disease agents. Further analysis of FIA data will be necessary in a few years.

Observations of compacted crown ratio, DBH and height of individual trees and basal area and site index of the stand provide the input for the estimation of bough weight, however estimates are relatively insensitive to changes in basal area or site index. In the absence of individual tree observations, total stand basal area and the basal area of balsam in the stand can provide an estimate of the bough yield, however these estimates are primarily useful in large area planning due to the high degree of variability within and between individual stands.

Harvesting guidelines have not been followed on most trees where harvesting was observed on FIA plots in the first year of Stage 3 of the study; however, this reflects only 28 plots where harvesting was observed. More data and a complete analysis are required before definite conclusions can be reached.

### Survey Design Discussion

This study could serve as a “template” for designing future studies of Special Forest Products (SFP). For that reason, the following discussion and recommendations for future surveys are presented below.

**Stage 1:** An error in instructions to the field crews that measured bough weights in Stage 1 resulted in no measurements being taken for trees less than 1 in. diameter. It would have been worthwhile to take measurements of smaller fir, but project funds for field measurement were already exhausted before the error was discovered.

**Stage 4:** The wreathmaking business is highly competitive and much of the information gathered in the survey was proprietary. For this reason, it was invaluable to have a Stage 4 survey contractor that was known and trusted by industry companies.

**Stage 4:** A reliable statewide bough harvest-level figure was determined. However, some wreathmakers were unwilling to provide county-level harvest information, so it turned out to be impossible to determine precise bough harvest levels for each county. Regarding county level harvest, the following two general statements were found to hold true: The majority of harvest takes place in St. Louis, Itasca, Cass and Aitkin counties. There is some bough harvest in many counties.



## Appendix A: Bough Buyer and Wreath Producer Survey Form

# Minnesota's Bough Resource An Evaluation of Current Use

You received this survey because you were identified as a retailer or wholesaler of products made from boughs harvested in Minnesota. Information gathered during this project will only be published in an aggregate form; no individual company's information will be identified. Please help us improve our management of this important resource and support continued health of the forest and bough industry by answering the following questions:

1. Please indicate the percentage of your bough business that fits into the following categories:

<b>Percentage</b>	<b>Business activity</b>
____ percent	Bough harvester
____ percent	Bough buyer for Minnesota wreath and greens producers
____ percent	Bough buyer for producers located in other states
____ percent	Major manufacturer and distributor of wreaths and decorative items
____ percent	Small manufacturer (cottage industry) selling to another distributor
____ percent	Cottage industry selling directly to the public

2. Approximately how many tons of boughs did you purchase in 2003?

From within Minnesota \_\_\_\_\_ tons

From outside Minnesota \_\_\_\_\_ tons

2a. In 2002, did you purchase: More \_\_\_\_ Less \_\_\_\_ About the same \_\_\_\_ tonnage?

2b. In 2004, do you anticipate purchasing: More \_\_\_\_ Less \_\_\_\_ About the same \_\_\_\_ tonnage?

3. What species of boughs did you purchase in 2003?

	<b><u>Species</u></b>	<b><u>Approximate percentage of total</u></b>
a.	Balsam fir	_____ percent
b.	Cedar	_____ percent
c.	Pine	_____ percent
d.	Other (specify) _____	_____ percent

4. County or counties in Minnesota where boughs you purchased in 2003 were harvested:

	<b><i>County</i></b>	<b><i>Approximate percentage of total</i></b>
a.	_____	_____ percent
b.	_____	_____ percent
c.	_____	_____ percent
d.	_____	_____ percent
e.	_____	_____ percent

5. If you know, please estimate the percentage of your total bough resource that comes from the following land ownership categories:

	<b><i>Landowner</i></b>	<b><i>Approximate percentage of total</i></b>
a.	County	_____ percent
b.	State	_____ percent
c.	Tribal	_____ percent
d.	Federal	_____ percent
e.	Private industrial land	_____ percent
f.	Non-industrial private land	_____ percent

6. If you are a small manufacturer (cottage industry) how many wreaths did you sell to distributors?

7. If you are a major manufacturer and distributor, how many wreaths did you purchase from cottage wreath industry?

8. **Optional:** How many people do you employ in your wreath or bough business?

Full time seasonal employees \_\_\_\_\_  
Part-time seasonal employees \_\_\_\_\_  
Part-time seasonal bough harvesters supplying you \_\_\_\_\_

9. Any other comments for us as we work together on sustainably managing our balsam bough resource and industry?

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10. The University of Minnesota is examining educational needs for non-timber forest products.

Do you harvest \_\_\_ or purchase \_\_\_ other types of non-traditional forest products such as birch bark, twigs, moss, cones, etc.?

Thank you for helping us improve our knowledge about this valuable Minnesota forest resource! Survey results will be available late in 2004

## Appendix B: Tables of Estimated Bough Weights

**Table 1. Acres of non-reserved forest land by county and balsam bough class (Guideline harvest level - pounds per acre), Minnesota, 2003.**

		Balsam bough class (guideline pounds/acre)											
Unit	County	No balsam	0-500	500-1000	1000-1500	1500-2000	2000-2500	2500-3000	3000-3500	3500-4000	4000+	Total	
1	Carlton	187,621	117,639	2,125								307,385	
	Cook	221,143	328,295	40,550	6,380	7,632				848	1,474	606,323	
	Koochiching	944,233	598,393	47,842	17,581	7,135	2,676					1,617,859	
	Lake	323,434	455,022	95,176	35,021	16,047	9,642	4,636				1,800	940,780
	St. Louis	1,448,774	1,017,764	185,247	83,260	28,827	7,896	4,409	848			4,667	2,781,694
Unit 1 Total		3,125,205	2,517,113	370,941	142,243	59,642	20,213	9,045	848	848	7,941	6,254,040	
2	Aitkin	582,389	163,675	10,836								756,901	
	Becker	301,233	34,445	9,456								345,134	
	Beltrami	683,470	182,441	19,522	8,072	3,536	1,558				2,340	900,938	
	Cass	679,116	144,180				825					824,121	
	Clearwater	230,313	76,865	4,615		2,725						314,519	
	Crow Wing	325,567	27,428	1,525								354,519	
	Hubbard	317,833	45,718	4,134	84							367,769	
	Itasca	801,187	449,194	40,700	10,164	2,548	821					1,304,614	
	Lake of the Woods	348,139	115,448	17,045	3,540		885					485,057	
	Mahnomen	98,397	9,662									108,060	
	Roseau	223,695	16,697	5,005								245,397	
Wadena	117,846		1,242								119,088		
Unit 2 Total		4,709,185	1,265,753	114,079	21,860	8,809	4,089				2,340	6,126,116	
Unit 3 Total		2,247,778	66,218	816			3,389					2,318,200	
Unit 4 Total		570,218	5,221									589,521	
State total		10,666,469	3,854,305	485,837	164,103	68,451	27,691	9,045	848	848	10,281	15,287,878	

