
Development of Empirical Yield Curves

For the HD1

Standard Forest Unit

PREPARED FOR:

Forestry Research Partnership

PREPARED BY:

Margaret Penner, Ph.D.
Forest Analysis Ltd.
Box 407, R.R. 4
Huntsville, ON P1H 2J6



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Abstract

Yield curves are an integral part of forest management planning. This report presents preliminary results for the tolerant hardwood selection forest unit (HD1). The results are presented in the context of the Nipissing Management Unit.

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1 Objective

The purpose of this project is to develop yield curves based on field data for the analysis of wood supply. These curves should represent a range of current and potential management intensities (Table 2) for the standard northeast forest units (Watt et al. 2001) and southcentral (draft) forest units. The curves should be compatible with the sustainable forest management model (SFMM) (Davis 1999) and be applicable to forest management units (FMUs) within Tembec's operating area in Ontario.

The intent of the project was to use all available growth and yield plot data

2 Background

Much of the background to this project can be found in Penner (2003).

2.1 The forest and forest units

The Nipissing forest consists of approximately 500,000 ha dominated by tolerant hardwoods (sugar maple, yellow birch, red maple, red oak, beech, white ash, and black cherry), white and red pine, and intolerant hardwoods (white birch and trembling aspen) (Table 1). The most valuable products are high quality hardwood and pine sawlogs as well as veneer.

Table 1. The standard forest units in the Nipissing forest are described.

Standard forest unit	Silvicultural system	Weighted average species composition ¹	Site class	Stoc king	Area (ha)	% of Forest
White Birch, Poplar Mix (BW)	Clearcut	Bw ₄ Po ₂ Bf ₁ Mr ₁ Mh ₁ Sw ₁	2.0	0.88	65,6523	13.1
Yellow Birch (BY)	2C Uniform Shelterwood	By ₅ Mh ₂ Bf ₁ Mr ₁ Ce ₁	1.7	0.80	12,208	2.4
Tolerant Hardwood Selection (HD1)	Selection	Mh ₆ Or ₁ By ₁ Mr ₁ He ₁	1.1	0.82	82,887	16.6
Tolerant Hardwood Uniform Shelterwood (HDUS)	2C Uniform Shelterwood	Mh ₂ Mr ₂ Or ₁ By ₁ Bw ₁ He ₁ Po ₁ Bf ₁	1.6	0.79	38,963	7.8
Hemlock (HE)	2C Uniform Shelterwood	He ₅ By ₂ Mh ₁ Mr ₁ Bf ₁	1.7	0.81	8,556	1.7
Lowland Mixedwood (LWMX)	2C Uniform Shelterwood	Ce ₂ By ₂ Mr ₁ Ab ₁ Bf ₁ Sb ₁ Bw ₁ Sw ₁	1.6	0.76	14,186	2.8
Mixed Conifer Lowland (MCL)	Clearcut	Sb ₄ Ce ₃ Bf ₁ La ₁ Sw ₁	1.7	0.72	18,275	3.7
Mixedwood (MW)	Clearcut	Bw ₂ Po ₂ Bf ₂ Sw ₁ Mr ₁ Sb ₁ By ₁	1.7	0.74	78,272	15.7
Jack Pine (PJ)	Clearcut	Pj ₈ Sb ₁ Po ₁	1.7	0.88	6,472	1.3
Jack Pine Upland Black Spruce Mix (PJSB)	Clearcut	Sb ₄ Pj ₃ Po ₁ Bw ₁ Bf ₁	1.2	0.72	15,195	3.0
Poplar (PO)	Clearcut	Po ₆ Bw ₁ Bf ₁ Mr ₁ Sw ₁	2.2	0.79	32,257	6.5

¹ Species codes are given in Hayden et al. (1995)

Standard forest unit	Silvicultural system	Weighted average species composition ¹	Site class	Stoc king	Area (ha)	% of Forest
Red Pine (PR)	Clearcut	Pr ₈ Bw ₁ Po ₁	0.9	0.82	7,879	1.6
White Pine Seed Tree (PWST)	Clearcut (Seed Tree)	Pw ₃ Po ₂ Bw ₂ Pr ₁ Bf ₁ Mr ₁	1.8	0.59	21,097	4.2
White Pine Uniform Shelterwood (PWUS)	3C Uniform Shelterwood	Pw ₄ Bw ₁ Po ₁ Pr ₁ Sw ₁ Bf ₁ Mr ₁	1.4	0.71	47,983	9.6
Spruce / Fir (SF)	Clearcut	Sb ₃ Bf ₂ Sw ₁ Ce ₁ Bw ₁ Pw ₁ Po ₁	1.2	0.70	49,676	9.9
Total					499,558	100.0

The forest unit discussed here is the uneven-aged tolerant hardwood forest. These forests are usually managed by implementing the single-tree selection silvicultural system in which mature and/or undesirable trees are removed individually over the whole area (Anderson and Rice 1993). These removals occur every 20 to 25 years (the cutting cycle) following marking of the trees to be cut. Tree-marking in selection management is usually controlled by basal area and structural targets. Trees are generally classed as acceptable growing stock (AGS – potential crop quality trees) and unacceptable growing stock (UGS – trees unlikely to be crop quality trees at the end of the next cutting cycle). Anderson and Rice (1993) give a detailed description of tree quality classifications and tree-marking objectives.

2.2 Forest management intensities (NEBIEs)

For the purposes of this project, the management intensities for the various forest units have been put in a standard framework with Natural, Extensive, Basic, Intensive, and Elite (NEBIE) levels (Table 2). These management intensities focus on silvicultural manipulations to achieve a target. Site modification (e.g., drainage, fertilization) and tree improvement are two additional dimensions of management intensity. Site modification is not considered here.

Table 2. The standard framework for the management intensities is given.

Level	Target/Focus	Planned Activity
Natural	Same conditions as natural	Present forest condition
Extensive	Manipulating species composition.	Natural regeneration (may include assisted natural regeneration (scarification and cone scattering))
Basic	Manipulating species composition Achieving full site occupancy.	Assisted natural regeneration and artificial regeneration (may include site prep and vegetation management) (e.g. SIP and planting with no other planned intervention after FTG)
Intensive	Manipulating species composition Achieving full site occupancy Controlling density to optimize individual tree growing space	Assisted natural regeneration and artificial regeneration featuring density regulation at a young age (may include site prep and vegetation management) (e.g. SIP and planting with planned spacing/thinning intervention after FTG stage)
Elite	Achieving higher product value	Practices designed to enhance the value or quality of the forest product (e.g. pruning, crop tree management)

Some management actions will result in a stand moving from one forest unit to another. In some cases, a low level of silvicultural investment will result in a conversion from a conifer unit to a mixedwood unit. In other cases, a higher level of silvicultural investment will result in the rehabilitation of a mixedwood unit to a conifer unit. Some forest units will secede to another forest unit with age. This project focuses on the stand development within a forest unit. If a stand moves to another forest unit following harvest, the yield curve for the new forest unit should be used to predict development.

