Alberta-Pacific FMA Area

2015 Forest Management Plan

Annex V: Yield Curve Development

2015

ALBERTA PACIFIC FOREST INDUSTRIES INC

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EXECUTIVE SUMMARY

Alberta-Pacific Forest Industries Inc. (Alberta-Pacific) developed 21 new yield curves for their Forest Management Area (FMA) located in northeastern Alberta. The curves were used to facilitate the timber supply analysis being completed in support of the 2015-2025 Forest Management Plan (FMP). This document describes the data, methods, assumptions and processes used to develop yield estimates for natural and managed stands in the timber harvesting netdown landbase (NLB).

The yield curve development process was based on permanent sample plot (PSP), temporary sample plot (TSP) and RSA performance survey data collected across the Alberta-Pacific FMA area.

Stratification was based on Alberta-Pacific's 9 base yield strata using either Alberta Vegetation Inventory (AVI) attributes in natural stands or a combination of silviculture declaration plus treatment information in managed stands. The strata are a modification of the Alberta Planning Standard (ASRD 2006) base 10 yield strata, minus the Douglas-fir (Fd) stratum.

Gross merchantable volumes were compiled to 10 cm top diameter inside bark and 15 cm stump diameter over bark at 30 cm stump height utilization standard for both coniferous and deciduous species groups. Cull and stand retention were not accounted for during yield curve development.

Alberta-Pacific identified five groups of stands within the THLB for yield curve development:

Natural stands: include all fire-origin stands and any managed stands harvested prior to May 1, 1991. Modeling was based on GYPSY in a semi-empirical fashion whereby top height and basal area at inventory age were used to constrain model projections. Strata are based on the AVI polygon.

Post-performance managed stands: represent a small population of stands that have been surveyed using the RSA performance survey protocols. Strata are based on the RSA sampling unit line work.

Intensive managed stands: include all Quota Holders' harvest areas without an RSA performance survey that were harvested after May 1, 1991 in the Alberta-Pacific FMA area. These stands are generally subjected to herbicide treatments as the primary herbaceous vegetation control. Growth and yield modeling is based on GYPSY. Strata are based on silviculture declaration and treatment at the opening level.

Extensive managed stands: represent all Alberta-Pacific harvest areas without an RSA performance survey that were harvested after May 1, 1991 in the Alberta-Pacific FMA area. These stands are subjected to manual tending which results in multiple cohorts of deciduous species due to re-suckering. Growth and yield modeling is based on the Mixedwood Growth Model (MGM). Strata are based on silviculture declaration and treatment at the opening level.

Understorey protection stands: involve a specialized method of harvesting, referred to as a strip-cut approach: removal of both conifer and deciduous in strips to form extraction trails, removal of deciduous on either side of each extraction trail to release understorey conifers, and retention of a deciduous buffer between reach areas to minimize wind-throw of the remaining conifers. Due to the complexity of stand structures, modeling is based on MGM. Strata are based on silviculture declaration and treatment at the opening level.

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1.1 Introduction

Alberta-Pacific Forest Industries Inc. (Al-Pac) submitted the 2015-2025 Forest Management Plan (FMP) *Yield Curve Development* report on February 11, 2016. In addition, Al-Pac also sent a letter summarizing the yield curve utilization and the silviculture matrix on November 1, 2016.

Al-Pac received a letter of agreement-in-principle (AIP) of the FMP yield projections from Alberta Agriculture and Forestry (AAF) on December 8, 2016. The letter outlined a number of conditions regarding:

1. Yield Curve Assignment to the Classified Landbase
2. Strata Transition and Yield Curve Assignment Post-Harvest
3. Understorey Protection[1]
4. Silviculture Matrix

In discussion with AAF, it was determined that the 2015-2025 FMP *Yield Curve Development* report will not be re-opened and amended as there were no changes to the yield curves, data or methods. Almost all changes to the document are in regards to managed stand strata transitions and associated updates to the Target MAI table and Silviculture Matrix which pose no risk to the actual approved yield curves. This addendum provides a summary of changes to Al-Pac's growth and yield approach as per the conditions in the AIP.

1.2 Yield Curve Assignment

As per the AAF letter, the classified landbase stratum assignment rules are as follows:

- **NAT**: All natural stands and any managed stand harvested prior to March 1, 1991 will be assigned to natural yield strata (Group A - Natural Stand Yield Curves 1-9).
- **RSA**: All managed stands that have received RSA performance survey prior to 2013 will be assigned to the RSA yield strata (Group B - Post-Performance Yield Curves 10-18).
- **ARIS-EXT**: All Al-Pac's managed stands pre-2013 without an RSA survey will be assigned to natural yield strata (Group A - Natural Stand Yield Curves 1-9).
- **ARIS-INT**: All Quota Holders' managed stands pre-2013 without an RSA survey will be assigned to the intensive management yield curves in AwSx, SxAw and Sw strata (Group C - Intensive Management Yield Curves 19-21). All other strata in these openings are assigned to a natural stand yield curve.

[1] The TSA Understory Protection transition is detailed in Chapter 6 of the FMP. The NE Alberta Operating Ground Rules will be updated to reflect the TSA direction.

- **ARIS-UP**: All existing openings subjected to high effort understorey protection will be assigned to the understorey protection yield strata (Group E - Understorey Protection Yield Curves 26-27).

None of the existing stands in the net landbase will be assigned to the Mixedwood Growth Model (MGM) based Group D - Extensive Management Yield Curves 22-25. The area summary of the current net landbase[2] by yield group is shown in Table 1.

Table 1. Net Landbase Area Summary by Yield Group and Stand Type Group

Yield Group	Stand Type					
	NAT	RSA	ARIS-EXT	ARIS-INT	ARIS-UP	Grand Total
01-Aw	544,112		78,077	1,821		*624,009*
02-AwU	333,335		1			*333,336*
03-AwSx	83,398		3,994			*87,392*
04-SxAw	70,462		4,099			*74,561*
05-Sw	173,108		10,082			*183,190*
06-SbFM	31,221					*31,221*
07-SbG	144,253		126	730		*145,109*
08-PjMx	54,616		315	213		*55,144*
09-Pj	351,057		1,727	2,211		*354,995*
10-Hw		3,315				*3,315*
11-HwSx		2,360				*2,360*
12-SwHw		1,593				*1,593*
13-Sw		4,355				*4,355*
14-SbHw		75				*75*
15-Sb		96				*96*
16-HwPl		40				*40*
17-PlHw		121				*121*
18-Pl		110				*110*
19-AwSx				5,169		*5,169*
20-SxAw				10,978		*10,978*
21-Sw				25,894		*25,894*
26-AwSw					1,225	*1,225*
27-SwAw					585	*585*
Grand Total	*1,785,561*	*12,068*	*98,422*	*47,017*	*1,810*	*1,944,877*

The yield curve summary is based on the final classified net landbase that was submitted to GoA in May 2015 (A-I-P December 2016). This NLB did not take into account the effect of the Horse River Fire on the FMA area. The GoA final fire boundary, including unburned islands is not currently available to the forest companies. Accordingly, the HRF can only be incorporated into a future analysis.

The current net landbase was adjusted to account for the known changes as follows:

[2] Net landbase version 8

1. Yield groups 22-25 were re-assigned to natural strata as per the A-I-P.
2. All AwU strata in FMU S14 were re-assigned to Aw due to a landbase scripting issue (there was no AVI understorey information captured in S14).
3. An area of 31,221 ha in FMUs A14 and L3 in the 06-SbFM was retained in the net landbase as per the wishes of Northland Forest Products Ltd.
4. All RSA yield group labels were renamed to the GoA standard regenerating strata labels.

1.3 Strata Transitions

As per the GoA letter, all operators should follow the 'back-to-natural' transition post-harvest including existing openings harvested post-2013. The one exception is the understorey protection yield strata. The strata transitions are shown in Table 2.

Table 2. Regeneration Transitions in the Al-Pac FMA

Population	Stand Type	Current Yield Group	Regenerate To
Natural Stands	NAT	01-Aw	01-Aw
	NAT	02-AwU*	
		<600s/ha Sw -100%	01-Aw
		≥600s/ha Sw - 70%	01-Aw
		≥600s/ha Sw - 15%	26-AwSw_UP
		≥600s/ha Sw - 15%	27-SwAw_UP
	NAT	03-AwSx	03-AwSx
	NAT	04-SxAw	04-SxAw
	NAT	05-Sw	05-Sw
	NAT	06-SbFM**	06-SbFM
	NAT	07-SbG	07-SbG
	NAT	08-PjMx	08-PjMx
	NAT	09-Pj	09-Pj
RSA Post-Perf	RSA	10-Hw	01-Aw
	RSA	11-HwSx	03-AwSx
	RSA	12-SwHw	04-SxAw
	RSA	13-Sw	05-Sw
	RSA	14-SbHw	07-SbG
	RSA	15-Sb	07-SbG
	RSA	16-HwPl	08-PjMx
	RSA	17-PlHw	08-PjMx
	RSA	18-Pl	09-Pj

Population	Stand Type	Current Yield Group	Regenerate To
Alpac Non-RSA	ARIS-EXT	01-Aw	01-Aw
	ARIS-EXT	03-AwSx	03-AwSx
	ARIS-EXT	04-SxAw	04-SxAw
	ARIS-EXT	05-Sw	05-Sw
	ARIS-EXT	07-SbG	07-SbG
	ARIS-EXT	08-PjMx	08-PjMx
	ARIS-EXT	09-Pj	09-Pj
Quota Holders Non-RSA	ARIS-INT	01-Aw	01-Aw
	ARIS-INT	19-AwSx	03-AwSx
	ARIS-INT	20-SxAw	04-SxAw
	ARIS-INT	21-Sw	05-Sw
	ARIS-INT	07-SbG	07-SbG
	ARIS-INT	08-PjMx	08-PjMx
	ARIS-INT	09-Pj	09-Pj
UP	ARIS-UP	26-AwSw_UP	03-AwSx
	ARIS-UP	27-SwAw_UP	04-SxAw

** post-harvest polygon selection is random within Patchworks to achieve % targets.*

*** Northland Forest Products Ltd. - area in L3 and A14 in the managed landbase.*

Detailed information on silviculture prescriptions, treatment and transition will be included in the Silviculture Matrix in the final FMP document.

1.4 Forest Succession Modelling in Yield Curves

The methodology for succession modelling in the Timber Supply Analysis (TSA) is detailed in the FMP TSA annex. The approach used in the TSA is to assume that older stands do not go through a full breakup and renewal to a healthy juvenile stand, but in the absence of disturbance persist as old forest stands indefinitely. The rationale for this choice is that the assumptions of breakup and renewal to even-aged stand conditions are poorly supported by available data in the western boreal forest, and anecdotal evidence and current literature review suggests that persistence of old forest conditions is more likely.

This approach will be implemented for the Al-Pac FMA area TSA by eliminating the breakup and renewal rules (as used in the approved 2006 Al-Pac FMA area TSA), and altering the later portions of the yield curves. Understanding of volume development in these older stands is poorly studied, but the Al-Pac FMA area TSA will assume that some merchantable timber remains and the volume curves will flat line to 50% of the of the maximum volume (Adjust 50).

Sensitivity analysis in two FMUs showed that there is no significant impact on AAC as compared to the original set of curves. Using the curves and succession assumptions (flat-line) in the Adjust 50 scenario allows the model to recognize that older stands on the undisturbed portion of the forest retain old forest characteristics as they age throughout the TSA timeline[3]. This will allow forest planners to explore strategies for managing the retention and distribution of old forest values throughout the FMA area. The final successional yield curves used in the TSA are presented in this update.

1.5 MAI Targets

As per the current Regeneration Standard of Alberta, the development of MAI standards is a mandatory component of the forest management planning process. MAI targets were selected as follows:

- All existing stands in the net landbase are transitioning back to natural as per the A-I-P letter. The only exception is understorey protection on 30% of the 02-AwU stratum where there is at least 600 stems/ha immature white spruce present (Table 2). 01-Aw is managed for deciduous yield, and therefore deciduous culmination was used to select MAI targets.
- All coniferous and mixedwood strata are managed primarily for coniferous yield, and therefore for coniferous culmination was used to select MAI targets.
- Understorey protection stands are managed for coniferous volume, however, because coniferous volume is present at year of harvest, coniferous volume culminates at year 10 and declines thereafter. As such, the minimum harvest age used for timber supply (100 years) was used for setting MAI targets for both UP strata.
- MAI targets are the same in all 12 FMUs (
- Table 3).

[3] Wildfire is not modeled within the TSA, thus harvesting is the only disturbance allowed within this environment.

Table 3. Culmination MAI Targets for the Al-Pac FMA

Yield Group	GoA Base 10	Yield Type	Culm. Age	Culmination MAI (m^3/ha/yr)	
				Conifer	Deciduous
01-Aw	Hw	DEC	80	0.24	2.86
03-AwSx	HwSx	CON	120	1.33	1.19
04-SxAw	SwHw	CON	120	1.55	0.83
	SbHw	CON	120	1.55	0.83
05-Sw	Sw	CON	120	1.72	0.58
06-SbFM	Sb	CON	140	0.43	0.01
07-SbG	Sb	CON	140	0.78	0.03
08-PjMx	PlHw	CON	90	1.50	0.85
	HwPl	CON	90	1.50	0.85
09-Pj	Pl	CON	90	1.48	0.14
26-AwSw_UP	HwSx	CON	100	1.25	1.45
27-SwAw_UP	SwHw	CON	100	1.76	0.96

1.6 FMP Submission Yield Curves

The following sections contain the yield curves as applied in the timber supply analysis and the Preferred Forest Management Scenario.

1.6.1 Natural Stands (Stand Type: NAT)

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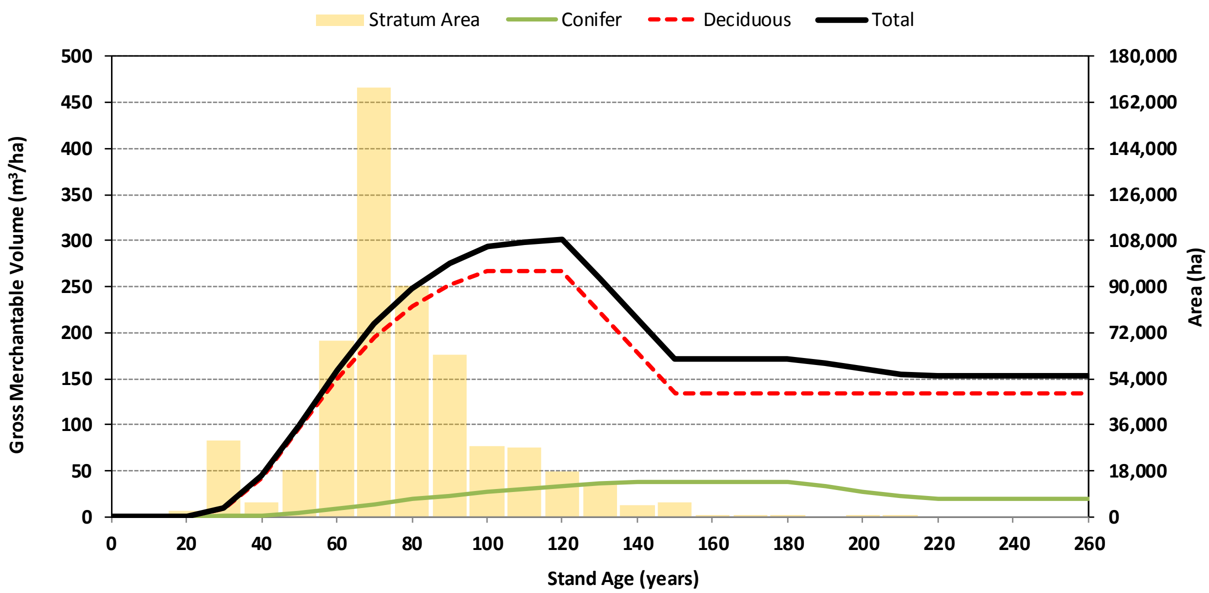
2015-2025 FOREST MANAGEMENT PLAN
YIELD CURVES

NATURAL STANDS

STRATUM: 01-Aw - TYPE: Deciduous

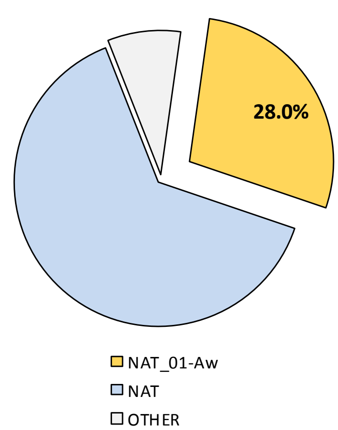


Stand Age	Gross Merchantable Volume (m³/ha)			Mean Annual Increment (m³/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.1	0.4	0.4	0.00	0.02	0.02
30	0.5	8.8	9.3	0.02	0.29	0.31
40	1.9	42.4	44.3	0.05	1.06	1.11
50	4.8	95.7	100.5	0.10	1.91	2.01
60	9.2	150.1	159.3	0.15	2.50	2.65
70	14.1	195.0	209.1	0.20	2.79	2.99
80	18.8	228.5	247.3	0.24	2.86	3.09
90	23.3	251.8	275.1	0.26	2.80	3.06
100	27.3	266.9	294.3	0.27	2.67	2.94
110	30.8	266.9	297.8	0.28	2.43	2.71
120	33.8	266.9	300.8	0.28	2.22	2.51
130	36.4	222.5	258.8	0.28	1.71	1.99
140	38.5	178.0	216.5	0.28	1.27	1.55
150	38.5	133.5	172.0	0.26	0.89	1.15
160	38.5	133.5	172.0	0.24	0.83	1.08
170	38.5	133.5	172.0	0.23	0.79	1.01
180	38.5	133.5	172.0	0.21	0.74	0.96
190	33.0	133.5	166.5	0.17	0.70	0.88
200	27.5	133.5	161.0	0.14	0.67	0.80
210	22.0	133.5	155.5	0.10	0.64	0.74
220	19.3	133.5	152.7	0.09	0.61	0.69
230	19.3	133.5	152.7	0.08	0.58	0.66
240	19.3	133.5	152.7	0.08	0.56	0.64
250	19.3	133.5	152.7	0.08	0.53	0.61
260	19.3	133.5	152.7	0.07	0.51	0.59

Area Distribution

Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	NAT	1,785,561	91.8%
Stratum	**NAT_01-Aw**	**544,112**	**28.0%**

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber m3	Standing Timber m3/ha
Conifer	15/10/30/366/TL	9,398,535	17
Deciduous	15/10/30/366/TL	105,997,896	195
Total		115,396,643	212

Note: *Peak MAIs are based on main species group and highlighted in yellow.*
Standing timber volumes are approximate.

ALBERTA-PACIFIC FOREST INDUSTRIES INC.
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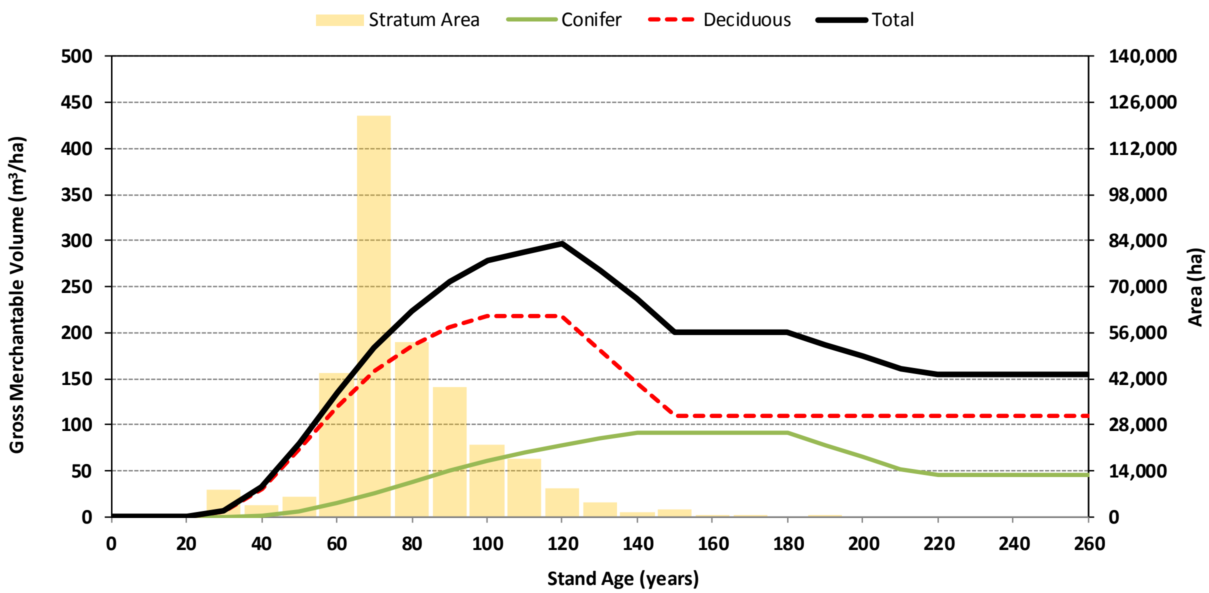
YIELD CURVES

NATURAL STANDS

STRATUM: 02-AwU - TYPE: Deciduous

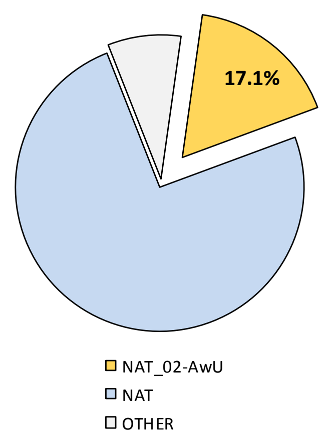


Stand Age	Gross Merchantable Volume (m³/ha)			Mean Annual Increment (m³/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.0	0.3	0.3	0.00	0.01	0.01
30	0.3	6.3	6.6	0.01	0.21	0.22
40	2.0	30.8	32.8	0.05	0.77	0.82
50	6.5	73.4	80.0	0.13	1.47	1.60
60	14.9	119.3	134.2	0.25	1.99	2.24
70	25.9	157.8	183.7	0.37	2.25	2.62
80	37.9	186.3	224.2	**0.47**	**2.33**	**2.80**
90	49.6	205.8	255.4	0.55	2.29	2.84
100	60.4	218.3	278.7	0.60	2.18	2.79
110	70.0	218.3	288.3	0.64	1.98	2.62
120	78.2	218.3	296.5	0.65	1.82	2.47
130	85.3	181.9	267.2	0.66	1.40	2.06
140	91.4	145.5	236.9	0.65	1.04	1.69
150	91.4	109.2	200.6	0.61	0.73	1.34
160	91.4	109.2	200.6	0.57	0.68	1.25
170	91.4	109.2	200.6	0.54	0.64	1.18
180	91.4	109.2	200.6	0.51	0.61	1.11
190	78.3	109.2	187.5	0.41	0.57	0.99
200	65.3	109.2	174.4	0.33	0.55	0.87
210	52.2	109.2	161.4	0.25	0.52	0.77
220	45.7	109.2	154.9	0.21	0.50	0.70
230	45.7	109.2	154.9	0.20	0.47	0.67
240	45.7	109.2	154.9	0.19	0.45	0.65
250	45.7	109.2	154.9	0.18	0.44	0.62
260	45.7	109.2	154.9	0.18	0.42	0.60

Area Distribution

Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	NAT	1,785,561	91.8%
Stratum	NAT_02-AwU	333,335	17.1%

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber m3	Standing Timber m3/ha
Conifer	15/10/30/366/TL	11,781,068	35
Deciduous	15/10/30/366/TL	54,890,883	165
Total		66,672,151	200

Note: Peak MAIs are based on main species group and highlighted in yellow.
Standing timber volumes are approximate.

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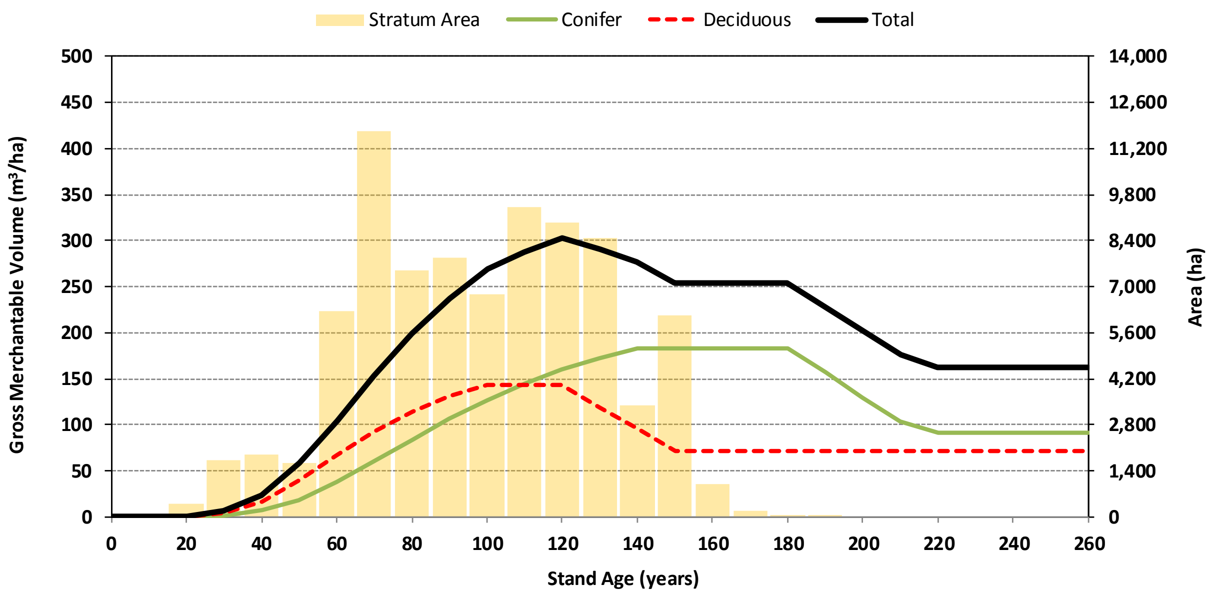
YIELD CURVES

NATURAL STANDS

STRATUM: 03-AwSx - TYPE: Coniferous

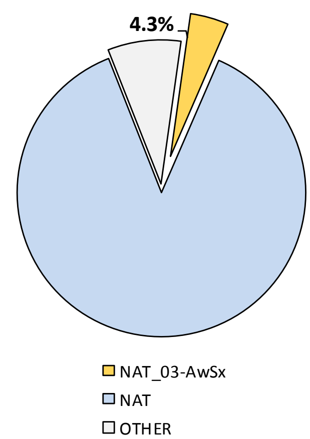


Stand Age	Gross Merchantable Volume (m³/ha)			Mean Annual Increment (m³/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.2	0.4	0.5	0.01	0.02	0.03
30	1.6	4.5	6.1	0.05	0.15	0.20
40	6.7	17.0	23.8	0.17	0.43	0.59
50	18.7	39.4	58.1	0.37	0.79	1.16
60	37.8	66.7	104.5	0.63	1.11	1.74
70	60.6	92.9	153.5	0.87	1.33	2.19
80	84.1	114.3	198.4	1.05	1.43	2.48
90	106.5	130.4	236.9	1.18	1.45	2.63
100	127.0	143.0	269.9	1.27	1.43	2.70
110	144.7	143.0	287.7	1.32	1.30	2.62
120	159.5	143.0	302.5	**1.33**	**1.19**	**2.52**
130	171.8	119.1	291.0	1.32	0.92	2.24
140	182.4	95.3	277.7	1.30	0.68	1.98
150	182.4	71.5	253.8	1.22	0.48	1.69
160	182.4	71.5	253.8	1.14	0.45	1.59
170	182.4	71.5	253.8	1.07	0.42	1.49
180	182.4	71.5	253.8	1.01	0.40	1.41
190	156.3	71.5	227.8	0.82	0.38	1.20
200	130.3	71.5	201.7	0.65	0.36	1.01
210	104.2	71.5	175.7	0.50	0.34	0.84
220	91.2	71.5	162.7	0.41	0.32	0.74
230	91.2	71.5	162.7	0.40	0.31	0.71
240	91.2	71.5	162.7	0.38	0.30	0.68
250	91.2	71.5	162.7	0.36	0.29	0.65
260	91.2	71.5	162.7	0.35	0.27	0.63

Area Distribution

Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	NAT	1,785,561	91.8%
Stratum	**NAT_03-AwSx**	**83,398**	**4.3%**

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber m3	Standing Timber m3/ha
Conifer	15/10/30/366/TL	9,530,783	114
Deciduous	15/10/30/366/TL	8,952,651	107
Total		18,483,656	222

Note: Peak MAIs are based on main species group and highlighted in yellow.
Standing timber volumes are approximate.

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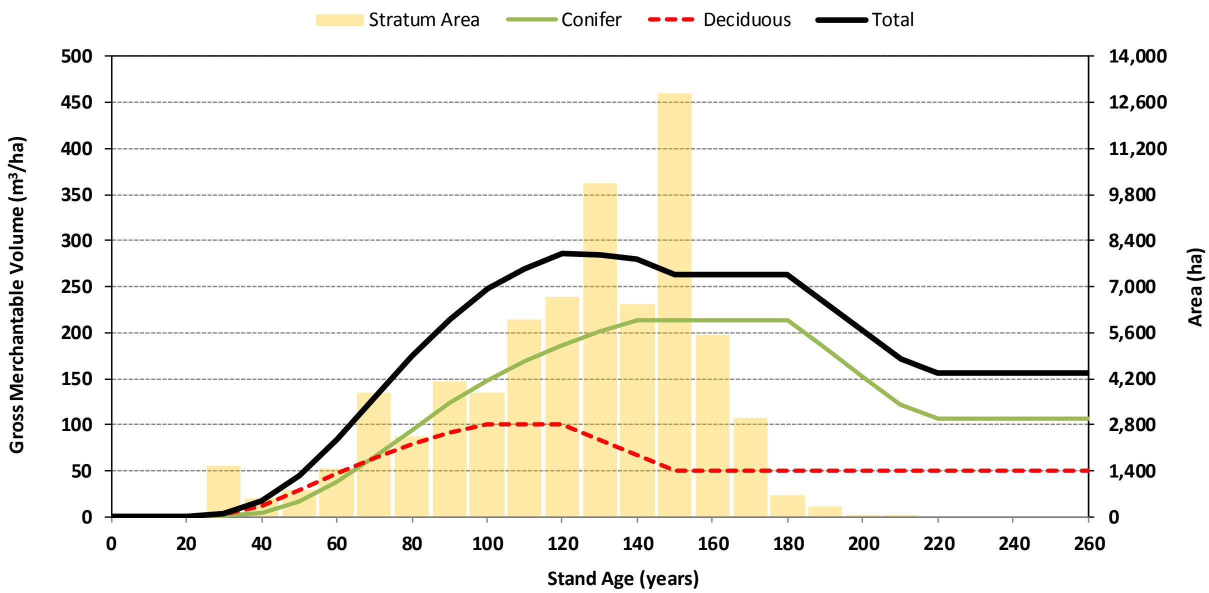
2015-2025 FOREST MANAGEMENT PLAN
YIELD CURVES

NATURAL STANDS

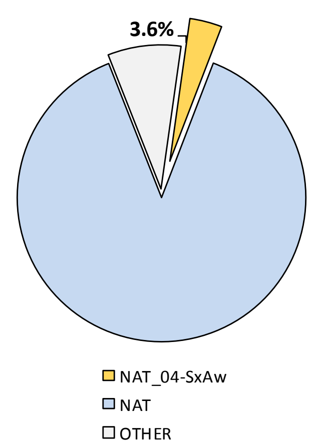
STRATUM: 04-SxAw - TYPE: Coniferous



Stand Age	Gross Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.1	0.2	0.2	0.00	0.01	0.01
30	1.0	2.9	3.9	0.03	0.10	0.13
40	5.1	12.3	17.4	0.13	0.31	0.43
50	16.7	28.1	44.7	0.33	0.56	0.89
60	37.7	46.3	84.0	0.63	0.77	1.40
70	65.4	64.0	129.4	0.93	0.91	1.85
80	95.0	79.2	174.2	1.19	0.99	2.18
90	123.2	91.2	214.4	1.37	1.01	2.38
100	148.1	100.0	248.1	1.48	1.00	2.48
110	169.0	100.0	269.1	1.54	0.91	2.45
120	186.5	100.0	286.5	**1.55**	**0.83**	**2.39**
130	201.1	83.4	284.4	1.55	0.64	2.19
140	213.4	66.7	280.1	1.52	0.48	2.00
150	213.4	50.0	263.4	1.42	0.33	1.76
160	213.4	50.0	263.4	1.33	0.31	1.65
170	213.4	50.0	263.4	1.26	0.29	1.55
180	213.4	50.0	263.4	1.19	0.28	1.46
190	182.9	50.0	232.9	0.96	0.26	1.23
200	152.4	50.0	202.4	0.76	0.25	1.01
210	121.9	50.0	171.9	0.58	0.24	0.82
220	106.7	50.0	156.7	0.48	0.23	0.71
230	106.7	50.0	156.7	0.46	0.22	0.68
240	106.7	50.0	156.7	0.44	0.21	0.65
250	106.7	50.0	156.7	0.43	0.20	0.63
260	106.7	50.0	156.7	0.41	0.19	0.60

Area Distribution			
Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	NAT	1,785,561	91.8%
Stratum	NAT_04-SxAw	70,462	3.6%

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber	
		m3	m3/ha
Conifer	15/10/30/366/TL	12,067,707	171
Deciduous	15/10/30/366/TL	4,957,005	70
Total		17,024,954	242

Note: Peak MAIs are based on main species group and highlighted in yellow.
Standing timber volumes are approximate.

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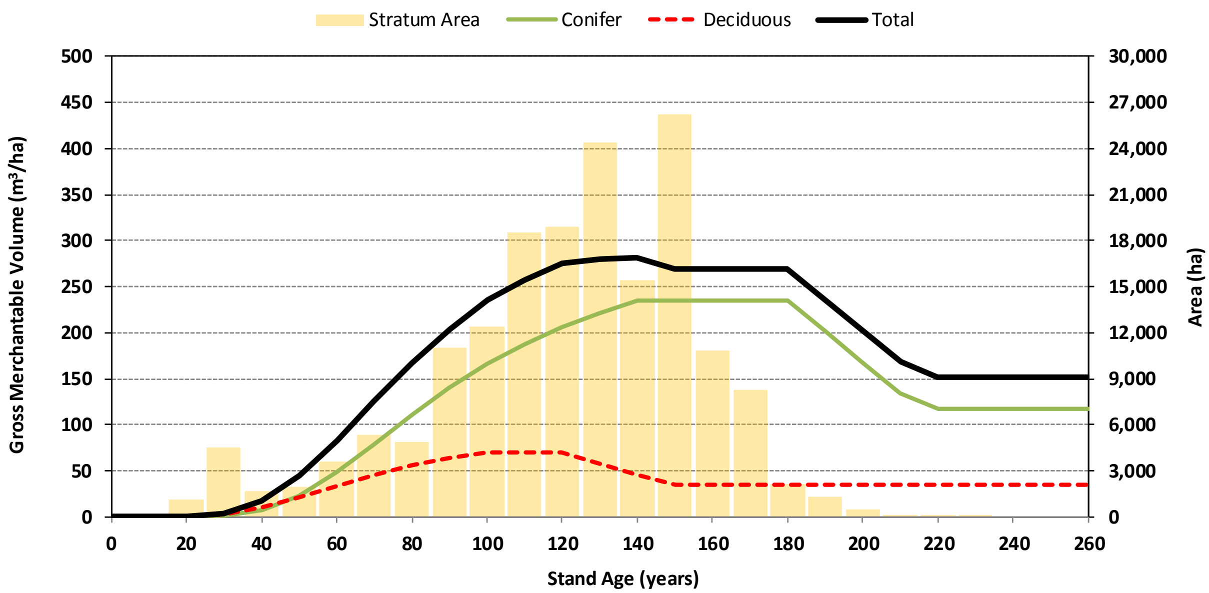
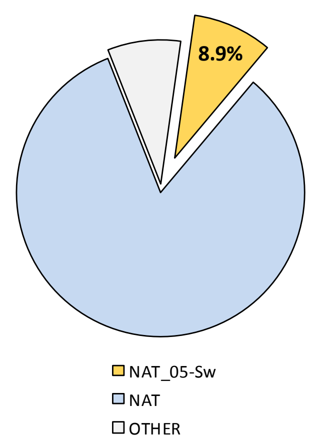
STRATUM: 05-Sw - TYPE: Coniferous



Stand Age	Gross Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.0	0.2	0.2	0.00	0.01	0.01
30	0.9	2.7	3.7	0.03	0.09	0.12
40	7.1	10.4	17.4	0.18	0.26	0.44
50	23.2	21.0	44.3	0.46	0.42	0.89
60	49.0	33.4	82.4	0.82	0.56	1.37
70	79.6	45.7	125.2	1.14	0.65	1.79
80	110.8	56.2	167.0	1.39	0.70	2.09
90	140.0	64.1	204.1	1.56	0.71	2.27
100	165.7	69.3	235.0	1.66	0.69	2.35
110	187.6	69.3	256.9	1.71	0.63	2.34
120	206.1	69.3	275.4	**1.72**	**0.58**	**2.29**
130	221.8	57.8	279.5	1.71	0.44	2.15
140	235.3	46.2	281.5	1.68	0.33	2.01
150	235.3	34.7	270.0	1.57	0.23	1.80
160	235.3	34.7	270.0	1.47	0.22	1.69
170	235.3	34.7	270.0	1.38	0.20	1.59
180	235.3	34.7	270.0	1.31	0.19	1.50
190	201.7	34.7	236.3	1.06	0.18	1.24
200	168.1	34.7	202.7	0.84	0.17	1.01
210	134.5	34.7	169.1	0.64	0.17	0.81
220	117.7	34.7	152.3	0.53	0.16	0.69
230	117.7	34.7	152.3	0.51	0.15	0.66
240	117.7	34.7	152.3	0.49	0.14	0.63
250	117.7	34.7	152.3	0.47	0.14	0.61
260	117.7	34.7	152.3	0.45	0.13	0.59

Area Distribution			
Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	NAT	1,785,561	91.8%
Stratum	**NAT_05-Sw**	**173,108**	**8.9%**

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber	
		m3	m3/ha
Conifer	15/10/30/366/TL	32,748,180	189
Deciduous	15/10/30/366/TL	8,702,556	50
Total		41,450,975	239

Note: Peak MAIs are based on main species group and highlighted in yellow.
Standing timber volumes are approximate.

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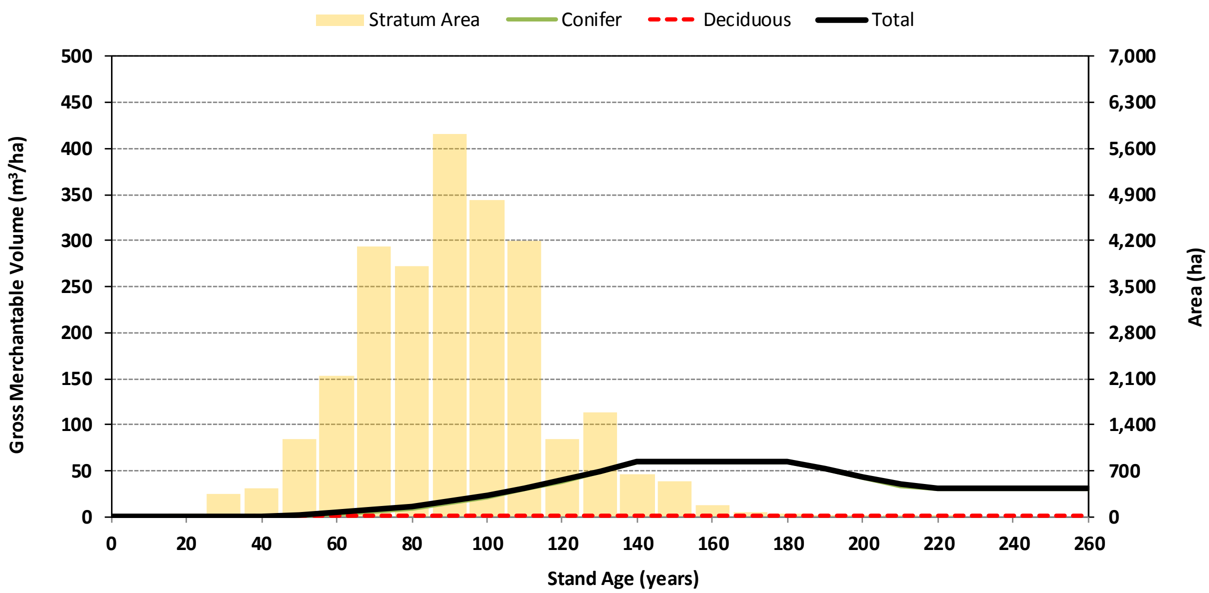
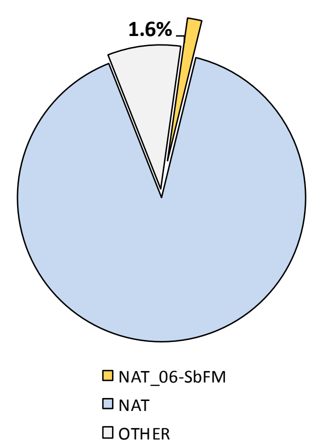
STRATUM: 06-SbFM - TYPE: Coniferous



Stand Age	Gross Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.0	0.1	0.1	0.00	0.00	0.00
30	0.1	0.3	0.4	0.00	0.01	0.01
40	0.4	0.8	1.2	0.01	0.02	0.03
50	1.1	1.4	2.5	0.02	0.03	0.05
60	2.6	1.8	4.4	0.04	0.03	0.07
70	5.4	2.0	7.4	0.08	0.03	0.11
80	9.5	2.0	11.5	0.12	0.03	0.14
90	14.9	1.9	16.8	0.17	0.02	0.19
100	21.6	1.6	23.2	0.22	0.02	0.23
110	29.8	1.6	31.5	0.27	0.01	0.29
120	38.6	1.6	40.2	0.32	0.01	0.33
130	48.7	1.4	50.0	0.37	0.01	0.38
140	59.7	1.1	60.7	0.43	0.01	0.43
150	59.7	1.0	60.7	0.40	0.01	0.40
160	59.7	1.0	60.7	0.37	0.01	0.38
170	59.7	1.0	60.7	0.35	0.01	0.36
180	59.7	1.0	60.7	0.33	0.01	0.34
190	51.1	1.0	52.2	0.27	0.01	0.27
200	42.6	1.0	43.6	0.21	0.01	0.22
210	34.1	1.0	35.1	0.16	0.00	0.17
220	29.8	1.0	30.8	0.14	0.00	0.14
230	29.8	1.0	30.8	0.13	0.00	0.13
240	29.8	1.0	30.8	0.12	0.00	0.13
250	29.8	1.0	30.8	0.12	0.00	0.12
260	29.8	1.0	30.8	0.11	0.00	0.12

Area Distribution			
Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	NAT	1,785,561	91.8%
Stratum	NAT_06-SbFM	31,221	1.6%

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber	
		m3	m3/ha
Conifer	15/10/30/366/TL	594,272	19
Deciduous	15/10/30/366/TL	53,288	2
Total		647,580	21

Note: *Peak MAIs are based on main species group and highlighted in yellow.*
Standing timber volumes are approximate.