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**Table 2. Acres of non-reserved forest land with balsam by county, ownership class, and balsam bough class (guideline harvest level - pounds per acre), Minnesota 2003.**

Unit	County	Ownership	0-500	500-1000	1000-1500	1500-2000	2000-2500	2500-3000	3000-3500	3500-4000	4000+	Total	
1	Carlton	CO MUN	8,106									8,106	
		OTH FED	2,989										2,989
		PRIVATE	77,536	518									78,054
		STATE	29,008	1,607									30,615
		All owners	117,639	2,125									119,764
Cook	Cook	CO MUN	1,377									1,377	
		NFS	213,336	16,961	3,392	4,240				848	1,474		240,251
		OTH FED	3,058										3,058
		PRIVATE	64,932	8,408	2,988								76,329
		STATE	45,592	15,181		3,392							64,165
All owners	328,295	40,550	6,380	7,632				848	1,474		385,180		
Koochiching	Koochiching	CO MUN	85,837	6,521	2,562							94,920	
		OTH FED	3,278									3,278	
		PRIVATE	165,093	21,451	3,278							189,822	
		STATE	344,185	19,870	11,741	7,135	2,676					385,607	
		All owners	598,393	47,842	17,581	7,135	2,676						673,626
Lake	Lake	CO MUN	51,831	8,876	3,214							63,921	
		NFS	185,556	39,484	19,081	7,124						997	252,242
		PRIVATE	123,249	29,959	12,726	3,832		3,832					173,599
		STATE	94,386	16,857		5,091	9,642	804				804	127,583
		All owners	455,022	95,176	35,021	16,047	9,642	4,636				1,800	617,345
St. Louis	St. Louis	CO MUN	232,714	28,769	10,446	4,176	976	2,621			1,091	280,793	
		NFS	207,017	45,139	20,514	5,936	1,556					280,162	
		OTH FED	31,121	6,092									37,213
		PRIVATE	390,942	82,180	39,241	8,909	5,364	1,788			3,576	532,000	
		STATE	155,971	23,067	13,060	9,807			848				202,752
All owners	1,017,764	185,247	83,260	28,827	7,896	4,409	848			4,667	1,332,919		
Unit 1 total	Unit 1 total	CO MUN	379,865	44,166	16,222	4,176	976	2,621			1,091	449,116	
		NFS	605,909	101,584	42,987	17,301	1,556			848	2,470	772,656	
		OTH FED	40,445	6,092									46,537
		PRIVATE	821,752	142,517	58,234	12,741	5,364	5,620			3,576	1,049,804	
		STATE	669,142	76,583	24,801	25,424	12,318	804	848			804	810,722
All owners	2,517,113	370,941	142,243	59,642	20,213	9,045	848	848	848	7,941	3,128,835		

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**Table 2 (continued). Acres of non-reserved forest land with balsam by county, ownership class, and balsam bough class (guideline harvest level - pounds per acre), Minnesota 2003.**

Unit	County	Ownership	0-500	500-1000	1000-1500	1500-2000	2000-2500	2500-3000	3000-3500	3500-4000	4000+	Total	
2	Aitkin	CO MUN	36,970									36,970	
		PRIVATE	76,927	1,305									78,232
		STATE	49,778	9,531								59,309	
		All owners	163,675	10,836								174,511	
Becker		CO MUN	3,179	3,179									6,358
		OTH FED	5,023										5,023
		PRIVATE	22,717	3,098									25,815
		STATE	3,525	3,179									6,704
		All owners	34,445	9,456								43,901	
Beltrami		CO MUN	8,992				1,558						10,550
		NFS	11,596	6,838									18,434
		PRIVATE	82,414	3,120	8,072	3,536						2,340	99,482
		STATE	79,438	9,564									89,002
		All owners	182,441	19,522	8,072	3,536	1,558				2,340	217,468	
Cass		CO MUN	10,563										10,563
		NFS	52,073										52,073
		PRIVATE	49,966				825						50,792
		STATE	31,578										31,578
		All owners	144,180				825					145,005	
Clearwater		CO MUN	3,974										3,974
		PRIVATE	70,280	4,615		2,725							77,620
		STATE	2,612										2,612
		All owners	76,865	4,615		2,725							84,206
Crow Wing		CO MUN	8,293										8,293
		PRIVATE	19,135	1,525									20,660
		All owners	27,428	1,525									28,953
Hubbard		CO MUN	13,188	2,384	84								15,656
		PRIVATE	22,993	1,750									24,743
		STATE	9,537										9,537
		All owners	45,718	4,134	84								49,935
Itasca		CO MUN	61,225	14,747		2,548							78,520
		NFS	104,596	2,931	3,360								110,887
		PRIVATE	174,451	11,486	4,905		821						191,664
		STATE	108,922	11,537	1,898								122,356
		All owners	449,194	40,700	10,164	2,548	821					503,427	
Lake of the Woods		OTH FED	13,641	3,540	3,540								20,722
		PRIVATE	30,989	3,540									34,529
		STATE	70,817	9,964				885					81,667
		All owners	115,448	17,045	3,540			885					136,918
Mahnomon		PRIVATE	5,897										5,897
		STATE	3,766										3,766
		All owners	9,662										9,662
Reseau		PRIVATE	3,897										3,897
		STATE	12,800	5,005									17,805
		All owners	16,697	5,005									21,702
Wadena		PRIVATE		1,242									1,242
		All owners		1,242									1,242
Unit 2 total		CO MUN	146,384	20,310	84	2,548	1,558						170,884
		NFS	168,265	9,769	3,360								181,394
		OTH FED	18,664	3,540	3,540								25,745
		PRIVATE	559,666	31,681	12,977	6,261	1,646					2,340	614,572
		STATE	372,773	48,779	1,898		885						424,335
		All owners	1,265,753	114,079	21,860	8,809	4,089					2,340	1,416,931