The management intensities for the HD1 forest units are given in Table 3.

Table 3. Management intensities are given for the HD1 forest unit.

FU	Intensity	Stand description and Target	Silviculture
HD1	Natural	Average of the forest unit Spp Mh ₆ Or ₁ By ₁ Mr ₁ He ₁ , stocking =0.82, SC = 1.1	Natural (unknown) origin
	Extensive	BA reduction to 18 m ² /ha, 70%UGS, 30%AGS. 10% improvement in AGS %, 10% logging damage, 2m ² /ha UGS left as a result of not undertaking stand improvement	Tree marking Removal of stems > 10"
	Basic	BA reduction to 18 m ² /ha, 70%UGS, 30%AGS. 10% improvement in AGS %, 5% logging damage	Tree marking Stand improvement (marking down to 4")
	Intensive	BA reduction to 18 m ² /ha, 70%UGS, 30%AGS. 10% improvement in AGS %, 3% logging damage	Tree marking Stand improvement (marking down to 4") Lower logging damage (3%)
	Elite	Increased value	

2.3 Existing curves

The Sustainable Forest Management Model (SFMM) uses a basal area yield function, combined with volume to basal area ratios (vbars) to define the yields for selection forest units. It also requires the fraction of the basal area classified as AGS to assign products to the yields. The basal area yield function predicts the basal area in annual time steps as a function of the basal area at the beginning of the prediction interval.

3 Data

The datasets are described in Appendix B. The tree quality classifications were standardized to AGS/UGS classes based on Table 4. Conifers were assigned a quality class of "other growing stock" (OGS). Tree species with codes greater than 100 (Hayden et al. 1995) are essentially non-commercial hardwoods and were ignored in the analysis. The data are summarized in Table 5. Where multiple plots were located in a single stand, given the same treatment, and measured in the same years, the plots were combined. Heights were often not measured and ages rarely measured on tolerant hardwood plots. Ht-dbh curves were estimated by species based on the available data and applied to all the sample plots. Volumes were estimated using Zackzewski's taper model. In the HD1 unit, only trees 10cm and up were used. Trees 5cm and up were used for all other forest units.

Table 4. Translation of Historic 5 Class Numeric Quality Class to Algonquin 6 Class System based on discussion with Harvey Anderson Feb 6, 2002.

5 Class Numeric	Algonquin 6 Class	AGS/UGS
1	A1	AGS
2	B1	AGS
3	A or B	UGS
4 ¹	C	UGS
5 ²	D	UGS

¹ Trees had to be a minimum of 25cm (10")

² Trees had to be a minimum of 30.5cm (12")

Table 5. Plots from the tolerant hardwood forest units are summarized. Means are followed by the data ranges in brackets. Only trees greater than 10cm dbh are included.

Tolerance	Plots	Msmts	Age (years) ¹	BA (m ² /ha)	Density (stems/ha)	Sawlog %	AGS %	Volume (m ³ /ha)
By	10	27	NA	23.4 (5.3–32.6)	502 (125-840)	0.61 (0.07-0.87)	0.43 (0.10-0.72)	148 (26-267)
Mid	27	55	NA	25.5 (14.0-34.4)	319 (225-927)	0.60 (0.07-0.92)	0.43 (0.10-0.77)	206 (117-332)
Other	356	1569	NA	22.6 (3.5-43.7)	358 (31-1033)	0.79 (0.18-1.00)	0.41 (0.00-0.97)	186 (30-363)

¹ Ages were only available for 2 plots in the HD1 forest unit.

4 Methods

4.1 Factors affecting yield

Leak et al. (1987) indicate net growth is a function of site index, residual basal area, and percent residual sawtimber.

Leak (1996) found that the reverse J-shaped curve did not fit stands 35 years after cutting as well as unmanaged stands.

The distribution of the cut affects the yields. The distribution of cut has a limited influence on the basal area growth but has a large influence on the volume growth. Cuts that concentrate removals on smaller stems have higher volume growth than stands that concentrate removals on the average or larger stems (Marquis 1994). If there is more than 20 ft/acre (4.6m²/ha) in the sapling class, any thinnings should include removals from the sapling class. They also recommend no precommercial thinnings unless there are many good-quality stems of high-value species being overtopped by poor-quality trees or undesirable species (p. 269 Marquis 1994). Relative density is the ratio of the actual basal area to that of a stand at the average maximum basal area observed (p. 88 Marquis 1994). They indicate that cutting should occur if the stand has a relative density greater than 80% and that the residual relative density should be 60% (no more than 35% relative density removed in any single cut).

Site index (or site class based on height and age) is a less useful attribute for tolerant hardwoods and management by selection system because the stands are generally unevenaged and/or contain a mixture of species. Site index is most appropriate for

evenaged stands dominated by a single species. In general, age was not available for the tolerant hardwood plots. Heights were often not measured but were estimated from ht-dbh curves developed from those measurements with heights. Stocking also relies on an estimate of stand age (in order to compare the BA to Plonski's yield tables at the same age) so was not used.

The q associated with each remeasurement was calculated by placing the stems in 5cm diameter classes (10–15, 15-20, 20-25, 25-30, 35-40, 40-45, 45-50). A linear regression was estimated between the natural logarithm of density (stems/ha) and dbh class. The slope of the line is q .

Crow et al. (1981) compared 5, 10, and 15 year cutting cycles to residual BAs of 50, 70, and 90 ft²/acre. They found that net growth decreased with increase in cutting cycle length but the differences were not significant. The survivor growth was slightly higher for the 70 ft²/ac residual BA but the net growth for the 50 ft²/acre residual BA was higher due to a greater ingrowth. The 90 ft²/acre residual BA had the highest mortality, the lowest ingrowth, and the lowest survivor growth and therefore had the lowest net growth. Some of the low growth of the highest residual BA stands was attributed to lower selection intensities for stems with good growth potential.