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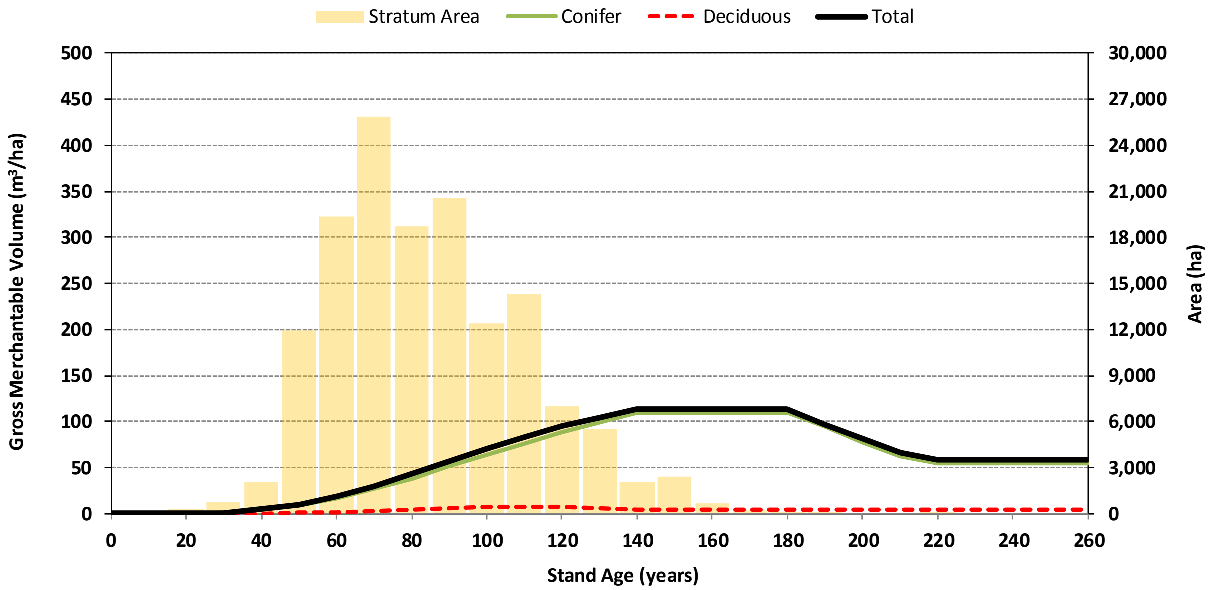
STRATUM: 07-SbG - TYPE: Coniferous

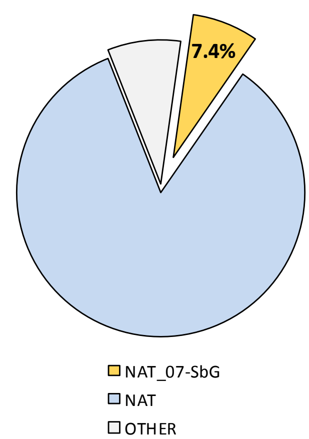


Stand Age	Gross Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.1	0.0	0.1	0.00	0.00	0.00
30	1.2	0.0	1.3	0.04	0.00	0.04
40	4.2	0.2	4.4	0.11	0.01	0.11
50	9.3	0.8	10.0	0.19	0.02	0.20
60	16.8	1.8	18.6	0.28	0.03	0.31
70	26.8	3.2	30.0	0.38	0.05	0.43
80	38.5	4.7	43.2	0.48	0.06	0.54
90	51.0	6.1	57.1	0.57	0.07	0.63
100	63.7	7.2	70.9	0.64	0.07	0.71
110	76.0	7.2	83.2	0.69	0.07	0.76
120	87.7	7.2	94.9	0.73	0.06	0.79
130	98.8	6.0	104.8	0.76	0.05	0.81
140	109.3	4.8	114.1	**0.78**	**0.03**	**0.81**
150	109.3	3.6	112.9	0.73	0.02	0.75
160	109.3	3.6	112.9	0.68	0.02	0.71
170	109.3	3.6	112.9	0.64	0.02	0.66
180	109.3	3.6	112.9	0.61	0.02	0.63
190	93.7	3.6	97.3	0.49	0.02	0.51
200	78.1	3.6	81.7	0.39	0.02	0.41
210	62.5	3.6	66.1	0.30	0.02	0.31
220	54.6	3.6	58.2	0.25	0.02	0.26
230	54.6	3.6	58.2	0.24	0.02	0.25
240	54.6	3.6	58.2	0.23	0.01	0.24
250	54.6	3.6	58.2	0.22	0.01	0.23
260	54.6	3.6	58.2	0.21	0.01	0.22

Area Distribution

Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	NAT	1,785,561	91.8%
Stratum	NAT_07-SbG	144,253	7.4%

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber m3	Standing Timber m3/ha
Conifer	15/10/30/366/TL	6,536,121	45
Deciduous	15/10/30/366/TL	639,725	4
Total		7,175,896	50

Note: *Peak MAIs are based on main species group and highlighted in yellow.*
Standing timber volumes are approximate.

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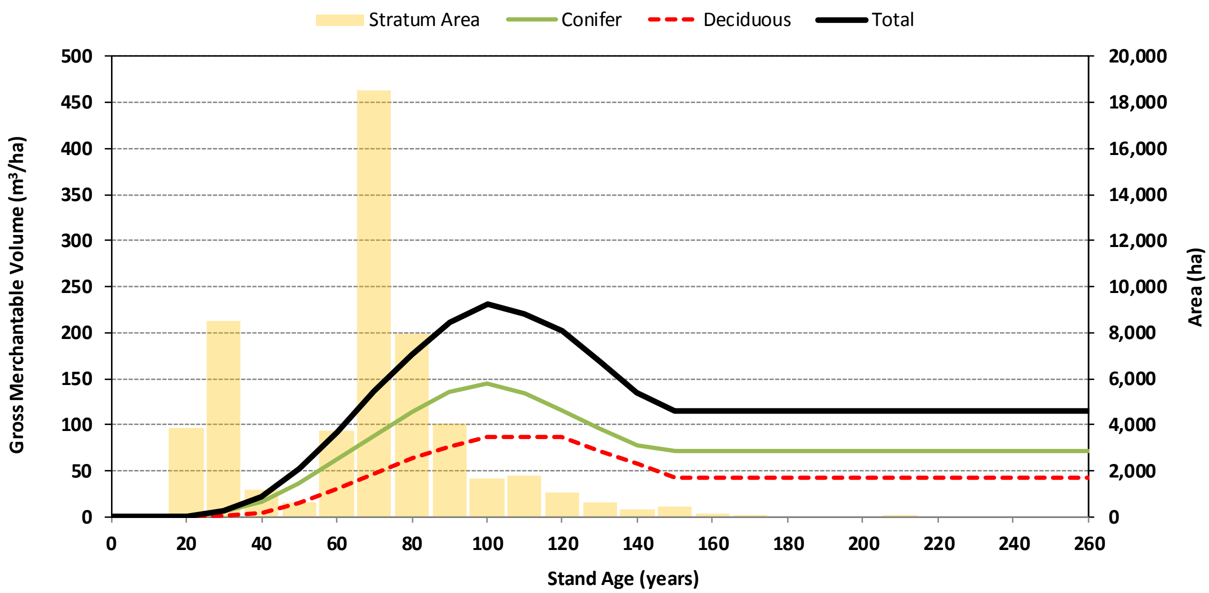
NATURAL STANDS

STRATUM: 08-PjMx - TYPE: Coniferous

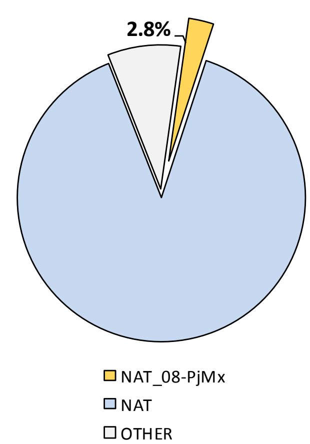


Stand Age	Gross Merchantable Volume (m³/ha)			Mean Annual Increment (m³/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.5	0.0	0.5	0.02	0.00	0.03
30	5.3	0.6	5.9	0.18	0.02	0.20
40	16.9	4.7	21.6	0.42	0.12	0.54
50	36.3	15.5	51.9	0.73	0.31	1.04
60	62.1	30.4	92.5	1.03	0.51	1.54
70	89.0	47.0	136.0	1.27	0.67	1.94
80	113.6	63.3	176.9	1.42	0.79	2.21
90	135.0	76.7	211.6	**1.50**	**0.85**	**2.35**
100	144.4	86.2	230.7	1.44	0.86	2.31
110	134.8	86.2	221.0	1.23	0.78	2.01
120	115.5	86.2	201.8	0.96	0.72	1.68
130	96.3	71.9	168.2	0.74	0.55	1.29
140	77.0	57.5	134.5	0.55	0.41	0.96
150	72.2	43.1	115.3	0.48	0.29	0.77
160	72.2	43.1	115.3	0.45	0.27	0.72
170	72.2	43.1	115.3	0.42	0.25	0.68
180	72.2	43.1	115.3	0.40	0.24	0.64
190	72.2	43.1	115.3	0.38	0.23	0.61
200	72.2	43.1	115.3	0.36	0.22	0.58
210	72.2	43.1	115.3	0.34	0.21	0.55
220	72.2	43.1	115.3	0.33	0.20	0.52
230	72.2	43.1	115.3	0.31	0.19	0.50
240	72.2	43.1	115.3	0.30	0.18	0.48
250	72.2	43.1	115.3	0.29	0.17	0.46
260	72.2	43.1	115.3	0.28	0.17	0.44

Area Distribution

Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	NAT	1,785,561	91.8%
Stratum	NAT_08-PjMx	54,616	2.8%

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber m3	Standing Timber m3/ha
Conifer	15/10/30/366/TL	4,155,823	76
Deciduous	15/10/30/366/TL	2,298,267	42
Total		6,454,208	118

Note: *Peak MAIs are based on main species group and highlighted in yellow.*
Standing timber volumes are approximate.

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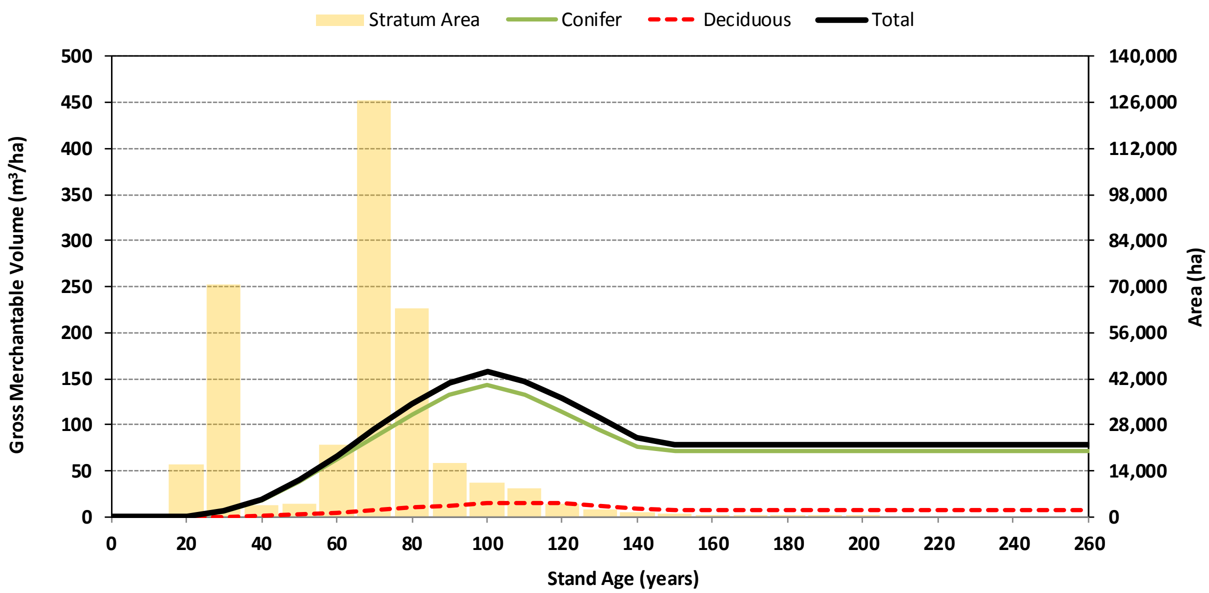
STRATUM: 09-Pj - TYPE: Coniferous

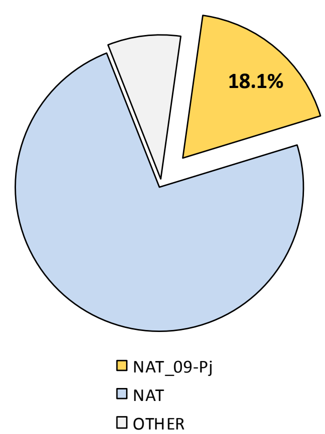


Stand Age	Gross Merchantable Volume (m³/ha)			Mean Annual Increment (m³/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.4	0.0	0.5	0.02	0.00	0.02
30	5.8	0.2	6.0	0.19	0.01	0.20
40	18.5	0.8	19.2	0.46	0.02	0.48
50	37.7	2.2	39.9	0.75	0.04	0.80
60	61.8	4.3	66.1	1.03	0.07	1.10
70	87.4	7.1	94.5	1.25	0.10	1.35
80	111.8	10.1	121.9	1.40	0.13	1.52
90	133.3	12.7	145.9	**1.48**	**0.14**	**1.62**
100	142.8	14.4	157.1	1.43	0.14	1.57
110	133.2	14.4	147.6	1.21	0.13	1.34
120	114.2	14.4	128.6	0.95	0.12	1.07
130	95.2	12.0	107.2	0.73	0.09	0.82
140	76.1	9.6	85.7	0.54	0.07	0.61
150	71.4	7.2	78.6	0.48	0.05	0.52
160	71.4	7.2	78.6	0.45	0.04	0.49
170	71.4	7.2	78.6	0.42	0.04	0.46
180	71.4	7.2	78.6	0.40	0.04	0.44
190	71.4	7.2	78.6	0.38	0.04	0.41
200	71.4	7.2	78.6	0.36	0.04	0.39
210	71.4	7.2	78.6	0.34	0.03	0.37
220	71.4	7.2	78.6	0.32	0.03	0.36
230	71.4	7.2	78.6	0.31	0.03	0.34
240	71.4	7.2	78.6	0.30	0.03	0.33
250	71.4	7.2	78.6	0.29	0.03	0.31
260	71.4	7.2	78.6	0.27	0.03	0.30

Area Distribution

Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	NAT	1,785,561	91.8%
Stratum	**NAT_09-Pj**	**351,057**	**18.1%**

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber m3	Standing Timber m3/ha
Conifer	15/10/30/366/TL	25,854,995	74
Deciduous	15/10/30/366/TL	2,254,742	6
Total		28,109,817	80

Note: *Peak MAIs are based on main species group and highlighted in yellow.*
Standing timber volumes are approximate.

1.6.2 Post-Performance Stands (Stand Type: RSA)

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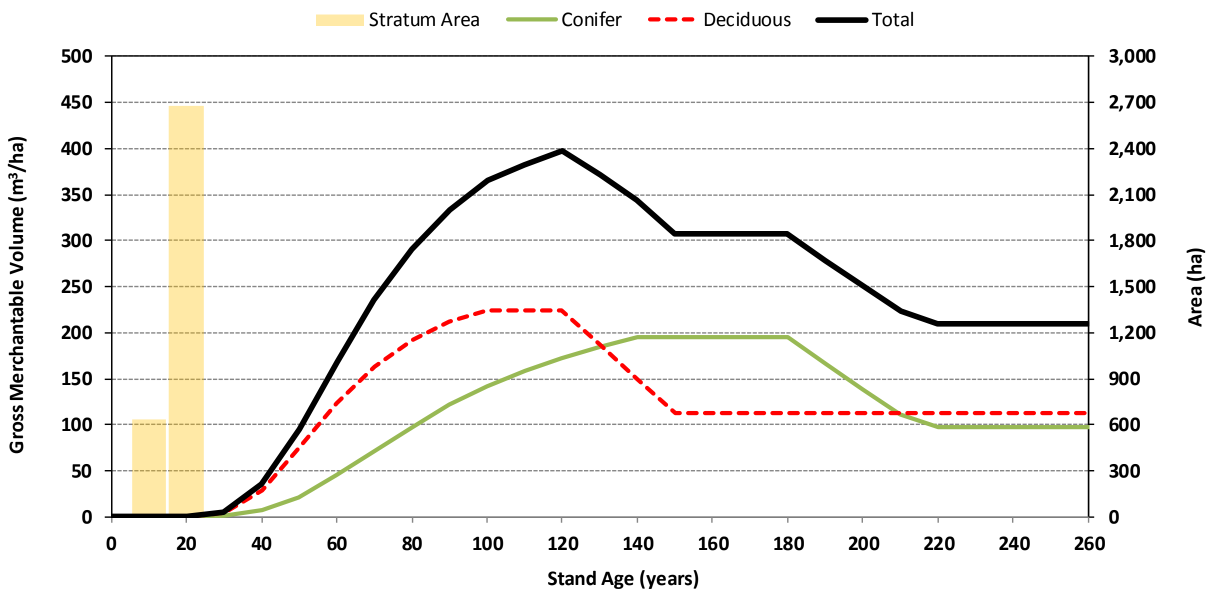
RSA

STRATUM: 10-Hw - TYPE: Deciduous

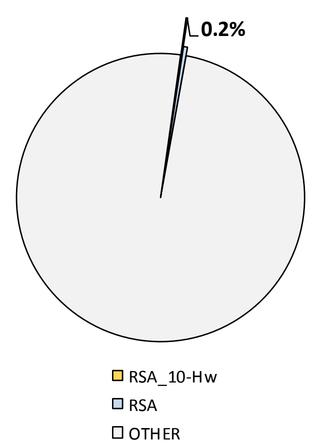


Stand Age	Gross Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.1	0.2	0.3	0.00	0.01	0.01
30	1.0	4.8	5.8	0.03	0.16	0.19
40	6.7	28.6	35.3	0.17	0.72	0.88
50	21.6	74.3	95.9	0.43	1.49	1.92
60	45.0	123.1	168.1	0.75	2.05	2.80
70	71.9	163.1	235.0	1.03	2.33	3.36
80	98.1	192.3	290.4	**1.23**	**2.40**	**3.63**
90	121.4	212.2	333.6	1.35	2.36	3.71
100	141.4	224.6	366.0	1.41	2.25	3.66
110	158.3	224.6	382.9	1.44	2.04	3.48
120	172.6	224.6	397.2	1.44	1.87	3.31
130	184.5	187.2	371.7	1.42	1.44	2.86
140	194.7	149.7	344.4	1.39	1.07	2.46
150	194.7	112.3	307.0	1.30	0.75	2.05
160	194.7	112.3	307.0	1.22	0.70	1.92
170	194.7	112.3	307.0	1.15	0.66	1.81
180	194.7	112.3	307.0	1.08	0.62	1.71
190	166.9	112.3	279.2	0.88	0.59	1.47
200	139.1	112.3	251.3	0.70	0.56	1.26
210	111.2	112.3	223.5	0.53	0.53	1.06
220	97.3	112.3	209.6	0.44	0.51	0.95
230	97.3	112.3	209.6	0.42	0.49	0.91
240	97.3	112.3	209.6	0.41	0.47	0.87
250	97.3	112.3	209.6	0.39	0.45	0.84
260	97.3	112.3	209.6	0.37	0.43	0.81

Area Distribution

Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	RSA	12,068	0.6%
Stratum	**RSA_10-Hw**	**3,315**	**0.2%**

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber m3	Standing Timber m3/ha
Conifer	15/10/30/366/TL	134	0
Deciduous	15/10/30/366/TL	536	0
Total		670	0

Note: *Peak MAIs are based on main species group and highlighted in yellow.*
Standing timber volumes are approximate.

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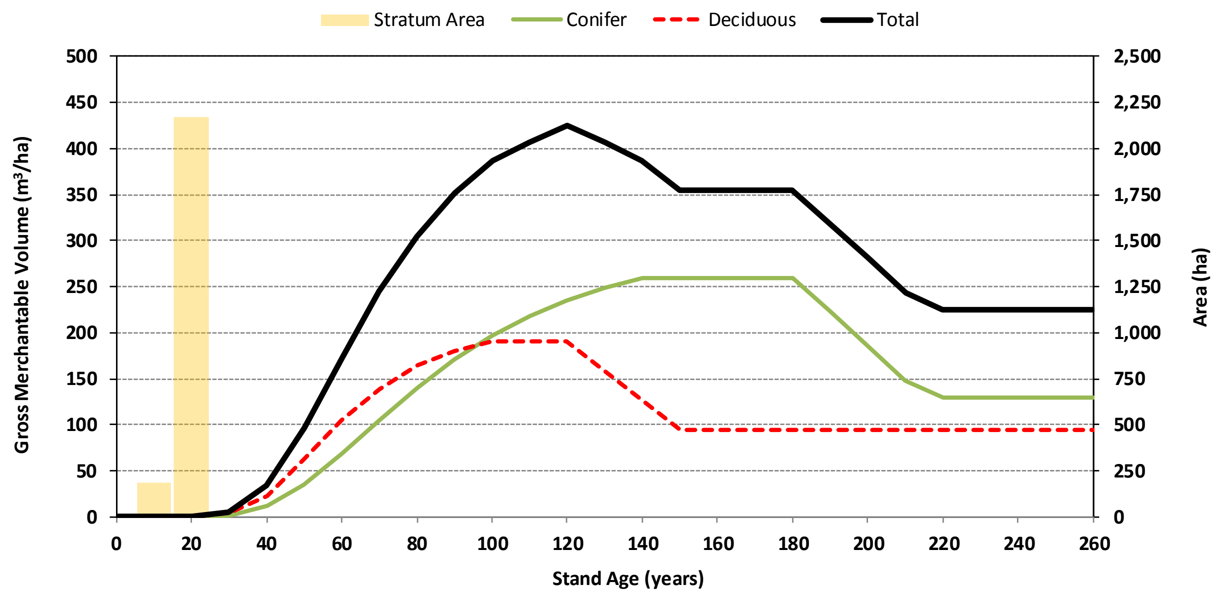
RSA

STRATUM: 11-HwSx - TYPE: Coniferous

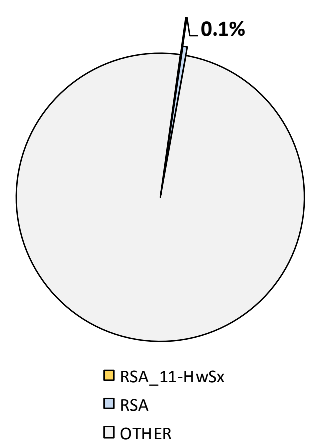


Stand Age	Gross Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.0	0.1	0.2	0.00	0.01	0.01
30	1.5	3.6	5.1	0.05	0.12	0.17
40	11.2	23.1	34.3	0.28	0.58	0.86
50	34.8	61.9	96.7	0.70	1.24	1.93
60	68.7	104.4	173.0	1.14	1.74	2.88
70	105.6	139.3	244.9	1.51	1.99	3.50
80	140.5	164.3	304.8	1.76	2.05	3.81
90	171.0	180.6	351.5	1.90	2.01	3.91
100	196.5	189.9	386.4	1.96	1.90	3.86
110	217.4	189.9	407.4	**1.98**	**1.73**	**3.70**
120	234.5	189.9	424.4	1.95	1.58	3.54
130	248.5	158.3	406.8	1.91	1.22	3.13
140	260.1	126.6	386.7	1.86	0.90	2.76
150	260.1	95.0	355.0	1.73	0.63	2.37
160	260.1	95.0	355.0	1.63	0.59	2.22
170	260.1	95.0	355.0	1.53	0.56	2.09
180	260.1	95.0	355.0	1.44	0.53	1.97
190	222.9	95.0	317.9	1.17	0.50	1.67
200	185.8	95.0	280.7	0.93	0.47	1.40
210	148.6	95.0	243.6	0.71	0.45	1.16
220	130.0	95.0	225.0	0.59	0.43	1.02
230	130.0	95.0	225.0	0.57	0.41	0.98
240	130.0	95.0	225.0	0.54	0.40	0.94
250	130.0	95.0	225.0	0.52	0.38	0.90
260	130.0	95.0	225.0	0.50	0.37	0.87

Area Distribution

Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	RSA	12,068	0.6%
Stratum	**RSA_11-HwSx**	**2,360**	**0.1%**

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber m3	Standing Timber m3/ha
Conifer	15/10/30/366/TL	87	0
Deciduous	15/10/30/366/TL	261	0
Total		348	0

Note: *Peak MAIs are based on main species group and highlighted in yellow.*
Standing timber volumes are approximate.

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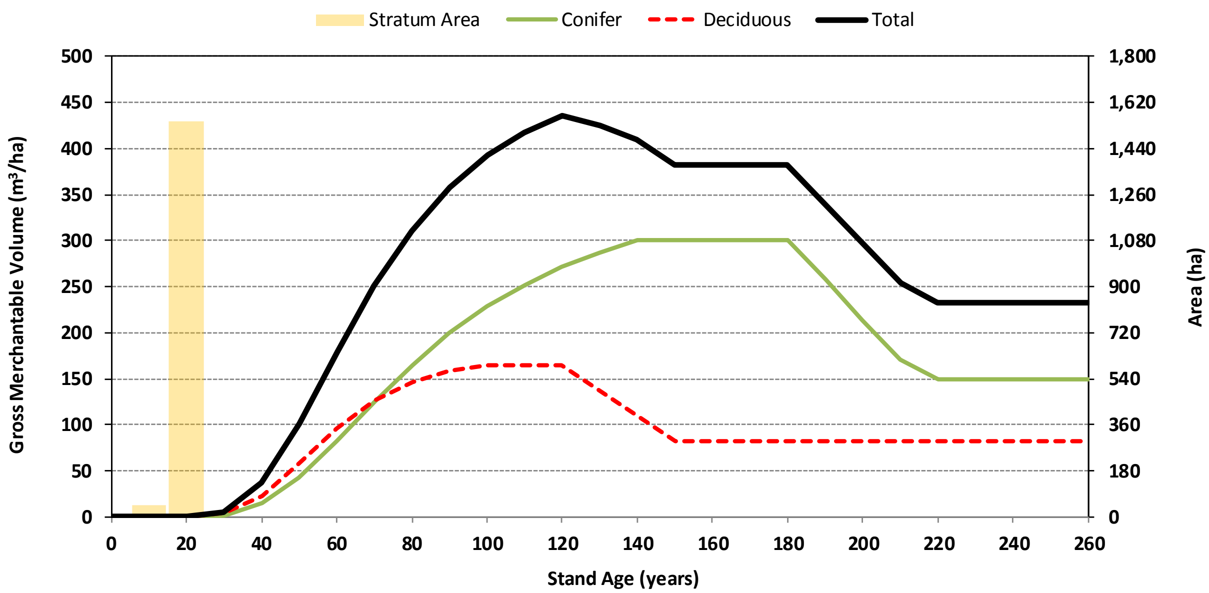
RSA

STRATUM: 12-SwHw - TYPE: Coniferous

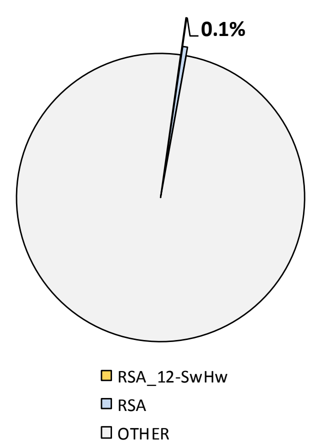


Stand Age	Gross Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.1	0.1	0.2	0.00	0.01	0.01
30	2.0	3.6	5.6	0.07	0.12	0.19
40	14.3	22.3	36.6	0.36	0.56	0.92
50	42.7	58.5	101.2	0.85	1.17	2.02
60	82.2	96.5	178.7	1.37	1.61	2.98
70	124.8	126.2	251.0	1.78	1.80	3.59
80	164.7	146.4	311.1	2.06	1.83	3.89
90	199.3	158.9	358.2	2.21	1.77	3.98
100	228.2	165.3	393.4	2.28	1.65	3.93
110	251.8	165.3	417.1	**2.29**	**1.50**	**3.79**
120	271.1	165.3	436.3	2.26	1.38	3.64
130	286.9	137.7	424.6	2.21	1.06	3.27
140	299.9	110.2	410.1	2.14	0.79	2.93
150	299.9	82.6	382.5	2.00	0.55	2.55
160	299.9	82.6	382.5	1.87	0.52	2.39
170	299.9	82.6	382.5	1.76	0.49	2.25
180	299.9	82.6	382.5	1.67	0.46	2.13
190	257.1	82.6	339.7	1.35	0.43	1.79
200	214.2	82.6	296.8	1.07	0.41	1.48
210	171.4	82.6	254.0	0.82	0.39	1.21
220	150.0	82.6	232.6	0.68	0.38	1.06
230	150.0	82.6	232.6	0.65	0.36	1.01
240	150.0	82.6	232.6	0.62	0.34	0.97
250	150.0	82.6	232.6	0.60	0.33	0.93
260	150.0	82.6	232.6	0.58	0.32	0.89

Area Distribution

Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	RSA	12,068	0.6%
Stratum	**RSA_12-SwHw**	**1,593**	**0.1%**

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber m3	Standing Timber m3/ha
Conifer	15/10/30/366/TL	77	0
Deciduous	15/10/30/366/TL	201	0
Total		278	0

Note: *Peak MAIs are based on main species group and highlighted in yellow.*
Standing timber volumes are approximate.

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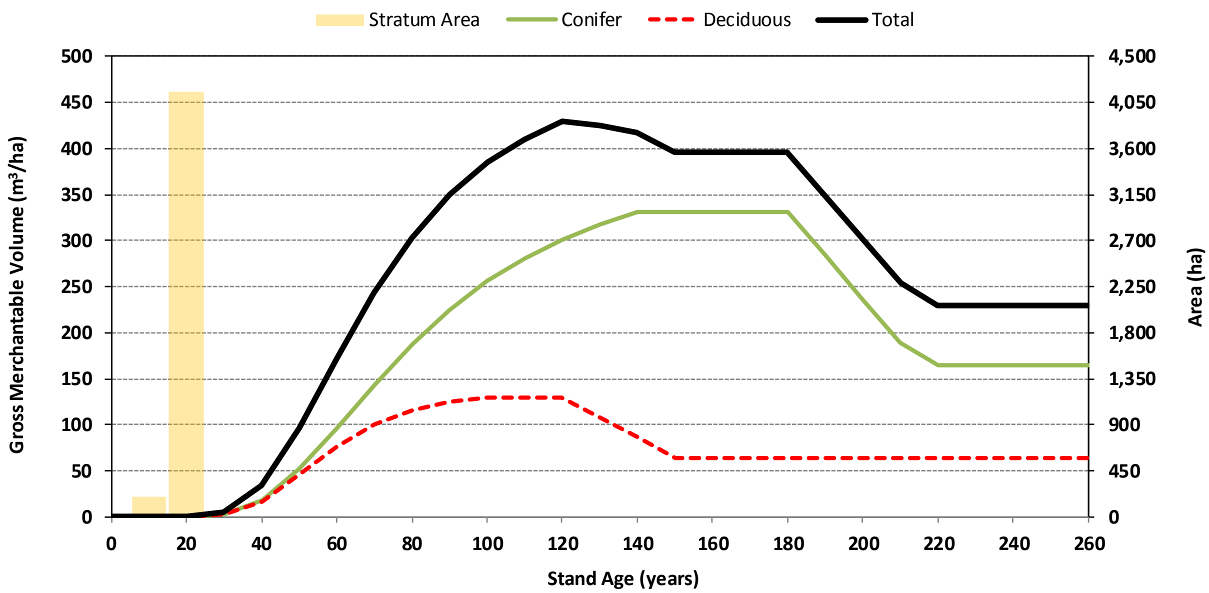
RSA

STRATUM: 13-Sw - TYPE: Coniferous

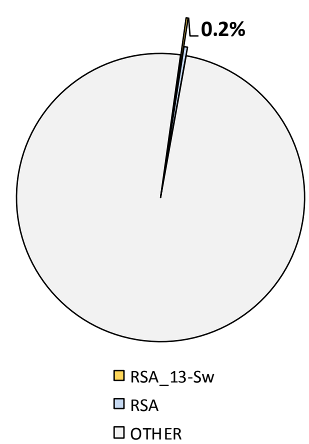


Stand Age	Gross Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.1	0.1	0.2	0.01	0.01	0.01
30	2.6	2.8	5.4	0.09	0.09	0.18
40	17.6	17.1	34.7	0.44	0.43	0.87
50	51.2	45.7	96.9	1.02	0.91	1.94
60	96.3	76.2	172.5	1.61	1.27	2.88
70	143.7	100.0	243.6	2.05	1.43	3.48
80	187.3	115.9	303.1	2.34	1.45	3.79
90	224.7	125.1	349.8	2.50	1.39	3.89
100	255.5	129.1	384.6	**2.56**	**1.29**	**3.85**
110	280.6	129.1	409.6	2.55	1.17	3.72
120	300.8	129.1	429.9	2.51	1.08	3.58
130	317.3	107.6	424.8	2.44	0.83	3.27
140	330.8	86.1	416.9	2.36	0.61	2.98
150	330.8	64.5	395.4	2.21	0.43	2.64
160	330.8	64.5	395.4	2.07	0.40	2.47
170	330.8	64.5	395.4	1.95	0.38	2.33
180	330.8	64.5	395.4	1.84	0.36	2.20
190	283.6	64.5	348.1	1.49	0.34	1.83
200	236.3	64.5	300.9	1.18	0.32	1.50
210	189.1	64.5	253.6	0.90	0.31	1.21
220	165.4	64.5	230.0	0.75	0.29	1.05
230	165.4	64.5	230.0	0.72	0.28	1.00
240	165.4	64.5	230.0	0.69	0.27	0.96
250	165.4	64.5	230.0	0.66	0.26	0.92
260	165.4	64.5	230.0	0.64	0.25	0.88

Area Distribution

Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	RSA	12,068	0.6%
Stratum	**RSA_13-Sw**	**4,355**	**0.2%**

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber m3	Standing Timber m3/ha
Conifer	15/10/30/366/TL	416	0
Deciduous	15/10/30/366/TL	416	0
Total		832	0

Note: *Peak MAIs are based on main species group and highlighted in yellow.*
Standing timber volumes are approximate.

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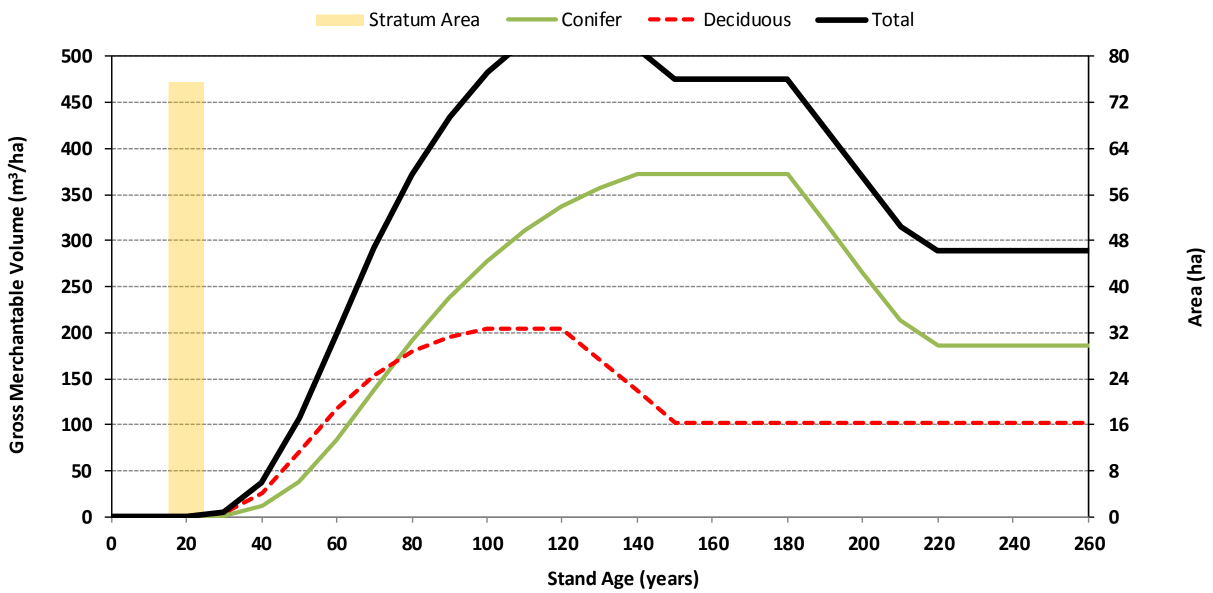
RSA

STRATUM: 14-SbHw - TYPE: Coniferous

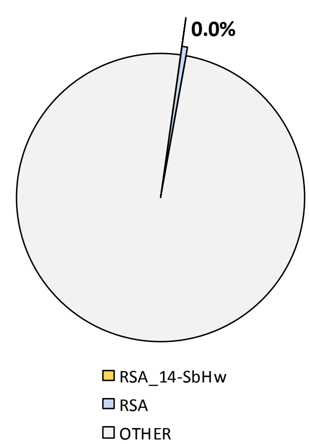


Stand Age	Gross Merchantable Volume (m³/ha)			Mean Annual Increment (m³/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.1	0.1	0.2	0.00	0.01	0.01
30	1.7	3.7	5.5	0.06	0.12	0.18
40	11.5	25.5	36.9	0.29	0.64	0.92
50	37.9	70.1	108.0	0.76	1.40	2.16
60	83.8	117.3	201.1	1.40	1.95	3.35
70	139.0	153.9	292.9	1.99	2.20	4.18
80	191.7	179.3	370.9	2.40	2.24	4.64
90	238.4	195.7	434.1	2.65	2.17	4.82
100	278.4	205.1	483.5	2.78	2.05	4.83
110	311.2	205.1	516.3	**2.83**	**1.86**	**4.69**
120	337.1	205.1	542.1	2.81	1.71	4.52
130	357.1	170.9	528.0	2.75	1.31	4.06
140	372.5	136.7	509.2	2.66	0.98	3.64
150	372.5	102.5	475.1	2.48	0.68	3.17
160	372.5	102.5	475.1	2.33	0.64	2.97
170	372.5	102.5	475.1	2.19	0.60	2.79
180	372.5	102.5	475.1	2.07	0.57	2.64
190	319.3	102.5	421.8	1.68	0.54	2.22
200	266.1	102.5	368.6	1.33	0.51	1.84
210	212.9	102.5	315.4	1.01	0.49	1.50
220	186.3	102.5	288.8	0.85	0.47	1.31
230	186.3	102.5	288.8	0.81	0.45	1.26
240	186.3	102.5	288.8	0.78	0.43	1.20
250	186.3	102.5	288.8	0.75	0.41	1.16
260	186.3	102.5	288.8	0.72	0.39	1.11

Area Distribution

Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	RSA	12,068	0.6%
Stratum	**RSA_14-SbHw**	**75**	**0.0%**

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber m3	Standing Timber m3/ha
Conifer	15/10/30/366/TL	6	0
Deciduous	15/10/30/366/TL	9	0
Total		15	0

Note: Peak MAIs are based on main species group and highlighted in yellow.
Standing timber volumes are approximate.