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**Table 2 (continued). Acres of non-reserved forest land with balsam by county, ownership class, and balsam bough class (guideline harvest level - pounds per acre), Minnesota 2003.**

Unit	County	Ownership	0-500	500-1000	1000-1500	1500-2000	2000-2500	2500-3000	3000-3500	3500-4000	4000+	Total	
3	Kanabec	PRIVATE	10,242									10,242	
		All owners	10,242										10,242
	Mille Lacs	PRIVATE	2,182										2,182
		All owners	2,182										2,182
	Otter Tail	PRIVATE	3,763										3,763
		All owners	3,763										3,763
	Pine	CO MUN	1,694										1,694
		PRIVATE	31,444										31,444
		STATE	12,714	816			3,389						16,919
		All owners	45,852	816			3,389						50,057
	Todd	STATE	4,179										4,179
		All owners	4,179										4,179
	Unit 3 total	CO MUN	1,694										1,694
		PRIVATE	47,630										47,630
		STATE	16,893	816			3,389						21,098
		All owners	66,218	816			3,389						70,423
4	Marshall	PRIVATE	2,102									2,102	
		All owners	2,102										2,102
	Polk	PRIVATE	3,119									3,119	
		All owners	3,119										3,119
Unit 4 total	All owners	5,221										5,221	
State total			3,854,305	485,837	164,103	68,451	27,691	9,045	848	848	10,281	4,621,409	

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**Table 3. Tons of available balsam boughs (wt guideline) on non-reserved forest land with balsam by county, ownership class, and balsam bough class (Guideline harvest level – pounds per acre), Minnesota 2003.**

Unit	County	Ownership	0-500	500-1000	1000-1500	1500-2000	2000-2500	2500-3000	3000-3500	3500-4000	4000+	Total	
1	Carlton	CO MUN	456									456	
		OTH FED	101										101
		PRIVATE	4,427	179									4,606
		STATE	1,616	624									2,240
		All owners	6,599	803									7,402
Cook	CO MUN	244										244	
	NFS	13,688	6,086	2,183	3,585				1,595	4,863		32,001	
	OTH FED	304										304	
	PRIVATE	4,387	3,263	1,678								9,328	
	STATE	2,089	5,111		3,074							10,274	
All owners	20,712	14,460	3,861	6,659				1,595	4,863		52,150		
Koochiching	CO MUN	5,929	3,121	1,474								10,524	
	OTH FED	487										487	
	PRIVATE	9,745	8,342	2,336								20,422	
	STATE	24,109	6,449	6,424	5,721	2,729						45,432	
	All owners	40,270	17,912	10,233	5,721	2,729						76,866	
Lake	CO MUN	5,845	3,189	1,651								10,685	
	NFS	14,908	13,227	11,938	6,045						2,089	48,207	
	PRIVATE	11,938	10,390	8,331	2,999		5,044					38,701	
	STATE	8,296	6,282		4,485	10,505	1,113				2,702	33,382	
	All owners	40,987	33,088	21,920	13,528	10,505	6,157				4,790	130,975	
St. Louis	CO MUN	15,769	10,146	7,293	3,621	1,085	3,386				3,841	45,142	
	NFS	16,397	14,886	12,979	5,257	1,697						51,216	
	OTH FED	2,190	1,976									4,166	
	PRIVATE	33,279	28,478	24,364	8,309	6,212	2,430				8,152	111,224	
	STATE	13,013	8,095	7,704	8,679			1,396				38,888	
All owners	80,648	63,581	52,341	25,865	8,994	5,816	1,396			11,993	250,635		
Unit 1 total	CO MUN	28,244	16,456	10,418	3,621	1,085	3,386				3,841	67,051	
	NFS	44,993	34,198	27,100	14,887	1,697			1,595	6,952		131,423	
	OTH FED	3,082	1,976									5,057	
	PRIVATE	63,774	50,653	36,709	11,307	6,212	7,474				8,152	184,281	
	STATE	49,123	26,562	14,128	21,959	13,233	1,113	1,396			2,702	130,216	
All owners	189,216	129,845	88,355	51,774	22,228	11,973	1,396	1,595	21,647		518,029		

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**Table 3 (continued). Tons of available balsam boughs (wt\_guideline) on non-reserved forest land with balsam by county, ownership class, and balsam bough class (Guideline harvest level – pounds per acre), Minnesota 2003.**

Unit	County	Ownership	0-500	500-1000	1000-1500	1500-2000	2000-2500	2500-3000	3000-3500	3500-4000	4000+	Total	
2	Aitkin	CO MUN	1,550									1,550	
		PRIVATE	3,974	348									4,322
		STATE	2,631	3,145									5,775
		All owners	8,155	3,493								11,648	
Becker		CO MUN	233	799									1,032
		OTH FED	57										57
		PRIVATE	1,023	837									1,861
		STATE	325	948									1,273
		All owners	1,638	2,585									4,223
Beltrami		CO MUN	933				1,769						2,702
		NFS	631	1,902									2,532
		PRIVATE	4,648	1,385	4,369	3,086					6,547		20,035
		STATE	3,380	3,253									6,633
		All owners	9,592	6,539	4,369	3,086	1,769				6,547		31,902
Cass		CO MUN	753										753
		NFS	1,561										1,561
		PRIVATE	1,763				890						2,652
		STATE	2,419										2,419
		All owners	6,496				890						7,386
Clearwater		CO MUN	722										722
		PRIVATE	4,614	1,842		2,448							8,903
		STATE	200										200
		All owners	5,537	1,842		2,448							9,826
Crow Wing		CO MUN	772										772
		PRIVATE	1,436	473									1,910
		All owners	2,208	473									2,681
Hubbard		CO MUN	1,104	650	50								1,805
		PRIVATE	1,275	694									1,969
		STATE	378										378
		All owners	2,757	1,344	50								4,152
Itasca		CO MUN	2,601	5,195		2,239							10,034
		NFS	7,009	1,067	2,206								10,282
		PRIVATE	14,709	4,221	3,146		926						23,003
		STATE	6,018	3,812	1,396								11,226
		All owners	30,337	14,294	6,748	2,239	926						54,544
Lake of the Woods		OTH FED	2,454	928	2,257								5,639
		PRIVATE	2,964	1,440									4,405
		STATE	4,996	3,339			977						9,312
		All owners	10,415	5,707	2,257		977						19,356
Mahnommen		PRIVATE	295										295
		STATE	113										113
		All owners	408										408
Reseau		PRIVATE	341										341
		STATE	1,566	1,334									2,900
		All owners	1,907	1,334									3,241
Wadena		PRIVATE		380									380
		All owners		380									380
		All owners		380									380
Unit 2 total		CO MUN	8,667	6,644	50	2,239	1,769						19,370
		NFS	9,201	2,969	2,206								14,375
		OTH FED	2,511	928	2,257								5,696
		PRIVATE	37,043	11,621	7,515	5,534	1,816				6,547		70,076
		STATE	22,026	15,831	1,396		977						40,231
All owners	79,448	37,992	13,425	7,772	4,563				6,547		149,747		