A number of variables were selected as potential predictors of basal area growth. These included Dq (quadratic mean dbh), q (as described above), current BA, sawlog fraction (fraction of BA in trees greater than 25cm dbh), top height, basal area, AGS fraction (AGS BA/ total BA), the BA removed (only applies to post cut growth), and the fraction of BA in dominant and codominant stems. Of this list, only top height and basal area (obtained from age, stocking and site class) are available from the inventory. Not all variables were available for all remeasurement periods. Observations were weighted by the square root of the product of plot area and number of years in the remeasurement period so that large plots with long remeasurment periods had the most weight. For yellow birch and maple dominated plots, the current BA and the AGS fraction had the highest correlation with future growth. For the mid tolerants, only 4 out of 19 remeasurment periods had quality class measurements. For the mid tolerants, current BA and sawlog fraction had the highest correlation with future growth. In all cases, residual BA was negatively correlated with BA growth (Figure 1) and AGS fraction or sawlog fraction were positively correlated with growth (Figure 2). Current BA and AGS fraction were selected for predicting BA growth because of their high correlation with BA growth and their availability. Although AGS fraction is not available from the inventory, it should be available from the tree marking prescription).

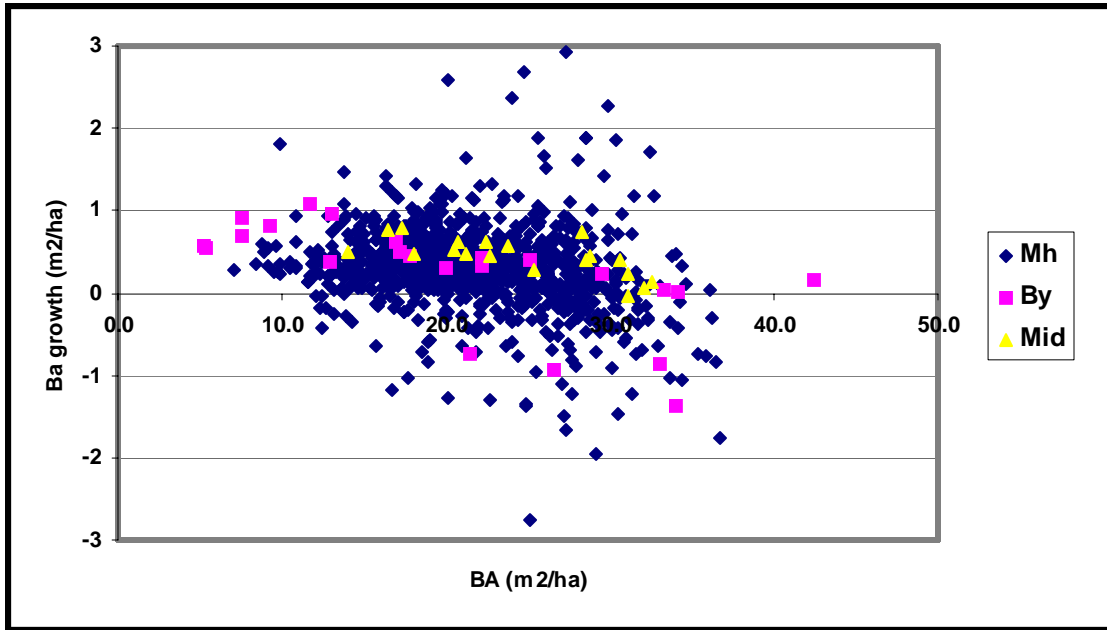


Figure 1. The relationship between BA growth and BA is shown for the HD1 forest unit by tolerance class. Three observations (one with a high growth rate and two with low rates) were omitted from this and subsequent figures to keep the scales reasonable.

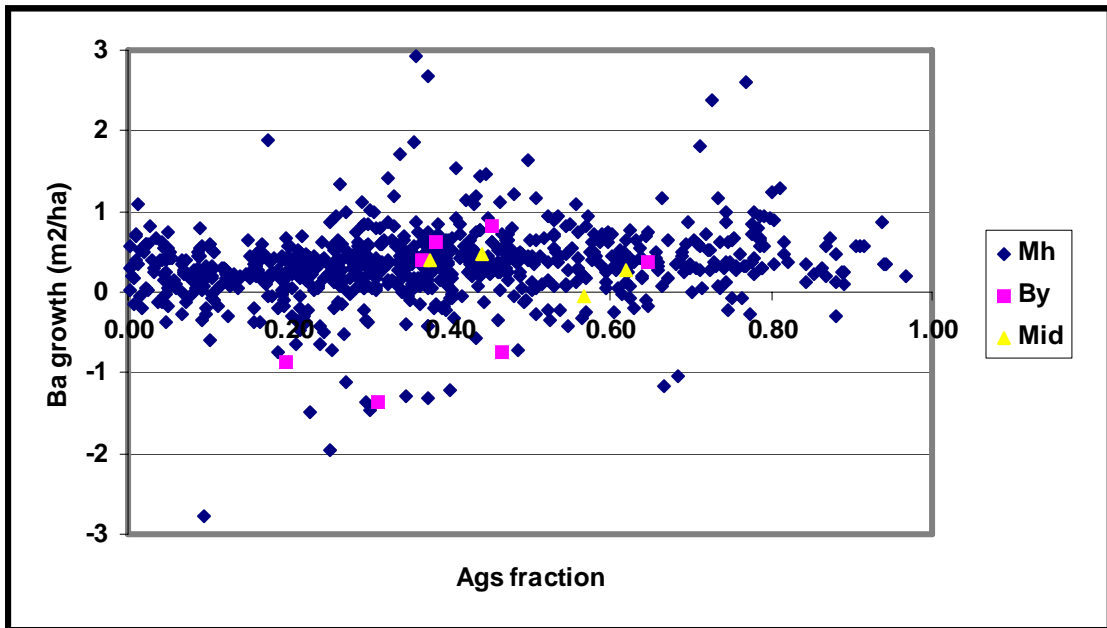


Figure 2. The relationship between BA growth and AGS fraction is shown for the HD1 forest unit by tolerance class.

4.2 BA growth

As noted previously, basal area growth was a function of basal area and proportion of basal area in AGS. Basal area was put in $2\text{m}^2/\text{ha}$ classes and basal area growth fit as a function of proportion AGS. The results are given in the following figure.