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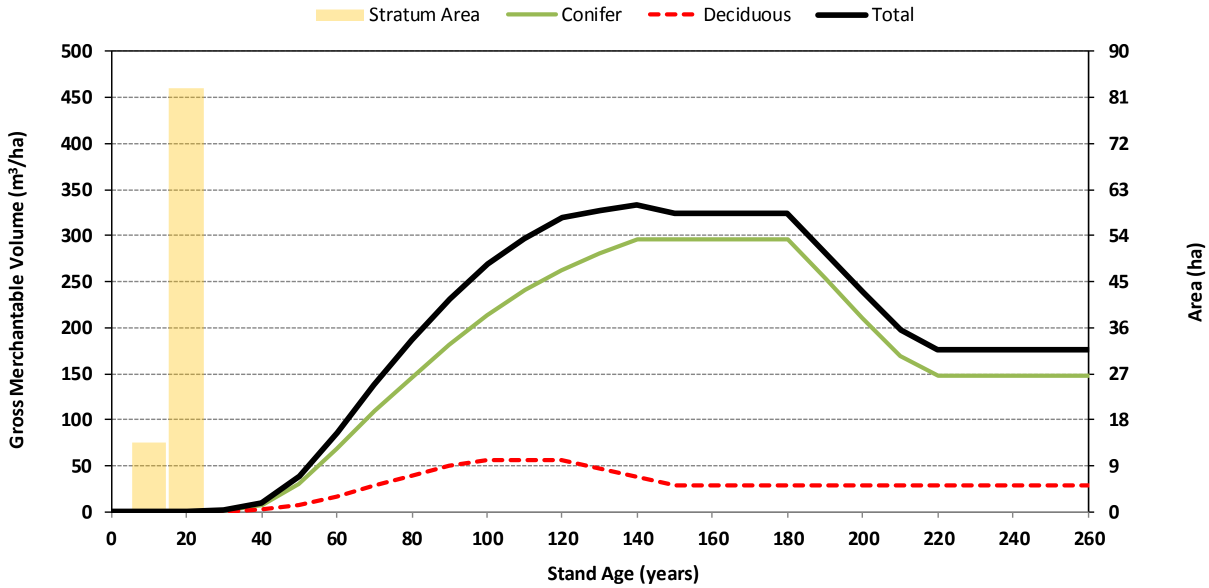
RSA

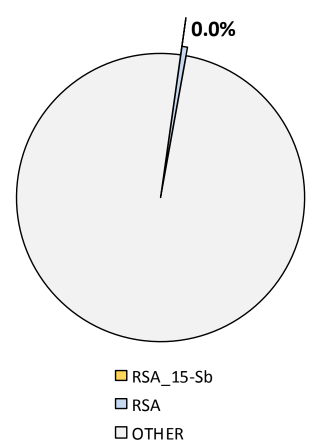
STRATUM: 15-Sb - TYPE: Coniferous



Stand Age	Gross Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.0	0.0	0.0	0.00	0.00	0.00
30	0.9	0.4	1.3	0.03	0.01	0.04
40	7.6	2.7	10.2	0.19	0.07	0.26
50	30.3	8.1	38.4	0.61	0.16	0.77
60	68.6	16.8	85.3	1.14	0.28	1.42
70	109.2	28.0	137.3	1.56	0.40	1.96
80	147.1	39.7	186.8	1.84	0.50	2.33
90	182.0	49.4	231.4	2.02	0.55	2.57
100	213.4	56.1	269.5	2.13	0.56	2.70
110	240.4	56.1	296.5	2.19	0.51	2.70
120	262.8	56.1	319.0	**2.19**	**0.47**	**2.66**
130	281.0	46.8	327.8	2.16	0.36	2.52
140	295.6	37.4	333.1	2.11	0.27	2.38
150	295.6	28.1	323.7	1.97	0.19	2.16
160	295.6	28.1	323.7	1.85	0.18	2.02
170	295.6	28.1	323.7	1.74	0.17	1.90
180	295.6	28.1	323.7	1.64	0.16	1.80
190	253.4	28.1	281.5	1.33	0.15	1.48
200	211.2	28.1	239.2	1.06	0.14	1.20
210	168.9	28.1	197.0	0.80	0.13	0.94
220	147.8	28.1	175.9	0.67	0.13	0.80
230	147.8	28.1	175.9	0.64	0.12	0.76
240	147.8	28.1	175.9	0.62	0.12	0.73
250	147.8	28.1	175.9	0.59	0.11	0.70
260	147.8	28.1	175.9	0.57	0.11	0.68

Area Distribution			
Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	RSA	12,068	0.6%
Stratum	**RSA_15-Sb**	**96**	**0.0%**

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber	
		m3	m3/ha
Conifer	15/10/30/366/TL	2	0
Deciduous	15/10/30/366/TL	1	0
Total		3	0

Note: Peak MAIs are based on main species group and highlighted in yellow.
Standing timber volumes are approximate.

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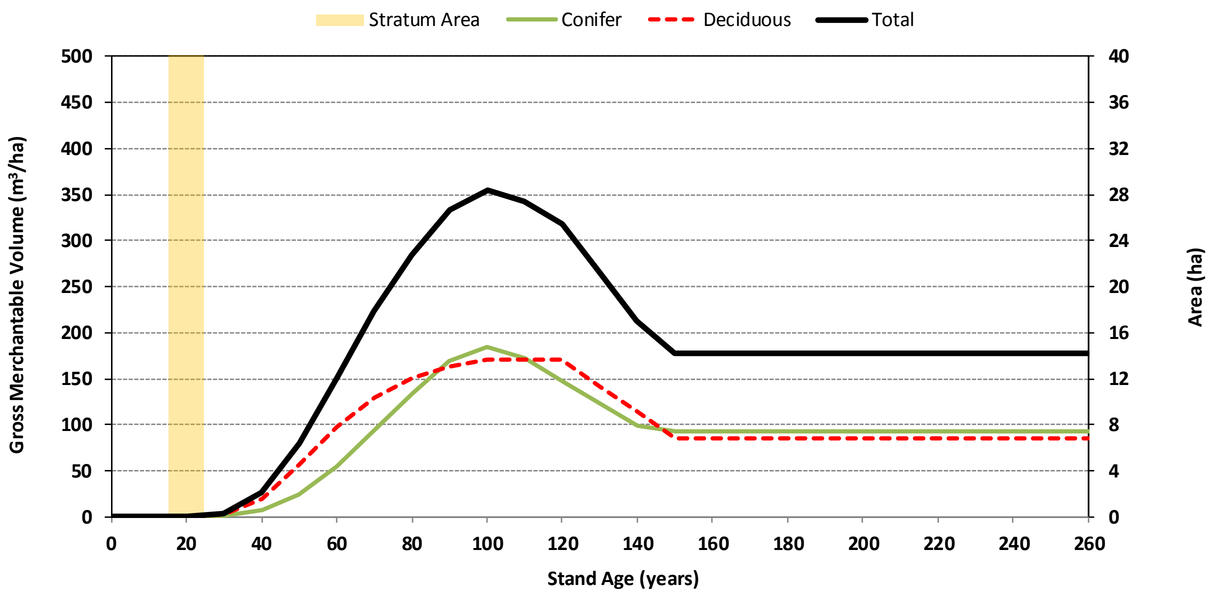
RSA

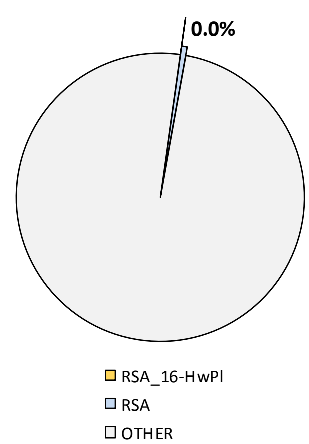
STRATUM: 16-HwPl - TYPE: Coniferous



Stand Age	Gross Merchantable Volume (m³/ha)			Mean Annual Increment (m³/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.0	0.1	0.1	0.00	0.01	0.01
30	0.8	3.0	3.9	0.03	0.10	0.13
40	6.9	20.0	26.8	0.17	0.50	0.67
50	24.0	56.5	80.5	0.48	1.13	1.61
60	54.0	97.1	151.1	0.90	1.62	2.52
70	93.8	128.9	222.7	1.34	1.84	3.18
80	134.7	150.4	285.1	1.68	1.88	3.56
90	169.9	163.5	333.4	1.89	1.82	3.70
100	184.8	170.3	355.1	1.85	1.70	3.55
110	172.5	170.3	342.7	1.57	1.55	3.12
120	147.8	170.3	318.1	1.23	1.42	2.65
130	123.2	141.9	265.1	0.95	1.09	2.04
140	98.6	113.5	212.1	0.70	0.81	1.51
150	92.4	85.1	177.5	0.62	0.57	1.18
160	92.4	85.1	177.5	0.58	0.53	1.11
170	92.4	85.1	177.5	0.54	0.50	1.04
180	92.4	85.1	177.5	0.51	0.47	0.99
190	92.4	85.1	177.5	0.49	0.45	0.93
200	92.4	85.1	177.5	0.46	0.43	0.89
210	92.4	85.1	177.5	0.44	0.41	0.85
220	92.4	85.1	177.5	0.42	0.39	0.81
230	92.4	85.1	177.5	0.40	0.37	0.77
240	92.4	85.1	177.5	0.38	0.35	0.74
250	92.4	85.1	177.5	0.37	0.34	0.71
260	92.4	85.1	177.5	0.36	0.33	0.68

Area Distribution			
Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	RSA	12,068	0.6%
Stratum	RSA_16-HwPl	40	0.0%

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber m3	Standing Timber m3/ha
Conifer	15/10/30/366/TL	1	0
Deciduous	15/10/30/366/TL	4	0
Total		5	0

Note: *Peak MAIs are based on main species group and highlighted in yellow.*
Standing timber volumes are approximate.

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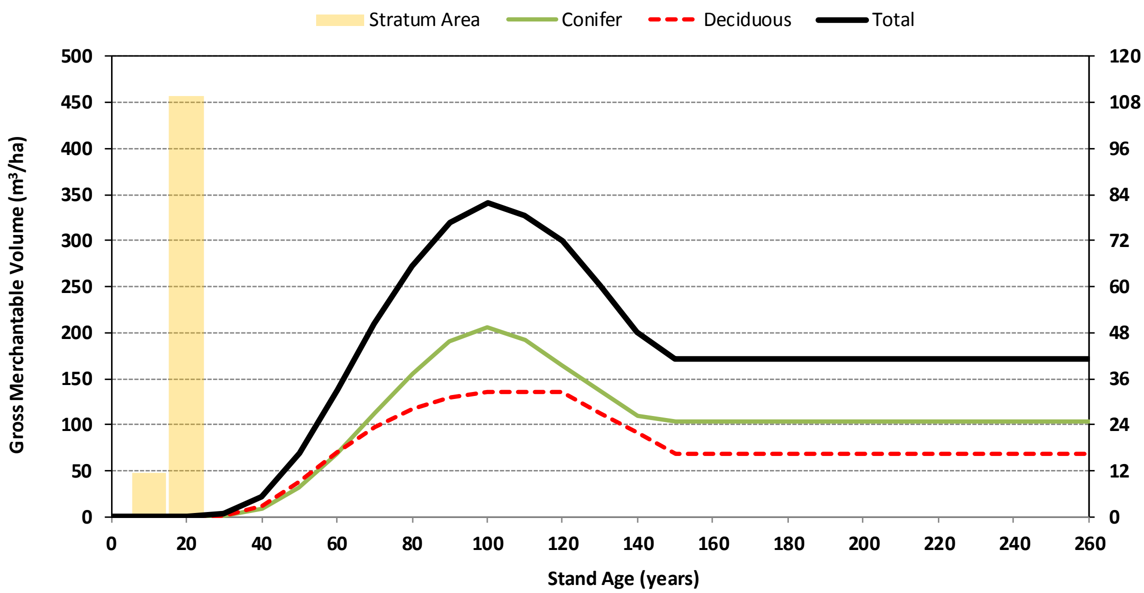
RSA

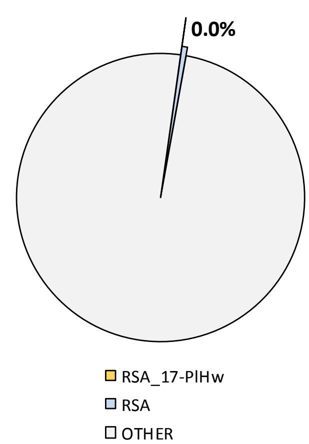
STRATUM: 17-PlHw - TYPE: Coniferous



Stand Age	Gross Merchantable Volume (m³/ha)			Mean Annual Increment (m³/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.0	0.1	0.1	0.00	0.00	0.01
30	1.3	1.9	3.2	0.04	0.06	0.11
40	9.2	12.6	21.8	0.23	0.32	0.54
50	31.2	38.0	69.2	0.62	0.76	1.38
60	68.5	69.8	138.3	1.14	1.16	2.30
70	112.9	97.3	210.1	1.61	1.39	3.00
80	154.8	116.9	271.8	1.94	1.46	3.40
90	190.4	129.4	319.8	**2.12**	**1.44**	**3.55**
100	205.7	136.0	341.6	2.06	1.36	3.42
110	192.0	136.0	327.9	1.75	1.24	2.98
120	164.5	136.0	300.5	1.37	1.13	2.50
130	137.1	113.3	250.4	1.05	0.87	1.93
140	109.7	90.6	200.3	0.78	0.65	1.43
150	102.8	68.0	170.8	0.69	0.45	1.14
160	102.8	68.0	170.8	0.64	0.42	1.07
170	102.8	68.0	170.8	0.60	0.40	1.00
180	102.8	68.0	170.8	0.57	0.38	0.95
190	102.8	68.0	170.8	0.54	0.36	0.90
200	102.8	68.0	170.8	0.51	0.34	0.85
210	102.8	68.0	170.8	0.49	0.32	0.81
220	102.8	68.0	170.8	0.47	0.31	0.78
230	102.8	68.0	170.8	0.45	0.30	0.74
240	102.8	68.0	170.8	0.43	0.28	0.71
250	102.8	68.0	170.8	0.41	0.27	0.68
260	102.8	68.0	170.8	0.40	0.26	0.66

Area Distribution			
Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	RSA	12,068	0.6%
Stratum	**RSA_17-PlHw**	**121**	**0.0%**

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber	
		m3	m3/ha
Conifer	15/10/30/366/TL	4	0
Deciduous	15/10/30/366/TL	9	0
Total		13	0

Note: Peak MAIs are based on main species group and highlighted in yellow.
Standing timber volumes are approximate.

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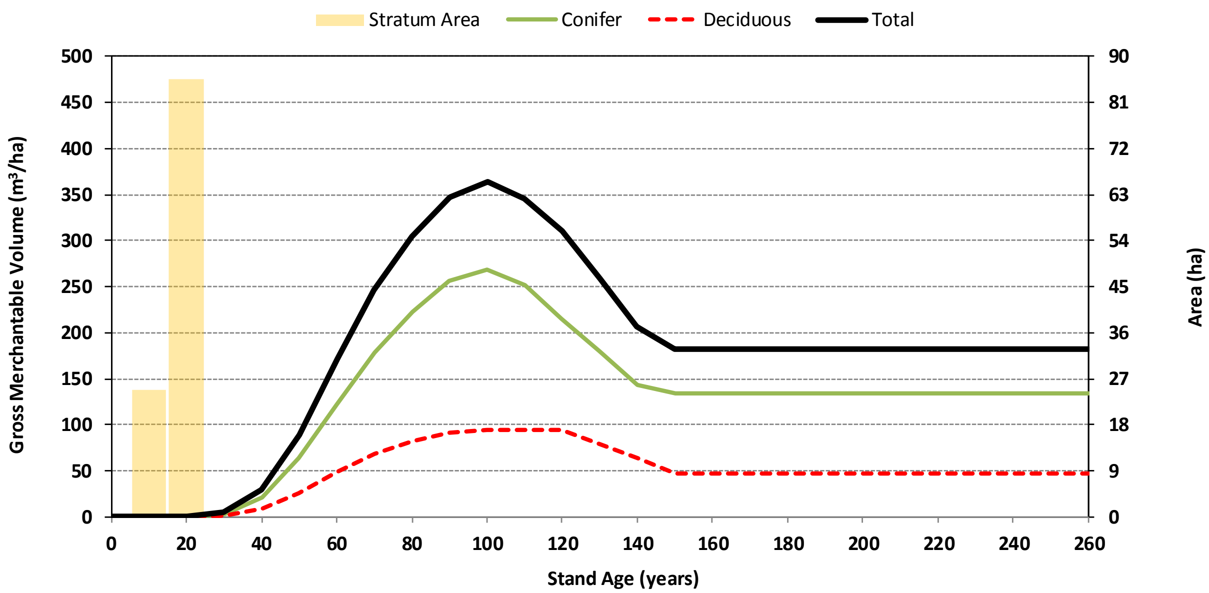
RSA

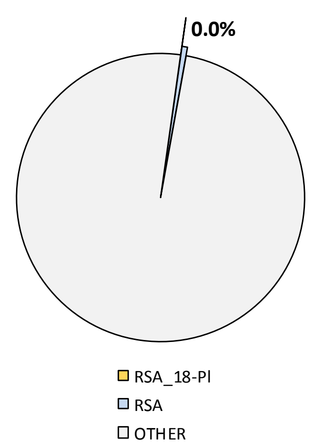
STRATUM: 18-Pl - TYPE: Coniferous



Stand Age	Gross Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.2	0.0	0.2	0.01	0.00	0.01
30	3.5	1.1	4.6	0.12	0.04	0.15
40	20.8	8.2	29.0	0.52	0.20	0.73
50	63.4	25.8	89.2	1.27	0.52	1.78
60	122.6	48.4	171.0	2.04	0.81	2.85
70	178.4	68.2	246.6	2.55	0.97	3.52
80	222.5	82.3	304.7	2.78	1.03	3.81
90	255.6	90.9	346.5	**2.84**	**1.01**	**3.85**
100	268.9	95.0	363.9	2.69	0.95	3.64
110	251.0	95.0	346.0	2.28	0.86	3.15
120	215.1	95.0	310.1	1.79	0.79	2.58
130	179.3	79.2	258.4	1.38	0.61	1.99
140	143.4	63.4	206.8	1.02	0.45	1.48
150	134.4	47.5	182.0	0.90	0.32	1.21
160	134.4	47.5	182.0	0.84	0.30	1.14
170	134.4	47.5	182.0	0.79	0.28	1.07
180	134.4	47.5	182.0	0.75	0.26	1.01
190	134.4	47.5	182.0	0.71	0.25	0.96
200	134.4	47.5	182.0	0.67	0.24	0.91
210	134.4	47.5	182.0	0.64	0.23	0.87
220	134.4	47.5	182.0	0.61	0.22	0.83
230	134.4	47.5	182.0	0.58	0.21	0.79
240	134.4	47.5	182.0	0.56	0.20	0.76
250	134.4	47.5	182.0	0.54	0.19	0.73
260	134.4	47.5	182.0	0.52	0.18	0.70

Area Distribution			
Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	RSA	12,068	0.6%
Stratum	RSA_18-Pl	110	0.0%

Stratum % of the Active Landbase

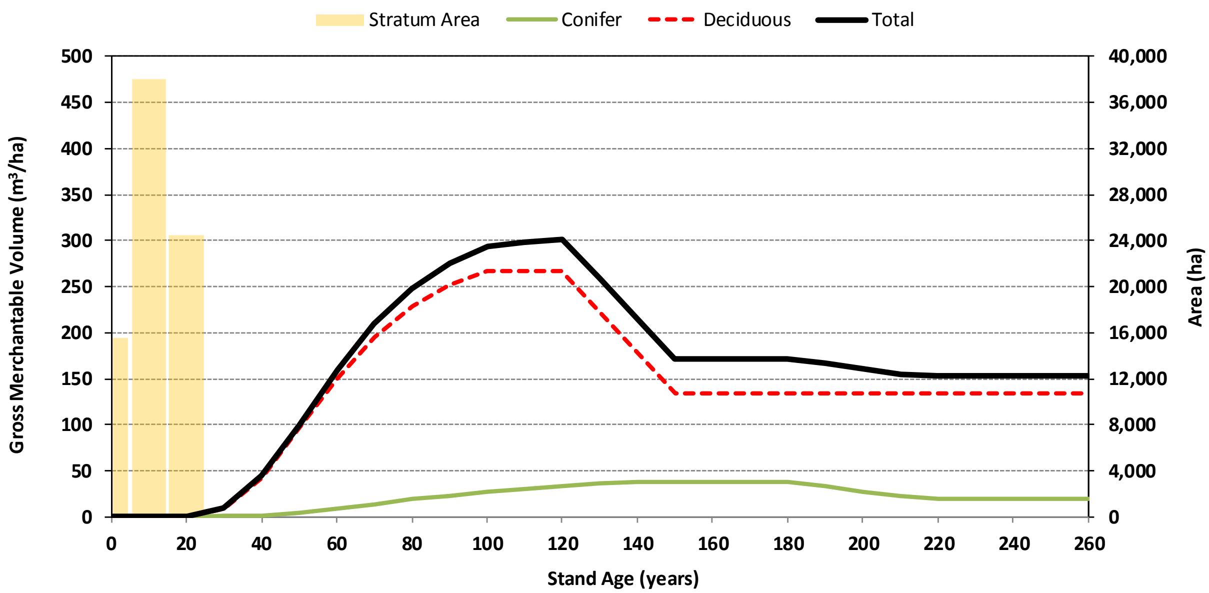


FMA Baseline Utilization		Standing Timber	
		m3	m3/ha
Conifer	15/10/30/366/TL	13	0
Deciduous	15/10/30/366/TL	3	0
Total		16	0

Note: *Peak MAIs are based on main species group and highlighted in yellow.*
Standing timber volumes are approximate.

1.6.3 Extensive Management Stands (Stand Type: ARIS-EXT)

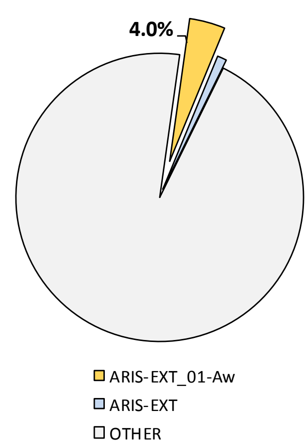
ALBERTA-PACIFIC FOREST INDUSTRIES INC. 2015-2025 FOREST MANAGEMENT PLAN YIELD CURVES	ARIS-EXT STRATUM: 01-Aw - TYPE: Deciduous



Stand Age	Gross Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.1	0.4	0.4	0.00	0.02	0.02
30	0.5	8.8	9.3	0.02	0.29	0.31
40	1.9	42.4	44.3	0.05	1.06	1.11
50	4.8	95.7	100.5	0.10	1.91	2.01
60	9.2	150.1	159.3	0.15	2.50	2.65
70	14.1	195.0	209.1	0.20	2.79	2.99
80	18.8	228.5	247.3	0.24	2.86	3.09
90	23.3	251.8	275.1	0.26	2.80	3.06
100	27.3	266.9	294.3	0.27	2.67	2.94
110	30.8	266.9	297.8	0.28	2.43	2.71
120	33.8	266.9	300.8	0.28	2.22	2.51
130	36.4	222.5	258.8	0.28	1.71	1.99
140	38.5	178.0	216.5	0.28	1.27	1.55
150	38.5	133.5	172.0	0.26	0.89	1.15
160	38.5	133.5	172.0	0.24	0.83	1.08
170	38.5	133.5	172.0	0.23	0.79	1.01
180	38.5	133.5	172.0	0.21	0.74	0.96
190	33.0	133.5	166.5	0.17	0.70	0.88
200	27.5	133.5	161.0	0.14	0.67	0.80
210	22.0	133.5	155.5	0.10	0.64	0.74
220	19.3	133.5	152.7	0.09	0.61	0.69
230	19.3	133.5	152.7	0.08	0.58	0.66
240	19.3	133.5	152.7	0.08	0.56	0.64
250	19.3	133.5	152.7	0.08	0.53	0.61
260	19.3	133.5	152.7	0.07	0.51	0.59

Area Distribution			
Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	ARIS-EXT	98,422	5.1%
Stratum	ARIS-EXT_01-Aw	78,077	4.0%

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber	
		m3	m3/ha
Conifer	15/10/30/366/TL	1,500	0
Deciduous	15/10/30/366/TL	9,451	0
Total		10,952	0

Note: *Peak MAIs are based on main species group and highlighted in yellow.*
Standing timber volumes are approximate.

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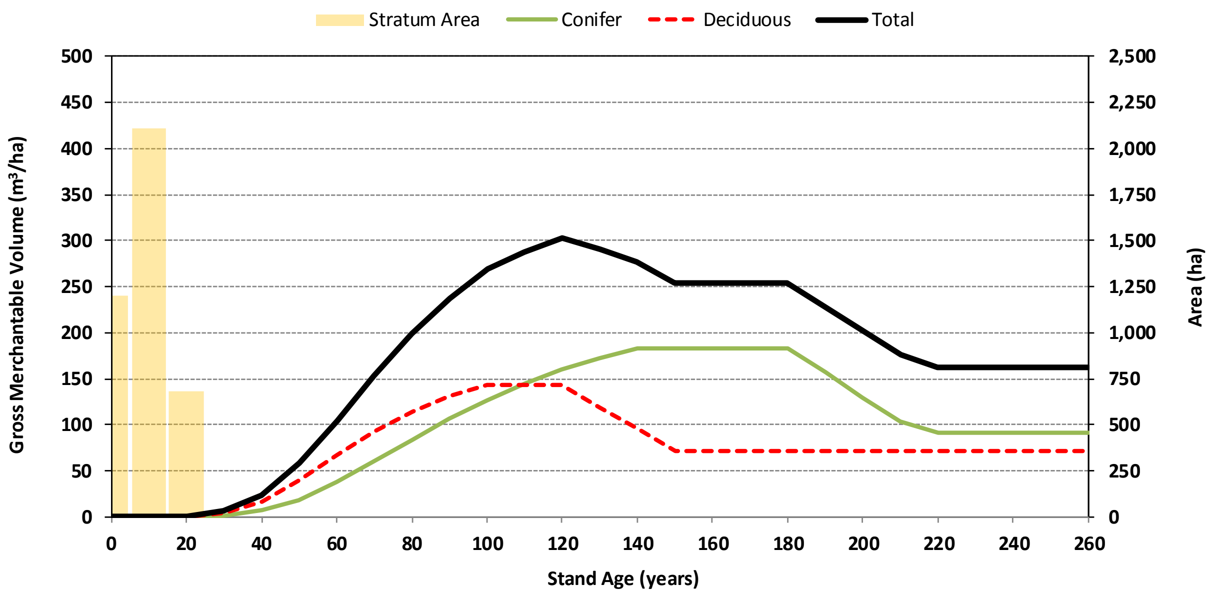
ARIS-EXT

STRATUM: 03-AwSx - TYPE: Coniferous

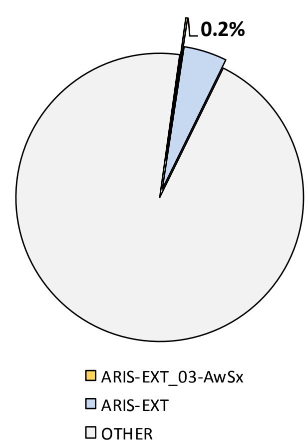


Stand Age	Gross Merchantable Volume (m³/ha)			Mean Annual Increment (m³/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.2	0.4	0.5	0.01	0.02	0.03
30	1.6	4.5	6.1	0.05	0.15	0.20
40	6.7	17.0	23.8	0.17	0.43	0.59
50	18.7	39.4	58.1	0.37	0.79	1.16
60	37.8	66.7	104.5	0.63	1.11	1.74
70	60.6	92.9	153.5	0.87	1.33	2.19
80	84.1	114.3	198.4	1.05	1.43	2.48
90	106.5	130.4	236.9	1.18	1.45	2.63
100	127.0	143.0	269.9	1.27	1.43	2.70
110	144.7	143.0	287.7	1.32	1.30	2.62
120	159.5	143.0	302.5	1.33	1.19	2.52
130	171.8	119.1	291.0	1.32	0.92	2.24
140	182.4	95.3	277.7	1.30	0.68	1.98
150	182.4	71.5	253.8	1.22	0.48	1.69
160	182.4	71.5	253.8	1.14	0.45	1.59
170	182.4	71.5	253.8	1.07	0.42	1.49
180	182.4	71.5	253.8	1.01	0.40	1.41
190	156.3	71.5	227.8	0.82	0.38	1.20
200	130.3	71.5	201.7	0.65	0.36	1.01
210	104.2	71.5	175.7	0.50	0.34	0.84
220	91.2	71.5	162.7	0.41	0.32	0.74
230	91.2	71.5	162.7	0.40	0.31	0.71
240	91.2	71.5	162.7	0.38	0.30	0.68
250	91.2	71.5	162.7	0.36	0.29	0.65
260	91.2	71.5	162.7	0.35	0.27	0.63

Area Distribution

Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	ARIS-EXT	98,422	5.1%
Stratum	**ARIS-EXT_03-AwSx**	**3,994**	**0.2%**

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber m3	Standing Timber m3/ha
Conifer	15/10/30/366/TL	118	0
Deciduous	15/10/30/366/TL	261	0
Total		379	0

Note: *Peak MAIs are based on main species group and highlighted in yellow.*
Standing timber volumes are approximate.

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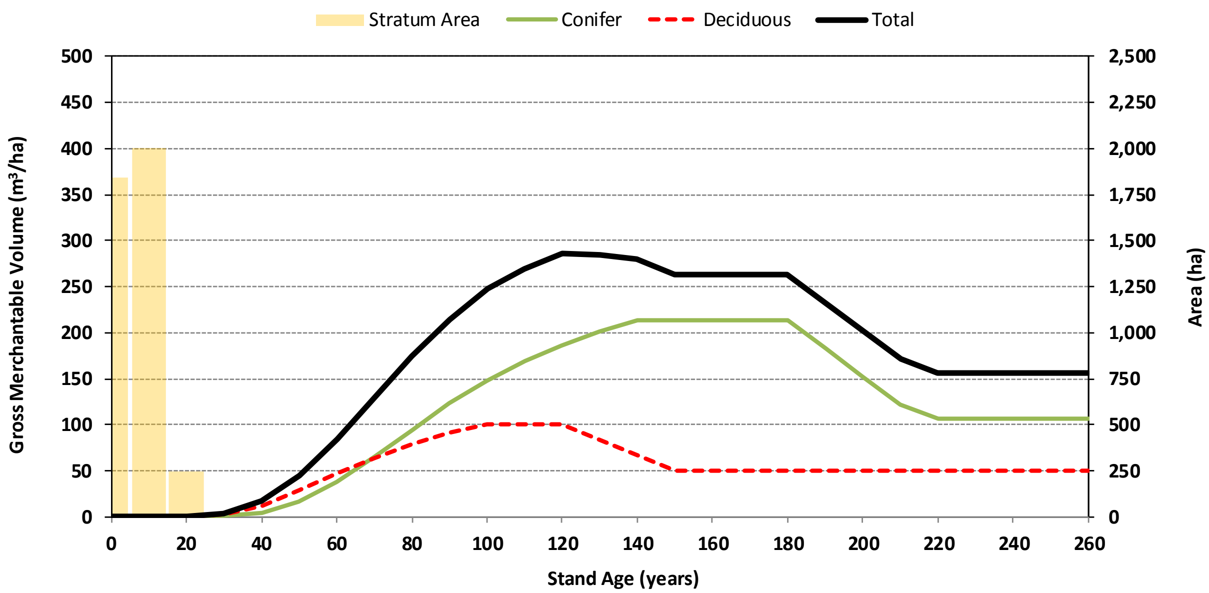
ARIS-EXT

STRATUM: 04-SxAw - TYPE: Coniferous

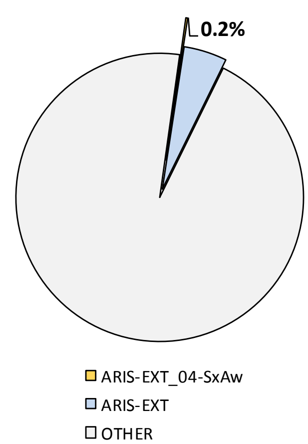


Stand Age	Gross Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.1	0.2	0.2	0.00	0.01	0.01
30	1.0	2.9	3.9	0.03	0.10	0.13
40	5.1	12.3	17.4	0.13	0.31	0.43
50	16.7	28.1	44.7	0.33	0.56	0.89
60	37.7	46.3	84.0	0.63	0.77	1.40
70	65.4	64.0	129.4	0.93	0.91	1.85
80	95.0	79.2	174.2	1.19	0.99	2.18
90	123.2	91.2	214.4	1.37	1.01	2.38
100	148.1	100.0	248.1	1.48	1.00	2.48
110	169.0	100.0	269.1	1.54	0.91	2.45
120	186.5	100.0	286.5	**1.55**	**0.83**	**2.39**
130	201.1	83.4	284.4	1.55	0.64	2.19
140	213.4	66.7	280.1	1.52	0.48	2.00
150	213.4	50.0	263.4	1.42	0.33	1.76
160	213.4	50.0	263.4	1.33	0.31	1.65
170	213.4	50.0	263.4	1.26	0.29	1.55
180	213.4	50.0	263.4	1.19	0.28	1.46
190	182.9	50.0	232.9	0.96	0.26	1.23
200	152.4	50.0	202.4	0.76	0.25	1.01
210	121.9	50.0	171.9	0.58	0.24	0.82
220	106.7	50.0	156.7	0.48	0.23	0.71
230	106.7	50.0	156.7	0.46	0.22	0.68
240	106.7	50.0	156.7	0.44	0.21	0.65
250	106.7	50.0	156.7	0.43	0.20	0.63
260	106.7	50.0	156.7	0.41	0.19	0.60

Area Distribution

Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	ARIS-EXT	98,422	5.1%
Stratum	**ARIS-EXT_04-SxAw**	**4,099**	**0.2%**

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber m3	Standing Timber m3/ha
Conifer	15/10/30/366/TL	21	0
Deciduous	15/10/30/366/TL	39	0
Total		60	0

Note: *Peak MAIs are based on main species group and highlighted in yellow.*
Standing timber volumes are approximate.

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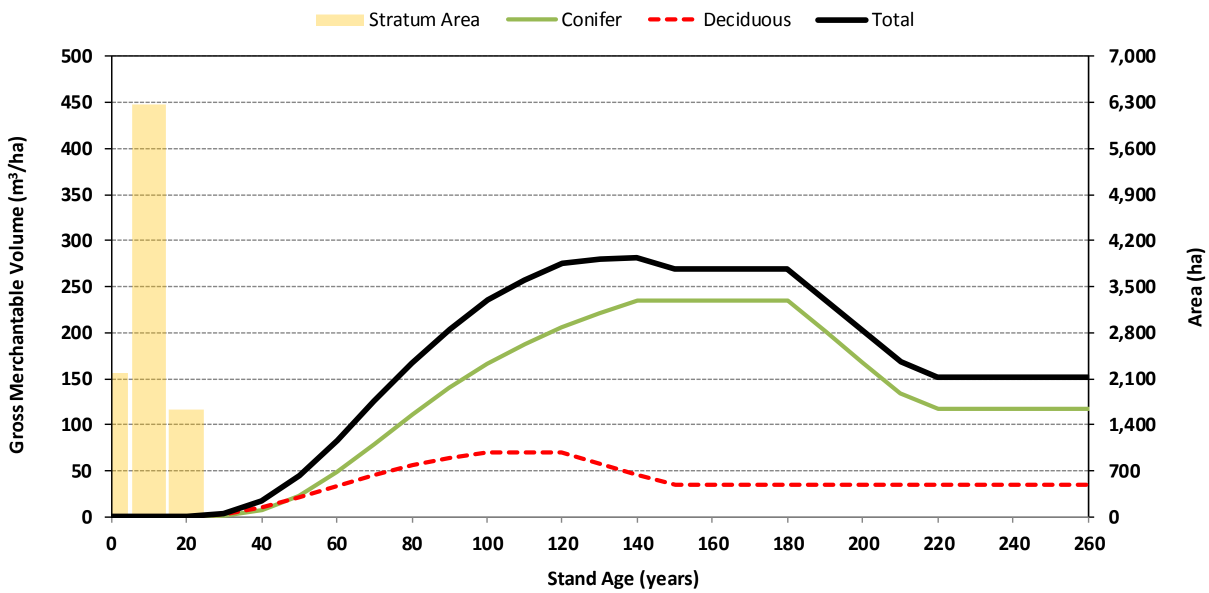
ARIS-EXT

STRATUM: 05-Sw - TYPE: Coniferous

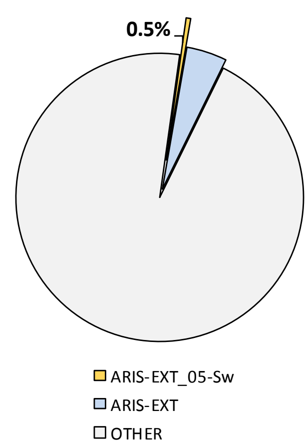


Stand Age	Gross Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.0	0.2	0.2	0.00	0.01	0.01
30	0.9	2.7	3.7	0.03	0.09	0.12
40	7.1	10.4	17.4	0.18	0.26	0.44
50	23.2	21.0	44.3	0.46	0.42	0.89
60	49.0	33.4	82.4	0.82	0.56	1.37
70	79.6	45.7	125.2	1.14	0.65	1.79
80	110.8	56.2	167.0	1.39	0.70	2.09
90	140.0	64.1	204.1	1.56	0.71	2.27
100	165.7	69.3	235.0	1.66	0.69	2.35
110	187.6	69.3	256.9	1.71	0.63	2.34
120	206.1	69.3	275.4	1.72	0.58	2.29
130	221.8	57.8	279.5	1.71	0.44	2.15
140	235.3	46.2	281.5	1.68	0.33	2.01
150	235.3	34.7	270.0	1.57	0.23	1.80
160	235.3	34.7	270.0	1.47	0.22	1.69
170	235.3	34.7	270.0	1.38	0.20	1.59
180	235.3	34.7	270.0	1.31	0.19	1.50
190	201.7	34.7	236.3	1.06	0.18	1.24
200	168.1	34.7	202.7	0.84	0.17	1.01
210	134.5	34.7	169.1	0.64	0.17	0.81
220	117.7	34.7	152.3	0.53	0.16	0.69
230	117.7	34.7	152.3	0.51	0.15	0.66
240	117.7	34.7	152.3	0.49	0.14	0.63
250	117.7	34.7	152.3	0.47	0.14	0.61
260	117.7	34.7	152.3	0.45	0.13	0.59

Area Distribution

Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	ARIS-EXT	98,422	5.1%
Stratum	ARIS-EXT_05-Sw	10,082	0.5%

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber m3	Standing Timber m3/ha
Conifer	15/10/30/366/TL	37	0
Deciduous	15/10/30/366/TL	278	0
Total		315	0

Note: *Peak MAIs are based on main species group and highlighted in yellow.*
Standing timber volumes are approximate.

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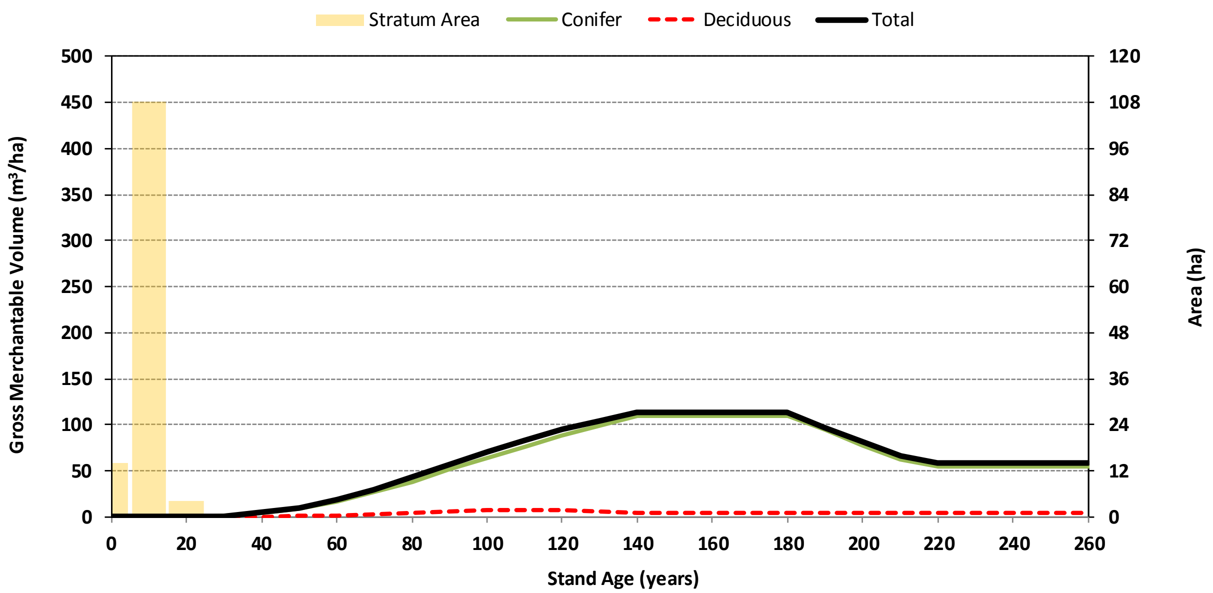
ARIS-EXT

STRATUM: 07-SbG - TYPE: Coniferous

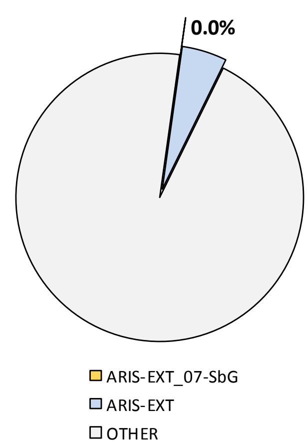


Stand Age	Gross Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.1	0.0	0.1	0.00	0.00	0.00
30	1.2	0.0	1.3	0.04	0.00	0.04
40	4.2	0.2	4.4	0.11	0.01	0.11
50	9.3	0.8	10.0	0.19	0.02	0.20
60	16.8	1.8	18.6	0.28	0.03	0.31
70	26.8	3.2	30.0	0.38	0.05	0.43
80	38.5	4.7	43.2	0.48	0.06	0.54
90	51.0	6.1	57.1	0.57	0.07	0.63
100	63.7	7.2	70.9	0.64	0.07	0.71
110	76.0	7.2	83.2	0.69	0.07	0.76
120	87.7	7.2	94.9	0.73	0.06	0.79
130	98.8	6.0	104.8	0.76	0.05	0.81
140	109.3	4.8	114.1	**0.78**	**0.03**	**0.81**
150	109.3	3.6	112.9	0.73	0.02	0.75
160	109.3	3.6	112.9	0.68	0.02	0.71
170	109.3	3.6	112.9	0.64	0.02	0.66
180	109.3	3.6	112.9	0.61	0.02	0.63
190	93.7	3.6	97.3	0.49	0.02	0.51
200	78.1	3.6	81.7	0.39	0.02	0.41
210	62.5	3.6	66.1	0.30	0.02	0.31
220	54.6	3.6	58.2	0.25	0.02	0.26
230	54.6	3.6	58.2	0.24	0.02	0.25
240	54.6	3.6	58.2	0.23	0.01	0.24
250	54.6	3.6	58.2	0.22	0.01	0.23
260	54.6	3.6	58.2	0.21	0.01	0.22

Area Distribution

Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	ARIS-EXT	98,422	5.1%
Stratum	**ARIS-EXT_07-SbG**	**126**	**0.0%**

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber m3	Standing Timber m3/ha
Conifer	15/10/30/366/TL	0	0
Deciduous	15/10/30/366/TL	0	0
Total		0	0

Note: *Peak MAIs are based on main species group and highlighted in yellow.*
Standing timber volumes are approximate.