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**Table 3 (continued). Tons of available balsam boughs (wt\_guideline) on non-reserved forest land with balsam by county, ownership class, and balsam bough class (Guideline harvest level – pounds per acre), Minnesota 2003.**

Unit	County	Ownership	0-500	500-1000	1000-1500	1500-2000	2000-2500	2500-3000	3000-3500	3500-4000	4000+	Total	
3	Kanabec	PRIVATE	97									97	
		All owners	97										97
	Mille Lacs	PRIVATE	303										303
		All owners	303										303
	Otter Tail	PRIVATE	19										19
		All owners	19										19
	Pine	CO MUN	119										119
		PRIVATE	1,467										1,467
		STATE	1,324	269			4,112						5,705
		All owners	2,910	269			4,112						7,291
	Todd	STATE	129										129
		All owners	129										129
Unit 3 total	CO MUN	119										119	
	PRIVATE	1,886										1,886	
	STATE	1,453	269			4,112						5,835	
	All owners	3,458	269			4,112						7,839	
4	Marshall	PRIVATE	350									350	
		All owners	350									350	
	Polk	PRIVATE	21									21	
		All owners	21									21	
	Unit 4 total		372									372	
	State total		272,494	168,105	101,779	59,546	30,903	11,973	1,396	1,595	28,194	675,987	

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**Table 4. Estimates of Tons of available balsam boughs (wt\_guideline) on non-reserved forest land by county, using 2 different models.**

Unit	County	Model 1 wt_guideline = $b_1 dbh^{3/2}$ (ht * ((100-cr)/100))		Model 2 wt_guideline = $b_1(17ba) + b_2si + b_3 dbh^{3/2}$ (ht * ((100-cr)/100))	
		Fit by region	Fit for state	Fit by region	Fit for state
		1	17 Carlton	8,997	14,548
1	31 Cook	55,685	55,801	52,150	53,581
1	71 Koochiching	96,126	100,531	76,866	77,769
1	75 Lake	137,645	137,261	130,975	133,311
1	137 St. Louis	284,350	274,804	250,635	245,560
	Unit 1	582,804	582,945	518,029	520,541
2	1 Aitkin	11,523	21,075	11,648	17,535
2	5 Becker	4,326	6,683	4,223	6,345
2	7 Beltrami	34,373	33,750	31,902	32,404
2	21 Cass	8,097	14,847	7,386	12,664
2	29 Clearwater	11,056	10,877	9,826	10,253
2	35 Crow Wing	3,896	7,484	2,681	5,298
2	57 Hubbard	3,507	5,706	4,152	5,107
2	61 Itasca	68,657	66,376	54,544	51,668
	Lake of the				
2	77 Woods	24,838	25,313	19,356	19,478
2	87 Mahnomen	234	631	408	847
2	135 Roseau	4,121	3,955	3,241	3,110
2	159 Wadena	453	646	380	343
	Unit 2	174,628	196,698	149,368	164,710
3	65 Kanabec	148	316	97	156
3	95 Mille Lacs	232	715	303	769
3	111 Otter Tail	17	24	19	21
3	115 Pine	6,765	10,061	7,291	8,808
3	153 Todd	305	436	129	286
4	89 Marshall	757	1,080	350	252
4	119 Polk	18	26	21	30
	Unit 3+4	8,244	12,658	8,211	10,321
	State total	766,129	792,948	675,987	695,914

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**Table 5. Estimates of total balsam boughs on non-reserved forest land by DBH class.**

DBH class	Total weight (tons)			Estimate # of Trees (million)	Percent of Total Guideline Wt
	Guideline	Aggressive	All Boughs		
1 to 1.9	186,506	398,248	1,254,528	550.4	27.59%
2 to 3.9	222,177	420,969	1,945,095	419.6	32.87%
4 to 5.9	114,489	197,788	1,164,921	131.4	16.94%
6 to 7.9	71,315	117,051	788,755	55.7	10.55%
8 to 9.9	46,938	71,602	467,279	24.4	6.94%
10 to 11.9	19,710	28,765	184,536	7.6	2.92%
12 to 13.9	9,701	13,562	77,134	2.5	1.44%
14 to 15.9	4,437	6,109	34,218	0.9	0.66%
16 to 17.9	598	825	4,992	0.1	0.09%
18 to 19.9	116	156	908	0.0	0.02%
<b>Total</b>	<b>675,987</b>	<b>1,255,075</b>	<b>5,922,365</b>	<b>1,192.7</b>	<b>100.00%</b>

DBH class	Average weight (pounds per tree)		
	Guideline	Aggressive	All boughs
1 to 1.9	0.7	1.4	4.6
2 to 3.9	1.1	2.0	9.3
4 to 5.9	1.7	3.0	17.7
6 to 7.9	2.6	4.2	28.3
8 to 9.9	3.8	5.9	38.3
10 to 11.9	5.2	7.5	48.3
12 to 13.9	7.8	11.0	62.4
14 to 15.9	9.5	13.1	73.4
16 to 17.9	9.5	13.1	79.2
18 to 19.9	12.0	16.2	93.9
<b>Total</b>	<b>1.1</b>	<b>2.1</b>	<b>9.9</b>