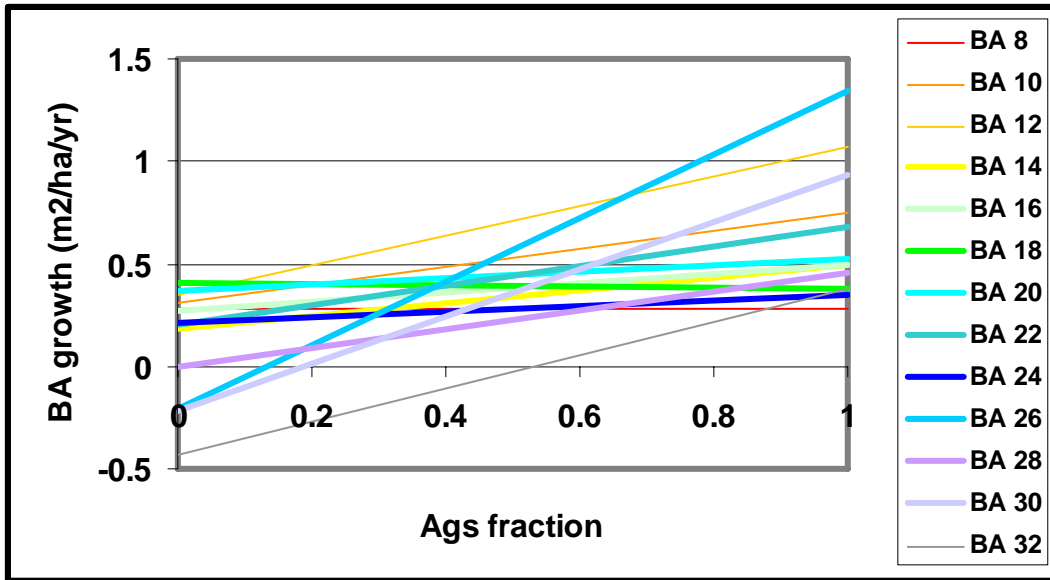


Figure 3. Relationship between basal area growth and proportion BA is given by basal area class. Basal area classes with less than 50 observations are indicated with narrow lines.

In general, the slope was not statistically significant ($\alpha < 5\%$) but the intercept was. There was a trend of increasing intercept as the basal area class went from $8\text{m}^2/\text{ha}$ to about $18\text{m}^2/\text{ha}$ and then decreasing. The trend of slope with basal area class was less clear but generally increasing.

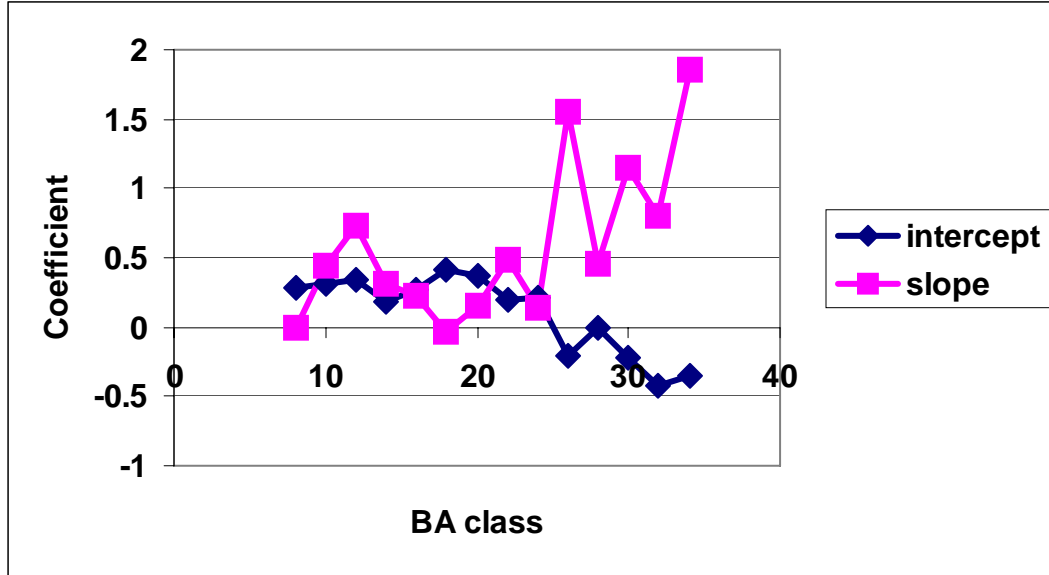


Figure 4. Relationship between the coefficients of the linear relationship between fraction AGS and basal area growth rate are given by BA class.

The intercept was initially predicted using the following equation, which is the differential form of the Chapman-Richards growth function (Pienaar and Turnbull 1973). The number of observations used to compute the intercept was used as a weight.

$$(1) \quad \text{intercept} = \alpha_1 \cdot BA^{\beta_1} - \gamma_1 \cdot BA$$

The model overpredicted for small BA classes so various modifications were tried. The following model had the best fit.

$$(2) \quad \text{intercept} = \alpha_1 + \beta_1 \cdot BA^{\gamma_1} - \delta_1 \cdot BA^{\eta_1}$$

The following model was used to predict the slope.

$$(3) \quad \text{slope} = \alpha_2 \cdot BA^{\beta_2}$$

The predictions are given in Figure 5. Substituting the coefficient predictions back into the equation to predict slope resulted in the following model.

$$(4) \quad \begin{aligned} \frac{dBA}{dt} &= \text{intercept} + \text{slope} \cdot AGS \\ \frac{dBA}{dt} &= (\alpha_1 + \beta_1 \cdot BA^{\gamma_1} - \delta_1 \cdot BA^{\eta_1}) + (\alpha_2 \cdot BA^{\beta_2}) \cdot AGS \end{aligned}$$

Model (4) was fit to the data, simplified, and some non-significant terms removed, resulting in the following equation. The first coefficient was expanded to be a function of AGS fraction as follows.