ALBERTA-PACIFIC FOREST INDUSTRIES INC.
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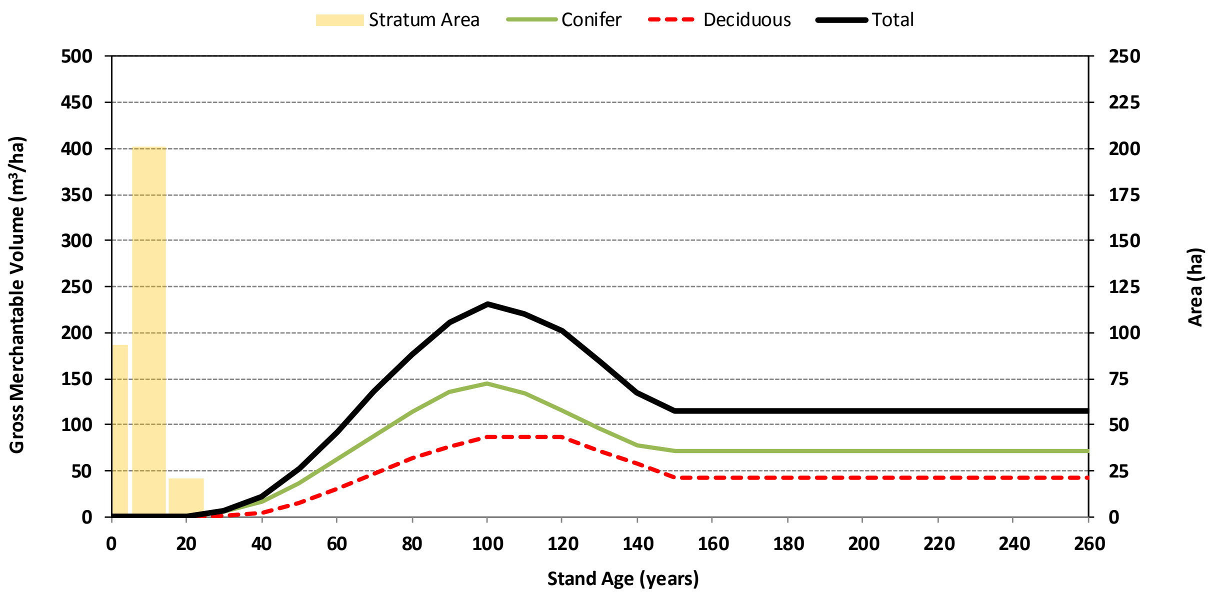
ARIS-EXT

STRATUM: 08-PjMx - TYPE: Coniferous

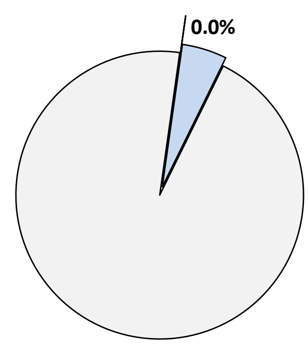


Stand Age	Gross Merchantable Volume (m³/ha)			Mean Annual Increment (m³/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.5	0.0	0.5	0.02	0.00	0.03
30	5.3	0.6	5.9	0.18	0.02	0.20
40	16.9	4.7	21.6	0.42	0.12	0.54
50	36.3	15.5	51.9	0.73	0.31	1.04
60	62.1	30.4	92.5	1.03	0.51	1.54
70	89.0	47.0	136.0	1.27	0.67	1.94
80	113.6	63.3	176.9	1.42	0.79	2.21
90	135.0	76.7	211.6	**1.50**	**0.85**	**2.35**
100	144.4	86.2	230.7	1.44	0.86	2.31
110	134.8	86.2	221.0	1.23	0.78	2.01
120	115.5	86.2	201.8	0.96	0.72	1.68
130	96.3	71.9	168.2	0.74	0.55	1.29
140	77.0	57.5	134.5	0.55	0.41	0.96
150	72.2	43.1	115.3	0.48	0.29	0.77
160	72.2	43.1	115.3	0.45	0.27	0.72
170	72.2	43.1	115.3	0.42	0.25	0.68
180	72.2	43.1	115.3	0.40	0.24	0.64
190	72.2	43.1	115.3	0.38	0.23	0.61
200	72.2	43.1	115.3	0.36	0.22	0.58
210	72.2	43.1	115.3	0.34	0.21	0.55
220	72.2	43.1	115.3	0.33	0.20	0.52
230	72.2	43.1	115.3	0.31	0.19	0.50
240	72.2	43.1	115.3	0.30	0.18	0.48
250	72.2	43.1	115.3	0.29	0.17	0.46
260	72.2	43.1	115.3	0.28	0.17	0.44

Area Distribution

Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	ARIS-EXT	98,422	5.1%
Stratum	**ARIS-EXT_08-PjMx**	**315**	**0.0%**

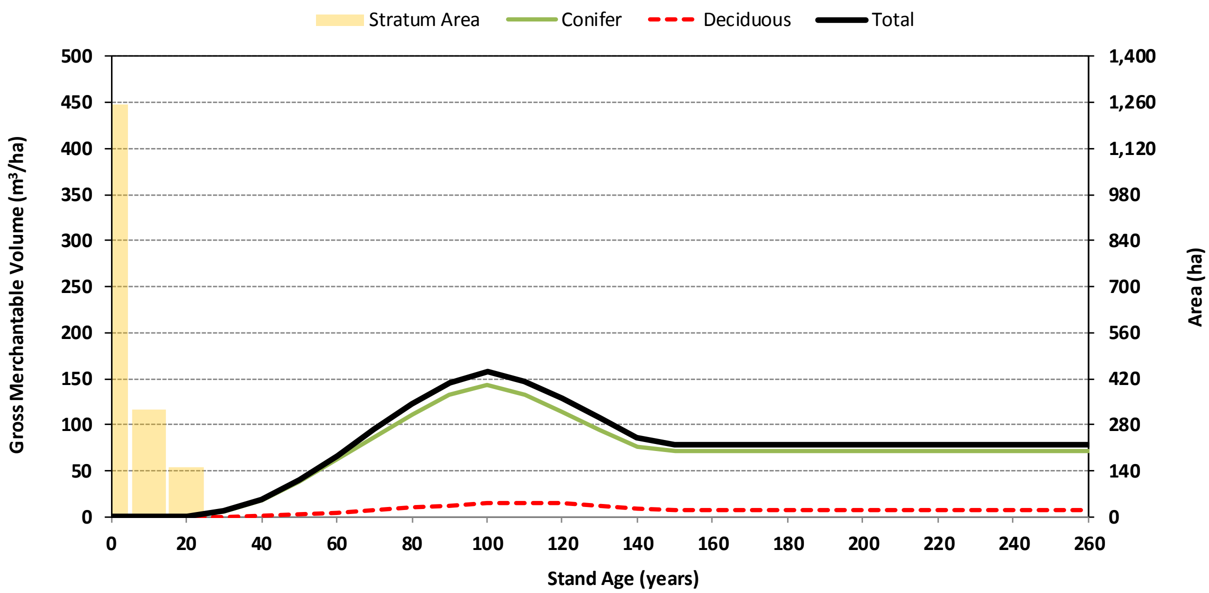
Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber m3	Standing Timber m3/ha
Conifer	15/10/30/366/TL	10	0
Deciduous	15/10/30/366/TL	0	0
Total		11	0

Note: *Peak MAIs are based on main species group and highlighted in yellow.*
Standing timber volumes are approximate.

ALBERTA-PACIFIC FOREST INDUSTRIES INC. 2015-2025 FOREST MANAGEMENT PLAN YIELD CURVES	ARIS-EXT STRATUM: 09-Pj - TYPE: Coniferous

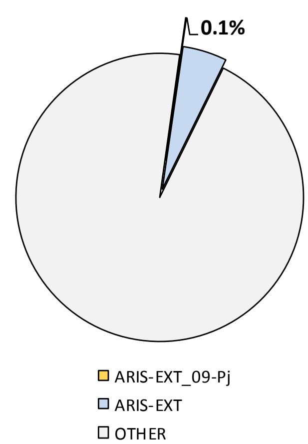


Stand Age	Gross Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.4	0.0	0.5	0.02	0.00	0.02
30	5.8	0.2	6.0	0.19	0.01	0.20
40	18.5	0.8	19.2	0.46	0.02	0.48
50	37.7	2.2	39.9	0.75	0.04	0.80
60	61.8	4.3	66.1	1.03	0.07	1.10
70	87.4	7.1	94.5	1.25	0.10	1.35
80	111.8	10.1	121.9	1.40	0.13	1.52
90	133.3	12.7	145.9	**1.48**	**0.14**	**1.62**
100	142.8	14.4	157.1	1.43	0.14	1.57
110	133.2	14.4	147.6	1.21	0.13	1.34
120	114.2	14.4	128.6	0.95	0.12	1.07
130	95.2	12.0	107.2	0.73	0.09	0.82
140	76.1	9.6	85.7	0.54	0.07	0.61
150	71.4	7.2	78.6	0.48	0.05	0.52
160	71.4	7.2	78.6	0.45	0.04	0.49
170	71.4	7.2	78.6	0.42	0.04	0.46
180	71.4	7.2	78.6	0.40	0.04	0.44
190	71.4	7.2	78.6	0.38	0.04	0.41
200	71.4	7.2	78.6	0.36	0.04	0.39
210	71.4	7.2	78.6	0.34	0.03	0.37
220	71.4	7.2	78.6	0.32	0.03	0.36
230	71.4	7.2	78.6	0.31	0.03	0.34
240	71.4	7.2	78.6	0.30	0.03	0.33
250	71.4	7.2	78.6	0.29	0.03	0.31
260	71.4	7.2	78.6	0.27	0.03	0.30

Area Distribution

Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	ARIS-EXT	98,422	5.1%
Stratum	**ARIS-EXT_09-Pj**	**1,727**	**0.1%**

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber m3	Standing Timber m3/ha
Conifer	15/10/30/366/TL	65	0
Deciduous	15/10/30/366/TL	3	0
Total		68	0

Note: Peak MAIs are based on main species group and highlighted in yellow.
Standing timber volumes are approximate.

1.6.4 Intensive Management Stands (Stand Type: ARIS-INT)

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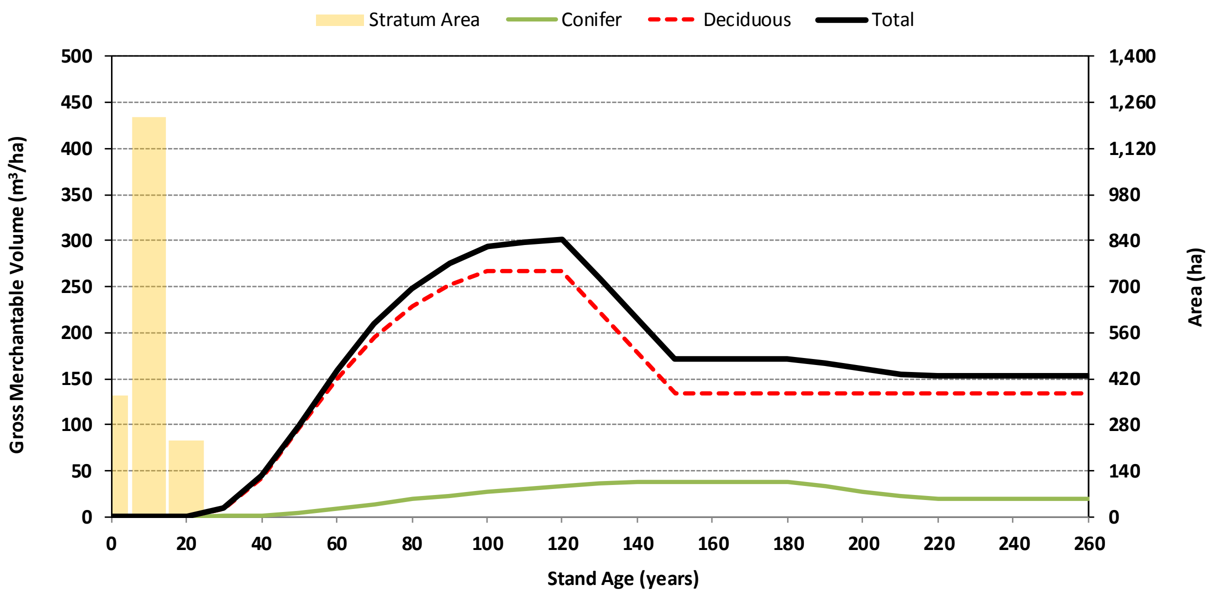
ARIS-INT

STRATUM: 01-Aw - TYPE: Deciduous

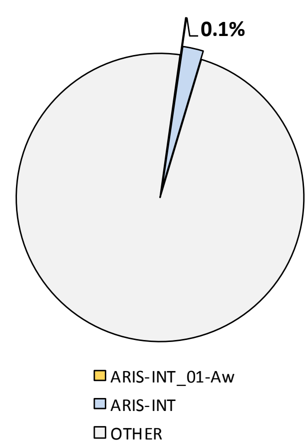


Stand Age	Gross Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.1	0.4	0.4	0.00	0.02	0.02
30	0.5	8.8	9.3	0.02	0.29	0.31
40	1.9	42.4	44.3	0.05	1.06	1.11
50	4.8	95.7	100.5	0.10	1.91	2.01
60	9.2	150.1	159.3	0.15	2.50	2.65
70	14.1	195.0	209.1	0.20	2.79	2.99
80	18.8	228.5	247.3	**0.24**	**2.86**	**3.09**
90	23.3	251.8	275.1	0.26	2.80	3.06
100	27.3	266.9	294.3	0.27	2.67	2.94
110	30.8	266.9	297.8	0.28	2.43	2.71
120	33.8	266.9	300.8	0.28	2.22	2.51
130	36.4	222.5	258.8	0.28	1.71	1.99
140	38.5	178.0	216.5	0.28	1.27	1.55
150	38.5	133.5	172.0	0.26	0.89	1.15
160	38.5	133.5	172.0	0.24	0.83	1.08
170	38.5	133.5	172.0	0.23	0.79	1.01
180	38.5	133.5	172.0	0.21	0.74	0.96
190	33.0	133.5	166.5	0.17	0.70	0.88
200	27.5	133.5	161.0	0.14	0.67	0.80
210	22.0	133.5	155.5	0.10	0.64	0.74
220	19.3	133.5	152.7	0.09	0.61	0.69
230	19.3	133.5	152.7	0.08	0.58	0.66
240	19.3	133.5	152.7	0.08	0.56	0.64
250	19.3	133.5	152.7	0.08	0.53	0.61
260	19.3	133.5	152.7	0.07	0.51	0.59

Area Distribution

Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	ARIS-INT	47,017	2.4%
Stratum	**ARIS-INT_01-Aw**	**1,821**	**0.1%**

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber m3	Standing Timber m3/ha
Conifer	15/10/30/366/TL	14	0
Deciduous	15/10/30/366/TL	91	0
Total		105	0

Note: *Peak MAIs are based on main species group and highlighted in yellow.*
Standing timber volumes are approximate.

ALBERTA-PACIFIC FOREST INDUSTRIES INC.
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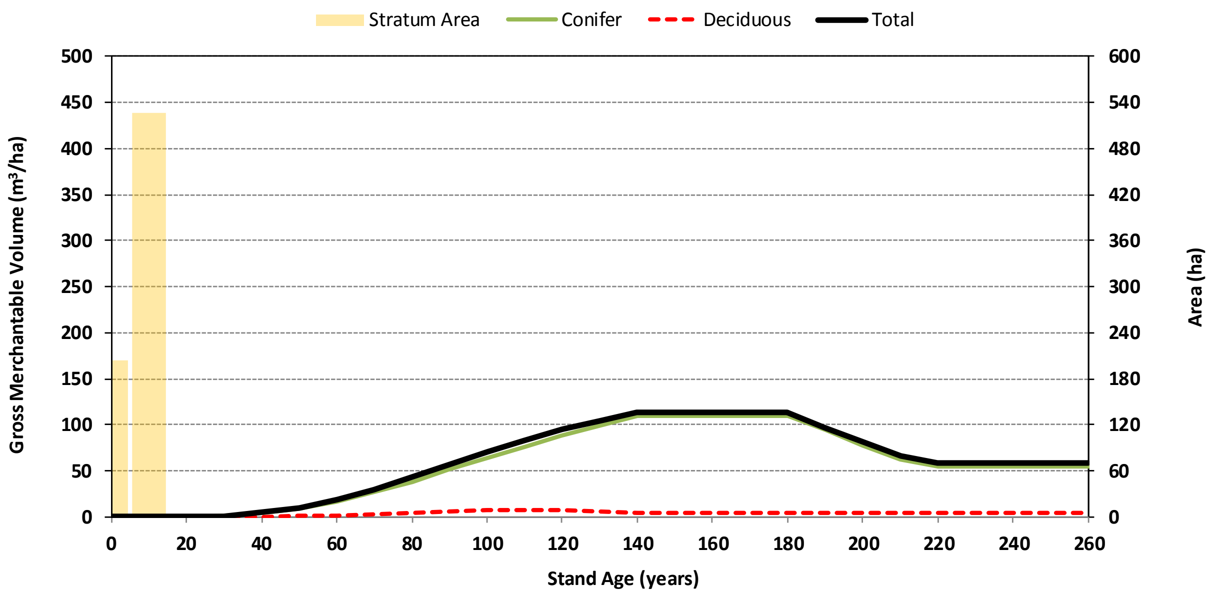
ARIS-INT

STRATUM: 07-SbG - TYPE: Coniferous

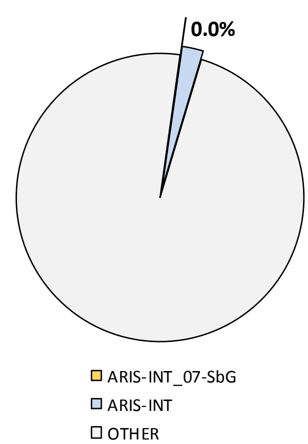


Stand Age	Gross Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.1	0.0	0.1	0.00	0.00	0.00
30	1.2	0.0	1.3	0.04	0.00	0.04
40	4.2	0.2	4.4	0.11	0.01	0.11
50	9.3	0.8	10.0	0.19	0.02	0.20
60	16.8	1.8	18.6	0.28	0.03	0.31
70	26.8	3.2	30.0	0.38	0.05	0.43
80	38.5	4.7	43.2	0.48	0.06	0.54
90	51.0	6.1	57.1	0.57	0.07	0.63
100	63.7	7.2	70.9	0.64	0.07	0.71
110	76.0	7.2	83.2	0.69	0.07	0.76
120	87.7	7.2	94.9	0.73	0.06	0.79
130	98.8	6.0	104.8	0.76	0.05	0.81
140	109.3	4.8	114.1	**0.78**	**0.03**	**0.81**
150	109.3	3.6	112.9	0.73	0.02	0.75
160	109.3	3.6	112.9	0.68	0.02	0.71
170	109.3	3.6	112.9	0.64	0.02	0.66
180	109.3	3.6	112.9	0.61	0.02	0.63
190	93.7	3.6	97.3	0.49	0.02	0.51
200	78.1	3.6	81.7	0.39	0.02	0.41
210	62.5	3.6	66.1	0.30	0.02	0.31
220	54.6	3.6	58.2	0.25	0.02	0.26
230	54.6	3.6	58.2	0.24	0.02	0.25
240	54.6	3.6	58.2	0.23	0.01	0.24
250	54.6	3.6	58.2	0.22	0.01	0.23
260	54.6	3.6	58.2	0.21	0.01	0.22

Area Distribution

Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	ARIS-INT	47,017	2.4%
Stratum	ARIS-INT_07-SbG	730	0.0%

Stratum % of the Active Landbase



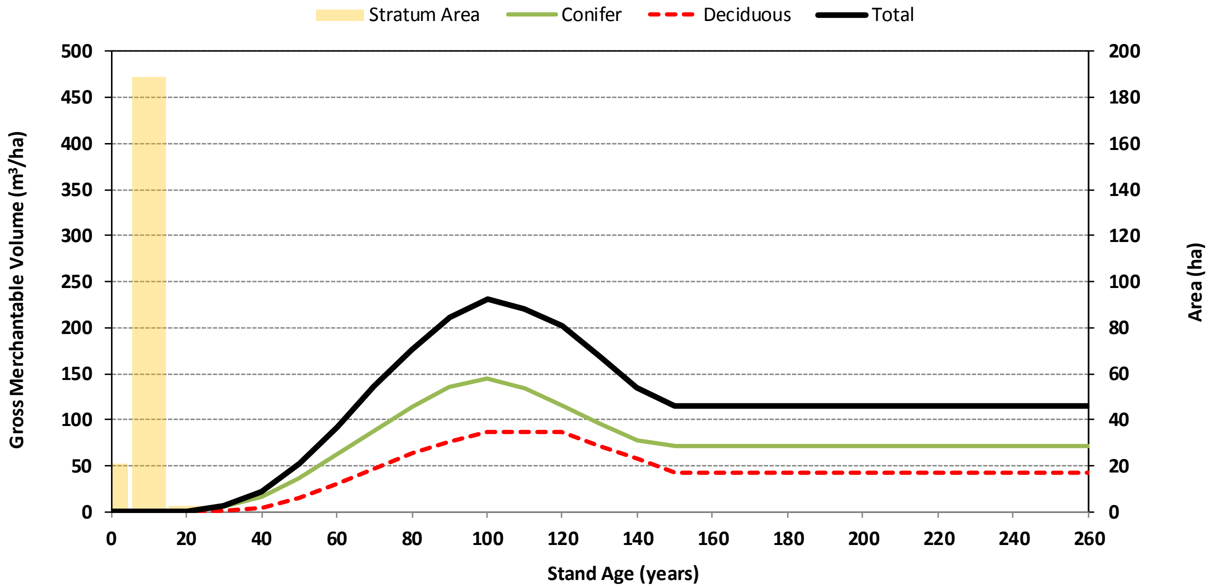
FMA Baseline Utilization		Standing Timber m3	Standing Timber m3/ha
Conifer	15/10/30/366/TL	0	0
Deciduous	15/10/30/366/TL	0	0
Total		0	0

Note: *Peak MAIs are based on main species group and highlighted in yellow.*
Standing timber volumes are approximate.

ALBERTA-PACIFIC FOREST INDUSTRIES INC.
2015-2025 FOREST MANAGEMENT PLAN
YIELD CURVES

ARIS-INT

STRATUM: 08-PjMx - TYPE: Coniferous

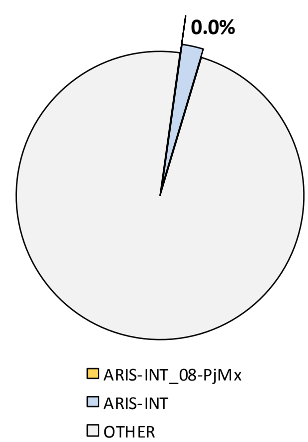


Stand Age	Gross Merchantable Volume (m³/ha)			Mean Annual Increment (m³/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.5	0.0	0.5	0.02	0.00	0.03
30	5.3	0.6	5.9	0.18	0.02	0.20
40	16.9	4.7	21.6	0.42	0.12	0.54
50	36.3	15.5	51.9	0.73	0.31	1.04
60	62.1	30.4	92.5	1.03	0.51	1.54
70	89.0	47.0	136.0	1.27	0.67	1.94
80	113.6	63.3	176.9	1.42	0.79	2.21
90	135.0	76.7	211.6	**1.50**	**0.85**	**2.35**
100	144.4	86.2	230.7	1.44	0.86	2.31
110	134.8	86.2	221.0	1.23	0.78	2.01
120	115.5	86.2	201.8	0.96	0.72	1.68
130	96.3	71.9	168.2	0.74	0.55	1.29
140	77.0	57.5	134.5	0.55	0.41	0.96
150	72.2	43.1	115.3	0.48	0.29	0.77
160	72.2	43.1	115.3	0.45	0.27	0.72
170	72.2	43.1	115.3	0.42	0.25	0.68
180	72.2	43.1	115.3	0.40	0.24	0.64
190	72.2	43.1	115.3	0.38	0.23	0.61
200	72.2	43.1	115.3	0.36	0.22	0.58
210	72.2	43.1	115.3	0.34	0.21	0.55
220	72.2	43.1	115.3	0.33	0.20	0.52
230	72.2	43.1	115.3	0.31	0.19	0.50
240	72.2	43.1	115.3	0.30	0.18	0.48
250	72.2	43.1	115.3	0.29	0.17	0.46
260	72.2	43.1	115.3	0.28	0.17	0.44

Area Distribution

Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	ARIS-INT	47,017	2.4%
Stratum	**ARIS-INT_08-PjMx**	**213**	**0.0%**

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber m3	Standing Timber m3/ha
Conifer	15/10/30/366/TL	1	0
Deciduous	15/10/30/366/TL	0	0
Total		1	0

Note: *Peak MAIs are based on main species group and highlighted in yellow.*
Standing timber volumes are approximate.

ALBERTA-PACIFIC FOREST INDUSTRIES INC.
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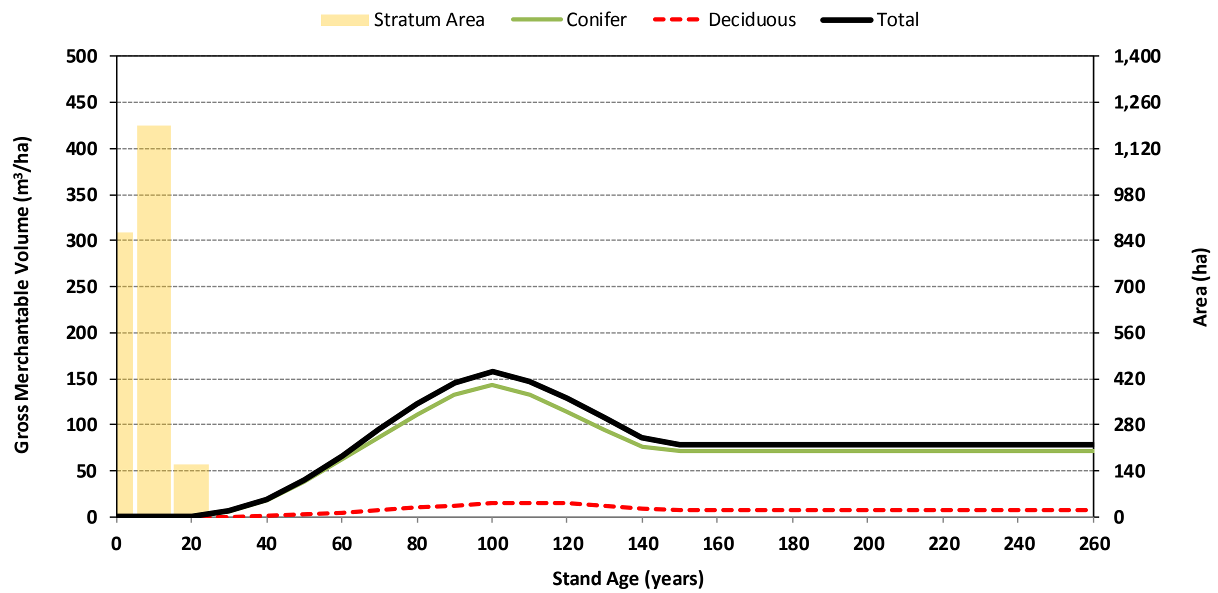
ARIS-INT

STRATUM: 09-Pj - TYPE: Coniferous

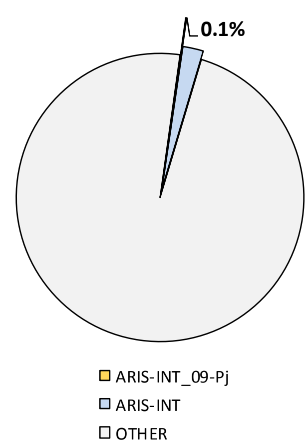


Stand Age	Gross Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.4	0.0	0.5	0.02	0.00	0.02
30	5.8	0.2	6.0	0.19	0.01	0.20
40	18.5	0.8	19.2	0.46	0.02	0.48
50	37.7	2.2	39.9	0.75	0.04	0.80
60	61.8	4.3	66.1	1.03	0.07	1.10
70	87.4	7.1	94.5	1.25	0.10	1.35
80	111.8	10.1	121.9	1.40	0.13	1.52
90	133.3	12.7	145.9	**1.48**	**0.14**	**1.62**
100	142.8	14.4	157.1	1.43	0.14	1.57
110	133.2	14.4	147.6	1.21	0.13	1.34
120	114.2	14.4	128.6	0.95	0.12	1.07
130	95.2	12.0	107.2	0.73	0.09	0.82
140	76.1	9.6	85.7	0.54	0.07	0.61
150	71.4	7.2	78.6	0.48	0.05	0.52
160	71.4	7.2	78.6	0.45	0.04	0.49
170	71.4	7.2	78.6	0.42	0.04	0.46
180	71.4	7.2	78.6	0.40	0.04	0.44
190	71.4	7.2	78.6	0.38	0.04	0.41
200	71.4	7.2	78.6	0.36	0.04	0.39
210	71.4	7.2	78.6	0.34	0.03	0.37
220	71.4	7.2	78.6	0.32	0.03	0.36
230	71.4	7.2	78.6	0.31	0.03	0.34
240	71.4	7.2	78.6	0.30	0.03	0.33
250	71.4	7.2	78.6	0.29	0.03	0.31
260	71.4	7.2	78.6	0.27	0.03	0.30

Area Distribution

Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	ARIS-INT	47,017	2.4%
Stratum	**ARIS-INT_09-Pj**	**2,211**	**0.1%**

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber m3	Standing Timber m3/ha
Conifer	15/10/30/366/TL	70	0
Deciduous	15/10/30/366/TL	3	0
Total		73	0

Note: *Peak MAIs are based on main species group and highlighted in yellow.*
Standing timber volumes are approximate.

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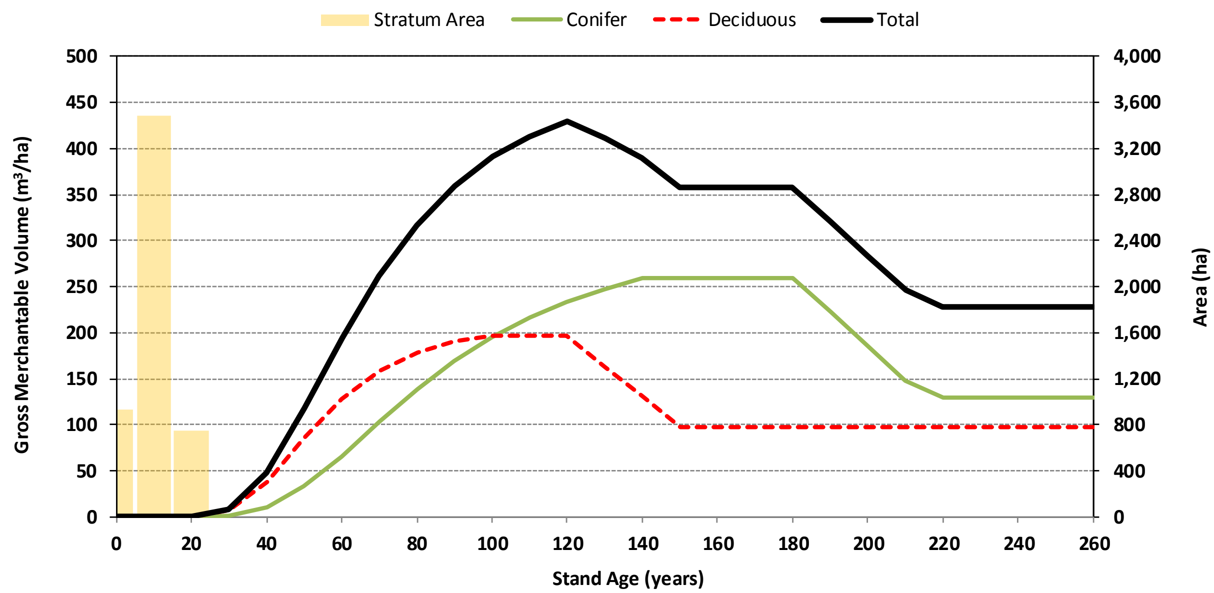
YIELD CURVES

ARIS-INT

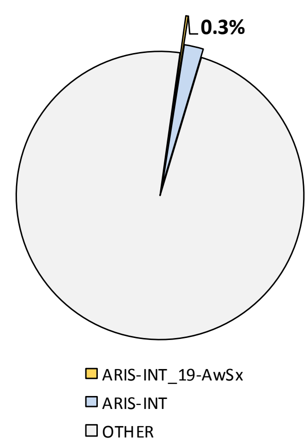
STRATUM: 19-AwSx - TYPE: Coniferous



Stand Age	Gross Merchantable Volume (m³/ha)			Mean Annual Increment (m³/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.0	0.3	0.3	0.00	0.02	0.02
30	1.3	7.1	8.4	0.04	0.24	0.28
40	10.2	37.6	47.8	0.26	0.94	1.19
50	32.8	85.3	118.0	0.66	1.71	2.36
60	66.0	127.8	193.8	1.10	2.13	3.23
70	102.9	158.2	261.1	1.47	2.26	3.73
80	138.0	178.2	316.2	1.73	2.23	3.95
90	168.8	190.2	359.0	1.88	2.11	3.99
100	194.8	196.1	390.9	1.95	1.96	3.91
110	216.1	196.1	412.2	**1.96**	**1.78**	**3.75**
120	233.5	196.1	429.7	1.95	1.63	3.58
130	247.8	163.4	411.3	1.91	1.26	3.16
140	259.7	130.8	390.4	1.85	0.93	2.79
150	259.7	98.1	357.7	1.73	0.65	2.38
160	259.7	98.1	357.7	1.62	0.61	2.24
170	259.7	98.1	357.7	1.53	0.58	2.10
180	259.7	98.1	357.7	1.44	0.54	1.99
190	222.6	98.1	320.6	1.17	0.52	1.69
200	185.5	98.1	283.5	0.93	0.49	1.42
210	148.4	98.1	246.5	0.71	0.47	1.17
220	129.8	98.1	227.9	0.59	0.45	1.04
230	129.8	98.1	227.9	0.56	0.43	0.99
240	129.8	98.1	227.9	0.54	0.41	0.95
250	129.8	98.1	227.9	0.52	0.39	0.91
260	129.8	98.1	227.9	0.50	0.38	0.88

Area Distribution			
Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	ARIS-INT	47,017	2.4%
Stratum	**ARIS-INT_19-AwSx**	**5,169**	**0.3%**

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber	
		m3	m3/ha
Conifer	15/10/30/366/TL	21	0
Deciduous	15/10/30/366/TL	227	0
Total		248	0

Note: *Peak MAIs are based on main species group and highlighted in yellow.*
Standing timber volumes are approximate.

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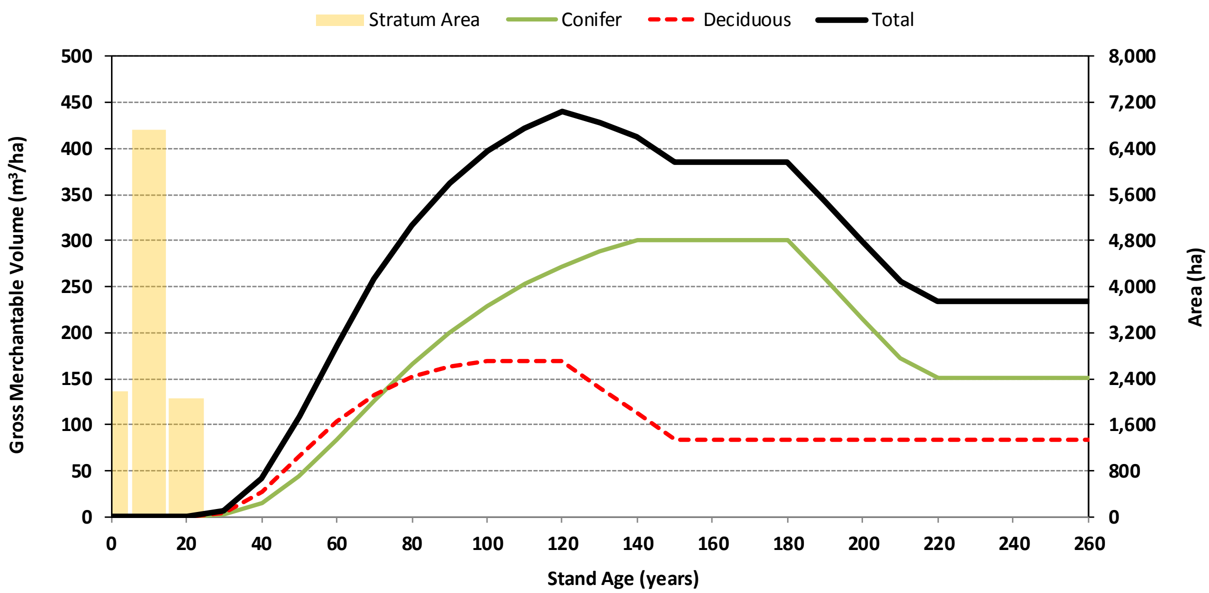
ARIS-INT

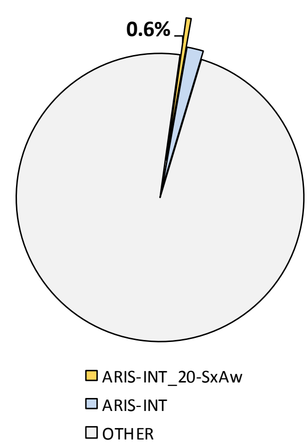
STRATUM: 20-SxAw - TYPE: Coniferous



Stand Age	Gross Merchantable Volume (m³/ha)			Mean Annual Increment (m³/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.1	0.2	0.2	0.00	0.01	0.01
30	2.2	4.6	6.8	0.07	0.15	0.23
40	14.8	26.7	41.5	0.37	0.67	1.04
50	43.5	65.9	109.3	0.87	1.32	2.19
60	83.3	104.1	187.4	1.39	1.74	3.12
70	125.9	132.8	258.6	1.80	1.90	3.69
80	165.6	151.8	317.3	2.07	1.90	3.97
90	200.0	163.1	363.2	2.22	1.81	4.04
100	228.9	168.6	397.5	2.29	1.69	3.98
110	252.7	168.6	421.2	**2.30**	**1.53**	**3.83**
120	271.9	168.6	440.5	2.27	1.40	3.67
130	287.6	140.5	428.1	2.21	1.08	3.29
140	300.5	112.4	412.9	2.15	0.80	2.95
150	300.5	84.3	384.8	2.00	0.56	2.57
160	300.5	84.3	384.8	1.88	0.53	2.40
170	300.5	84.3	384.8	1.77	0.50	2.26
180	300.5	84.3	384.8	1.67	0.47	2.14
190	257.6	84.3	341.9	1.36	0.44	1.80
200	214.6	84.3	298.9	1.07	0.42	1.49
210	171.7	84.3	256.0	0.82	0.40	1.22
220	150.3	84.3	234.5	0.68	0.38	1.07
230	150.3	84.3	234.5	0.65	0.37	1.02
240	150.3	84.3	234.5	0.63	0.35	0.98
250	150.3	84.3	234.5	0.60	0.34	0.94
260	150.3	84.3	234.5	0.58	0.32	0.90

Area Distribution			
Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	ARIS-INT	47,017	2.4%
Stratum	**ARIS-INT_20-SxAw**	**10,978**	**0.6%**

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber m3	Standing Timber m3/ha
Conifer	15/10/30/366/TL	158	0
Deciduous	15/10/30/366/TL	352	0
Total		511	0

Note: *Peak MAIs are based on main species group and highlighted in yellow.*
Standing timber volumes are approximate.