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**Table 6. Estimates of Tons of boughs (Guideline harvest level) and area with balsam by distance to improved road, all non-reserved forest land with balsam.**

ACRES Distance to Road	CLASS (Guideline pounds per acre)										Total	Percent of Grand Total
	0-500	500-1000	1000-1500	1500-2000	2000-2500	2500-3000	3000-3500	3500-4000	4000+			
100 ft or less	212,927	41,238	18,610	2,470	1,558	3,832					280,634	6.1%
101 to 300 ft	351,655	41,098	18,453	7,513							418,718	9.1%
301 to 500 ft	346,687	43,058	4,636	2,896						3,576	400,853	8.7%
501 to 1000 ft	580,571	60,755	31,127	22,925	4,214	1,788					701,379	15.2%
1001 ft to 1/2 mile	1,123,203	128,677	57,996	28,534	11,262	3,425		848	5,901		1,359,846	29.4%
1/2 to 1 mile	667,989	82,568	19,882	3,311	7,443		848		804		782,846	16.9%
1 to 3 miles	475,520	70,346	10,122	804	3,214						560,005	12.1%
3 to 5 miles	42,955	14,886	3,278								61,120	1.3%
Greater than 5 miles	52,797	3,212									56,009	1.2%
<b>Grand Total</b>	<b>3,854,305</b>	<b>485,837</b>	<b>164,103</b>	<b>68,451</b>	<b>27,691</b>	<b>9,045</b>	<b>848</b>	<b>848</b>	<b>10,281</b>		<b>4,621,409</b>	<b>100.0%</b>

WT_GUIDELINE (TONS) Distance to Road	CLASS (Guideline pounds per acre)										Total	Percent of Grand Total
	0-500	500-1000	1000-1500	1500-2000	2000-2500	2500-3000	3000-3500	3500-4000	4000+			
100 ft or less	14,352	14,844	11,953	2,036	1,769	5,044					49,998	7.4%
101 to 300 ft	25,602	14,517	11,051	6,676							57,846	8.6%
301 to 500 ft	24,774	15,104	3,167	2,575						8,152	53,772	8.0%
501 to 1000 ft	37,221	20,936	19,746	20,308	5,002	2,430					105,643	15.6%
1001 ft to 1/2 mile	86,962	42,754	35,703	24,051	11,991	4,500		1,595	17,341		224,897	33.3%
1/2 to 1 mile	43,410	29,047	11,510	3,148	8,202		1,396		2,702		99,415	14.7%
1 to 3 miles	34,496	24,714	6,314	752	3,938						70,214	10.4%
3 to 5 miles	3,172	4,845	2,336								10,352	1.5%
Greater than 5 miles	2,505	1,345									3,850	0.6%
<b>Grand Total</b>	<b>272,494</b>	<b>168,105</b>	<b>101,779</b>	<b>59,546</b>	<b>30,903</b>	<b>11,973</b>	<b>1,396</b>	<b>1,595</b>	<b>28,194</b>		<b>675,987</b>	<b>100.0%</b>

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**Table 7. Estimates of tons of boughs (Guideline harvest level) and area by distance to improved road, all non-reserved forest land with at least 1,000 pounds per acre balsam boughs (Guideline harvest level).**

ACRES	FIA unit				Percent of Grand Total	
	Distance to road	1	2	3		Total
100 ft or less	22,522	3,948			26,470	9.4%
101 to 300 ft	21,037	4,928	0		25,965	9.2%
301 to 500 ft	9,954	1,154			11,108	3.9%
501 to 1000 ft	51,636	5,029	3,389		60,054	21.4%
1001 ft to ½ mile	93,003	14,962			107,966	38.4%
1/2 to 1 mile	28,751	3,537			32,288	11.5%
1 to 3 miles	10,599	3,540			14,139	5.0%
3 to 5 miles	3,278	0			3,278	1.2%
Grand Total	240,780	37,098	3,389		281,267	100.0%

WT_GUIDELINE (TONS)	FIA unit				Percent of Grand Total	
	Distance to road	1	2	3		Total
100 ft or less	17,835	2,967			20,802	8.8%
101 to 300 ft	14,699	3,028			17,727	7.5%
301 to 500 ft	12,857	1,036			13,894	5.9%
501 to 1000 ft	38,784	4,590	4,112		47,486	20.2%
1001 ft to 1/2 mile	79,269	15,911			95,181	40.4%
1/2 to 1 mile	24,441	2,517			26,958	11.5%
1 to 3 miles	8,747	2,257			11,004	4.7%
3 to 5 miles	2,336				2,336	1.0%
Grand Total	198,968	32,307	4,112		235,387	100.0%

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**Table 8. Predicted bough harvest weights for balsam fir using guideline, aggressive, and total bough harvesting methods.**

Estimates are based on Model 2; Guideline weight =  $b_1(1/BA) + b_2SI + b_3DBH^{3/2}/(ht * ((100-CCR)/100))$   
 fit across all regions and forest types, using BA = 80 sq. ft. per acre and SI = 60.