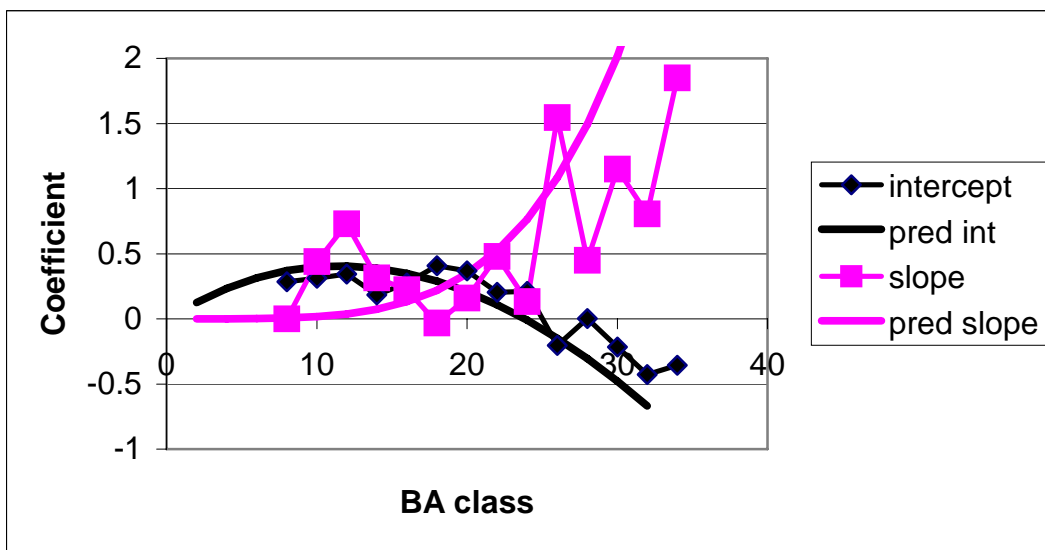


Figure 5. The coefficient predictions and actual values are plotted by basal area class.

$$\frac{dBA}{dt} = (\alpha_0 + \alpha_1 \cdot AGS) \cdot BA^\beta - \gamma \cdot BA^\delta$$

$$(5) \quad \frac{dBA}{dt} = (1.9385 + 0.0020 \cdot AGS) \cdot BA^{1.6559} - 1.9173 \cdot BA^{1.6593}$$

The model had a mean squared error of 0.1993, an F-value of 105 ($\alpha \leq 0.0001$) and an R^2 of 0.36. The inclusion of the δ term in equation (5) caused the α_1 to become statistically non-significant. Nevertheless, the δ term was retained because without it, the model predicted unrealistically large growth predictions at low basal areas, which have little data.

The results for the maple portion of the HD1 forest unit are given in Figure 6. The maple portion is used because the By and mid tolerant portions had only 7 and 4 observations respectively with AGS fraction (the maple portion had 790 observations).

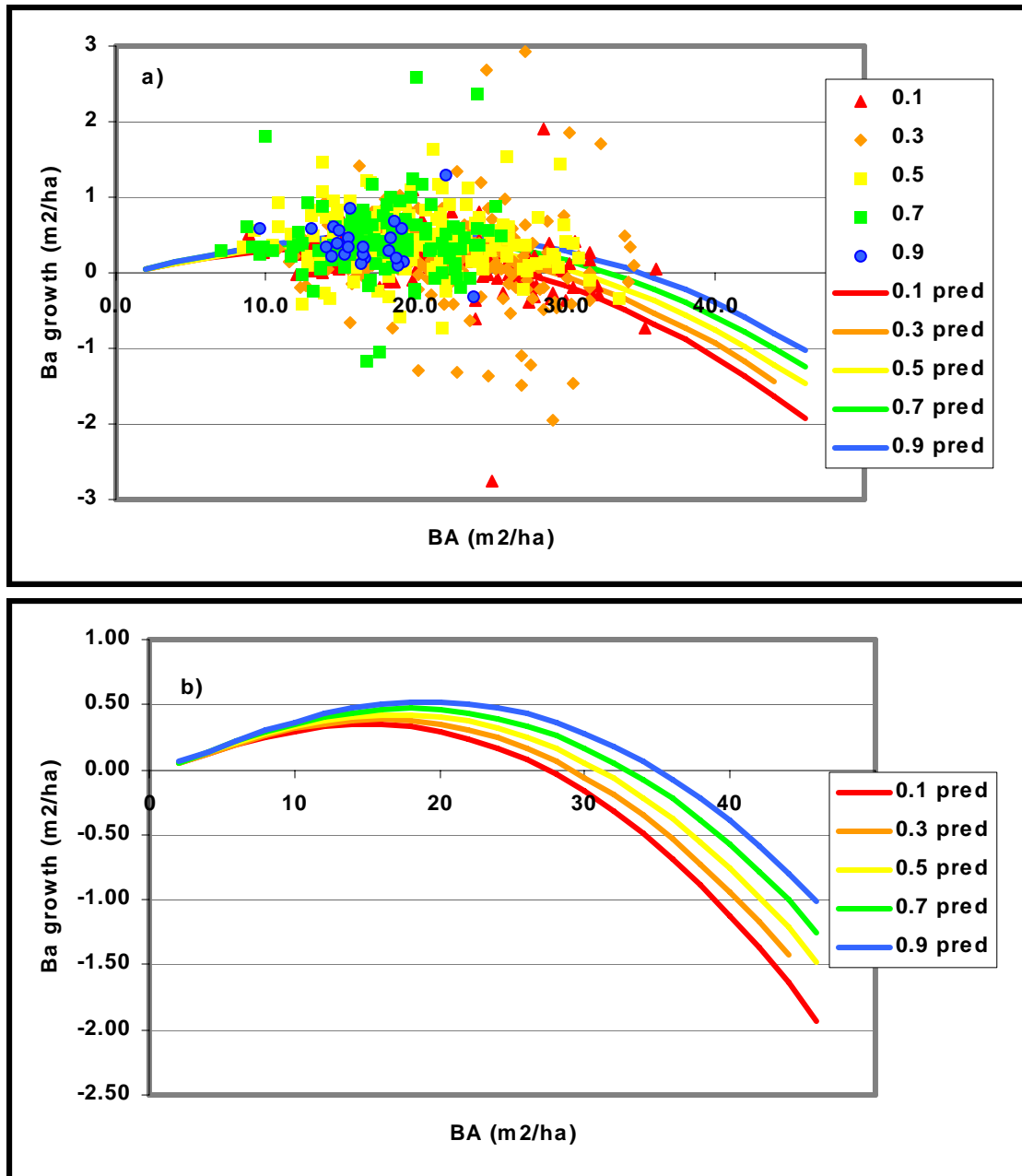


Figure 6. The results of fitting basal area growth as a function of BA and AGS fraction are given for the maple component of the HD1 forest unit with the data (a) and without the data (b). The data are plotted by AGS fraction (in 20% classes).