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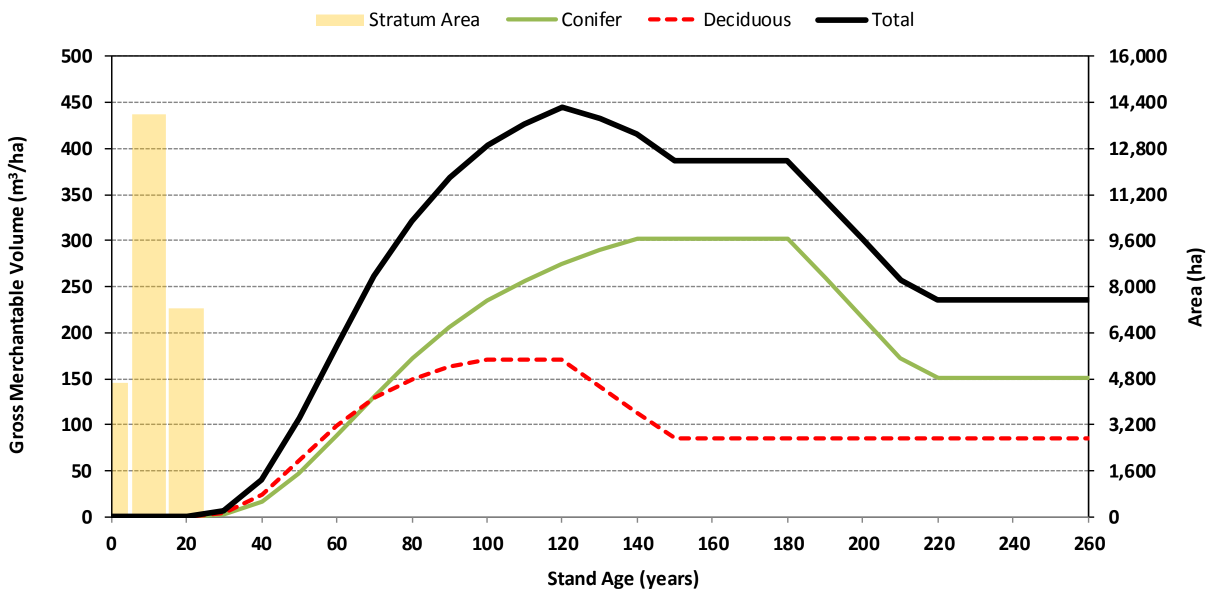
ARIS-INT

STRATUM: 21-Sw - TYPE: Coniferous

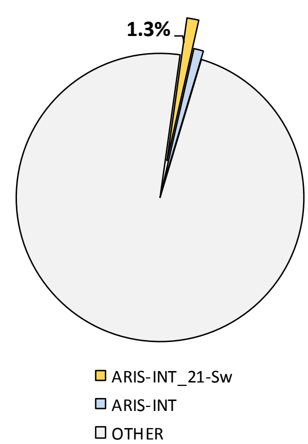


Stand Age	Gross Merchantable Volume (m^3/ha) Conifer	Deciduous	Total	Mean Annual Increment (m^3/ha/year) Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.1	0.1	0.2	0.00	0.01	0.01
30	2.3	3.9	6.2	0.08	0.13	0.21
40	15.8	24.1	39.9	0.39	0.60	1.00
50	46.4	61.5	107.9	0.93	1.23	2.16
60	88.0	99.5	187.6	1.47	1.66	3.13
70	131.7	129.3	261.0	1.88	1.85	3.73
80	171.8	150.1	321.9	2.15	1.88	4.02
90	206.1	163.2	369.2	2.29	1.81	4.10
100	234.2	170.2	404.4	**2.34**	**1.70**	**4.04**
110	257.0	170.2	427.2	2.34	1.55	3.88
120	275.3	170.2	445.5	2.29	1.42	3.71
130	290.1	141.8	431.9	2.23	1.09	3.32
140	302.2	113.5	415.7	2.16	0.81	2.97
150	302.2	85.1	387.3	2.01	0.57	2.58
160	302.2	85.1	387.3	1.89	0.53	2.42
170	302.2	85.1	387.3	1.78	0.50	2.28
180	302.2	85.1	387.3	1.68	0.47	2.15
190	259.1	85.1	344.2	1.36	0.45	1.81
200	215.9	85.1	301.0	1.08	0.43	1.50
210	172.7	85.1	257.8	0.82	0.41	1.23
220	151.1	85.1	236.2	0.69	0.39	1.07
230	151.1	85.1	236.2	0.66	0.37	1.03
240	151.1	85.1	236.2	0.63	0.35	0.98
250	151.1	85.1	236.2	0.60	0.34	0.94
260	151.1	85.1	236.2	0.58	0.33	0.91

Area Distribution

Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	ARIS-INT	47,017	2.4%
Stratum	**ARIS-INT_21-Sw**	**25,894**	**1.3%**

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber m3	m3/ha
Conifer	15/10/30/366/TL	572	0
Deciduous	15/10/30/366/TL	941	0
Total		1,513	0

Note: *Peak MAIs are based on main species group and highlighted in yellow.*
Standing timber volumes are approximate.

1.6.5 Understorey Protection Stands (Stand Type: ARIS-UP)

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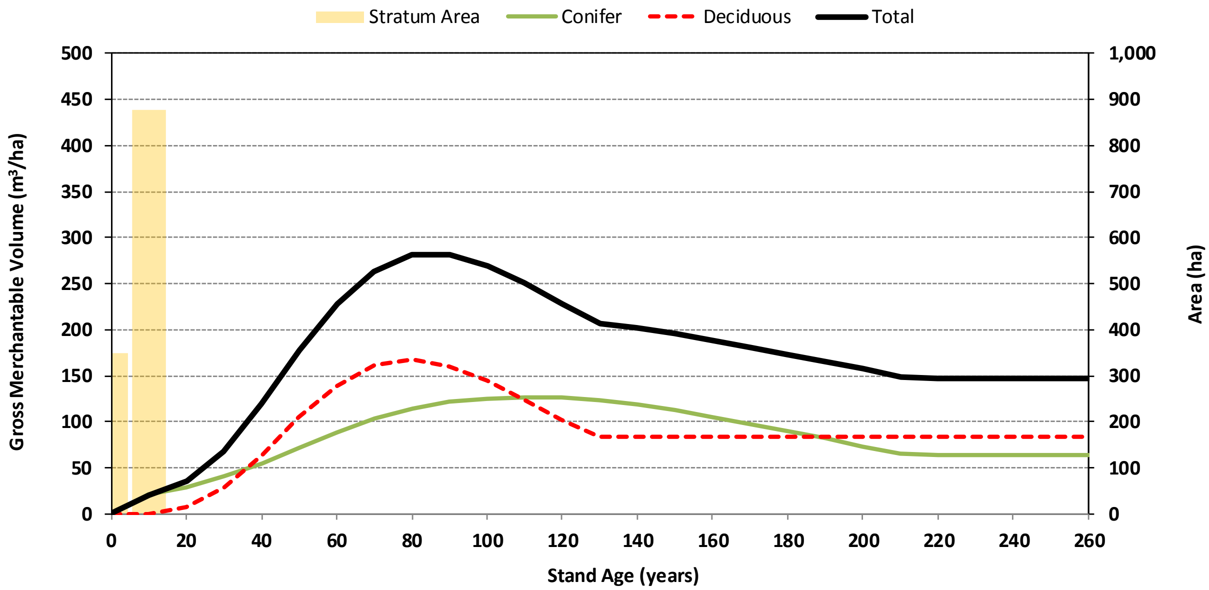
UNDERSTOREY PROTECTION

STRATUM: 26-AwSw - TYPE: Coniferous

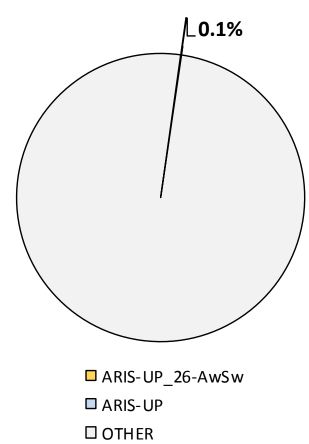


Stand Age	Gross Merchantable Volume (m³/ha)			Mean Annual Increment (m³/ha/year)		
	Conifer	Deciduous	Total	Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	20.4	0.4	20.7	2.04	0.04	2.07
20	28.7	6.8	35.5	1.43	0.34	1.77
30	40.2	28.2	68.4	1.34	0.94	2.28
40	55.2	64.0	119.1	1.38	1.60	2.98
50	72.2	104.7	176.9	1.44	2.09	3.54
60	89.1	139.4	228.4	1.48	2.32	3.81
70	103.1	160.8	263.9	1.47	2.30	3.77
80	113.8	167.2	281.0	1.42	2.09	3.51
90	121.2	160.4	281.6	1.35	1.78	3.13
100	125.4	144.6	269.9	**1.25**	**1.45**	**2.70**
110	126.8	123.8	250.6	1.15	1.13	2.28
120	125.8	101.6	227.4	1.05	0.85	1.90
130	122.9	83.6	206.5	0.95	0.64	1.59
140	118.2	83.6	201.8	0.84	0.60	1.44
150	112.3	83.6	195.9	0.75	0.56	1.31
160	105.3	83.6	188.9	0.66	0.52	1.18
170	97.8	83.6	181.3	0.58	0.49	1.07
180	89.7	83.6	173.3	0.50	0.46	0.96
190	81.7	83.6	165.3	0.43	0.44	0.87
200	73.7	83.6	157.3	0.37	0.42	0.79
210	65.7	83.6	149.3	0.31	0.40	0.71
220	63.4	83.6	147.0	0.29	0.38	0.67
230	63.4	83.6	147.0	0.28	0.36	0.64
240	63.4	83.6	147.0	0.26	0.35	0.61
250	63.4	83.6	147.0	0.25	0.33	0.59
260	63.4	83.6	147.0	0.24	0.32	0.57

Area Distribution

Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	ARIS-UP	1,810	0.1%
Stratum	**ARIS-UP_26-AwSw**	**1,225**	**0.1%**

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber m3	Standing Timber m3/ha
Conifer	15/10/30/366/TL	17,851	15
Deciduous	15/10/30/366/TL	337	0
Total		18,203	15

Note: *Peak MAIs are based on main species group and highlighted in yellow.*
Standing timber volumes are approximate.

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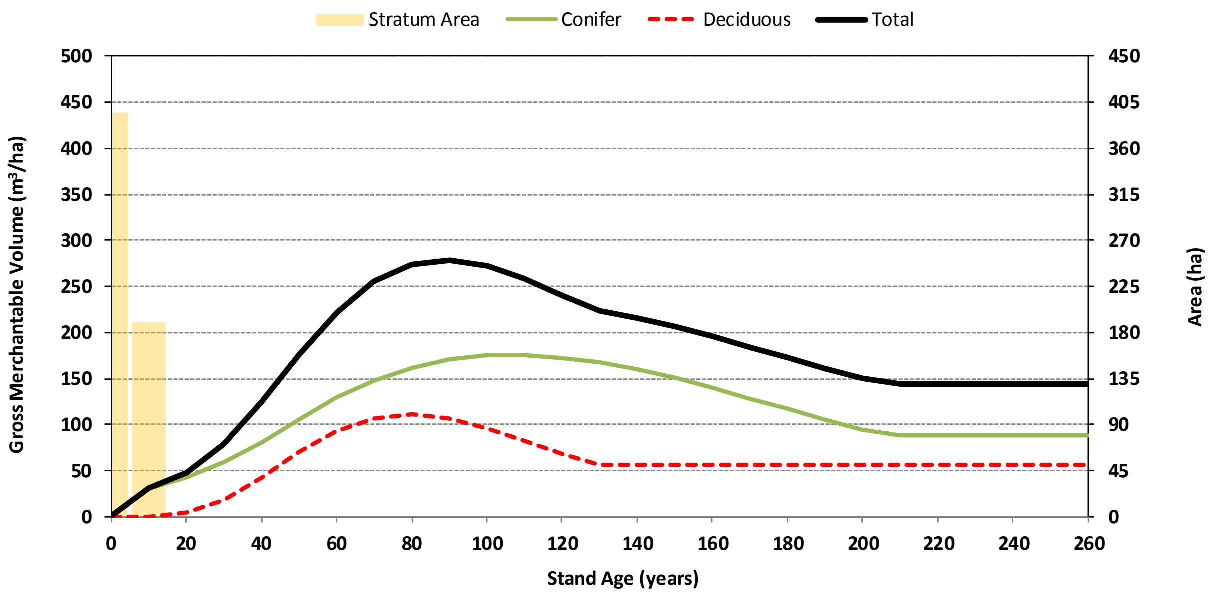
UNDERSTOREY PROTECTION

STRATUM: 27-SwAw - TYPE: Coniferous

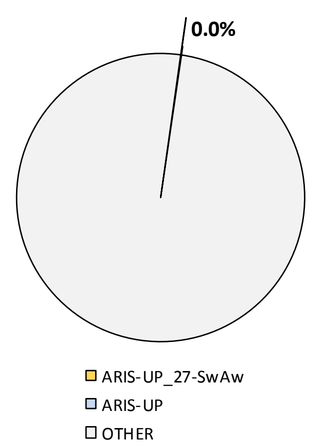


Stand Age	Gross Merchantable Volume (m^3/ha) Conifer	Deciduous	Total	Mean Annual Increment (m^3/ha/year) Conifer	Deciduous	Total
0	0.0	0.0	0.0	0.00	0.00	0.00
10	30.5	0.3	30.8	3.05	0.03	3.08
20	42.8	4.5	47.4	2.14	0.23	2.37
30	59.8	18.8	78.6	1.99	0.63	2.62
40	81.4	42.6	124.0	2.03	1.07	3.10
50	105.7	69.8	175.5	2.11	1.40	3.51
60	129.3	92.9	222.2	2.15	1.55	3.70
70	148.4	107.2	255.6	2.12	1.53	3.65
80	162.3	111.5	273.8	2.03	1.39	3.42
90	171.4	107.0	278.3	1.90	1.19	3.09
100	175.7	96.4	272.0	**1.76**	**0.96**	**2.72**
110	176.0	82.5	258.5	1.60	0.75	2.35
120	173.1	67.8	240.8	1.44	0.56	2.01
130	167.5	55.7	223.2	1.29	0.43	1.72
140	159.7	55.7	215.4	1.14	0.40	1.54
150	150.2	55.7	206.0	1.00	0.37	1.37
160	139.6	55.7	195.3	0.87	0.35	1.22
170	128.4	55.7	184.1	0.76	0.33	1.08
180	116.6	55.7	172.4	0.65	0.31	0.96
190	105.1	55.7	160.9	0.55	0.29	0.85
200	93.9	55.7	149.6	0.47	0.28	0.75
210	88.1	55.7	143.9	0.42	0.27	0.69
220	88.1	55.7	143.9	0.40	0.25	0.65
230	88.1	55.7	143.9	0.38	0.24	0.63
240	88.1	55.7	143.9	0.37	0.23	0.60
250	88.1	55.7	143.9	0.35	0.22	0.58
260	88.1	55.7	143.9	0.34	0.21	0.55

Area Distribution

Landbase Category		(ha)	(%)
Active Landbase		*1,944,877*	
LB Type	ARIS-UP	1,810	0.1%
Stratum	ARIS-UP_27-SwAw	585	0.0%

Stratum % of the Active Landbase



FMA Baseline Utilization		Standing Timber m3	m3/ha
Conifer	15/10/30/366/TL	5,822	10
Deciduous	15/10/30/366/TL	49	0
Total		5,881	10

Note: *Peak MAIs are based on main species group and highlighted in yellow.*
Standing timber volumes are approximate.

The remainder of this document is the version submitted for A-I-P and it describes the development of the yield curves as submitted for A-I-P. Heading and page numbers have been updated to reflect the insertion of the update content.

2 Overview (A-I-P Submission)

New yield curves are required for Alberta-Pacific Forest Industries Inc.'s (Alberta-Pacific) 2015-2025 Forest Management Plan (FMP). This document describes the data, methods, assumptions and processes used to develop yield estimates for natural and managed stands in support of the 2015 FMP.

Some of the information contained in this document is a simplification of the work completed within the landbase netdown process. This information is provided solely as context for the yield curve document. Please refer to Annex IV for the full detailed documentation of the landbase netdown process and description of associated attributes.

2.1 Landbase Classification and Base Yield Strata

The landbase is initially defined based on Alberta Vegetation Inventory (AVI) polygons (AFLW 1991). Alterations to the harvest area and landbase polygon set occur through the cutblock reconciliation process or as an outcome of aerial or non-photo stratification as part of performance surveys. Additional modifications occur through overlays of other relevant spatial information such as land use layers and disposition boundaries. Through this process, the timber harvesting netdown landbase (NLB) (polygons eligible for forest management activities) is defined.

Polygons within the timber harvesting landbase are then assigned into yield strata using either AVI attributes or, in the case of managed stands, a combination of silviculture declaration plus treatment information (e.g., planting, seeding and/or leave for natural treatments). In stands which have undergone a Regeneration Standard of Alberta (RSA) performance survey (referred to as post-performance managed stands), yield strata are defined based on either new photo-interpreted aerial attributes or ground survey data for stands where aerial photos are not available. All stand groups are differentiated into the same base set of yield strata, regardless of differences in rule sets used to assign the strata; Alberta-Pacific's 9 base yield strata are described in Table 2-1. The strata are a modification of the Alberta Planning Standard (ASRD 2006) base 10 yield strata, minus the Douglas-fir (Fd) stratum.

Table 2-1. Description of Alberta-Pacific base yield strata.

Alberta-Pacific Yield Stratum	AESRD Yield Stratum	Broad Cover Group	Description
Aw	Hw	D	Pure deciduous stand.
AwU	Hw	D	Pure deciduous stand with coniferous understory.
AwSx	HwSx	DC	Spruce-aspen mixedwood, deciduous leading.
SxAw	SwHw, SbHw	CD	Spruce-aspen mixedwood, coniferous leading.
Sw	Sw	C	Pure coniferous stand, white spruce leading.
SbFM	Sb	C	Pure coniferous stand, black spruce leading, fair or medium timber productivity rating.
SbG	Sb	C	Pure coniferous stand, black spruce leading, good timber productivity rating.
PjMx	HwPl, PlHw	DC, CD	Pine-aspen mixedwood.
Pj	Pl	C	Pure coniferous stand, pine leading.

2.2 Groups of Stands

Alberta-Pacific has identified five groups of stands within their timber harvesting landbase for purposes of yield curve development:

A. Natural Stands

This population includes all fire origin stands, plus any managed stands which were harvested prior to May 1, 1991 (referred to as pre-91 stands).

B. Post-Performance Managed Stands

Post-performance stands are a small population of managed stands that have been surveyed using the newer Regeneration Standard of Alberta (RSA) performance survey protocols (AESRD 2013[4]). While these blocks do not represent a specific silviculture management regime, they represent a set of blocks with distinctive scale of implementation (sampling unit or SU level as opposed to opening level) and method of yield stratum assignment.

C. Intensive Management Stands

The population of intensive management stands represents all harvest areas harvested after May 1, 1991 that have been harvested by quota holders[5] (QH) in the Alberta-Pacific FMA area (exclusive of group B). Intensive management stands are all coniferous-leading harvest areas distributed throughout the FMA area, and generally involve use of herbicide treatments as the primary herbaceous vegetation control method, which results in spatially discrete patterns of regeneration within harvested openings. All quota holders are considered intensive operators.

D. Extensive Management Stands

Extensive management stands are defined as all harvest areas harvested after May 1, 1991 that are managed through less intensive management techniques (exclusive of group B). In general, this means stand management in the absence of herbicide control. Alberta-Pacific is the primary extensive management practitioner, with a very specific silviculture practice of manual tending. Subsequent deciduous re-suckering results in multiple cohorts of deciduous species and atypical (as compared to natural stands) size relationships between deciduous and coniferous species.

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[4] The 2013 Regeneration Standard of Alberta is referenced here rather than the current (2014) version, since in 2014 significant changes were made in terms of sample selection methods. The 2013 methods are representative of the data used in development of Alberta-Pacific's 2015 yield curves.

[5] There are currently nine conifer Quota Holders within the FMA area, each with tenure in association with one of the 12 designated Forest Management Units. The nine QHs are: Alberta Plywood (S18); Vanderwell Contractors (S18 / L2 / S22); Sehta (represented by Alberta Plywood in S14); S-11 Logging (S11); Millar Western (L3 / A14 / L8 / L1); St. Jean Lumber (L8); Bobocel Lumber (L1 / L2 / S7); Northland Forest Products (A15); Alberta Forest Industries (Inactive in L1). GOA has conifer allocations within L1, L2, L11, A14, A15 S7, S11 and S22.

E. Understorey Protection Stands

Understorey protection (UP) stands involve a specialized method of harvesting, referred to as a strip-cut approach: removal of both conifer and deciduous in strips to form extraction trails, removal of deciduous on either side of each extraction trail to release understorey conifers (“reach” areas), and retention of a deciduous buffer between reach areas to minimize wind-throw of the remaining conifers. Pre-harvest involves ~370,000 hectares of AwU that transition within Patchworks to DU post-harvest stands that are aspen-white spruce mixtures, although other species may be present. The landbase also contains ~3,700 hectares of DU from past understorey protection treatments.

2.3 Available Growth Models

There are only two growth models available for use in Alberta; an alternative option for yield curve development is to use empirical (regression-based) yield curve methods, however, this is an option only for natural, not managed stands. Alberta-Pacific chose to use both of the existing growth models for yield curve development; the choice of model was specific to each stand group, constrained within availability of approved models and FMP requirements. A brief description of each model is provided for context while the following section (2.4) describes the choice and rationale for each model selection.

2.3.1 GYPSY

The Growth and Yield Projection System (GYPSY) model is a stand-level growth model developed by the Province of Alberta (Huang et al. 2009a, 2009b). Model inputs include stand age plus species group[6]-specific inputs: top height or site index (SI), age, density, stocking (optional) and basal area (optional). Spatial patterning is modelled via an (optional) stocking input, which modifies both the density and basal area increment functions within the GYPSY model. If stocking is not provided to the model, a non-spatial version of GYPSY is used. Huang at al. (2009a) recommend using the non-spatial version of GYSPY for fire origin stands, and wherever possible, the spatial version for post-harvest stands. Basal area inputs are used to localize (constrain) predicted basal area increment curves to observed plot data. Where basal area inputs are not available (for example, regeneration surveys without diameter measurements), basal area increment is predicted solely by the model. Competition between species is built into the model’s structure in two manners: via a species composition function (species group density relative to total density) as well as through interactions within several of the model functions. Aspen and black spruce species groups are unaffected by the presence of other species except via species composition equations embedded in the model. White spruce and pine species groups are affected by the presence of other species groups via modifiers to the density, basal area increment and percent stocking models.

2.3.2 MGM

The Mixedwood Growth Model (MGM) model (Bokalo 2013) is an individual tree growth model developed by researchers at the University of Alberta. The model can be initiated either with a tree list, or by using MGM’s tree list simulator to generate a tree list. Required model inputs include stand age, natural sub-region, species-specific site index and a tree list including species, diameter at breast height (DBH), height, age and tree factor (trees/hectare) for each tree in the list.

[6] Species groups: AW (aspen, birch +and poplar), PL (pines + larch), SB (black spruce), SW (white spruce + fir).

Competitive interactions are modelled using various stand and individual tree competition indices: sum of basal area of larger trees, sum of DBH of larger trees and density. In young stands, growth and mortality of both white spruce and aspen is affected by the size and abundance (density) of deciduous species, while pine and black spruce are impacted by species composition (species density relative to total density). Growth of trees over 4 cm DBH is (in very general terms) affected by the presence of larger trees. Maximum size-density equations are used to cap density. The model also includes an optional stand breakup mortality adjustment to simulate stand breakup at older ages.

Spatial patterning is accounted for in one of two methods: via a “gap area loss” factor, or via a “volume loss adjustment”. The gap area loss increases competitive effect between trees to account for the fact that MGM assumes trees are evenly distributed across stands, but in fact gaps exist and trees are actually growing more densely in the remaining areas. Increasing competitive effect means that tree growth and mortality functions will be adjusted accordingly within the model. The volume loss approach does not impact the competitive effect between trees, but simply reduces the output volumes by a fixed percentage. The choice of metric relates primarily to the type of simulation (stand vs. plot level) and nature of the input data. For example, if a PSP program was established only in fully treed (stocked) portions of a stand, the PSP would be projected “as is”, and a volume loss would be applied later to account for the average area in holes (gaps) that were excluded from the sampling population.

2.4 Modelling Approach

A distinct modelling approach was developed for each type of stand based on the input datasets, type of stand and constraints relative to model use (i.e. approvals for model use). Each approach is described briefly here, and in more detail in each relevant chapter.

2.4.1 Natural Stands (Group A)

Currently, the only approved growth model for the Province of Alberta is the GYPSY model. GYPSY was developed primarily from natural stand data, including data from the Alberta-Pacific FMA area, and is considered a suitable model for natural stand growth projections. However, the Alberta Forest Management Planning Standard (ASRD 2006) requires that standing timber (e.g. natural stand) yield curves be validated against plot data using Alberta Vegetation Inventory (AVI)-based age as the basis for assigning stand age. This constraint required the use of GYPSY in a more “empirical” manner which is discussed further in Section 3.5.1. These yield curves represent all natural (fire origin) stands as well as pre-91 managed stands. Yield stratum assignments were based on AVI attributes at the polygon level as discussed in Section 3.2.2.

2.4.2 Post-Performance Managed Stands (Group B)

Post-performance managed yield curves were developed to represent the population of openings which have been surveyed under the Regeneration Standard of Alberta’s (2013) aerial and/or non-photo performance survey protocols. Yield curves were created at the SU level since AESRD requires SU boundaries to be cut into the net landbase. The GYPSY model was used for yield projections because it is currently the RSA standard, and yield stratum assignments were taken from RSA photo-interpreted strata (except in the case of non-photo surveys which lack aerial attributes); see details in Section 4.2.2. Because RSA stratum assignments were retained, they follow a different naming convention from other yield strata; see Table 2-2 for details.

2.4.3 Intensive Management Stands (Group C)

Intensive management yield curves were developed to represent managed stands for all quota holders within Alberta-Pacific's FMA area. Yield curves reflect management practices that primarily involve the use of herbicide as an herbaceous vegetation management tool. Because stands are less complex in terms of stand structure, the GYPSY model was used to develop yield curves for intensive management stands for pure white spruce, and spruce mixedwood stands. Alberta-Pacific will assume natural yields for intensively managed pine, pine mixedwood and black spruce strata due to lack of data.

These yield curves represent intensively managed openings lacking an RSA performance survey (generally, younger stands which are not yet of performance survey age). Yield stratum assignments are based on opening-level silviculture information (declaration, planting, seeding and leave for natural (LFN) information), described in further detail in Annex IV (ForCorp 2014).

2.4.4 Extensive Management Stands (Group D)

Extensive management yield curves were developed primarily to represent Alberta-Pacific's coniferous silviculture management practices. Alberta-Pacific does not employ herbicide for management of conifer species, but rather uses manual tending as a management tool. Manual tending removes deciduous competition from around coniferous species, but leaves existing deciduous where they are not causing competition. Vigorous re-suckering of tended deciduous often results in a 2-cohort mixture of deciduous species with atypical size relationships relative to coniferous species.

Because GYPSY is a stand-level model, i.e. assumes a single cohort of trees per species group, and the model architecture does not allow coniferous species to impact deciduous growth (even if deciduous are smaller), Alberta-Pacific and AESRD agreed to use the MGM model for simulating growth in extensively managed pure aspen, pure white spruce, and spruce-leading mixedwood stands. Alberta-Pacific will assume natural yields for extensively managed pine, pine mixedwood and black spruce strata where use of MGM is not appropriate.

These yield curves represent extensively managed openings lacking an RSA performance survey (e.g., younger stands which are not yet of performance survey age plus post-1991 deciduous stands for which performance surveys were not required under RSA standards). Yield stratum assignments are based on opening-level silviculture information (declaration, planting, seeding and leave for natural (LFN) information), described in further detail in Annex IV (ForCorp 2014).

2.4.5 Understorey Protection (Group E)

The method of strip cut harvesting in Alberta-Pacific's understorey protection blocks results in relatively complex spatial patterns and generally discrete yield strata within openings. This is often referred to as *high effort understorey protection (UP)*. Due to the complexity of stand structures, Alberta-Pacific also received agreement from GOA to use the MGM model for simulating growth in understorey protection stands. Two yield curves, $AwSw^{UP}$ and $SwAw^{UP}$, have been developed to represent different levels of understorey protection within cutblocks. See Section 7.5.1 for further discussion.

Understorey protection yield curves will be used to represent all UP harvested openings, since as of the effective date of the landbase, none of these openings had an RSA performance survey. Yield stratum assignments are based on opening-level silviculture information (declaration and silviculture method), described in further detail in Section 7.2.2.

2.5 Technical Specifications

2.5.1 Yield Curve Summary

A summary of all yield curves, including the model used for yield curve development, scale of application and method of stratum assignment, is provided in Table 2-2.

Table 2-2. Yield strata, models, scale and stratum assignment methods, 2015 FMP yield curves.

Yield Curve	ESRD Stratum	Model	Scale	Stratum Assignment
A. Natural: *Standing timber, juvenile post-fire and pre-91 managed stands*				
1 Aw	I	GYPSY	Opening	AVI attributes
2 AwU	I	GYPSY	Opening	AVI attributes
3 AwSx	III	GYPSY	Opening	AVI attributes
4 SxAw	IV, VI	GYPSY	Opening	AVI attributes
5 Sw	VII	GYPSY	Opening	AVI attributes
6 SbFM	IX	GYPSY	Opening	AVI attributes
7 SbG	IX	GYPSY	Opening	AVI attributes
8 PjMx	II, V	GYPSY	Opening	AVI attributes
9 Pj	VIII	GYPSY	Opening	AVI attributes
B. Post-Performance: *Population of blocks with RSA performance survey*				
10 Hw	I	GYPSY	RSA sampling unit	RSA attributes
11 HwSx	III	GYPSY	RSA sampling unit	RSA attributes
12 SwHw	VI	GYPSY	RSA sampling unit	RSA attributes
13 Sw	VII	GYPSY	RSA sampling unit	RSA attributes
14 SbHw	IV	GYPSY	RSA sampling unit	RSA attributes
15 Sb	IX	GYPSY	RSA sampling unit	RSA attributes
16 HwPl	II	GYPSY	RSA sampling unit	RSA attributes
17 PlHw	V	GYPSY	RSA sampling unit	RSA attributes
18 Pl	VIII	GYPSY	RSA sampling unit	RSA attributes
C. Intensive Management: *Openings pre-performance survey or no RSA performance survey*				
1[1] Aw	I	GYPSY	Opening	Declaration + silviculture
19 AwSx	III	GYPSY	Opening	Declaration + silviculture
20 SxAw	IV, VI	GYPSY	Opening	Declaration + silviculture
21 Sw	VII	GYPSY	Opening	Declaration + silviculture
6[1] SbFM	IX	GYPSY	Opening	Declaration + silviculture
7[1] SbG	IX	GYPSY	Opening	Declaration + silviculture
8[1] PjMx	II, V	GYPSY	Opening	Declaration + silviculture
9[1] Pj	VIII	GYPSY	Opening	Declaration + silviculture
D. Extensive Management: *Openings pre-performance or no RSA performance survey*				
22 Aw	I	MGM	Opening	Declaration + silviculture
23 AwSx	III	MGM	Opening	Declaration + silviculture
24 SxAw	IV, VI	MGM	Opening	Declaration + silviculture
25 Sw	VII	MGM	Opening	Declaration + silviculture
7[1] SbG	IX	GYPSY	Opening	Declaration + silviculture
8[1] PjMx	II, V	GYPSY	Opening	Declaration + silviculture
9[1] Pj	VIII	GYPSY	Opening	Declaration + silviculture
E. Understory Protection: *Openings harvested using strip cut understory protection methods*				
26 AwSw^{UP}	n/a	MGM	Opening	Declaration + silviculture
27 SwAw^{UP}	n/a	MGM	Opening	Declaration + silviculture

[1]The natural stand yield curve is used to represent managed stand yields for this yield stratum.

2.5.2 Eligible Species and Species Groups

Table 2-3 lists the species present in Alberta-Pacific's FMA area. Note that lodgepole pine is rare in the FMA area and is not differentiated from jack pine. All species are acceptable for the purposes of yield curve development with the exception of larch, which is considered a non-merchantable species. For GYPSY modelling purposes, species groups are used rather than individual species; species groupings are as shown in Table 2-3, as well as the corresponding species type (coniferous vs. deciduous).

Table 2-3. Species types and groups based on species present in Alberta-Pacific's FMA area, and acceptability for yield curve development.

Species Type	Species Group	Species Code	Common Name	Latin Name	Acceptable Species
Deciduous	AW	Aw	Aspen	*Populus tremuloides*	Y
		Bw	Birch	*Betula papyrifera*	Y
		Pb	Poplar	*Populus balsamifera*	Y
Coniferous	PL	Pj	Jack pine	*Pinus banksiana*	Y
		Pl	Lodgepole pine	*Pinus contorta*	Y
		Lt	Tamarack	*Larix laricina*	N
	SB	Sb	Black spruce	*Picea mariana*	Y
	SW	Sw	White spruce	*Picea glauca*	Y
		Fb	Balsam fir	*Abies balsamea*	Y

2.5.3 Utilization Standards

Utilization standards applied to all yield curves are presented in Table 2-4. Choice of utilization specifications were in part driven by the GYPSY model: the model allows users to specify stump height, top and stump diameters, but log length is set at 3.66 m (not explicitly stated in the model, but was used for developing merchantable volume equations within GYPSY[7]).

The second driver for the choice of utilization specifications was RSA. Managed stand yield curves are used to set culmination mean annual increment (MAI) targets for silviculture reporting and evaluation purposes within the Alberta Reforestation Information System (ARIS). According to the RSA manual (AESRD 2014b), MAI targets must be based on a 15 cm stump diameter, a 10 cm top diameter, a 30 cm stump height, and a 3.66 m log length with no reduction for cull.

Table 2-4. Utilization standards.

Description	Conifer	Deciduous
Top Diameter Inside Bark (cm)	10	10
Stump Diameter Outside Bark (cm)	15	15
Stump Height (cm)	30	30
Minimum Log Length (m)	3.66	3.66
Cull (per cent)	2	4
Stand Retention	tbd	5

Cull & Stand Retention implemented during TSA – provided here for information purposes only.

Cull and stand retention are included in the summary of utilization standards for reference only; application of yield reductions to account for cull and stand retention are applied within the timber

[7] C. Tansanu, Alberta Environment and Sustainable Resource Development, Pers. Comm. 2014.

supply analysis. Percent cull is based on numbers used in the approved 2006 Al-Pac FMA Area Forest Management Plan. Stand retention numbers are based on the current 2015 NE Alberta Operating Ground Rules and a new FMP target for conifer blocks. Stand retention values are not applicable to understorey protection harvesting activities.

2.5.4 Regeneration Lag

In managed stands, regeneration lag is incorporated into the yield curve development process by using skid clearance to determine stand age, while using plot-based species ages to initiate growth.

2.6 Available Data

Essential features of sample selection and data collection procedures used for yield curve development are briefly summarized here. For specific details on each sampling program, please refer to the documents referenced in each section. Data Dictionaries are provided as separate digital documents with the yield curve submission.

2.6.1 Permanent Sample Plots

Alberta-Pacific began establishing permanent sample plots (PSPs) on their FMA area in 1994. Sampling protocols were based on the government field manual in effect at that time (LFS 1994, ASRD 2005). The majority of Alberta-Pacific's natural stand PSPs were established between 1994 and 2001, with additional establishment at a slower rate until 2005. Beginning in 2000, PSPs were also established in managed stands under the same protocols. Five PSPs of this type were placed in strip cut understorey protection stands in 2001-2002.

The sampling frame for natural stand PSP establishment included all stands in the timber harvesting landbase. Priority was given to larger stands since they represented more area within the landbase. The objective for sample selection was to obtain a good distribution of samples by broad cover group, age class and Forest Management Unit (FMU). The distribution of plots by FMU is shown in Table 2-5.

Table 2-5. Distribution of PSPs by FMU.

		Managed[1]		
FMU	**Natural**	**CC**	**UP**	**Total**
A14	25	1		26
A15	26			26
L1	32	9	1	42
L2	19	4	4	27
L3	26			26
L8	12	2		14
L11	67	16		83
S7	23			23
S11	25			25
S14	20			20
S18	38	7		45
S22	29			29
Total	342	39	5	386

[1]CC= clearcut; UP = understory protection.

One PSP plot was established in each selected stand. Plot locations were pre-determined and plots were offset only if the entire plot did not fit into the target cover type, or if the plot did not fall in a homogeneous type. If a minimum of 50 trees was not achieved within a 1000 m^2 main plot, plot size was increased to 1500 m^2 or 2000 m^2 as required (LFS 1994). Plots were only offset if a plot size of 2000 m^2 could not meet the minimum target (which equates to less than 250 stems/ha).

PSP plots are between 1000 and 2000 m^2 in size, with a nested sapling and regeneration subplot located in the NW corner of the main plot, 1/16 the size of the main plot. In 2000, when PSP protocols began to be used for data collection in managed stands, a new rule was introduced for high density stands: high density plots could be reduced to 62 m^2 in size, including the main plot. In some cases, existing natural stand PSPs were downsized to this specification at re-measurement; conversely, the sapling plot size in some low density plots was increased to the main plot size. In 2011 Alberta-Pacific began the process of converting all plots back to their original plot design.

Within the main plot, all trees ≥ 9.1 cm in size were tagged and measured for diameter at breast height (DBH), height, and height to live crown. Crown position and condition codes were also recorded for each tree. The same measurements were taken for saplings (height ≥ 1.3m, and between 1994 and 1996, DBH ≥ 1.1 cm) within the sapling plot. All regeneration (trees ≥ 10 cm tall and below sapling height and/or DBH minima) within the regeneration plot was tallied by species and height class.

Age trees were sampled, generally at first measurement, within the buffer adjacent to the main plot. There was no fixed plot size for selection. A minimum of 3 dominant/codominant trees of each major species were selected for sampling, with no restriction to exclude veteran trees. For each tree, height, DBH, breast height age and stump height age were collected (where not impacted by rot). Detailed stem sectioning data were also obtained, mainly for the 1994-1996 installs.

In 2012, Alberta-Pacific began measuring top height in all PSPs at re-measurement[8]. Within a 300 m^2 plot located in the PSP buffer, the three largest diameter trees by species were selected for top height sampling, regardless of crown position. Veteran or advance trees were excluded from selection. Location of age measurement depended on tree size and age: for larger mature trees, age was taken at breast height; in younger stands, either total age (based on whorl counts) or root collar (based on cookies) age was collected.

Further details can be found in the *Permanent Sample Plot Field Procedures Manual* (LFS 1994) and *Alberta-Pacific PSP Re-Measurement Program: Field Protocols* (Froese Forestry Consulting 2014b).

2.6.2 Natural Stand Temporary Sample Plots

Alberta-Pacific undertook three temporary sample plot programs between 2002 and 2008 (all approved by AESRD), focusing sampling effort on three strata of interest:

- Pure deciduous (including deciduous with coniferous understorey) with a B, C or D AVI crown closure class (112 stands);
- Pure black spruce with a timber productivity rating (TPR) of good (124 stands); and
- Pure pine (no exclusions based on TPR or crown closure) (102 stands).

The sampling frame included only natural stands within the timber harvesting landbase as defined in the 2004 landbase netdown (Timberline 2005). Priority was given to larger stands since they represented

[8] Currently every 5 years until age 40, then every 10 years thereafter.

more area within the landbase. Black spruce and pine samples were selected proportionally to crown closure class, height class and TPR. Deciduous samples were selected proportionally to defined deciduous subgroups (see Timberline 2008), TPR and age class.

Three 100 m^2 plots were established in each selected stand, using a triangular plot layout. Plots were offset from active roads and other anthropogenic disturbances (including seismic disturbance), and to ensure that the entire plot fell within the target polygon. Plots were not offset from gaps or other non-forested/low density areas.

Within each plot, all trees (live and dead) ≥ 7.1 cm DBH were measured for DBH. Crown position (dominant, codominant, intermediate and suppressed) and condition codes were recorded for each tree. Where overstorey height was relatively uniform, two heights were measured per crown position. Where heights were variable, a total of four trees were measured across the range of heights. Height measurements did not exclude trees with broken or damaged tops.

Breast height ages (plus heights) were collected on all plots as follows:

- One storey/single species: select one dominant and two codominant.
- One storey/two species: select two trees of each species.
- One storey/multiple species: select two trees of each of the three dominant species.
- Complex with multiple species/size classes: up to 6 trees representative of the predominant species/size classes.

See *Alberta-Pacific Timber Supply Analysis: Jack Pine Yield Estimates* (Timberline 2007) and *Deciduous Forest Stands (D, D(C), DU) Temporary Sample Plot (TSP) Program for the Al-Pac FMA Area* (Timberline 2008) for further details on field protocols.