DBH	HT	Compacted Crown Ratio (CCR)																														
		Guideline weight (pounds)										Aggressive weight (pounds)										Total weight (pounds)										
		5	15	25	35	45	55	65	75	85	95	5	15	25	35	45	55	65	75	85	95	5	15	25	35	45	55	65	75	85	95	
1	8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.2	6.7	0.8	0.9	0.9	0.9	0.9	1.0	1.3	2.6	9.3	1	1	1	1	1	1	2	3	5	19		
1	10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	5.1	0.8	0.8	0.8	0.9	0.9	0.9	1.0	1.0	1.9	7.3	1	1	1	1	1	1	1	2	4	15	
1	12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	4.0	0.8	0.8	0.8	0.8	0.9	0.9	0.9	1.0	1.5	5.9	1	1	1	1	1	1	1	2	3	12	
1	14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	3.2	0.8	0.8	0.8	0.8	0.8	0.9	0.9	1.0	1.2	5.0	1	1	1	1	1	1	1	1	2	10	
1	16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	1.1	4.3	1	1	1	1	1	1	1	1	2	9	
1	18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	1.0	3.7	1	1	1	1	1	1	1	1	2	8	
2	12	0.0	0.0	0.0	0.0	0.0	0.2	0.7	1.6	3.7	13.9	0.9	1.0	1.0	1.0	1.1	1.4	2.0	3.0	5.6	18.2	5	5	5	5	5	6	7	10	15	41	
2	14	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.2	2.9	11.7	0.9	0.9	1.0	1.0	1.0	1.1	1.6	2.5	4.7	15.5	4	4	5	5	5	6	7	9	13	36	
2	16	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.8	2.4	10.1	0.9	0.9	0.9	1.0	1.0	1.0	1.3	2.1	4.0	13.5	4	4	4	5	5	5	6	8	12	31	
2	18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.9	8.8	0.9	0.9	0.9	0.9	1.0	1.0	1.1	1.8	3.5	11.9	4	4	4	5	5	5	6	7	11	28	
2	20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.6	7.8	0.9	0.9	0.9	0.9	0.9	1.0	1.1	1.5	3.0	10.6	4	4	4	4	5	5	5	7	10	26	
2	22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.3	6.9	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.3	2.7	9.6	4	4	4	4	4	5	5	6	9	23	
2	24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	6.2	0.8	0.9	0.9	0.9	0.9	0.9	1.0	1.2	2.4	8.7	4	4	4	4	4	5	5	6	8	22	
3	12	0.0	0.2	0.4	0.7	1.1	1.7	2.6	4.2	8.0	26.9	1.1	1.3	1.6	1.9	2.4	3.1	4.2	6.2	10.9	34.1	9	9	10	11	12	13	15	20	29	78	
3	16	0.0	0.0	0.0	0.1	0.4	0.9	1.5	2.8	5.6	19.8	1.0	1.0	1.1	1.3	1.6	2.2	3.0	4.5	8.0	25.4	8	9	9	9	10	11	13	16	23	60	
3	20	0.0	0.0	0.0	0.0	0.1	0.4	0.9	1.9	4.2	15.5	1.0	1.0	1.0	1.1	1.2	1.6	2.2	3.4	6.2	20.2	8	8	8	9	9	10	11	14	20	49	
3	24	0.0	0.0	0.0	0.0	0.0	0.1	0.5	1.3	3.2	12.7	0.9	1.0	1.0	1.0	1.1	1.2	1.8	2.7	5.1	16.7	8	8	8	8	9	9	10	12	17	41	
3	28	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.9	2.6	10.7	0.9	0.9	0.9	1.0	1.0	1.1	1.4	2.2	4.2	14.2	8	8	8	8	8	9	10	11	15	36	
3	32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	2.1	9.1	0.9	0.9	0.9	0.9	1.0	1.0	1.1	1.9	3.6	12.3	7	8	8	8	8	8	9	11	14	32	
3	36	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.7	8.0	0.9	0.9	0.9	0.9	1.0	1.0	1.1	1.6	3.1	10.9	7	7	8	8	8	8	8	9	10	13	29
3	40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.3	7.0	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.4	2.7	9.7	7	7	7	8	8	8	8	8	9	12	27
3	44	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.1	6.2	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.2	2.4	8.8	7	7	7	8	8	8	8	8	9	12	25
4	16	0.2	0.4	0.7	1.0	1.5	2.1	3.2	5.1	9.4	31.3	1.4	1.6	2.0	2.4	2.9	3.7	5.0	7.3	12.7	39.5	13	13	14	15	16	18	20	25	36	92	
4	20	0.0	0.0	0.3	0.5	0.9	1.4	2.2	3.7	7.2	24.7	1.1	1.2	1.4	1.7	2.2	2.8	3.9	5.7	10.0	31.4	12	12	13	14	14	16	18	22	31	76	
4	24	0.0	0.0	0.0	0.2	0.5	0.9	1.6	2.9	5.8	20.3	1.0	1.1	1.1	1.3	1.7	2.3	3.1	4.6	8.2	26.1	12	12	12	13	13	15	16	20	27	64	
4	28	0.0	0.0	0.0	0.0	0.2	0.6	1.2	2.2	4.7	17.2	1.0	1.0	1.1	1.1	1.4	1.8	2.6	3.9	6.9	22.2	11	12	12	12	13	14	15	18	24	56	
4	32	0.0	0.0	0.0	0.0	0.0	0.3	0.8	1.8	4.0	14.9	1.0	1.0	1.0	1.1	1.1	1.5	2.1	3.3	6.0	19.4	11	11	12	12	12	13	14	17	22	50	
4	36	0.0	0.0	0.0	0.0	0.0	0.1	0.6	1.4	3.4	13.1	0.9	1.0	1.0	1.0	1.1	1.3	1.8	2.8	5.2	17.1	11	11	11	12	12	13	14	16	21	46	
4	40	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.1	2.9	11.6	0.9	0.9	1.0	1.0	1.0	1.1	1.6	2.5	4.6	15.4	11	11	11	11	12	12	13	15	20	42	
4	44	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.9	2.5	10.4	0.9	0.9	1.0	1.0	1.0	1.1	1.4	2.2	4.1	13.9	11	11	11	11	12	12	13	14	19	39	
4	48	0.0	0.0	0.0	0.0	0.0	0.1	0.7	2.1	9.4	9.4	0.9	0.9	0.9	1.0	1.0	1.0	1.2	2.0	3.7	12.7	11	11	11	11	11	12	12	14	18	36	





**Table 9. Model based Guideline bough yields (tons per acre) from forest stands where live balsam fir is present.** Shaded cells indicate stands with model-based guideline bough yields of greater than .25 tons per acre.