As seen in Figure 6, as the fraction of AGS increases, basal area growth increases, peaks later, and becomes zero at a higher basal area.

The increase in growth rate with fraction AGS may have several causes.

- It may be a result of higher mortality in plots with higher proportions of UGS. That is, all the plots may have similar gross growth but the net growth may be higher on plots with more AGS due to lower mortality rates.
- The plots with more AGS may have had better management in the past. This may have resulted in a higher proportion of AGS but may also have led to better structure, spacing, and more vigorous trees.
- The plots with more AGS may be growing on more productive sites.

When using equation (5) to predict growth following cutting (and manipulating the AGS), the first two explanations of positive correlation between AGS and growth may be expected hold. However, if the cause of the positive correlation between AGS and growth is a result of a positive correlation between AGS and site, this is a poor prediction equation if the proportion of AGS changes as a result of management.

4.3 *Vbar*

The volume to basal area ratio (*Vbar*) was estimated by species based on the net merchantable volume. The results are given in Table 6.

Table 6. The volume to basal area ratio (*Vbar*) is given by species. For some species (Ob, Ow), none of the trees were large enough to be merchantable and had a *vbar* of zero.

Species	N	<i>Vbar</i> (m ³ /m ²)	Standard Error
Ab	77	5.3	0.35
Aw	107	2.7	0.24
Bd	201	5.7	0.19
Be	1197	5.0	0.07
Bf	257	4.5	0.13
Bw	118	6.4	0.17
By	924	5.9	0.08
Cb	196	5.0	0.22
Ce	64	5.2	0.11
Ew	58	3.0	0.49
He	534	6.4	0.04
Id	781	0.2	0.03
Mh	1991	5.8	0.03
Ms	446	3.4	0.12
OH	109	0.3	0.13
Ob	4	0.0	0.00
Or	148	5.7	0.15
Ow	3	0.0	0.00
Pj	1	5.9	
Po	73	7.5	0.34
Pr	8	9.8	0.47
Pw	48	5.1	0.59
Sb	10	1.7	0.42
Sw	214	4.7	0.13

5 Results

The results of the basal area predictions are given in Figure 7 and Figure 8. The *basic* and *intensive* management intensities have higher growth rates than *extensive* as a result of a lower residual basal areas ($18\text{m}^2/\text{ha}$ vs. $20\text{m}^2/\text{ha}$) and higher AGS fractions. The confidence intervals associated with the basal area growth predictions are relatively wide (Figure 7b). Half the width of the 90% confidence interval ranges from $0.21\text{m}^2/\text{ha}/\text{yr}$ to $0.14\text{m}^2/\text{ha}/\text{yr}$. The basal area yield curves are given in Figure 8. The same 90% confidence intervals from Figure 7b look relatively narrow in Figure 8b despite representing a 5 year prediction in Figure 8.

For a 20 year cutting cycle for the *basic* management intensity, the basal area growth prediction is $6.2\text{m}^2/\text{ha}$ with a 90% confidence interval of $\pm 3.8\text{m}^2/\text{ha}$. The 20 year prediction for the *intensive* management intensity is $6.3\text{m}^2/\text{ha}$ with a 90% confidence interval of $\pm 3.7\text{m}^2/\text{ha}$. The 20 year prediction for the *extensive* management intensity is $5.0\text{m}^2/\text{ha}$ with a 90% confidence interval of $\pm 3.6\text{m}^2/\text{ha}$.