2.6.3 Managed Stand Temporary Sample Plots

Establishment of managed stand TSPs began in 2012. The program in 2012 focused solely on pure deciduous cutblocks, while the 2013 program targeted a number of regenerating stand types in order to fill data in mixedwood and conifer blocks. In 2013, mixedwood cutblocks were also differentiated into tended and untended portions, which were sampled as separate populations. Selection of stands was random (not selected with probability proportional to size). A total of 44 openings were sampled within the 2-year window: 20 samples in pure deciduous openings, and 24 samples in coniferous and mixedwood openings. Because mixedwood openings generally had two installations (one in each of the tended and untended portions of the opening), a total of 37 installations were actually established in 2013.

Three 100 m^2 plots were established in each selected stand, using a triangular plot layout. Plots were offset from active roads and other anthropogenic disturbances, unharvested patches, lakes and permanent/ semi-permanent streams, and seismic initiated after reforestation activities. Plots were not offset from gaps, in-block roads or other non-forested/low density areas. Plots were permanently marked and GPS'd to allow for future re-measurement if desired.

Within each plot, all conifers ≥ 0.3 m in height and all deciduous ≥ 1.3 m in height were tallied by species and origin (advance, post-harvest or post-tending). Conifers were also tallied separately above and below 1.3 m to allow calculation of basal area. In plots with high densities of deciduous stems, a half size plot was used for tallying deciduous species.

Ten trees by species and origin were measured for DBH and height. In addition, all "volume trees" (trees ≥ 7.1 cm DBH) were measured for DBH, with a minimum of 2 trees per species also measured for height. Dead trees were excluded from all measurements.

A 100 m^2 top height plot was established outside of each TSP plot to allow for destructive sampling. The largest diameter tree by species group was selected for height and age sampling. Initially, total age was collected, but in 2013 protocols were changed to measurement at 10 cm above the root collar for ease of destructive sampling (total age could still be recorded when based on a whorl count).

Further details can be found in *Alberta-Pacific Post-Harvest TSP Program: Field Protocols* (Froese Forestry Consulting 2013b).

2.6.4 Regeneration Standard of Alberta Performance Surveys

Regeneration Standard of Alberta (RSA) performance surveys collect detailed plot information within sampling units which can be at the opening or sub-opening level (AESRD 2013). The sampling frame for performance surveys in a given year was defined as all openings between 12 and 14 years of age belonging to a specific sustained yield unit[9].

RSA data were available from Alberta-Pacific as well as the majority of quota holders. The number of ground-sampled SUs available for yield curve development is presented in Table 2-6.

Openings were subdivided into sampling units (SUs) either via aerial photography (for larger programs) or field reconnaissance (for smaller programs, also called non-photo programs). Aerial programs employ a subsampling method in which a smaller subset of SUs were selected for ground sampling, whereas non-photo programs require a full ground sample (census) of SUs. Up to and including the 2013-14 timber year (the effective date for Alberta-Pacific's use of RSA data), the method for selecting aerial samples involved a slightly biased sample selection, which then required a complicated determination of a composite weight needed to account for this bias during the calculation of averaged results (described in detail in AESRD 2013).

Within SUs selected for ground sampling, 10 m^2 plots were established using a grid-based method, with the number of plots varying depending on SU size and type of program. The number in aerial programs ranged from 32-64 plots, and in non-photo programs generally ranged from 41 plots up to 2.77 plots/ha in larger SUs.

Data were collected on conifer ≥ 0.3 m in height and deciduous ≥ 1.3 m in height. The following information was collected:

- Every plot: tally trees by species and type (seedling vs. advanced), with a separate tally for pine with western gall rust.
- Every 4th plot: within a 100 m^2 plot centered around the 10 m^2 plot, select the largest DBH tree by species group and record height, DBH (optional) and total age.
- Every 4th plot (optional): within the 10 m^2 plot, measure DBH and height (optional) of the 1st three trees by species group and type (seedling or advanced) and tally the number of seedling conifers above and below 1.3 m by species (to allow for calculation of basal area).

[9] A sustained yield unit is defined as the unit upon which an annual allowable cut is calculated; i.e., the area within which a single timber supply analysis was run.

For more details on RSA performance survey programs and protocols, please refer to the *Reforestation Standard of Alberta* (AESRD 2013).

Table 2-6. Distribution of RSA performance surveys by location, company and management regime.

Company	Program Year	Program Type	Total # of Openings	Ground Sampled Openings	Ground Sampled SUs
Alberta-Pacific	2009-2010	Aerial	30	25	40
	2010-2011	Aerial	77	27	37
	2011-2012	Aerial	80	25	32
	2012-2013	Aerial	52	19	25
	2010-11	Non-Photo[1]	15	15	15
Alberta Plywood	2010-11	Aerial	42	18	22
	2010-11	Aerial	36	17	23
FRIAA	2009-10	Aerial	52	26	35
	2009-10	Non-Photo	21	21	25
	2010-11	Non-Photo	7	7	7
	2011-12	Non-Photo	10	10	10
	2012-13	Aerial	32	22	31
Millar Western	2009-2010	Aerial	42	18	22
	2009-2010	Non-Photo	1	1	1
	2010-2011	Aerial	137	23	43
	2012-2013	Non-Photo	3	3	3
	2012-2013	Non-Photo	35	35	35
Vanderwell	2010-2011	Aerial	57	50	52
Northland	2010-11	Non-Photo	6	6	6
Spruceland	2010-11	Non-Photo	28	28	28
Total			763	396	492

[1]Test deciduous performance surveys established by AESRD in Alberta-pacific cutblocks.

2.6.5 Non-Legislated Regeneration Standard of Alberta Performance Surveys

In 2013, 11 non-legislated RSA surveys were carried out in S14, with the objective of increasing sample size in the AwSx and SxAw yield strata for intensive management yield curves. Sample selection was undertaken as part of the 2013 TSP program (population), but data collection followed the Regeneration Standard of Alberta, non-photo system protocols (AESRD 2013). These data are referred to as "TSP-RSA" when used for intensive management yield curve development.

Note that 3 openings in this population were included as part of the 2010-2011 Alberta Plywood RSA program, but were not selected for ground survey; as such, they were deemed eligible for TSP sampling purposes.

2.6.6 Alberta Regeneration Surveys Transitioning to PSPs (ATP) Program

Alberta-Pacific's ATP Permanent Sample Plot Installation program began in 2010 in managed stands. Each year, Alberta-Pacific selected between 10 and 15 RSA performance-surveyed SUs and converted them into re-measured installations. Selection of plots was inversely proportional to composite weightings, theoretically resulting in a random sample (not selected with probability proportional to size). A total of 49 installations were established by 2013; no re-measurements have yet been taken[10].

The design is relatively complex: in each selected SU, 32-40 RSA plots (8-10 of which are detailed plots) were selected to become part of the installation. All basic plots remained basic plots, and data collection was the same as in RSA performance surveys. In the first year, basic plot data from the RSA performance survey were used to populate the database. All detailed plots were subsampled for height and DBH in a manner similar to RSA survey protocols, but by species instead of species group, and for both seedlings and advanced trees. These plots provide a stand-level re-measure of density and stocking over time for evaluation/calibration of growth models. In the first two years, top height was also measured at each detailed plot in a manner similar to RSA survey protocols (except by species instead of species group), but in 2013 protocols were changed to measuring top height in subplots outside of ATP100 and ATP400 plots (see next).

Three detailed plots were also selected for additional “ATP100” measurements, which involved measurement of height and DBH of all conifers ≥ 0.3 m in height and all deciduous ≥ 1.3 m in height within a 100 m^2 plot (with rules for subsampling height by species in high density plots). These plots provide unbiased TSP-style data (i.e. trees are not tagged) that is re-measured over time, and primarily addresses data needs for yield curve development.

In approximately 1/3 of selected SUs, an additional detailed plot was selected for “ATP400” (PSP-style) measurements. These plots are primarily intended for model development and calibration purposes. A 400 m^2 main plot was established and all live trees ≥ 5.1 cm DBH plus all planted conifers were tagged and measured (for height, DBH, height to live crown, crown position and condition codes). A 100 m^2 nested subplot (at the centre of the main plot) was used to tag and measure the same information for all conifers ≥ 0.3 m in height and all deciduous ≥ 1.3 m in height. Again, rules for subsampling heights by species were employed in high density plots.

Top height was collected in a 100 m^2 plot outside of each ATP100 and/or ATP400 plot. The largest DBH tree was selected by species and sampled for height and age. Initially total age was collected, but in 2013 the protocols were changed to measurement at 10 cm above the root collar for ease of destructive sampling (total age could still be recorded when based on a whorl count).

Detailed field protocols are described in the *Alberta-Pacific ATP Program: Field Protocols* (Froese Forestry Consulting 2013a).

[10] Installations are re-measured every 5 years until age 40, and every 10 years thereafter.

3 Natural Stand Yield Curves (Group A)

Standing timber yield curves representing all fire origin (natural) stands within the Alberta-Pacific FMA area (yield curves 1-9) as well as the pine and black spruce strata in extensive and intensive management stands.

3.1 Approach

Alberta-Pacific's preference for yield curve development was to use growth models for creating yield projections, rather than pursue a regression-based approach. The approach for natural stand yield curve development was constrained by availability of growth models: GYPSY is currently the only approved growth model for the Province of Alberta.

A second constraint was the Alberta Planning Standard's (2006) requirement to use (or at least validate yields against) inventory-based ages. The GYPSY model was thus used in a semi-empirical fashion whereby top height and basal area at inventory age were used to constrain model projections; this is described in further detail in Section 3.5.1.

3.2 Input Datasets

3.2.1 Source Data

All PSPs defined as natural origin in the Alberta-Pacific database were included in the preliminary set of plot data. The PSP data had been re-formatted to Provincial Growth and Yield (PGYI) specifications on February 22, 2014; this format was used for data compilation since this is likely to be the specification for future datasets. For further details see AESRD (2014a) and Tesera (2013). All 2002-2008 TSP data from natural stands (targeted programs in pure deciduous, pine and black spruce strata) were also included. Descriptions of the datasets are provided in Sections 2.6.1 and 2.6.2 respectively.

Note that unlike many other yield curve development processes, Alberta-Pacific has chosen to combine TSP data at the stand level, rather than treat each TSP as an individual observation (which inflates the number of individual observations, but ignores the fact that the data come from the same stand and are therefore not independent). As such, when referring to the "number of TSPs", this document is in fact referring to the number of stands with TSPs.

3.2.2 Yield Stratum Assignment

A preliminary set of attributes was extracted from the landbase (Version 6: June 11, 2015). Attributes for PSPs were obtained via a spatial linkage, and attributes for TSPs were extracted using an aspatial linkage via AVI opening number.

For natural stands, assignment of yield strata was based primarily on AVI overstorey attributes, with the exception of identifying deciduous stands with a coniferous understorey.

Table 3-1. Criteria for assigning yield strata to natural stands within the timber harvesting landbase.

		Overstory				Understory		
Yield Stratum	AESRD Stratum	Broad Cover	Crown Closure	Leading Conifer	TPR	Broad Cover	Crown Closure	Leading Conifer
Aw	I	D	B, C, D	any	any	D / none		
AwU	I	D	B, C, D	any	any	C/CD/DC	A, B, C, D	any
AwSx	III	DC	any	Sw, Sb	any	any		
SxAw	IV, VI	CD	any	Sw, Sb	any	any		
Sw	VII	C	any	Sw	any	any		
SbFM[1]	IX	C	any	Sb	F, M	any		
SbG	IX	C	any	Sb	G	any		
PjMx	II, V	CD, DC	B, C, D	Pj	any	any		
Pj	VIII	C	any	Pj	M, G	any		

[1]The SbFM stratum is only part of the timber harvesting landbase in FMUs L3 and A14. Millar Western is the only quota holder with AAC in this stratum.

As per the Alberta Planning Standard (ASRD 2006) Section 4.2.4.a, the calibration of yield projections for natural stands must be based on plot data from the Al-Pac FMA area. Alberta-Pacific opted to utilize most plots within the FMA area for natural stand yield curve development, with the exception of the following management and subjective deletions:

- "A" density crown closure in Aw, AwU and PjMx stands – inoperable stands;
- White birch leading stands on wet sites – meet non-timber wildlife objectives;
- Larch stands - inoperable stands; and
- Unproductive stands (TPR=U) - inoperable stands.

All other plots in the FMA proper inside or outside of the final net landbase were used in calibrating the natural yield curves[11].

However, the validation of natural stand yield curves were based on the last measurement of the plots that are within the harvestable netdown landbase (standing timber).

3.2.3 Data Exclusions

The following deletions from the initial dataset were applied (also see Table 3-2):

- Outside timber harvesting landbase based on subjective deletions defined by Alberta-Pacific: as described in Section 3.2.2.
- Inventory/landbase deletions:
    - CC modifier: AVI with a CC modifier indicating that the stand has been harvested.
    - Burned: stand burned after plot establishment.
    - No linkage to AVI: aspatial linkage via AVI polygon number was unsuccessful.
- Plot data issues:

[11] D. Cheyne, Alberta-Pacific, Pers. Comm. 2015.

- Outliers: 6 plots had very atypical volumes and were removed from the dataset.
- Header but no plot data: 4 TSPs had header information but were missing plot data.
- Juvenile nil tally: 3 TSPs were in stands too young to have trees ≥ 7.1 cm DBH.

The final number of observations by yield stratum is shown in Table 3-3.

Table 3-2. Natural stand data exclusions.

Plot Deletions		Number of Observations PSP	TSP	Total
Initial number of plots/stands[1]		**342**	**342**	**684**
Outside Active Landbase	A density crown closure	8	5	13
	Larch	1	1	2
	White birch leading stands on wet sites	3	0	3
	TPR U	0	1	1
Inventory/Landbase	CC modifier	1	0	1
	Burned	23	11	34
	No linkage to AVI	2	14	16
Plot Data Issues	Outlier/Suspect	4	2	6
	Header but no plot data	0	4	4
	Juvenile nil tally	0	3	3
Total observations used for natural yield curves		300	301	601

[1]PSPs represent the number of individual plots; TSPs represent the number of stands (3 plots/stand)

Table 3-3. Number of observations, by yield stratum, used in natural stand yield curve development.

Yield Stratum	PSP	TSP	Total
Aw	83	73	156
AwU	59	29	88
AwSx	30	2	32
SxAw	22	2	24
Sw	39	1	40
SbFM	10	0	10
SbG	9	51	60
PjMx	14	1	15
Pj	34	142	176
Total	300	301	601

[1]PSPs represent the number of individual plots; TSPs represent the number of stands (3 plots/ stand)

3.2.4 Landbase Representation

The representation of the net landbase by the PSP and TSP data is shown by height class in Table 3-4 and by age class in Table 3-5.

Table 3-4. Distribution of natural stand plots and landbase area by height class.

Yield Stratum	Metric	Actual by Height Class (m) 1-5	6-10	11-15	16-20	21-25	26+	Percentage by Height Class (m) 1-5	6-10	11-15	16-20	21-25	26+
Aw	Area (ha)	9,172	34,605	65,671	228,726	137,161	27,782	1%	2%	4%	14%	8%	2%
	# Plots[1]		6	16	55	51	12		1%	3%	11%	11%	3%
AwU	Area (ha)	3,016	11,363	64,884	183,279	94,422	14,243	0%	1%	4%	11%	6%	1%
	# Plots[1]	1	7	9	28	24	5	0%	1%	2%	6%	5%	1%
AwSx	Area (ha)	428	3,858	10,939	16,762	30,559	20,003	0%	0%	1%	1%	2%	1%
	# Plots[1]		2	1	4	16	5		0%	0%	1%	3%	1%
SxAw	Area (ha)	1,833	2,238	5,184	7,158	13,936	36,556	0%	0%	0%	0%	1%	2%
	# Plots[1]		1	2	4	3	9		0%	0%	1%	1%	2%
Sw	Area (ha)	4,469	5,524	9,745	28,302	49,569	74,457	0%	0%	1%	2%	3%	5%
	# Plots[1]	1			5	6	21	0%			1%	1%	4%
SbFM	Area (ha)	242	1,918	26,703	3,527	53		0%	0%	2%	0%	0%	
	# Plots[1]				1						0%		
SbG	Area (ha)	218	13,152	42,655	12,214	411		0%	1%	3%	1%	0%	
	# Plots[1]		3	24	16				1%	5%	3%		
PjMx	Area (ha)	2,853	2,895	13,022	21,303	5,483	605	0%	0%	1%	1%	0%	0%
	# Plots[1]		1	4	4				0%	1%	1%		
Pj	Area (ha)	1,161	17,109	141,613	98,240	12,312	348	0%	1%	9%	6%	1%	0%
	# Plots[1]		5	30	67	30			1%	6%	14%	6%	

[1]PSPs represent the number of individual plots; TSPs represent the number of stands (3 plots/stand).

Table 3-5. Distribution of natural stand plots and landbase area by age class.

Yield Stratum	Metric	Actual by Age Class 1-50	51-100	101-150	151-200	200+	Percentage by Age Class 1-50	51-100	101-150	151-200	200+
Aw	Area (ha)	31,200	378,727	87,044	6,132	14	2%	23%	5%	0%	0%
	# Plots[1]	4	104	30	2		1%	22%	6%	0%	
AwU	Area (ha)	11,220	298,588	58,681	2,718		1%	19%	4%	0%	
	# Plots[1]	6	51	17			1%	11%	4%		
AwSx	Area (ha)	2,339	35,161	37,692	7,354	3	0%	2%	2%	0%	0%
	# Plots[1]	1	11	14	2		0%	2%	3%	0%	
SxAw	Area (ha)	1,968	9,791	32,735	22,356	55	0%	1%	2%	1%	0%
	# Plots[1]		6	7	6			1%	1%	1%	
Sw	Area (ha)	4,044	27,025	91,493	48,971	532	0%	2%	6%	3%	0%
	# Plots[1]	1	4	19	9		0%	1%	4%	2%	
SbFM	Area (ha)	250	2,206	25,337	4,522	127	0%	0%	2%	0%	0%
	# Plots[1]				1					0%	
SbG	Area (ha)	278	26,843	38,176	3,352		0%	2%	2%	0%	
	# Plots[1]		6	36	1			1%	8%	0%	
PjMx	Area (ha)	5,011	34,997	5,521	633		0%	2%	0%	0%	
	# Plots[1]		9					2%			
Pj	Area (ha)	6,355	235,630	27,242	1,556		0%	15%	2%	0%	
	# Plots[1]	1	86	41	4		0%	18%	9%	1%	

[1]PSPs represent the number of individual plots; TSPs represent the number of stands (3 plots/stand).

Overall, there is reasonably close representation of the landbase by height class; although the medium height classes (11-20m) in the AwU stratum are underrepresented while the 16-20m height class is overrepresented in the same stratum. There is also reasonably close representation of the landbase by age class. There is an underrepresentation of the 51-100 years age class in the AwU stratum and overrepresentation occurs in the 101-150 years age class in the SbG and Pj strata.

3.3 Data Preparation

In preparation for the 2015 FMP, Alberta-Pacific spent considerable time reviewing and, where possible, correcting all of their PSP data using validation code which provided checks within and between measurements for each plot. Paper files were reviewed where necessary. Both datasets (PSP and TSP) were then reviewed to ensure that there were no additional outlier observations that required resolution.

3.3.1 Deletions

All trees with “dead” or “missing” condition codes were removed from each dataset. Age trees (which were sampled within the plot buffer) were removed from the PSP dataset and reserved for site index and age calculations. Two trees that were under 1.3 m in height were deleted from the PSP dataset. All larch trees were also removed from the dataset since these are ineligible species[12]. In addition, four PSP re-measurements were removed from the dataset due to issues with plot data that could not be resolved at that time.

3.3.2 Missing Diameters

Missing diameters from trees ≥ 1.3 m tall were filled in using the DBH from the previous measurement; if this was not available, the DBH from the subsequent measurement was used. In the three remaining cases, DBH values were obtained from a measurement of the tree after it had died.

3.3.3 Missing Heights

Missing heights were predicted using Huang et al.’s new *Population and Plot-Specific Individual Tree Height-Diameter Models for Major Alberta Tree Species* (Huang *et al*. 2013). The ratio of means approach as described in Huang *et al*. was used to adjust (localize) predicted heights based on available trees with measured heights, as described in the following paragraphs.

All trees with measured heights were given a predicted height using Huang *et al.*’s equations. These data were then screened to remove trees with broken or dead tops, severe lean, and/or unusual height-diameter relationships. An average ratio of predicted to actual height was calculated by species, which was used to adjust the predicted heights of trees without an actual measurement. Ratios were calculated using the following rules:

- PSPs: use ratio of means by species, plot and measurement; if no trees for that species are available, then use a ratio of means by species and plot (across measurements).

[12] Removing larch can affect the competitive interactions between species, e.g. altering the species composition inputs in GYPSY, however, since pine and larch are combined into a single species group for GYPSY modelling purposes, it cannot be removed from the model outputs, only the inputs.

- TSPs: use ratio of means by species and individual TSP plot; if no trees for that species are available, then use a ratio of means by species across all plots within the stand.

Any remaining trees without a valid ratio were assigned an unadjusted predicted height.

3.4 Data Compilation

Data were compiled to create species group-level inputs for the GYPSY model; these inputs could then be combined to create volume estimates by species type (coniferous vs. deciduous) for yield validation. Average density, basal area, volume were calculated on a unit-area (per hectare) basis by stand and species group. Top height, site index and age were calculated by stand and species group. Note that all compilation was by plot and measurement for PSPs, and by stand for all TSPs.

3.4.1 Density

Tree factors (number of stems represented by each sampled tree) were assigned to each tree in the tree list based on the inverse of plot size. TSP plots were all the same size (100 m^2); trees in the PSP dataset were assigned tree factors as follows:

- Trees ≥ 9. 1 cm DBH were assigned a tree factor based on the main plot size; and
- Trees < 9.1 cm DBH were assigned a tree factor based on the sapling plot size.

Plot size was defined at each measurement to ensure that those PSP plots with changes in plot size were correctly characterized. Tree factors were then summed by species group for each PSP measurement. Tree factors were summed by species group for each TSP plot, and then averaged across all TSPs in the stand (including nil tally plots). The sum of the tree factors represents density (stems/ha) by species group for each plot/measurement (PSPs) or stand (TSPs).

Densities were adjusted in eight young natural stand PSPs (plots with an AVI origin of 1970 or greater). In those plots, coniferous regeneration ≥ 0.3 m and deciduous regeneration ≥ 1.3 m were included in the density calculation[13]. Regeneration was not included for older PSPs since high densities of small shade tolerant ingress in mature stands could impact GYPSY model simulations in a non-meaningful manner.

3.4.2 Basal Area

Basal area (cross-sectional area of each tree at 1.3 m above point of germination, represented in m^2) was calculated for each tree from measured DBH. Basal area values were then multiplied by each tree factor. Resulting values were summed by species group for each PSP by measurement, and summed by species group for each TSP plot and averaged across all TSPs in a stand.

3.4.3 Volume Compilation

Both gross and merchantable volumes were determined for each tree in the dataset. Volume compilation followed a standardized process developed based on equations and coefficients provided in Huang's (1994b) *Ecologically Based Individual Tree Volume Estimation for Major Alberta Tree Species*. Trees with zero merchantable volume were assigned a value of 0.

[13] Since the PSP dataset used was formatted to PGYI standards, only regeneration meeting these minimum criteria were included in the original regeneration data table.

Gross and merchantable volumes were then multiplied by each tree factor. Resulting values were summed by species group for each PSP by measurement, and summed by species group for each TSP plot and then averaged across all TSPs in a stand.

3.4.4 Top Height

Top height was calculated by selecting the *n* largest DBH trees, by species group, from within the main plot. The target sample size for top height was 1 tree per 100 m^2 of plot size. Trees marked as veteran, dead, or with a broken or damaged top were excluded from selection.

For PSPs, only trees with measured heights were selected as top height trees (i.e., trees with predicted heights were excluded). In early years of PSP measurement tree heights were subsampled, therefore *n* was adjusted by the proportion of trees with measured heights.

In TSPs, a smaller subsample of trees had height measurements, and trees were generally selected for measurement by crown position; this could result in a non-representative sample within plots if used to determine top height. As such, all trees were included for top height selection regardless of whether heights were measured or predicted (recall that predicted heights were localized using measured plot data).

Average top height was then calculated for each PSP measurement/TSP stand by species group.

3.4.5 Stand Age

Stand age was calculated for each plot/measurement using inventory age and grow year. Grow year was based on the year of plot measurement; measurements on or after July 1 were considered part of the current calendar year, measurements prior to July 1 were considered part of the previous year's growing season (i.e., *grow year = measurement year – 1*).

3.4.6 Species Group Age

3.4.6.1 Age Calculations

Age trees were selected in a manner similar to top height tree selection. The *n* largest DBH trees per plot were selected with a target sample size for top height of 1 tree per 100 m^2 of plot size. Trees marked as veteran, dead, or with a broken or damaged top were excluded from selection.

In PSPs, age trees were sampled within the buffer, with a target of 3 trees per species, and in some cases by canopy layer (resulting in more than three trees per species). Some plots were sampled again at re-measurement. From the age tree dataset, the three largest diameter trees by species group were selected for each plot and measurement, as follows:

- Either aspen or poplar could be selected (no preference was given to species), but birch was only selected where no other deciduous species were available.
- White spruce was preferentially selected over fir.

In TSPs, multiple ages were measured within each 100 m^2 plot. The single largest diameter tree by species group was selected from each plot, using the same species preferences listed above.

Breast height and stump height ages were converted to total age using years to breast/stump height assumptions listed on page 5 of Huang et al. (2009a). No minimum number of observations by species group was required, however, birch was only included in calculations of the aspen species group age when no other deciduous species were present.

Because ages were sometimes re-evaluated at PSP re-measurement, but not every re-measurement necessarily had an age measurement, data were normalized and then used to create an observation for each PSP measurement. The procedure was as follows:

5. Calculate average age by species group for each plot/measurement.
6. Calculated origin year of each averaged age based on age and grow year[14] (*origin = grow year – age*).
7. Calculate average origin year by species group across all available measurements.
8. Append average origin year back onto to each plot/measurement.
9. At each measurement, calculate age for each species group as (*age = origin year – grow year*).
10. Where age was unavailable for a species group, age was taken from the AVI inventory (*age = AVI origin – grow year*).

The same approach was used for averaging TSP ages across plots.

3.4.6.2 Age Adjustments

Because yield curves were intended primarily to represent standing timber volumes, and because the Alberta Planning Standard (ASRD 2006) requires use of inventory age for model validation, age adjustments were required to align “plot” age with “stand” age (see rationale for this choice in Section 3.5.1). Adjustments were made as follows:

1. Determine the maximum plot age (stand initiation), defined as the maximum of deciduous or pine age, whichever is older, or spruce age if no deciduous or pine were present.
2. Cap spruce ages based on maximum age: if spruce age was greater than the maximum plot age, replace with the maximum age.[15]
3. Determine the difference between plot age and inventory age (*offset = stand age – max plot age*).
4. Adjust the age of each species group by the offset age (*adjusted age = species group age + offset*).

3.4.7 Site Index

Site index was calculated using the same dataset used for species group age calculations, with additional deletions as follows:

- All birch age trees.
- Deciduous or pine trees under 8 years total age and any spruce/fir under 10 years total age.

Site index was calculated for each age tree using GYPSY site index equations (Huang et al. 2009a). Site index was averaged across measurements for PSPs and across all plots for TSPs.

[14] If measurement month ≥ 7, grow year = measurement year; if measurement month < 7, grow year = measurement year - 1.
[15] This adjustment was necessary because in some cases, it was evident that veteran trees had been included in age data.

Where site index was not available, the average by yield stratum/species group was used to fill in missing values; if a SI value was not available for a specified species group within that yield stratum, an overall average was used.

3.5 Modelling

3.5.1 Growth Modelling Approach

The GYPSY growth model (Huang et al., 2009a and 2009b) was selected for model projections. Additional constraints governed how the model was used. The Alberta Planning Standard (ASRD 2006) requires use of inventory age for characterizing plots for yield validation. Several methods of implementing GYPSY were attempted before choosing the best approach for yield curve development within this constraint, as follows:

- Using plot-based stand age (taking the maximum observed species group age), site index and unadjusted (observed) species group age. Resulted in over prediction of volumes relative to inventory age-based validation data.
- Using inventory-based stand age, site index and unadjusted species group age. Resulted in under prediction of volumes at young ages, due to the fact that inventory age is generally much older than plot-based ages.
- Using inventory-based stand age, site index and unadjusted species group age; taking the resulting curve and shifting yields based on the average age difference between inventory and plot age. Resulted in an over prediction of volumes at mature ages.
- Using inventory-based stand age, site index and adjusted species group age. Resulted in over prediction of volumes relative to inventory age-based validation data.
- Using inventory-based stand age, top height and adjusted species group age. Resulted in good validation against inventory-based validation data, primarily due to the fact that the model is constrained to pass through an observed top height and basal area at a specified inventory age.

The last method was selected as the preferred approach since this more "empirical" use resulted in good correspondence with validation data at mature ages, and yield accumulation at young ages was more satisfactory than when using unadjusted plot ages.

3.5.2 Model Inputs

Inputs were provided as follows (for each PSP plot/measurement and for each TSP stand):

- Inventory-based stand age (based on AVI overstorey origin age); adjusted species group age, density, basal area and top height by species group.
- Percent stocking was left blank, as recommended by Huang (2009a) for use in natural stands.
- Site index was left for the model to calculate based on top height and age, for the reasons noted in Section 3.5.1. Where top height was not available (low density species, or young plots with regeneration data only), site index was included as an input and GYPSY was allowed to calculate top height.

Because GYPSY cannot project growth for low densities (≤ 30 stems/ha), any coniferous species groups present in densities under 30 stems/ha were merged into another coniferous species group. When this occurred, only the density input was modified on the target species group: basal area, top height, site index and age were not adjusted.

3.5.3 Model Outputs

The GYPSY model was run for each PSP measurement and for each TSP stand until age 300 (GYPSY grows the stand both backwards and forwards from the input condition, producing a yield output from age 0 to 300 for each observation). PSP yields were first averaged by plot across measurements to create a single result per PSP. PSP and TSP yields were then combined and averaged across all plots by yield stratum. Because plots were established with preference towards establishment in larger openings, weighting by polygon size (area) was not required[16].

3.5.4 Yield Adjustments

Decline due to breakup and mortality was underestimated in GYPSY, with yields showing insufficient reduction after maximum yield is expected. Alberta-Pacific chose to modify the resulting yield curves as follows:

- Deciduous volume (all yield strata): flat line deciduous volumes from 100 to 120 years, then implement a continuous decline in volume from ages 120 to 180, targeting zero volume at year 180.
- Coniferous volume (PjMx and Pj yield strata): flat line coniferous volumes from 95 to 105 years, then implement a continuous decline in volume from ages 105 to 180, targeting zero volume at year 180.
- Coniferous volume (all other yield strata): flat line coniferous volumes from 140 to 180 years, then implement a continuous decline in volume from ages 180 to 250, targeting zero volume at year 250.

3.5.5 Validation Statistics

Validation statistics were calculated using the most recent observation from each PSP and all TSP data. Percent bias, root mean squared error (RMSE) and the goodness of fit index (GOFI) were calculated for 1) the original unadjusted yield curves and 2) yield curves adjusted to account for mortality. Formulae are provided in Table 3-6.

Table 3-6. Formulae for natural stand validation statistics.

$Bias = \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)}{n}$	$Bias\% = \frac{Bias}{\bar{y}} \times 100$
$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{n}}$	$GoFI = 1 - \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2}$

[16] Generally, if initial sample selection includes probability of selection proportional to polygon size, simple averaging of the results is sufficient. In cases where completely random selection is undertaken, results should be averaged using polygon-based area weighting.

3.6 Results

3.6.1 Natural Stand Yield Curves

Preliminary (unadjusted) yield curves are presented in Figure 3-1. Final (adjusted) yield curves are presented in Figure 3-2. Adjustments for mortality have a considerable impact on final yields, particularly for the pine yield strata.

3.6.2 Validation Against Plot Data in the Net Landbase

Figure 3-3 presents the total merchantable yield for natural stands by yield stratum. Yields are compared against the **most recent observation** from PSP plots plus all TSP data grouped into 20-year intervals. **Only plots in the net landbase are used for yield validation**. Grey boxes represent the 95% confidence interval for the plot data, with the middle bar representing the mean. Green columns represent the number of observations in the validation dataset. Figure 3-4 presents the same information for deciduous volumes, and Figure 3-5 presents information for coniferous volumes. There is generally a good fit relative to validation data except at older ages.

Figure 3-6 presents the total merchantable yield for natural stands by yield stratum after mortality assumptions were applied. Yields are validated against the most recent observation from PSP plots plus all TSP data, grouped into 20-year intervals. Grey boxes represent the 95% confidence interval for the data, with the middle bar representing the mean. Green columns represent the number of observations in the validation dataset. Figure 3-7 presents the same information for deciduous volumes, and Figure 3-8 presents information for coniferous volumes. Older stand breakup is now better reflected, although in some cases yields are under predicted relative to the validation dataset.

3.6.3 Individual Growth Trajectories

Plot data were graphed against the natural stand yield curves; results are presented in Figure 3-9, Figure 3-10 and Figure 3-11 for total, deciduous and coniferous volumes, respectively. Data show the expected range of variability for this type of exercise.

3.6.4 Validation Statistics

Results are presented in Table 3-7. Percent bias is generally low, less than 10% for most yield curves. The SxAw yield curve shows a moderate level of under prediction for deciduous volume; however, since this yield curve is only supported by a modest number of plots, no upwards adjustment was made for this curve. In the AwSx, SxAw and Sw strata, adjusted deciduous yields show a poorer fit than original (unadjusted) curves; this is due to a lack of fit of older data points where curves have been reduced to reflect expected mortality trends. When adjusted, fit is improved for coniferous volumes for the pure Pj yield strata. The AwU yield curve also shows small under prediction for deciduous volume before and after the adjustment. The SbFM yield curve has only one plot available for validation as most PSPs are located outside the net harvestable landbase.

3.6.5 Final Yields

Final natural stand yield tables are provided in Appendix I.

Table 3-7. Fit statistics for original and adjusted natural stand yield curves.

Yield Stratum	# of Obs.	Curve Type[1]	Deciduous[2]		Coniferous[2]		Total	
			%Bias	RMSE	%Bias	RMSE	%Bias	RMSE
Aw	141	*Original*	*-3*	*105*	*1*	*42*	*-2*	*107*
		Adjusted	1	104	1	42	2	106
AwU	74	*Original*	*10*	*90*	*2*	*41*	*12*	*83*
		Adjusted	12	91	2	41	14	86
AwSx	28	*Original*	*-6*	*62*	*0*	*58*	*-6*	*73*
		Adjusted	5	62	0	57	5	65
SxAw	19	*Original*	*31*	*67*	*-10*	*81*	*21*	*87*
		Adjusted	54	86	-7	77	47	89
Sw	32	*Original*	*6*	*70*	*-3*	*103*	*4*	*113*
		Adjusted	23	77	3	104	27	121
SbFM	1	*Original*	*0*	*0*	*41*	*41*	*41*	*41*
		Adjusted	0	0	78	78	78	78
SbG	43	*Original*	*-1*	*13*	*-1*	*60*	*-2*	*68*
		Adjusted	0	13	-1	60	-1	68
PjMx	9	*Original*	*-6*	*36*	*-1*	*62*	*-7*	*46*
		Adjusted	-6	36	-1	62	-7	46
Pj	132	*Original*	*1*	*27*	*-11*	*72*	*-10*	*78*
		Adjusted	2	27	1	63	3	69

[1]Original = original unadjusted yield curves; Adjusted = curves adjusted for mortality assumptions

[2]Primary volume of interest shaded in blue

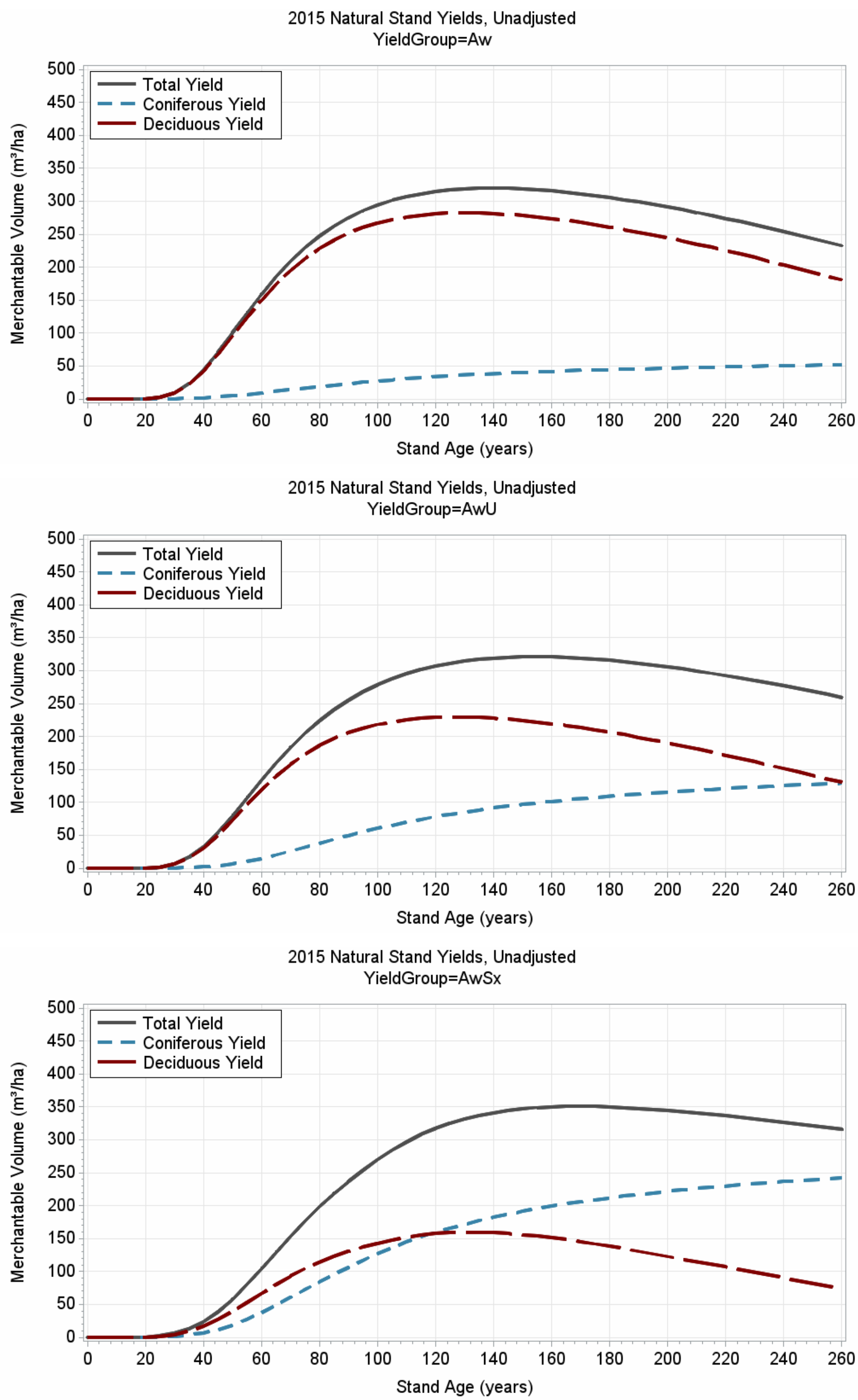


Figure 3-1. Natural stand yield curves, unadjusted.

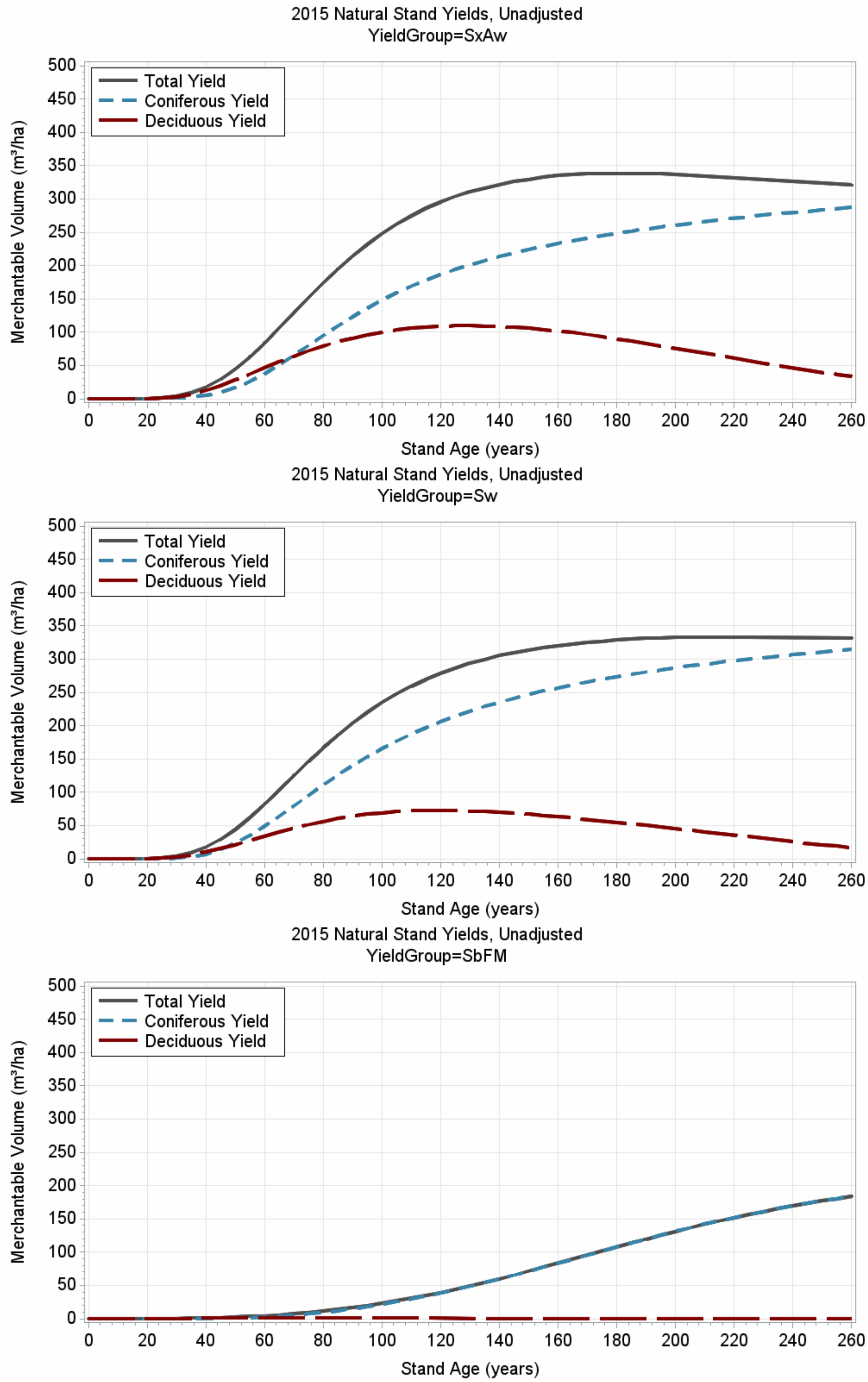


Figure 2-1. Natural stand yield curves, unadjusted.