Total stand basal area (ft <sup>2</sup> /acre)	Balsam fir basal area (ft <sup>2</sup> /acre)									
	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80+	
0-10	0.20									
10-20	0.13	0.24								
20-30	0.09	0.28	0.28							
30-40	0.08	0.25	0.33	0.31						
40-50	0.07	0.23	0.32	0.36	0.34	0.26				
50-60	0.08	0.21	0.30	0.36	0.38	0.35	0.30			
60-70	0.08	0.20	0.29	0.35	0.38	0.39	0.37	0.32		
70-80	0.08	0.18	0.27	0.33	0.37	0.40	0.40	0.38	0.34	
80-90	0.08	0.17	0.25	0.31	0.36	0.39	0.40	0.40	0.38	
90-100	0.08	0.16	0.24	0.30	0.34	0.38	0.40	0.41	0.40	
100-110	0.07	0.15	0.22	0.28	0.33	0.36	0.39	0.40	0.41	
110-120	0.07	0.14	0.21	0.26	0.31	0.34	0.37	0.39	0.41	
120-130	0.06	0.13	0.19	0.24	0.29	0.33	0.36	0.38	0.40	
130-140	0.06	0.12	0.18	0.23	0.27	0.31	0.34	0.37	0.39	
140-150	0.06	0.11	0.17	0.22	0.26	0.30	0.33	0.35	0.37	
150-160	0.05	0.11	0.16	0.20	0.25	0.28	0.31	0.34	0.36	
160-170	0.05	0.10	0.15	0.20	0.24	0.27	0.30	0.33	0.35	
170+	0.05	0.10	0.15	0.19	0.23	0.26	0.30	0.32	0.35	

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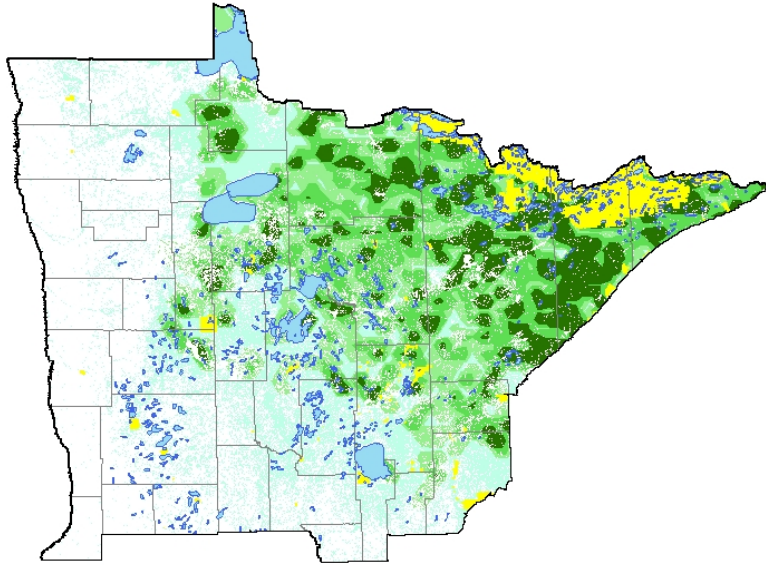
**Table 10. Percent of stands measured by FIA where the observed guideline bough yield was at least .25 tons (500 pounds) per acre.**

stand basal area (ft <sup>2</sup> /acre)	Balsam fir basal area (ft <sup>2</sup> /acre)									Total number of stands observed
	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80+	
0-10	0 %									23
10-20	6 %	29 %								56
20-30	2 %	23 %	0 %							60
30-40	3 %	39 %	67 %	75 %						63
40-50	5 %	27 %	40 %	100 %						92
50-60	5 %	35 %	10 %	40 %	100 %					103
60-70	11 %	24 %	65 %	33 %		100 %	0 %			120
70-80	3 %	8 %	9 %	0 %	20 %	100 %				127
80-90	4 %	18 %	25 %	50 %	50 %	33 %	100 %	0 %		140
90-100	5 %	15 %	30 %	40 %	86 %	0 %	0 %	0 %		137
100-110	7 %	6 %	32 %	23 %	43 %		0 %			125
110-120	2 %	16 %	38 %	42 %	29 %	33 %	100 %	100 %	100 %	122
120-130	12 %	17 %	36 %	40 %	0 %	100 %	0 %	100 %	67 %	89
130-140	0 %	0 %	67 %	14 %	50 %	33 %	100 %		0 %	75
140-150	0 %	22 %	18 %	14 %	50 %	0 %	50 %	0 %	33 %	55
150-160	7 %	0 %	0 %	57 %	25 %	33 %	100 %	100 %	100 %	39
160-170	14 %	20 %	40 %	33 %	25 %	50 %	33 %	0 %	0 %	31
170+	5 %	6 %	7 %	0 %	0 %	0 %	33 %		67 %	88
# stands	770	345	190	114	57	28	18	8	15	1,545

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## Appendix C: Maps of Expected Bough Levels



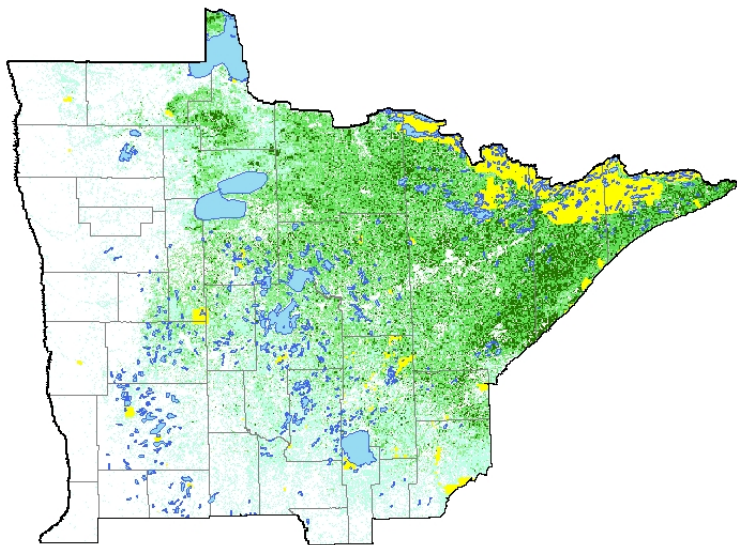
**Where Are Minnesota's Balsam Boughs?**



**Map 1.**

Expected available boughs at guideline harvest levels based on interpolation of observed plot values.

No balsam = less than 5 lbs per acre.  
 Low = 5 to 50 lbs per acre.  
 Medium = 50 to 200 lbs per acre  
 High = More than 200 lbs per acre.



**Where Are Minnesota's Balsam Boughs?**



**Map 2.**

Expected available boughs at guideline harvest levels based on nearest neighbor mapping of plot data to satellite imagery.