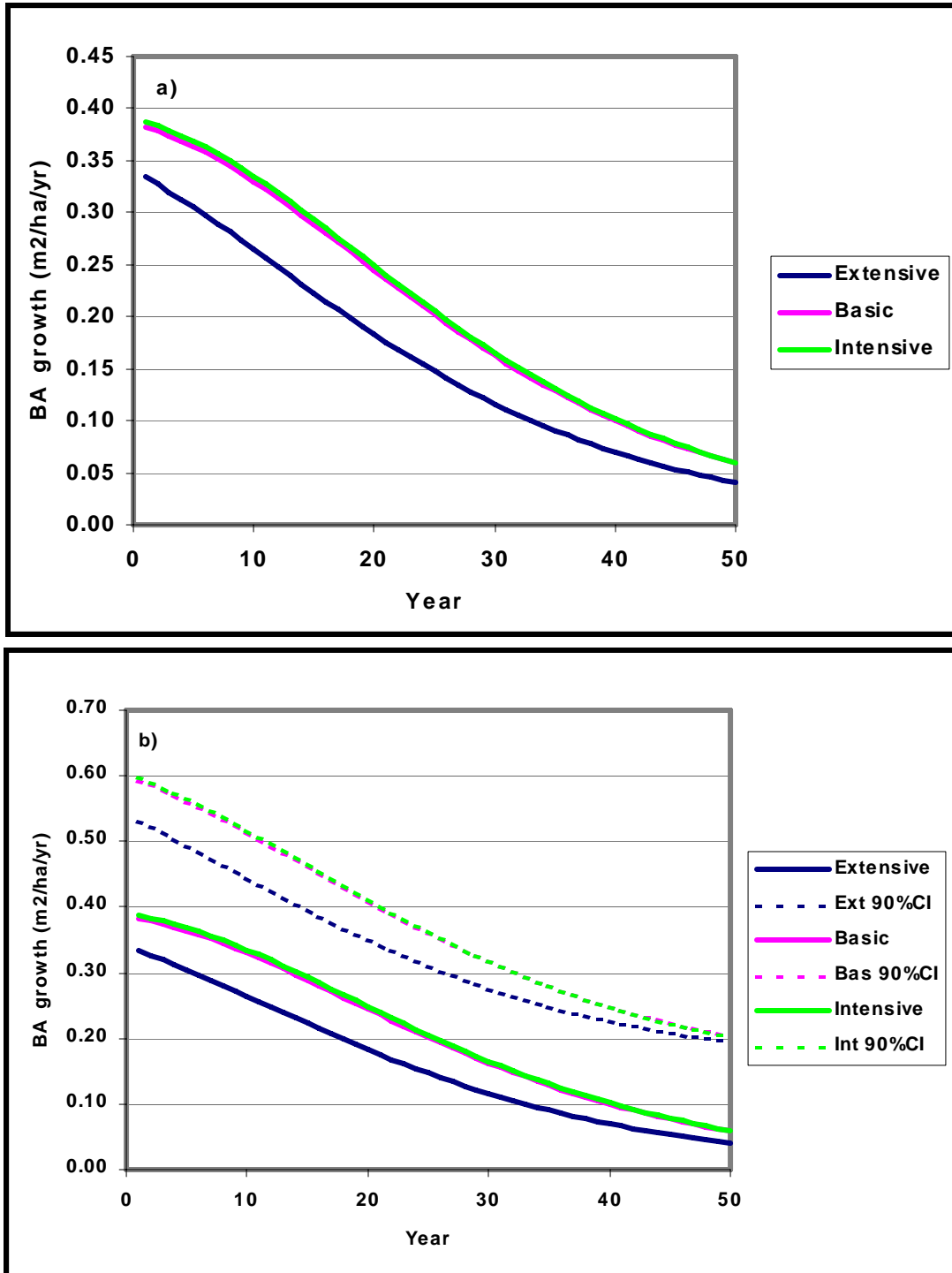


Figure 7. The basal area growth predictions are give by management intensity (as defined in Table 3) are give in (a) and the associated 90% confidence intervals are given in (b).

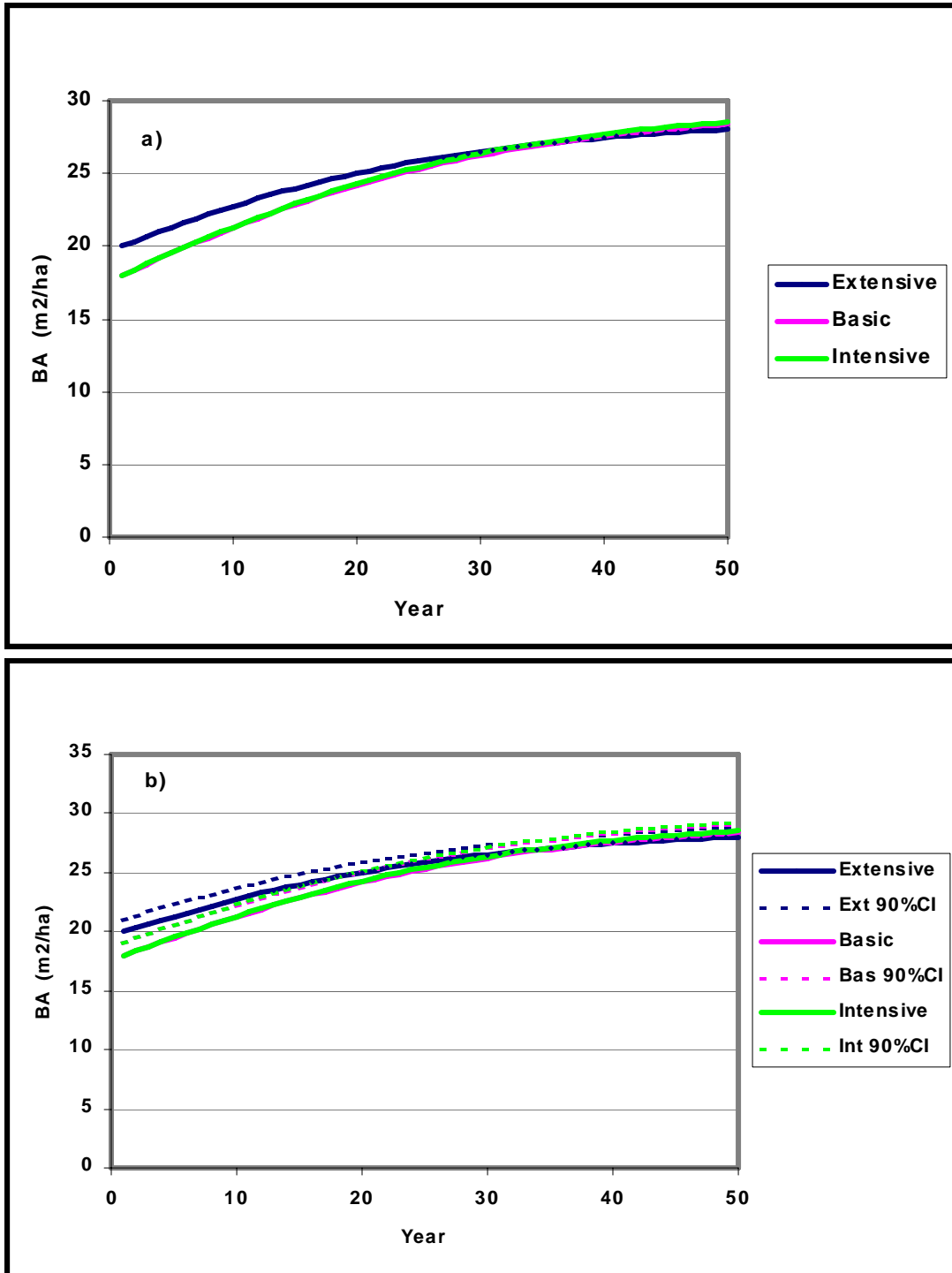


Figure 8. The basal area predictions are give by management intensity (as defined in Table 3) are give in (a) and the associated 90% confidence intervals (for a 5-year prediction) are given in (b).