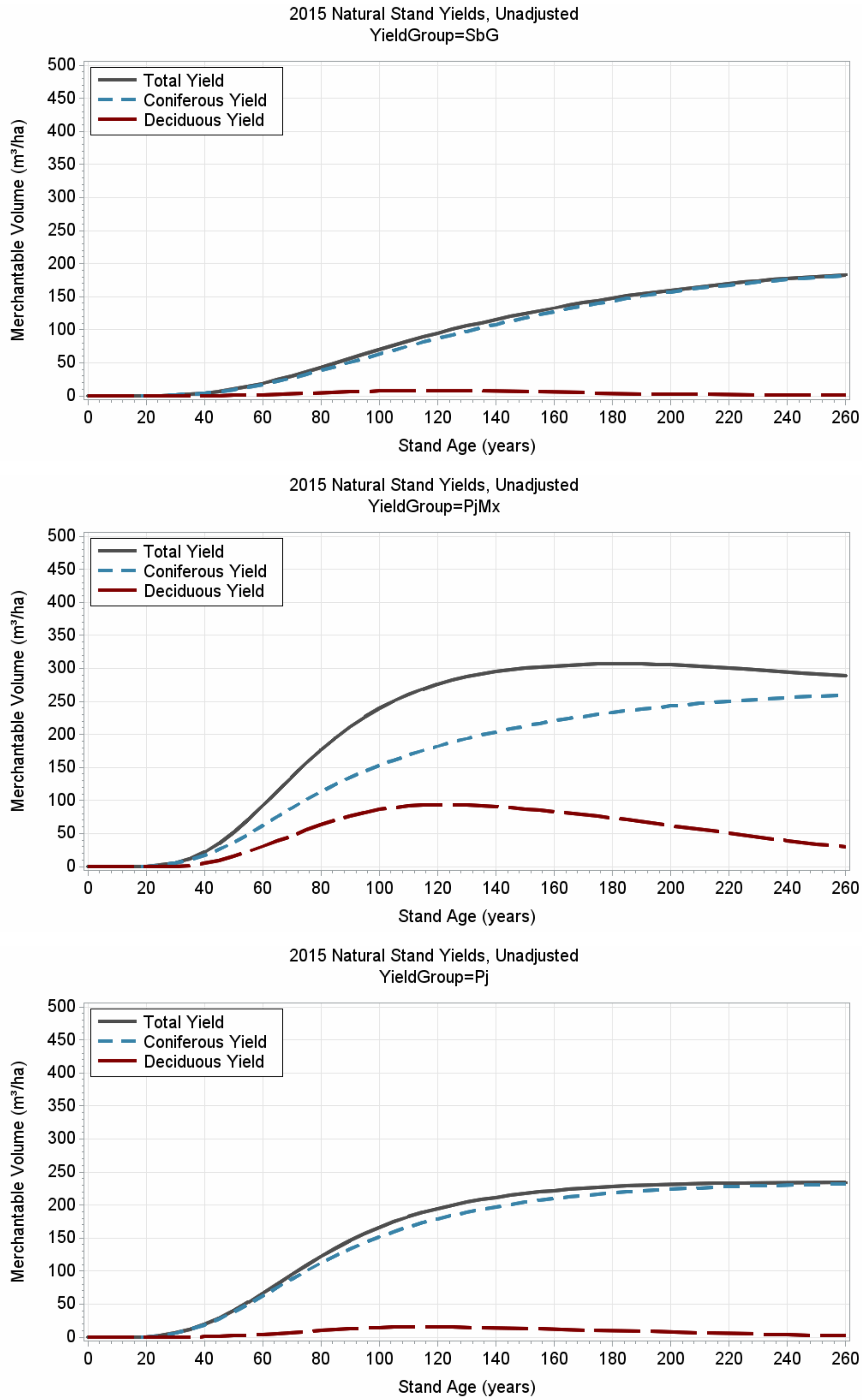


Figure 2-1. Natural stand yield curves, unadjusted.

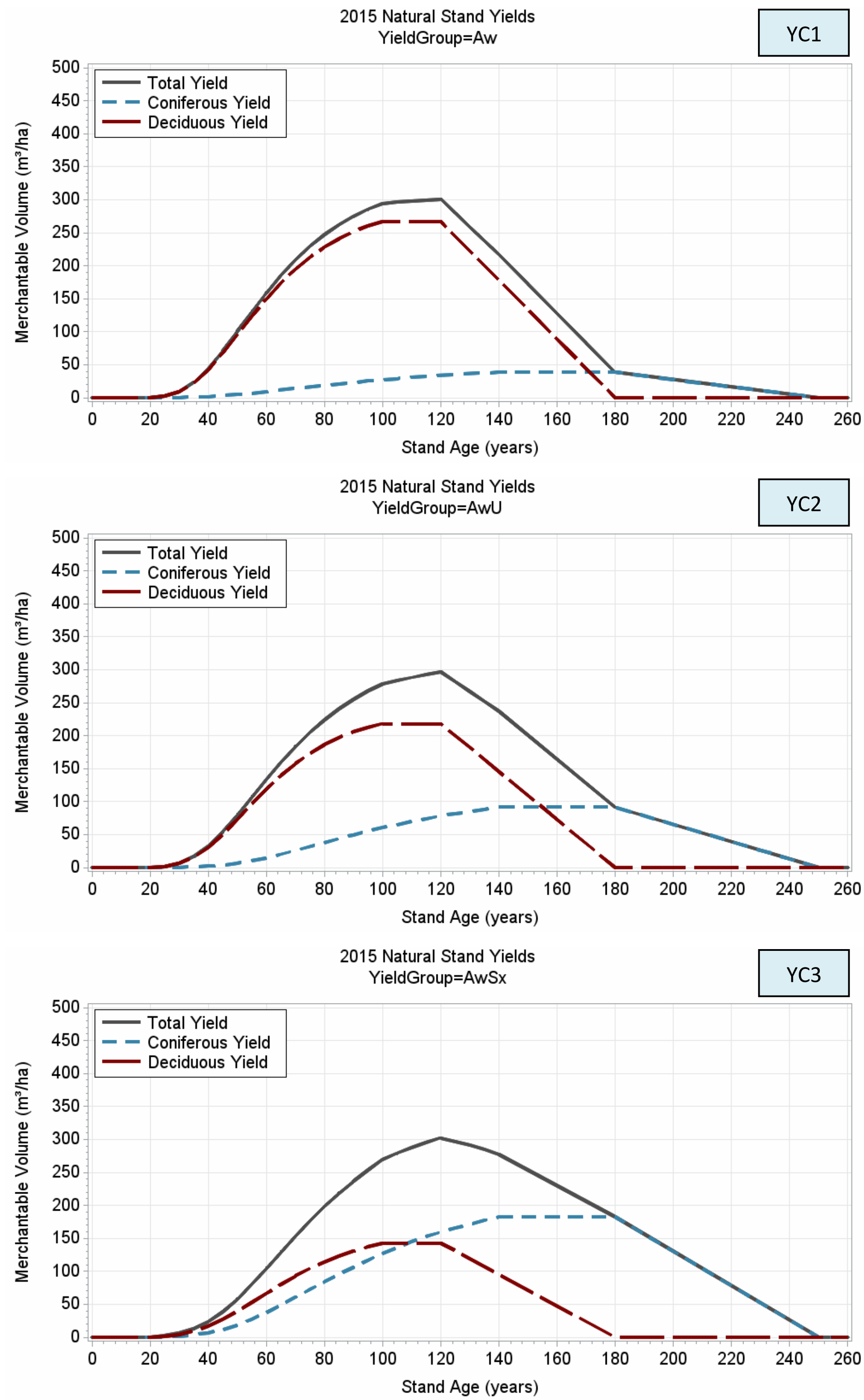


Figure 3-2. Final natural stand yield curves.

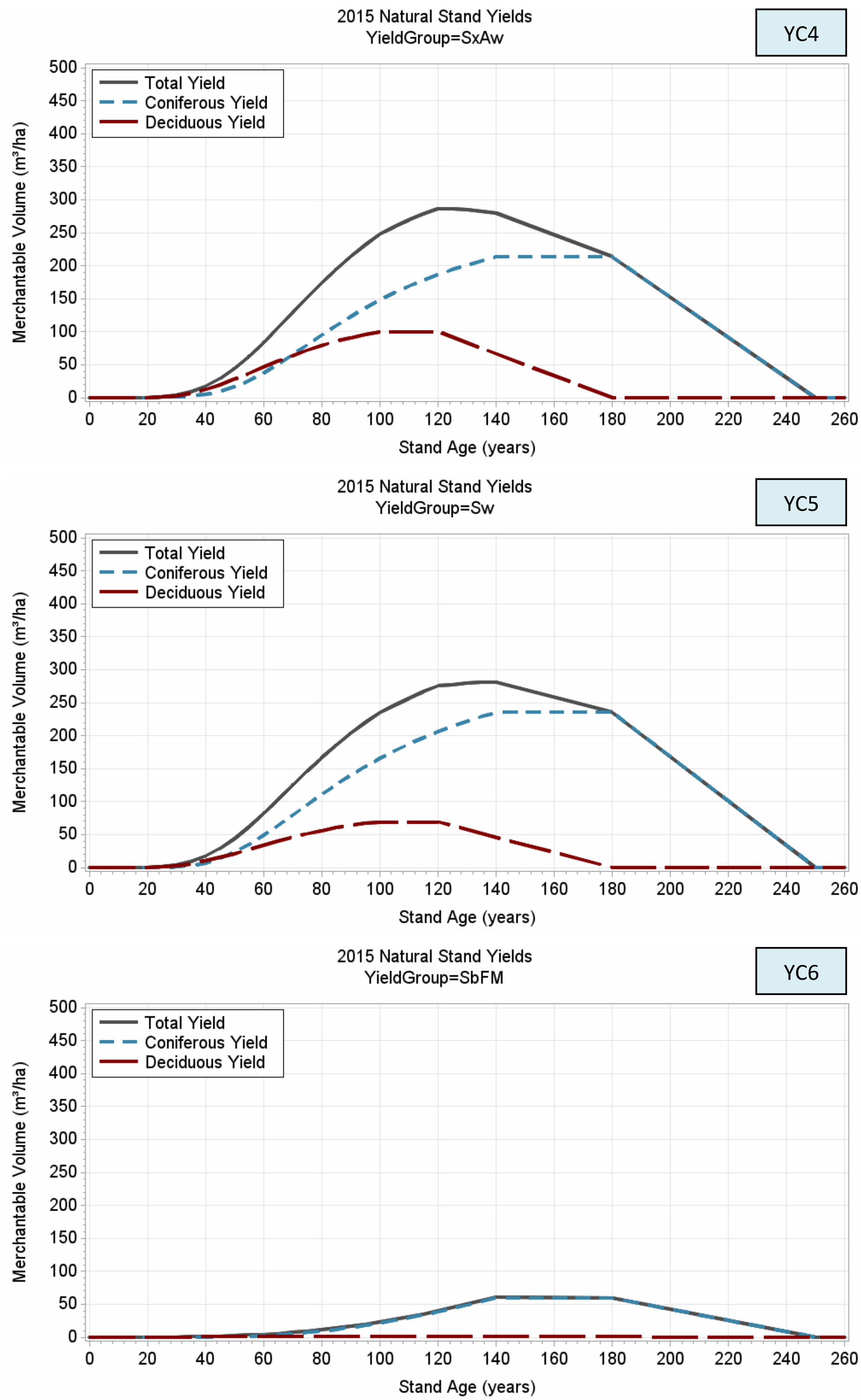


Figure 2-2. Final natural stand yield curves.

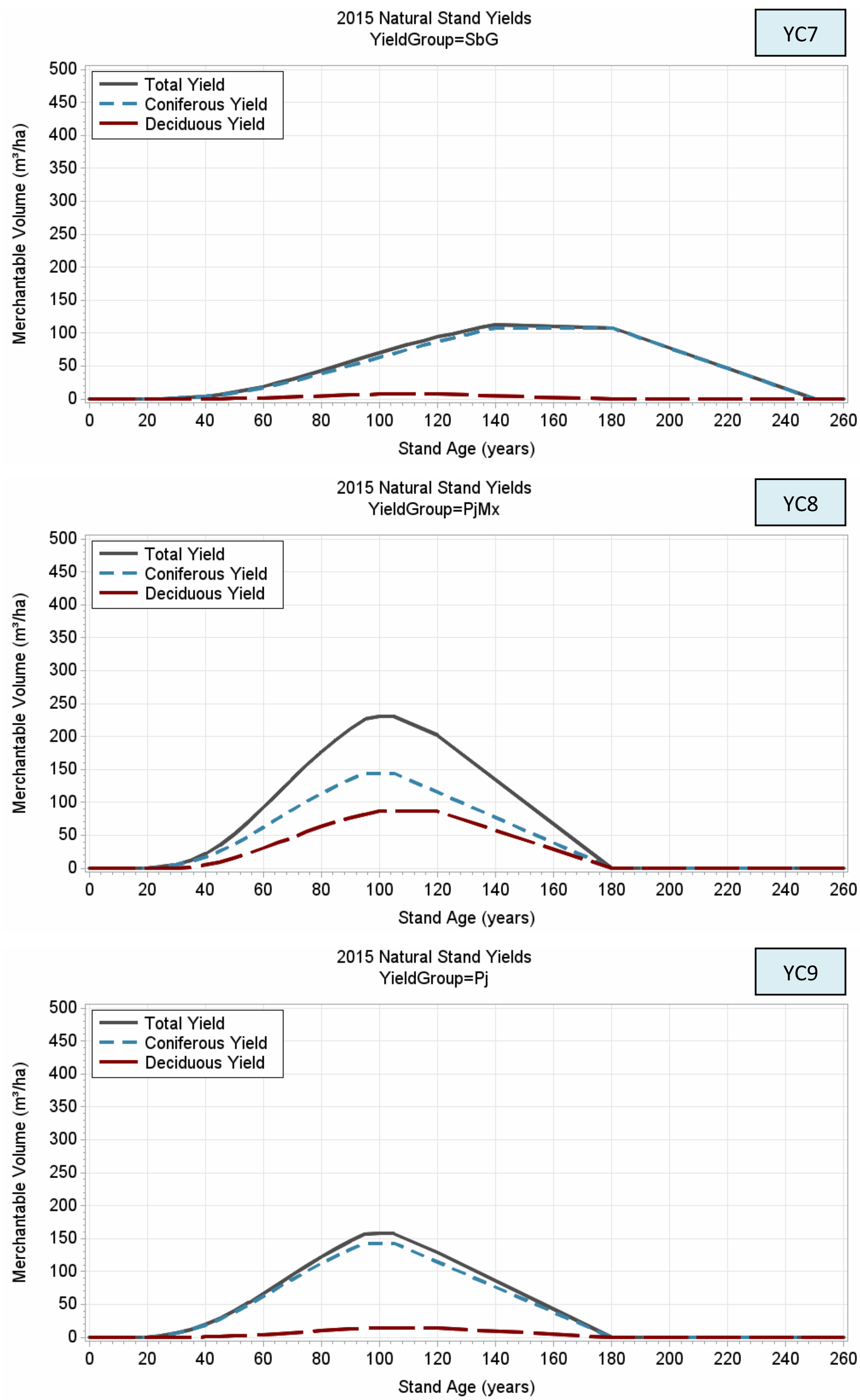


Figure 2-2. Final natural stand yield curves.

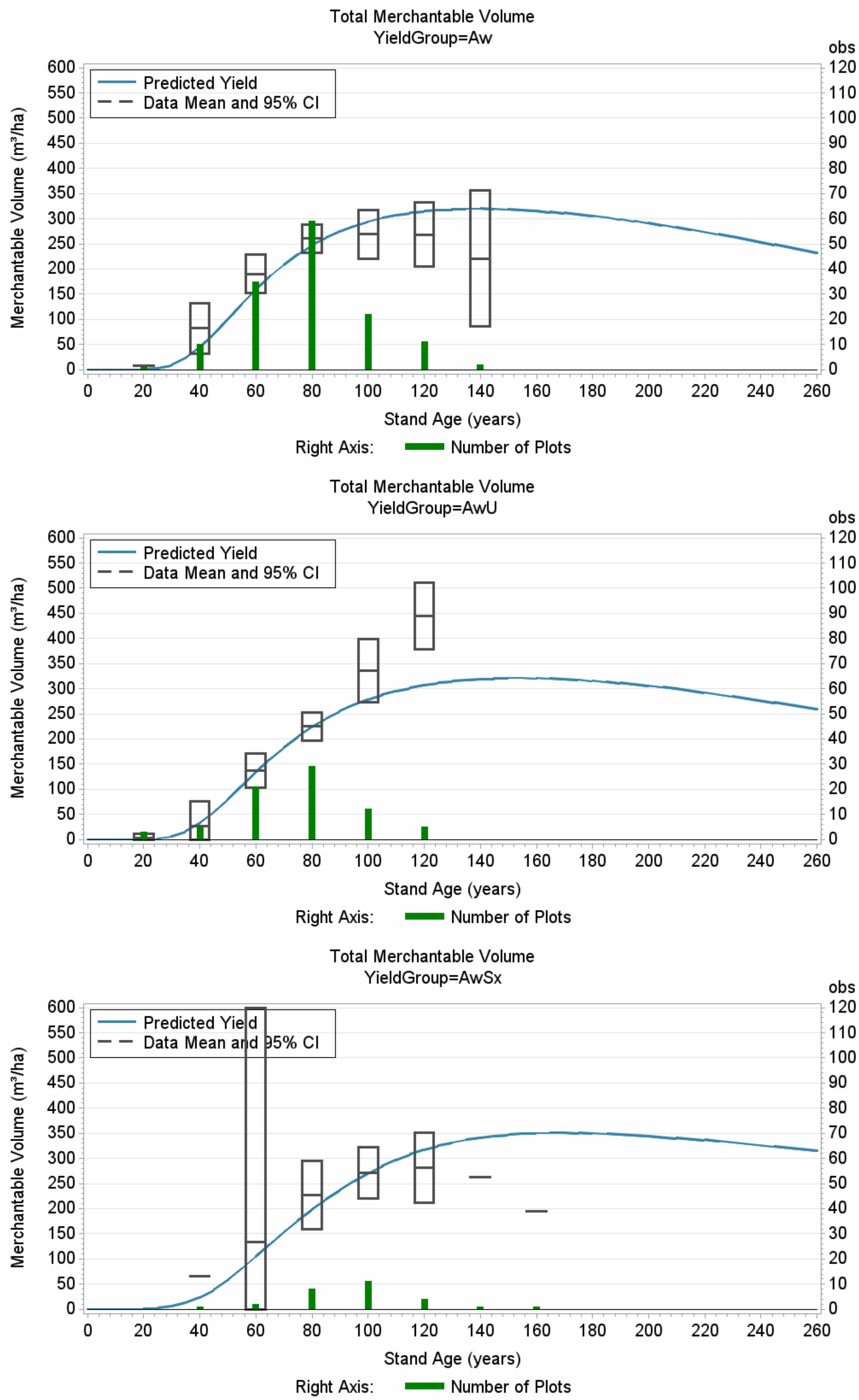


Figure 3-3. Natural stand total yield curves, unadjusted, against 20-year plot averages.

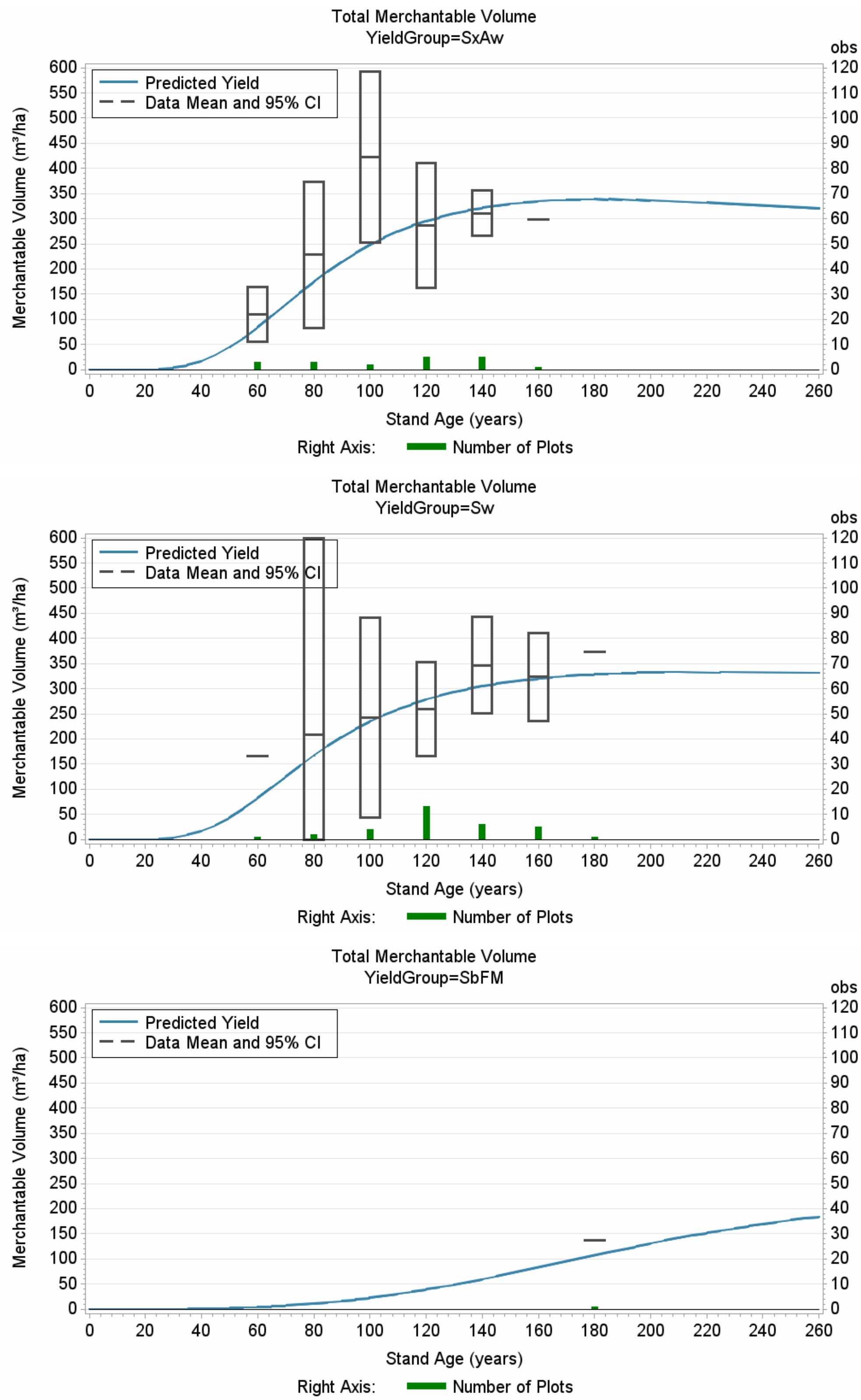
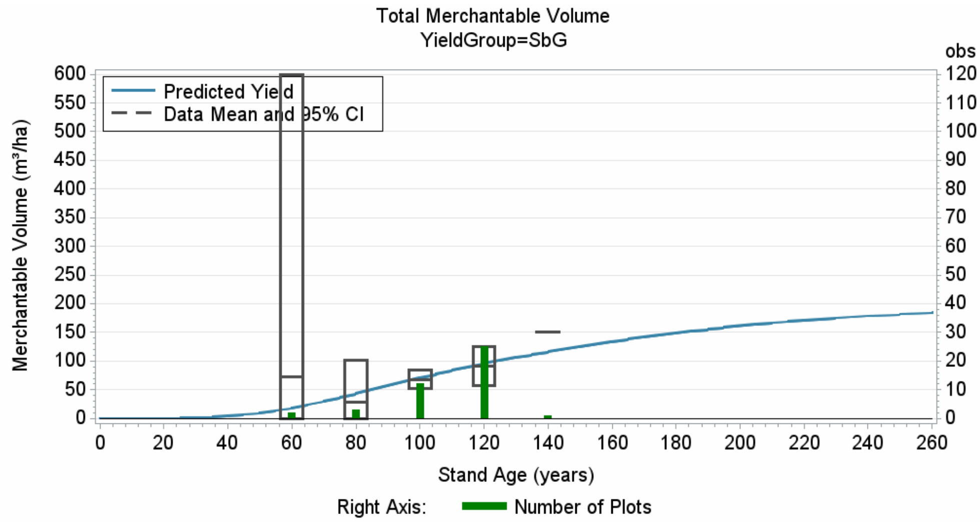
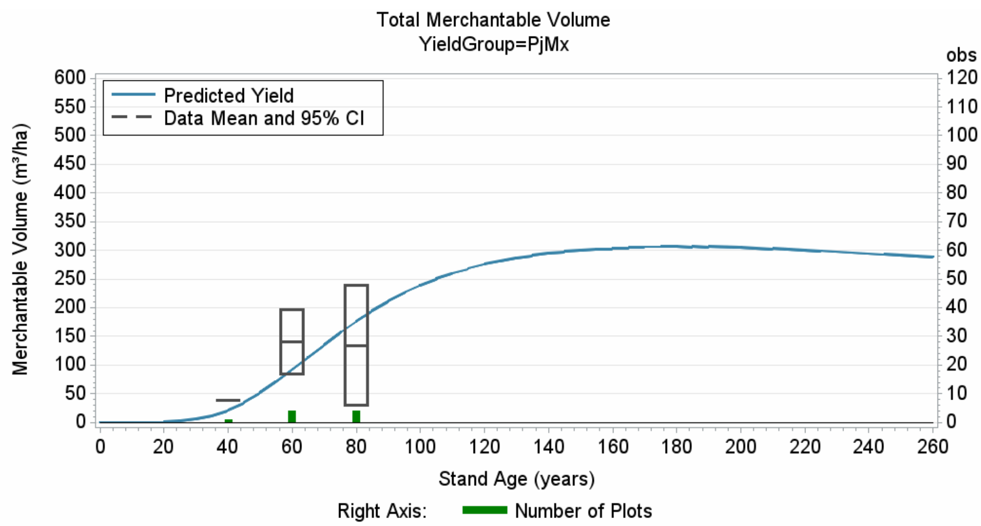


Figure 2-3. Natural stand total yield curves, unadjusted, against 20-year plot averages.





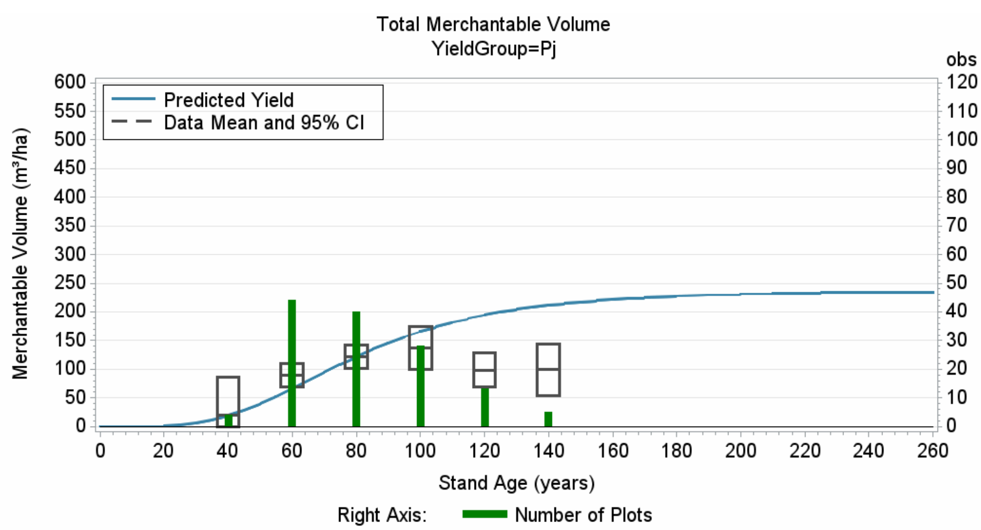


Figure 2-3. Natural stand total yield curves, unadjusted, against 20-year plot averages.

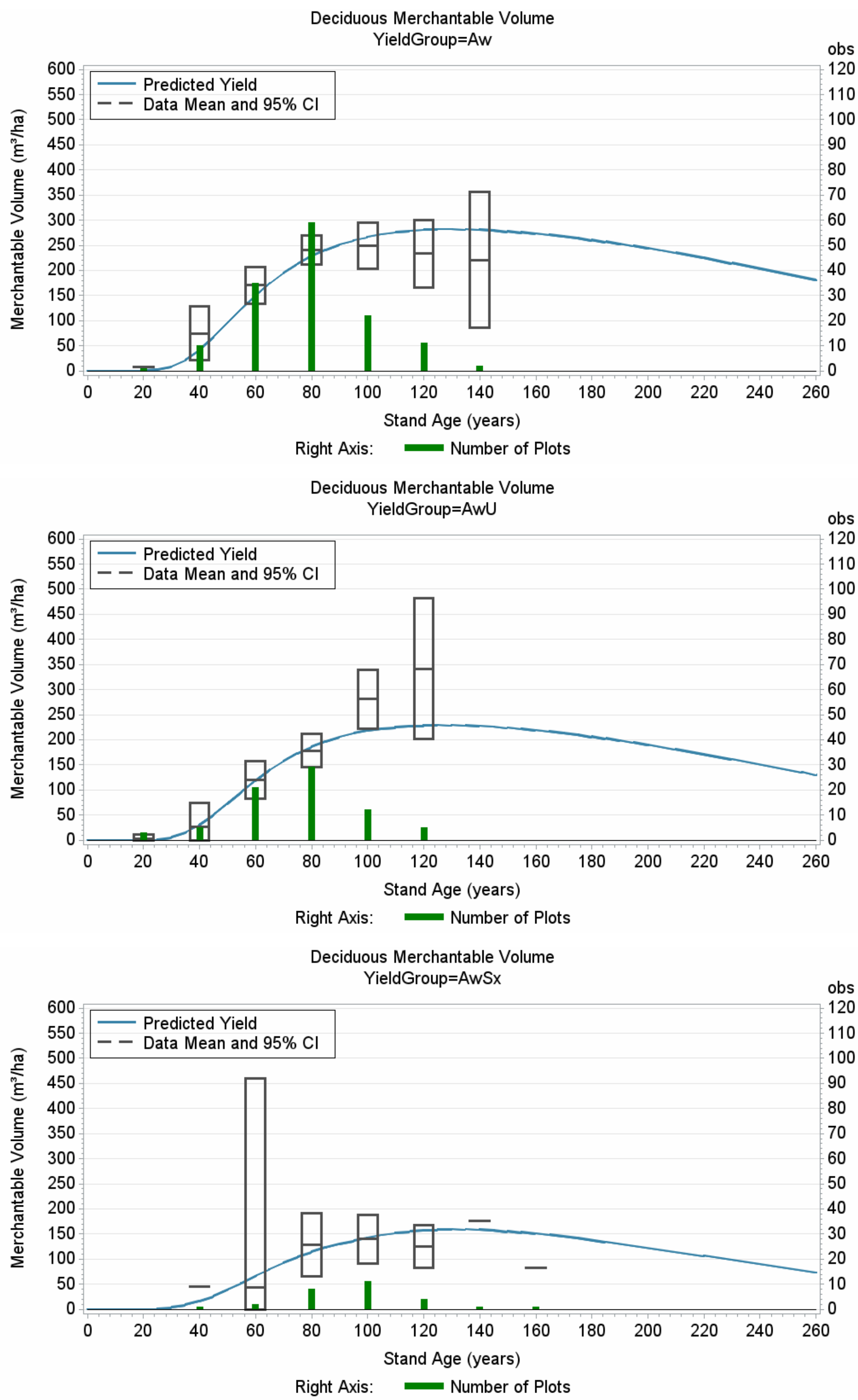


Figure 3-4. Natural stand deciduous yield curves, unadjusted, against 20-year plot averages.

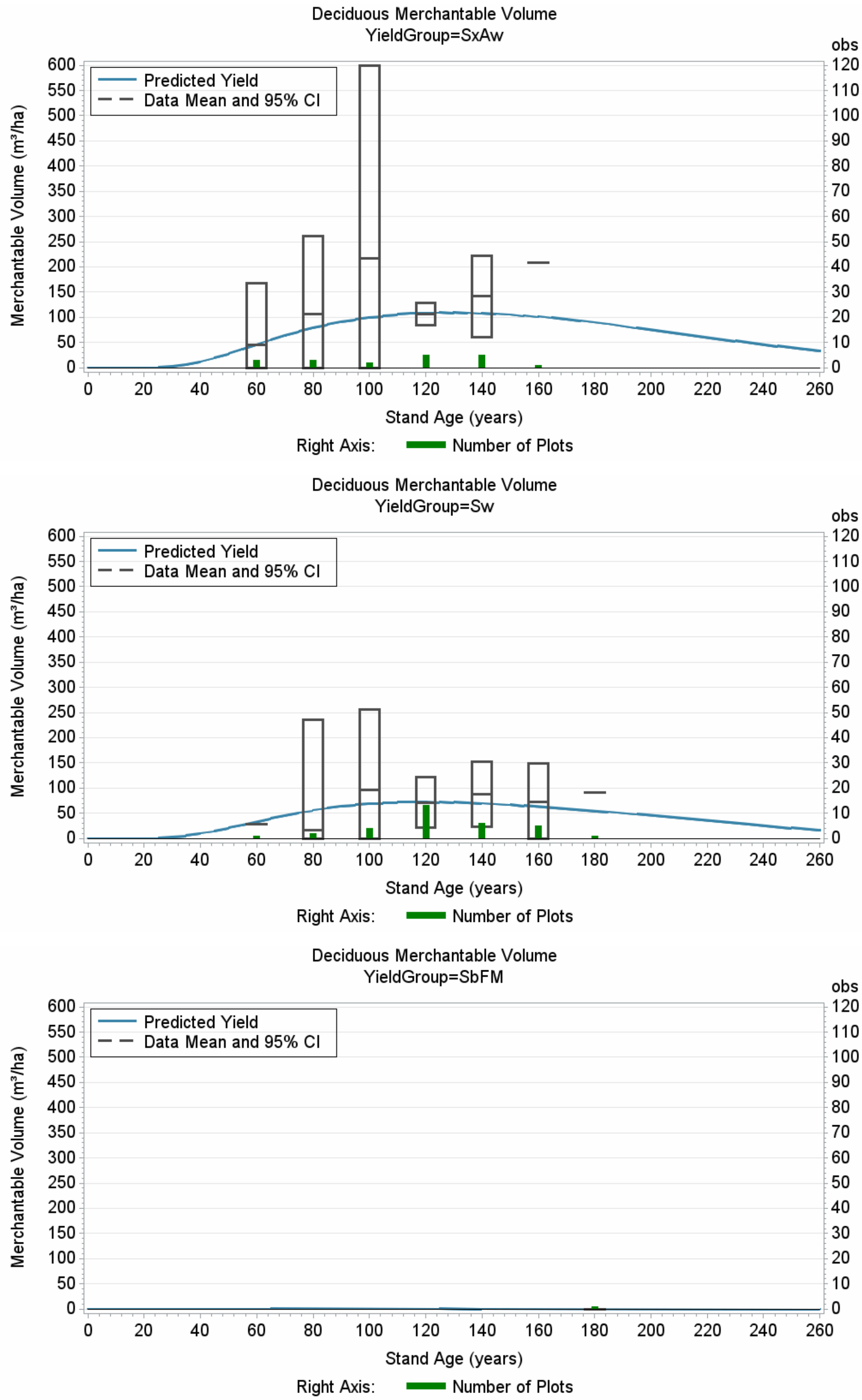


Figure 2-4. Natural stand deciduous yield curves, unadjusted, against 20-year plot averages.

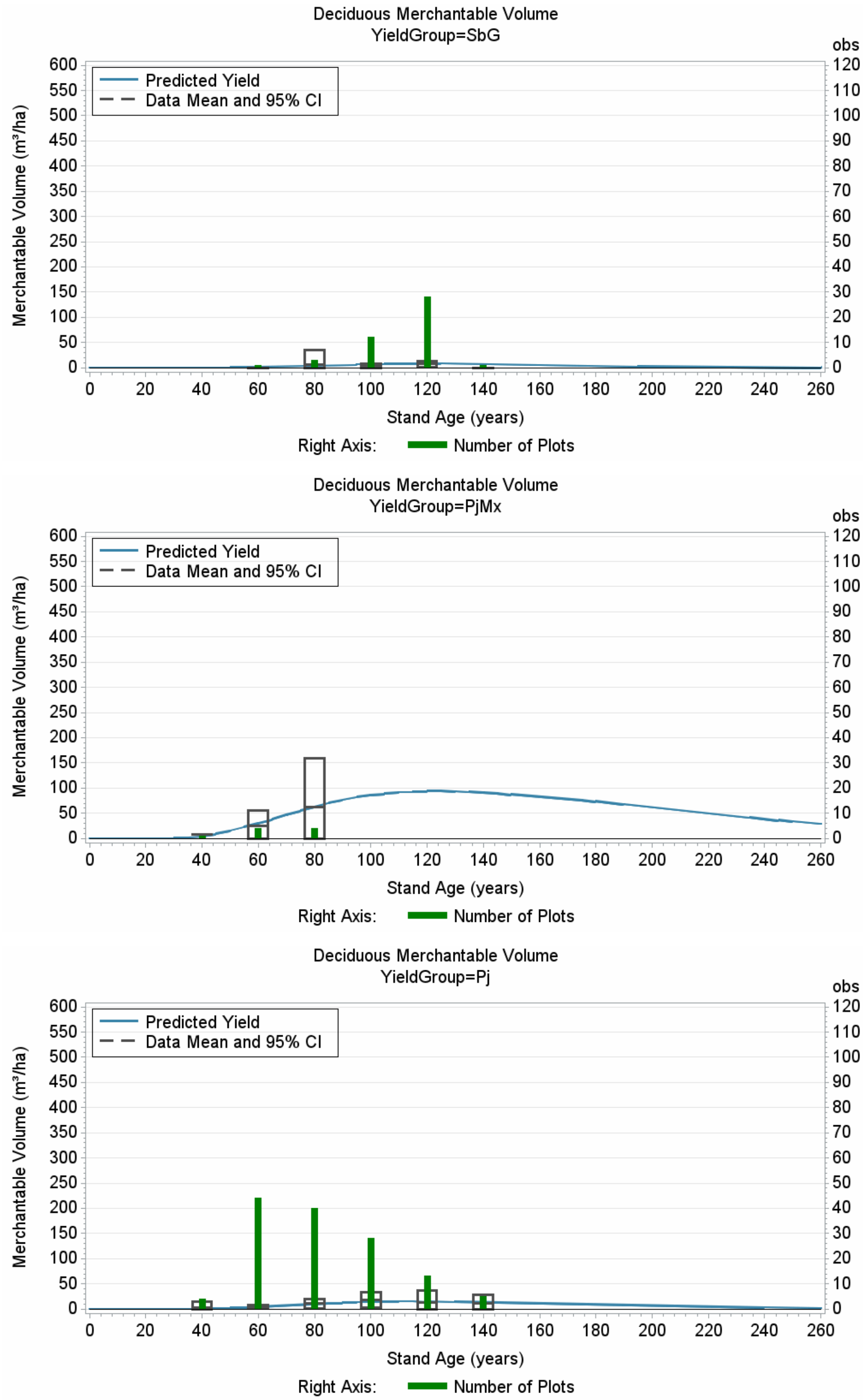


Figure 2-4. Natural stand deciduous yield curves, unadjusted, against 20-year plot averages.