No balsam = less than 5 lbs per acre.  
 Low = 5 to 50 lbs per acre.  
 Medium = 50 to 200 lbs per acre  
 High = More than 200 lbs per acre



## Appendix D: North Central FIA Balsam Bough Phase 2 Field Procedures

The following section was been added to NCFIA field procedure starting with the 2004 field season (October 1, 2003)

### 5.28NC BALSAM FIR BOUGHS

There is an increasing interest in the collection of balsam boughs for the manufacture of evergreen products. The information collected will be available to assess the health and sustainability of the balsam bough resource in the region.

#### 5.28.1NC BOUGHS AVAILABLE (BAVA = BOUGHS\_AVAILABLE)

Record the code for all live Balsam Fir (0012)  $\geq 1.0$  in DBH that describes if harvestable boughs are present. The tree must meet the following criteria to be coded as having Boughs Available:

Branches in the bottom 7.5 feet of the tree

At least one branch no larger in diameter than a pencil where clipped

At least 18 inches in length and at least 75 percent live needles throughout

When collected: All species 0012 trees  $\geq 1.0$  DBH

Field width: 1 digit

Tolerance: No errors

MQO: At least 80 percent of the time

Values:

0 No boughs available

1 Boughs available

#### 5.28.2NC BALSAM BOUGHS HARVESTED (BHAR = BOUGHS\_HRVST)

Record the code for all live Balsam Fir (0012)  $\geq 1.0$  in DBH that describes whether Balsam Boughs have been harvested or not.

When collected: All species 0012 trees  $\geq 1.0$  DBH

Field width: 1 digit

Tolerance: No errors

MQO: At least 80 percent of the time

Values:

0 Boughs have not been harvested

1 Boughs have been harvested

#### 5.28.3NC BOUGH HARVESTING GUIDELINES (GUID = HRVST\_GUIDELINE)

Record the code for all live Balsam Fir  $\geq 1.0$  in DBH that have had Balsam Bough harvesting, whether Standard Balsam Bough Harvesting Guidelines have been used. The guidelines are listed below:

Branches cut were no larger in diameter than a pencil

Part of the cut branches were left for growth and regeneration

On smaller trees at least 50 percent of the trees limbs were left in the upper portion of the tree

When collected: When BALSAM BOUGHS HARVESTED=1

Field width: 1 digit

Tolerance: No errors

MQO: At least 80 percent of the time

Values:

0 Guidelines not used

1 Guidelines used





## Appendix E: Preliminary Stage 3 Results From Plots Measured in 2004

**Table 11. Preliminary results from 2004 balsam bough data on FIA plots in the North Central region. Summary of live balsam tally trees by bough availability and harvesting.**

State	Diameter Class	Number of live tally balsam fir trees			Percent	
		All	With Available Boughs	Harvested	With Available Boughs	Harvested
Minnesota	1.0-1.9	547	435	9	79.5 %	2.1 %
	2.0-2.9	267	193	12	72.3 %	6.2 %
	3.0-3.9	129	82	4	63.6 %	4.9 %
	4.0-4.9	66	45	2	68.2 %	4.4 %
	5.0-5.9	468	240	10	51.3 %	4.2 %
	6.0-6.9	364	181	6	49.7 %	3.3 %
	7.0-7.9	220	119	3	54.1 %	2.5 %
	8.0+	372	195	5	52.4 %	2.6 %
	All trees	2433	1490	51	61.2 %	3.4 %
2.0 - 5.9"	930	560	28	60.2 %	5.0 %	
Michigan	1.0-1.9	1274	1043	12	81.9 %	1.2 %
	2.0-2.9	545	382	5	70.1 %	1.3 %
	3.0-3.9	237	130	4	54.9 %	3.1 %
	4.0-4.9	129	55	0	42.6 %	0.0 %
	5.0-5.9	1046	444	8	42.4 %	1.8 %
	6.0-6.9	612	241	7	39.4 %	2.9 %
	7.0-7.9	369	144	3	39.0 %	2.1 %
	8.0+	511	174	2	34.1 %	1.1 %
	All trees	4723	2613	41	55.3 %	1.6 %
2.0 - 5.9"	1957	1011	17	51.7 %	1.7 %	
Wisconsin	1.0-1.9	423	350	2	82.7 %	0.6 %
	2.0-2.9	200	139	4	69.5 %	2.9 %
	3.0-3.9	85	56	2	65.9 %	3.6 %
	4.0-4.9	41	18	0	43.9 %	0.0 %
	5.0-5.9	426	208	1	48.8 %	0.5 %
	6.0-6.9	268	118	1	44.0 %	0.8 %
	7.0-7.9	169	58	2	34.3 %	3.4 %
	8.0+	185	73	0	39.5 %	0.0 %
	All trees	1797	1020	12	56.8 %	1.2 %
2.0 - 5.9"	752	421	7	56.0 %	1.7 %	
Lake States Total	1.0-1.9	2244	1828	23	81.5 %	1.3 %
	2.0-2.9	1012	714	21	70.6 %	2.9 %
	3.0-3.9	451	268	10	59.4 %	3.7 %
	4.0-4.9	236	118	2	50.0 %	1.7 %
	5.0-5.9	1940	892	19	46.0 %	2.1 %
	6.0-6.9	1244	540	14	43.4 %	2.6 %
	7.0-7.9	758	321	8	42.3 %	2.5 %
	8.0+	1068	442	7	41.4 %	1.6 %
	All trees	8953	5123	104	57.2 %	2.0 %
2.0 - 5.9"	3639	1992	52	54.7 %	2.6 %	

**Table 12. Preliminary results from 2004 balsam bough data on FIA plots in the North Central region. Summary of balsam tally trees where harvesting of boughs has been observed.**

State	Ownership	Trees Harvested	Trees Harvested Under Guidelines	Percent Harvested Under Guidelines
Minnesota	Private	5	5	100.0 %
	Public	46	8	17.4 %
	All owners	51	13	25.5 %
Michigan	Private	20	5	25.0 %
	Public	21	13	61.9 %
	All owners	41	18	43.9 %
Wisconsin	Private	4	2	50.0 %
	Public	8	2	25.0 %
	All owners	12	4	33.3 %
Lake States Total	Private	29	12	41.4 %
	Public	75	23	30.7 %
	All owners	104	35	33.6 %