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7 Appendix A

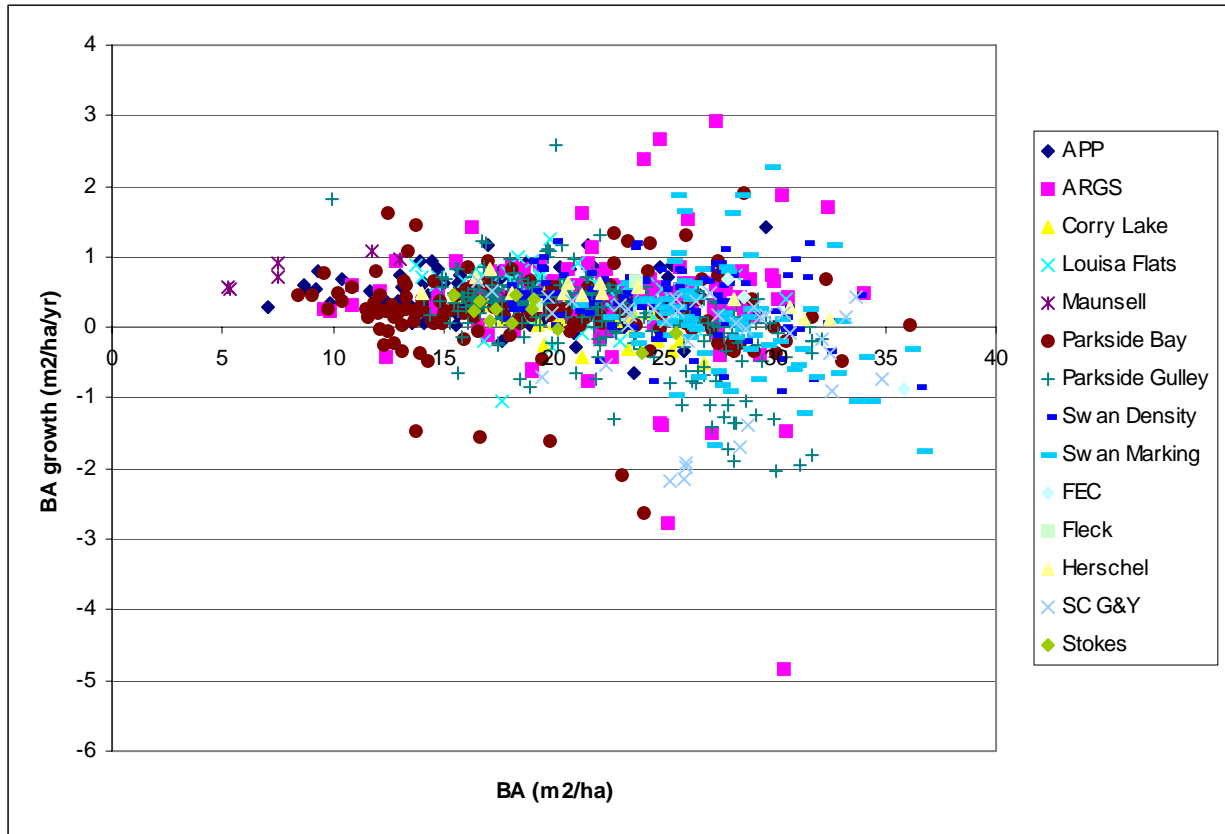


Figure 9. The data for plots in the HD1 forest unit are plotted by data source.

8 Appendix B

Table 7. The data sources are briefly described.

Forest unit	Dataset	Measurement years	Notes	Have (summarized)	Plots
HD1 HD2 PW4	Algonquin Polar plots	86, 91, 96	Control plots, uniform shelterwood, single tree selection. Poor – good sites Tree center Some logging damage	Y (Y)	>300 plots Plot size=0.04 ha round Aggregated by township and treatment HD1 – 86 plots HD2 20 plots PW4 12 plots
HD1	ARGS	77,82,87,89,90,92,94, 97	Control plots and single tree selection Good sites throughout Algonquin Park Treated plots cut in 1989. Post harvest assessment in 1990 Not cut operationally - tree centred plots	Y (Y)	Aggregated by township and treatment. - 0.04ha plots 36 observations from a total of 243 plots
HD2	Beckwith Roebbelen	Each dataset has its own measurement years,	These plots are not silviculturally treated. Some of them may have a tree taken out for fuelwood!! – Private land. Generally even aged.	Y (Y)	26 plots.
HD1	Corry Lake		No controls. Were managed to a volume target. Not a BA target.	Y (Y)	Variable plot sizes. Quality only in 1993. 8 plots
Evenaged Yield Curves	FEC		One remeasurement One plot per stand	Y	0.04ha HD1 – 3 plots HD2 – 5 plots + others
Assorted	G&Y		Assorted Evenaged Yield Curves for conifer and BA growth rates for some remeasured hws	Y (Y)	HD1 78 plots-38 twice HD2 24 plots-23 twice HE1 7 plots-1 twice Summarized by stand
HD1 - mid	Herschel Plots	1974, 1978, 1983, 1999	These are single tree selection 1/acre plots with a control. Mh-Basswood. Trees were not numbered in first measurements These plots are in the G&Y data as CE6204, 6205, 6206, 6207, 6208	Y (Y)	In 1999 3 X 400m ² plots were randomly located in each 1-acre original plot and trees numbered
HDSel	Louisa Flats	82, 83, 85, 90, 95, 98, 01	Multiple remeasurement Logging damage Many plots in one stand Good site Algonquin park	Y (Y)	30 grouped by 3s into 10 summaries - Tree Centred
HDUS? (See page 7 of Anderson and Ratz)	McCaulley Lake	Stand cut in 1961. Plots measured in 69, 76, 83, 89	Even-aged polewood release cut Control and thinned – However, control area not necessarily similar to treated area I think that this dataset may help us define some growth response to different residual BA's.	Y (Y)	10 plots [5 thinned, 5 controls] No quality 0.2 acres
HD1 - BY	Maunsel	67, 71, 77,	Yellow birch	Y (Y)	2 Plots

Forest unit	Dataset	Measurement years	Notes	Have (summarized)	Plots
	l Lake (PRF)	82, 92, 99			No quality
HDSEL	Parkside Bay	86, 89, 93, 94, 00	Single tree selection to a range of residual BAs	Y (Y)	53 plots 0.04ha
HDSEL	Parkside Gully	74, 80, 92, 98	Single tree selection Short cutting cycle Cut 3 times	Y (Y)	44 plots [25 cut, 19 controls] 0.4ha
	Scott Lake	Jim Rice - uncertain location	Not used		? plots [4 measurements]
HDSEL	Stokes	74, 80, 92, 98	Logging damage Large plots in one stand Good sites Operationally harvested	Y (Y)	20m radius 12 plots
HDsel	Swan Density plots	72, 73, 78, 84, 91	Only quality in 1991	Y (Y)	39 plots [33 cut/6 controls/5 measurements] 0.2ha
Hwdsel?	Swan Marking	66, 69, 74, 76, 80, 83, 89, 95	Uncut 14 plots, 5 measurements They represent unmanaged stand growth of uneven aged stands. That makes the selection.- I guess	Y (Y)	14 plots No quality before 1976 Bizarre quality in 1989 0.283ha
HDUS	Trout Creek	68, 69, 74, 79, 83, 89, 91	Treated plots to different BA	Y (Y)	33 plots, 0.04ha
PWUS	Achray		Various thinnings (from above, below)	Y (N)	15 plots
PwPlant	Copelands	Plots established in 1981		Y (Y)	5 plots – 2 or 3 measurements control plot and treated plots – 2 thinnings
PWplantation	Cedar Pt Pw	Plots established in 1979		Y (Y)	4 measurements - control and treated. - 1 thinning