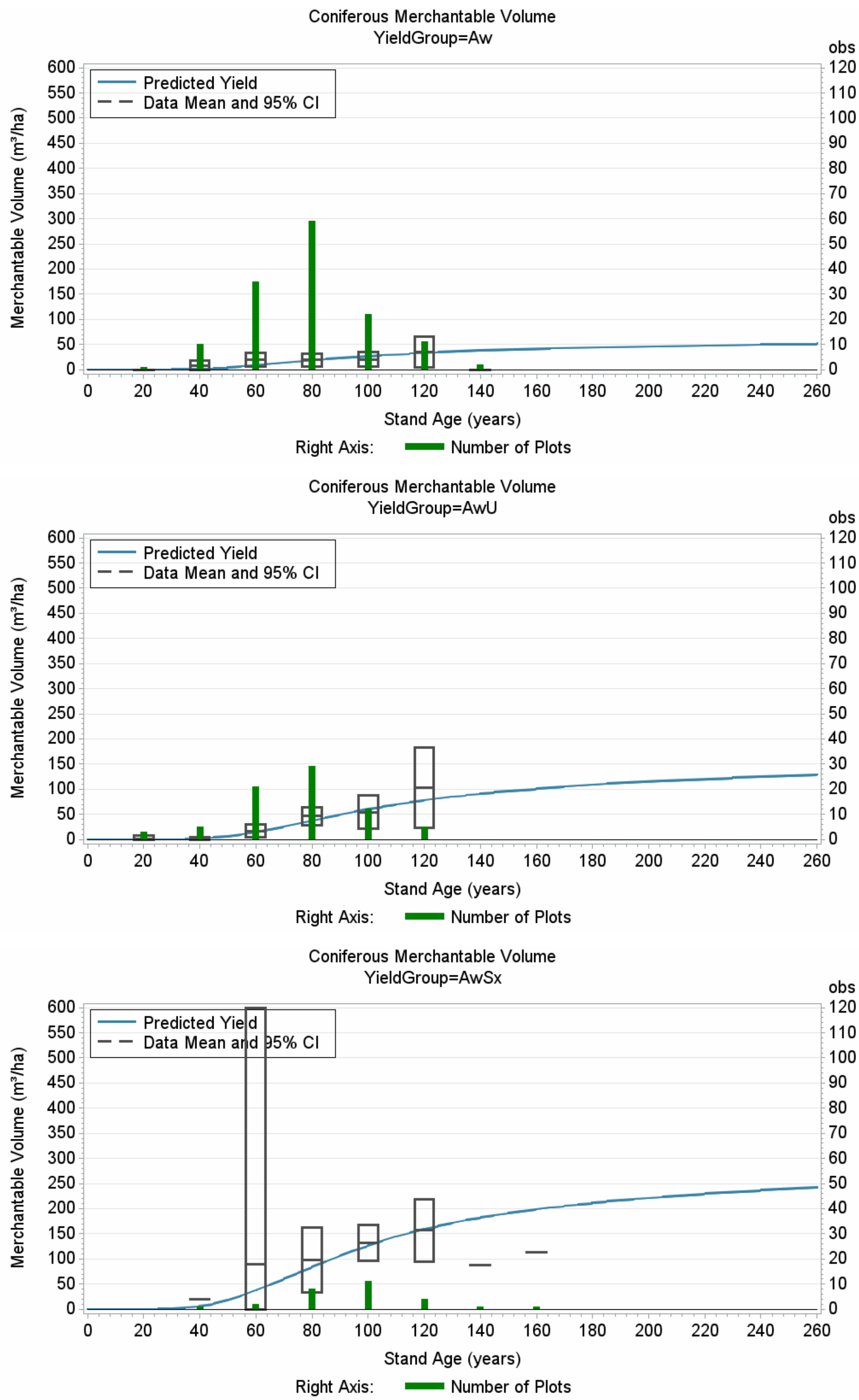


Figure 3-5. Natural stand coniferous yield curves, unadjusted, against 20-year plot averages.

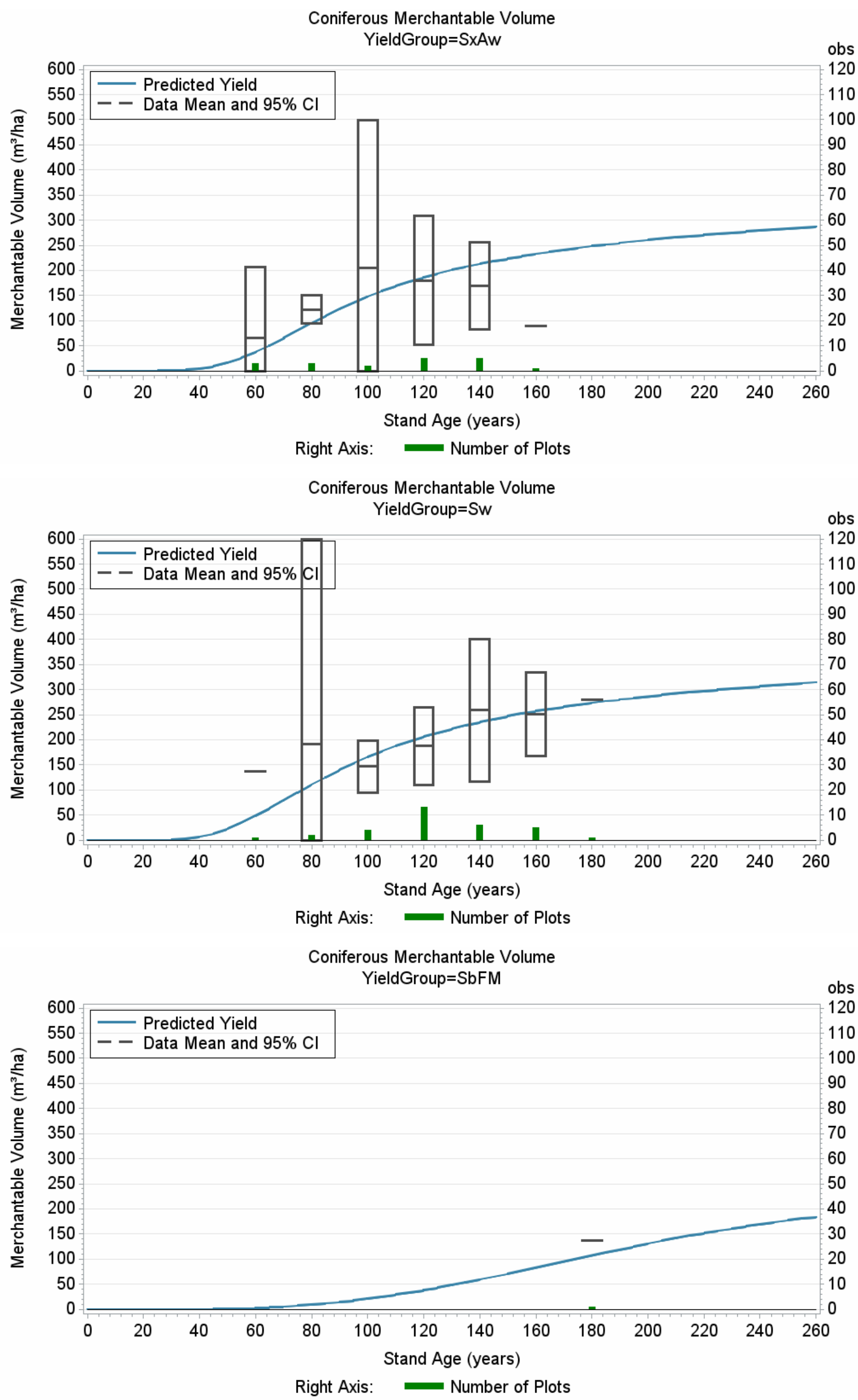


Figure 2-5. Natural stand coniferous yield curves, unadjusted, against 20-year plot averages.

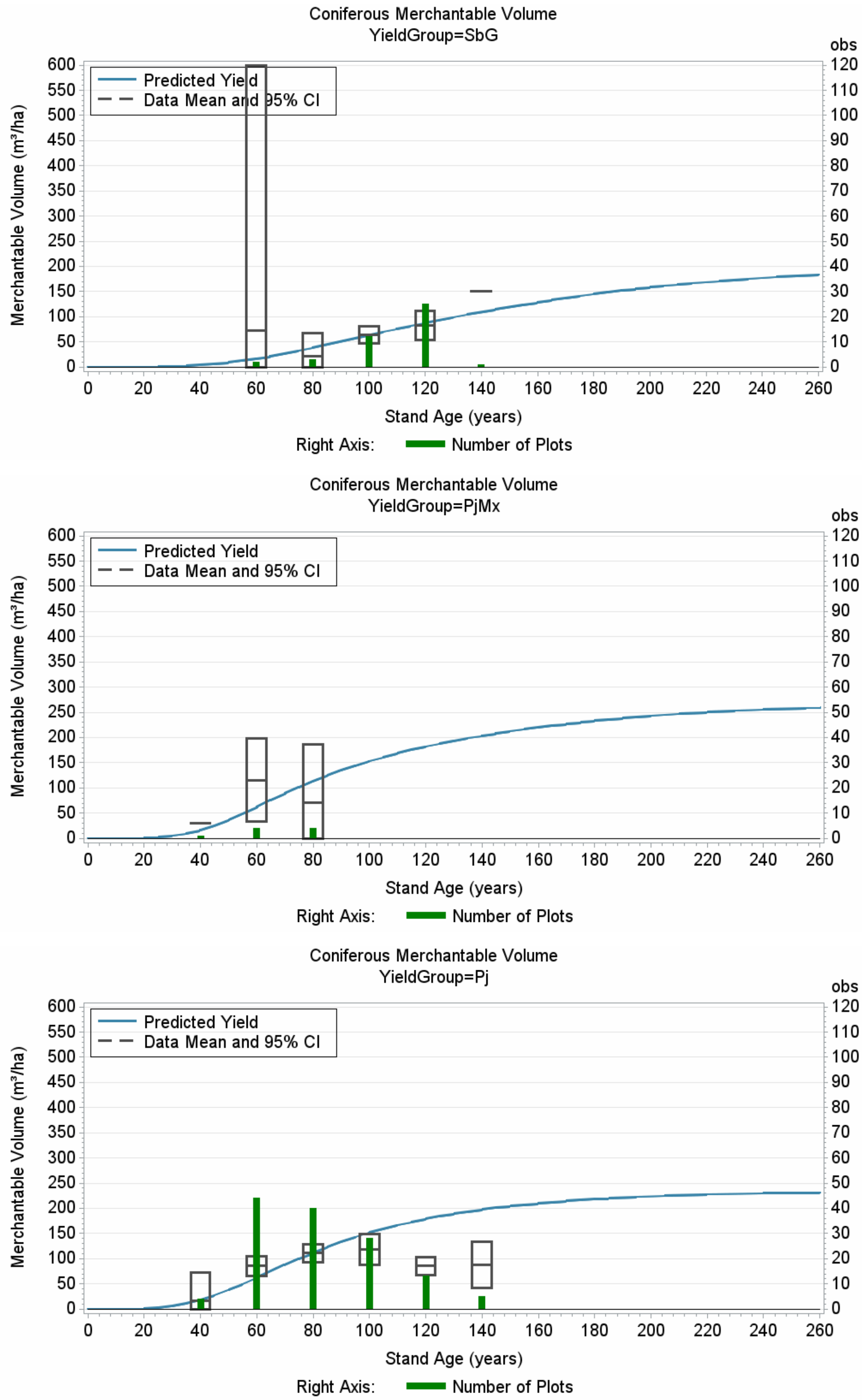


Figure 2-5. Natural stand coniferous yield curves, unadjusted, against 20-year plot averages.

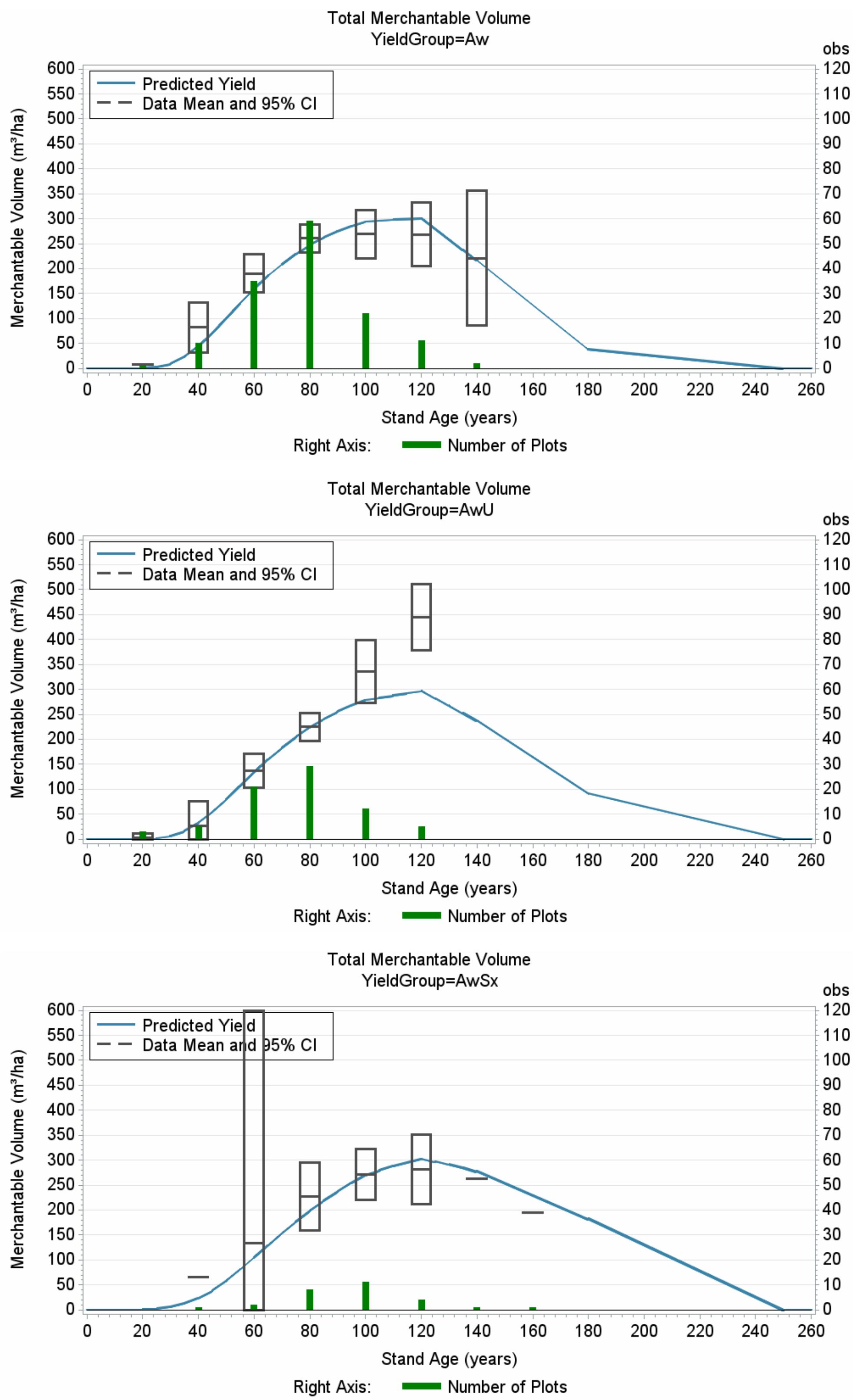


Figure 3-6. Final natural stand total yield curves against 20-year plot averages.

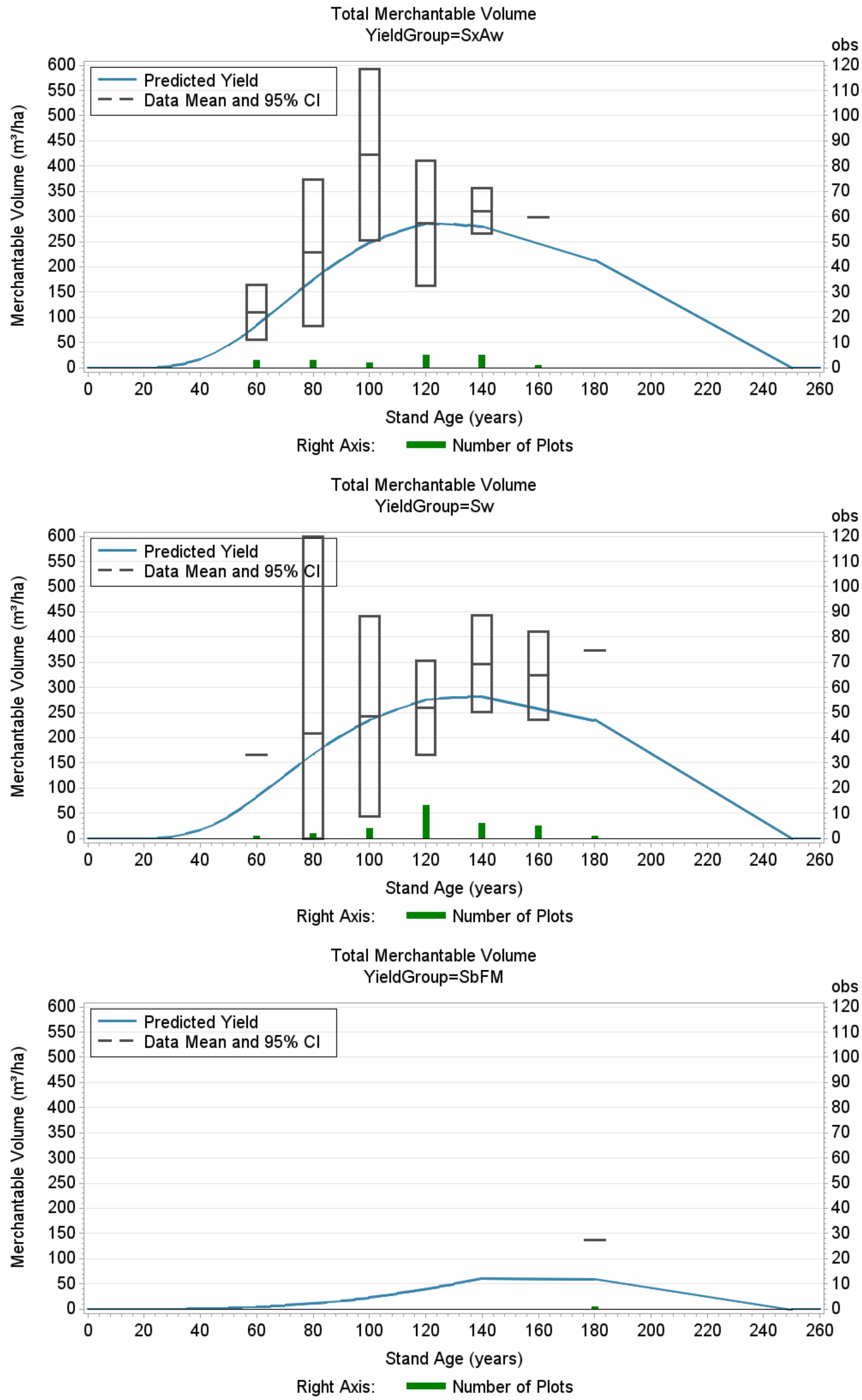


Figure 2-6. Final natural stand total yield curves against 20-year plot averages.

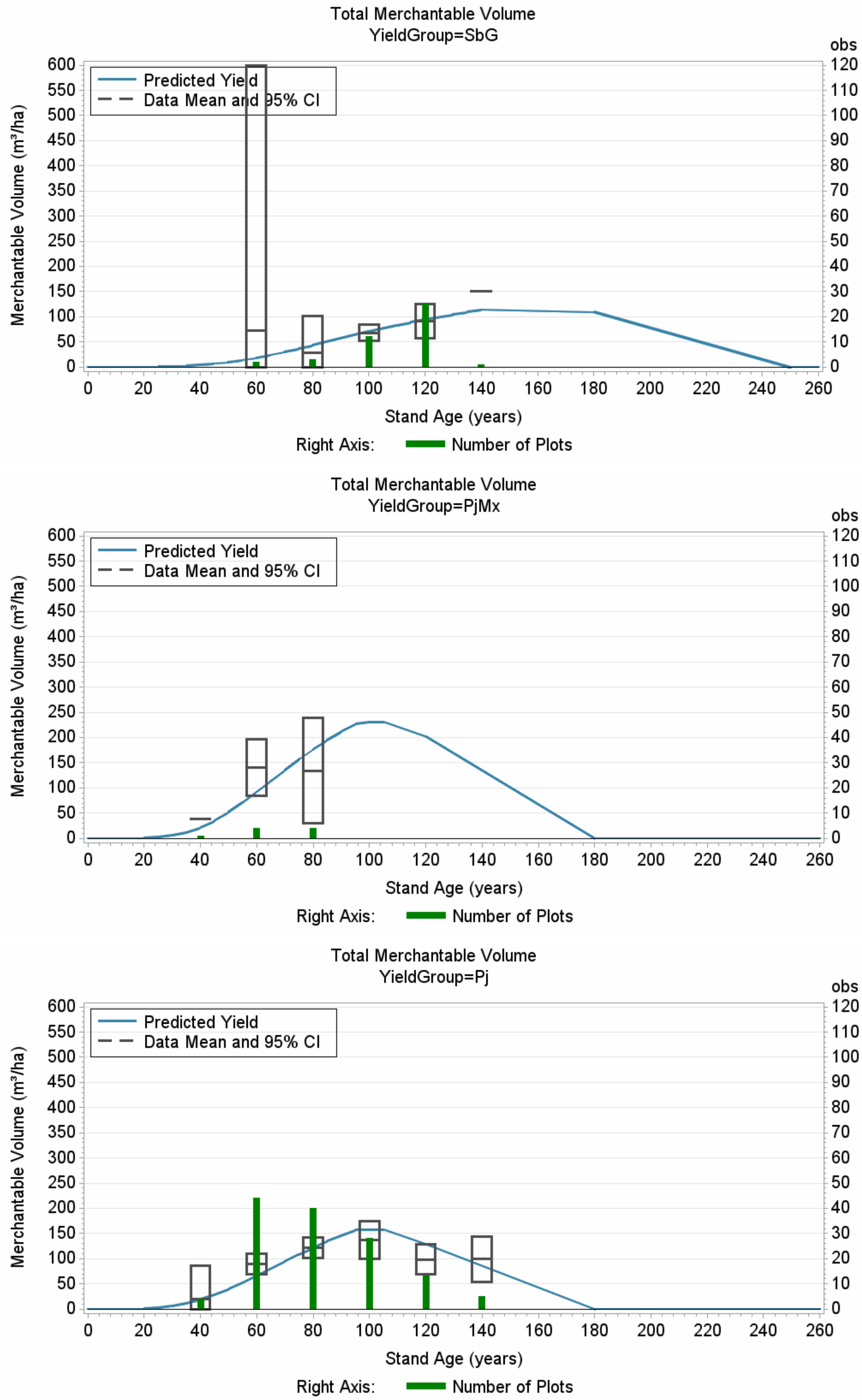


Figure 2-6. Final natural stand total yield curves against 20-year plot averages.

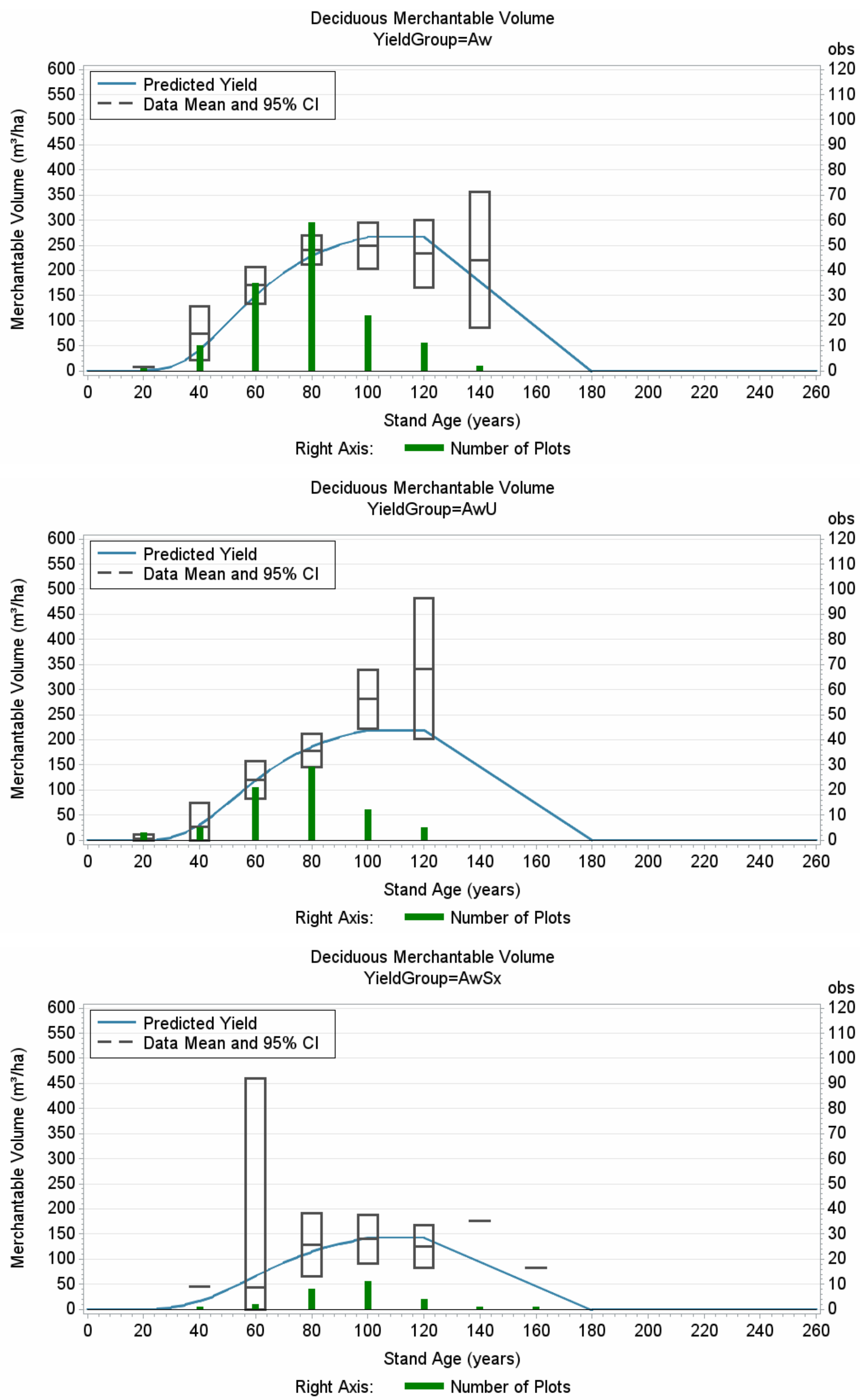


Figure 3-7. Final natural stand deciduous yield curves against 20-year plot averages.

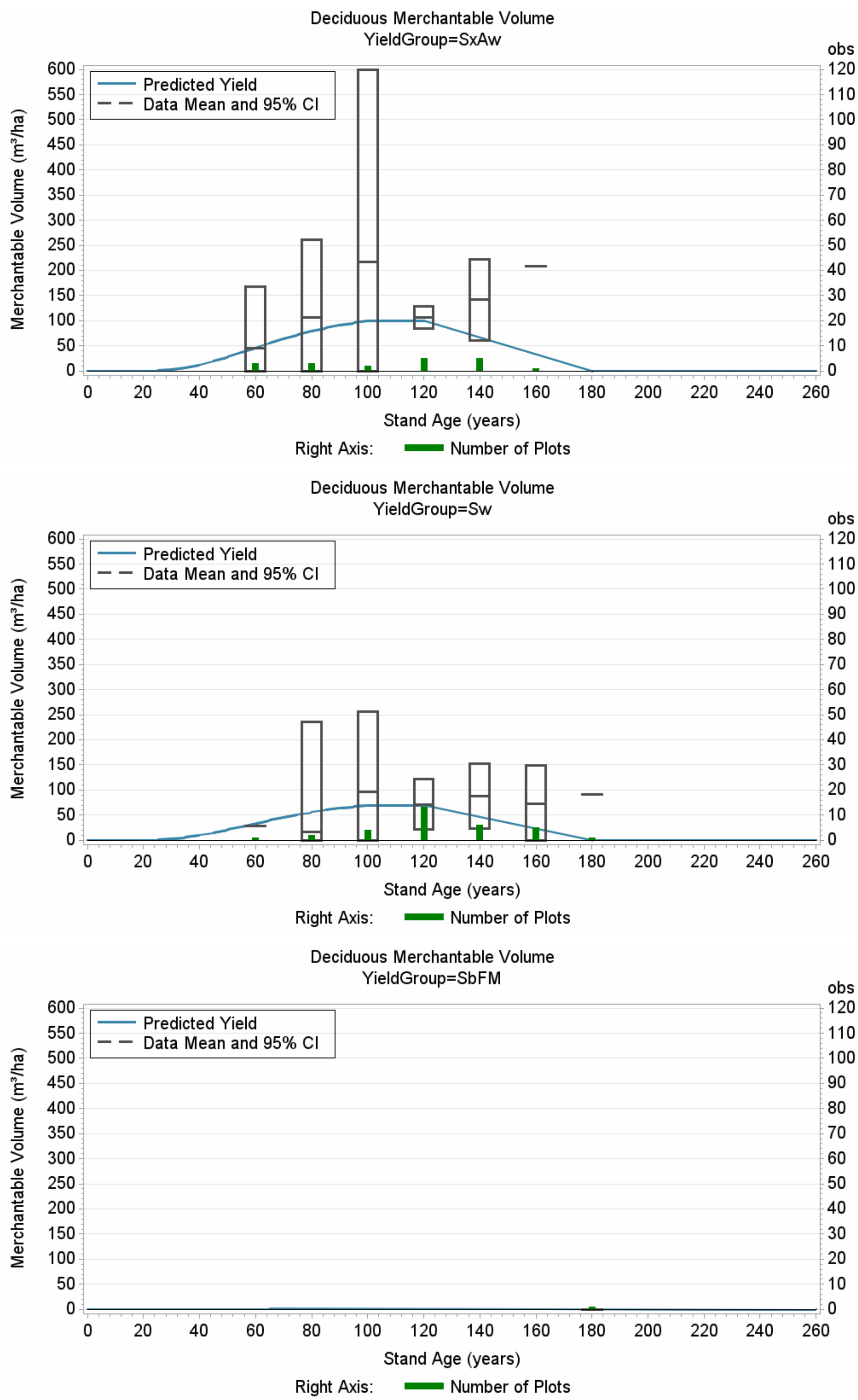


Figure 2-7. Final natural stand deciduous yield curves against 20-year plot averages.

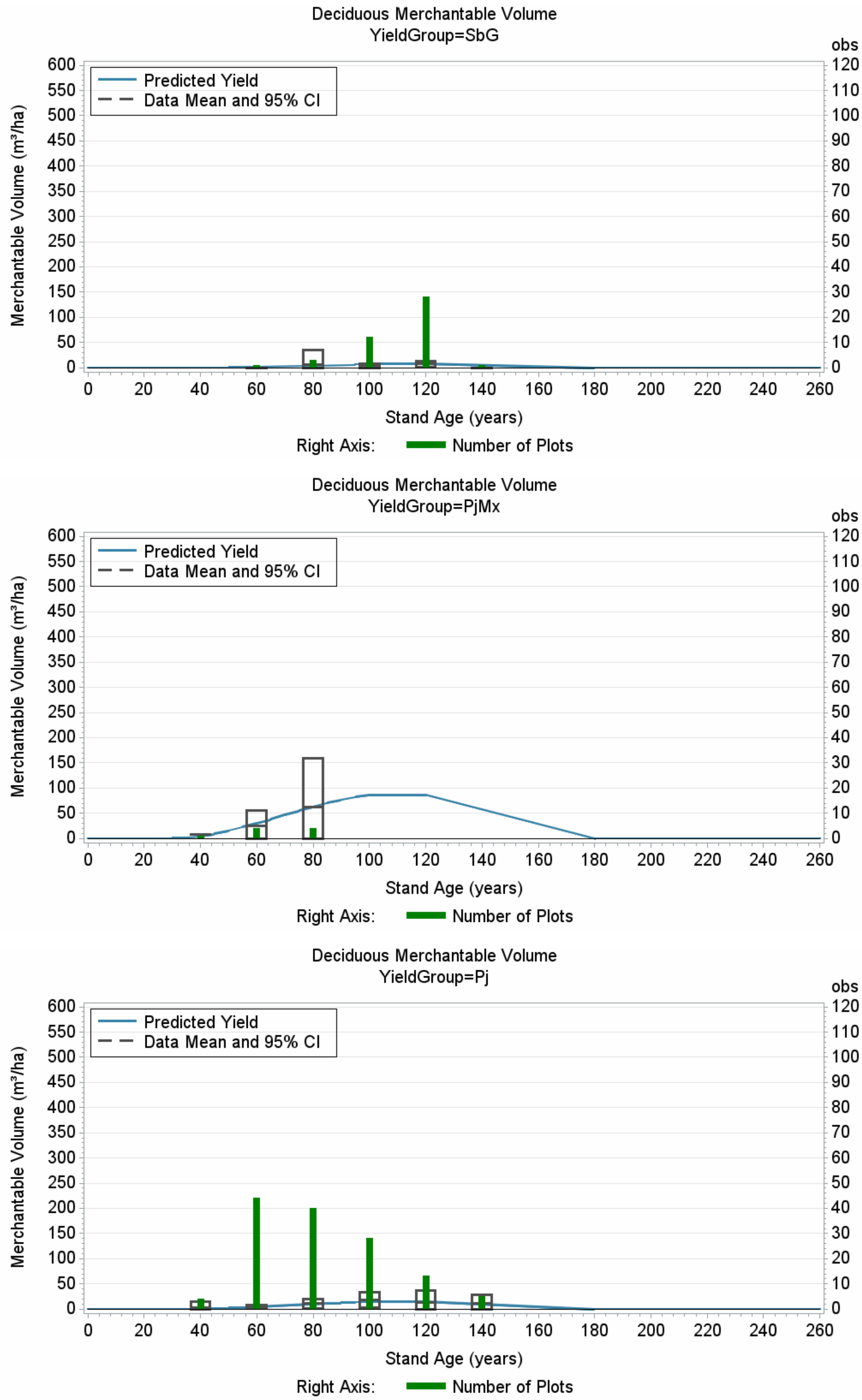


Figure 2-7. Final natural stand deciduous yield curves against 20-year plot averages.

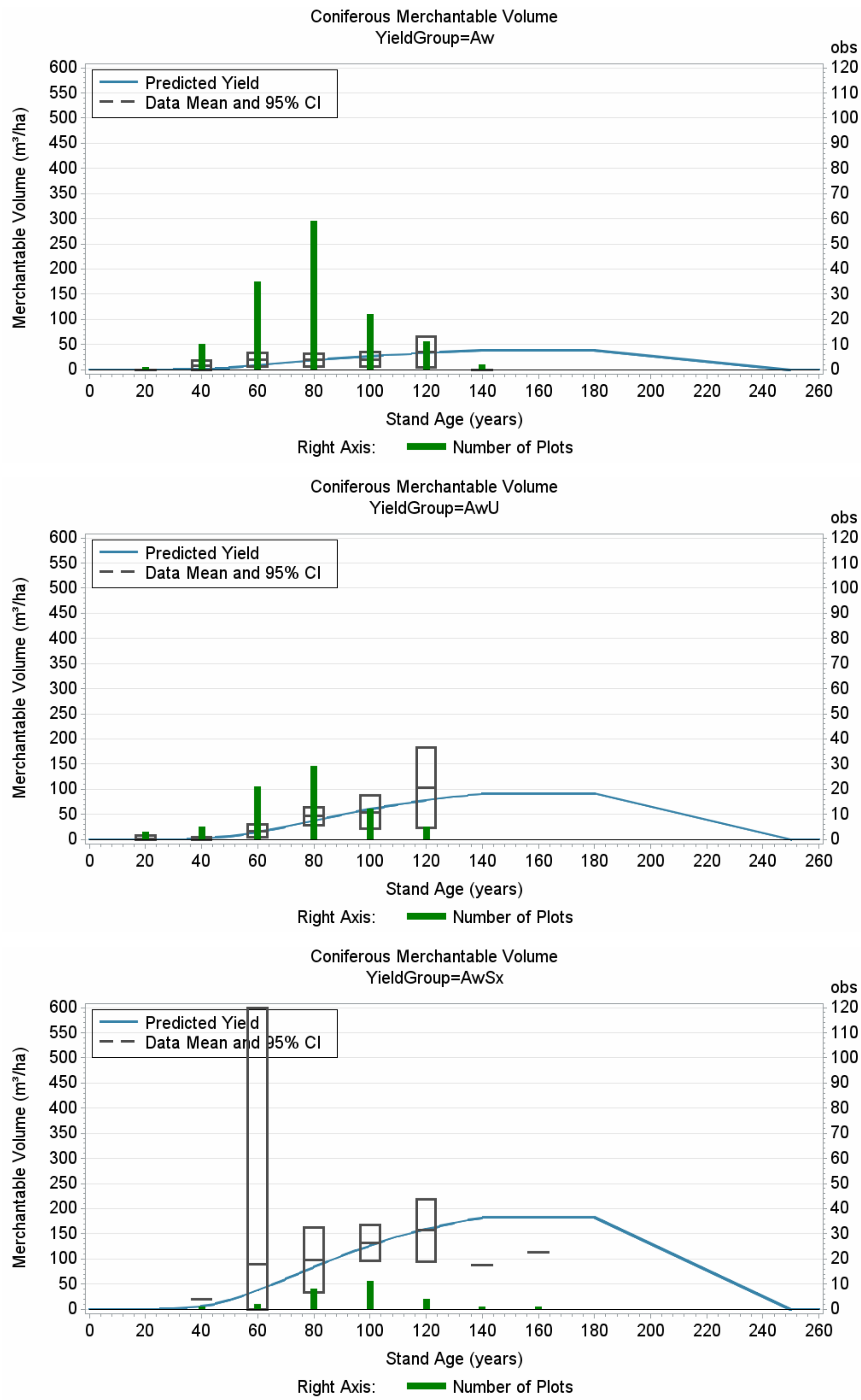


Figure 3-8. Final natural stand coniferous yield curves against 20-year plot averages.

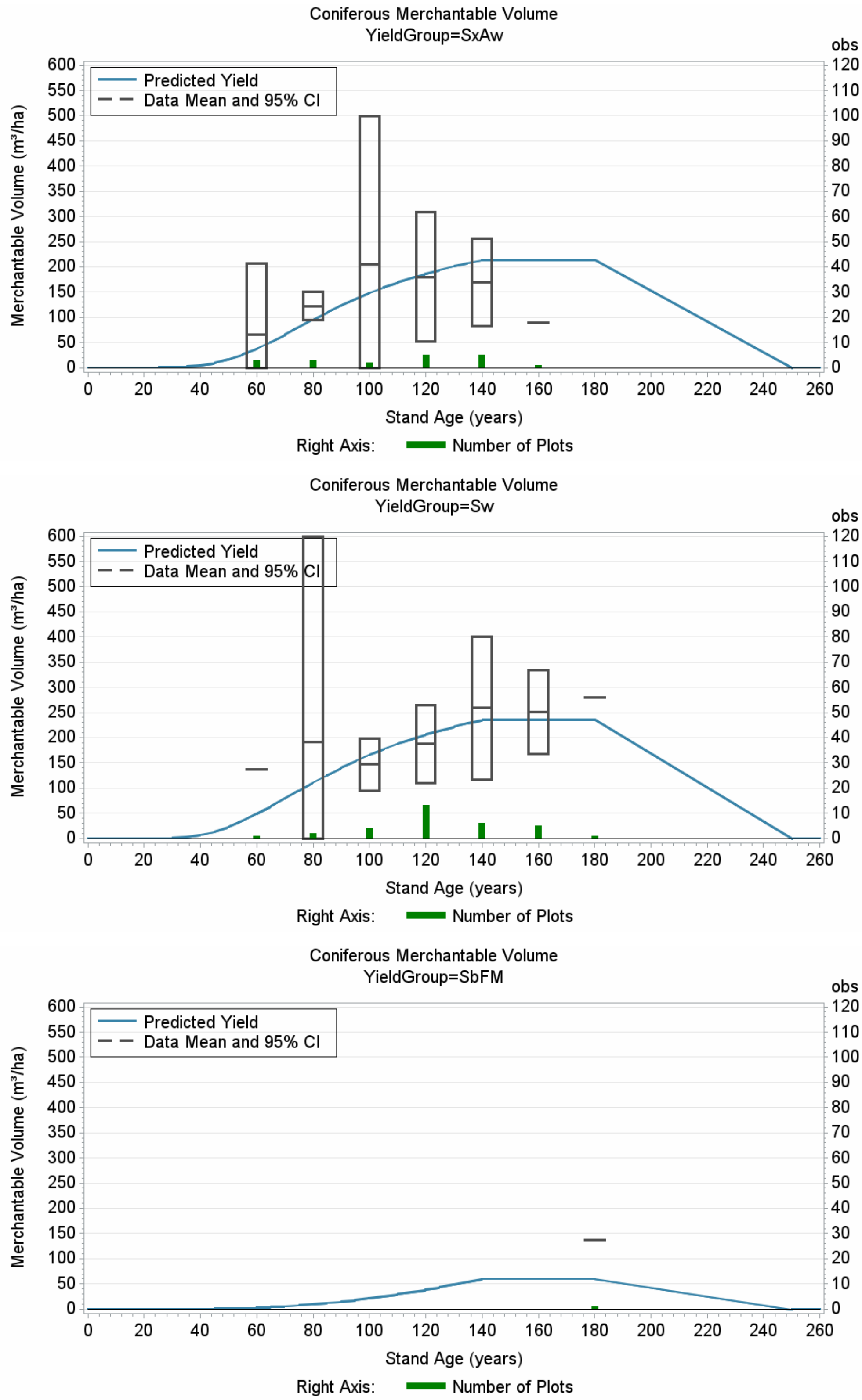


Figure 2-8. Final natural stand coniferous yield curves against 20-year plot averages.

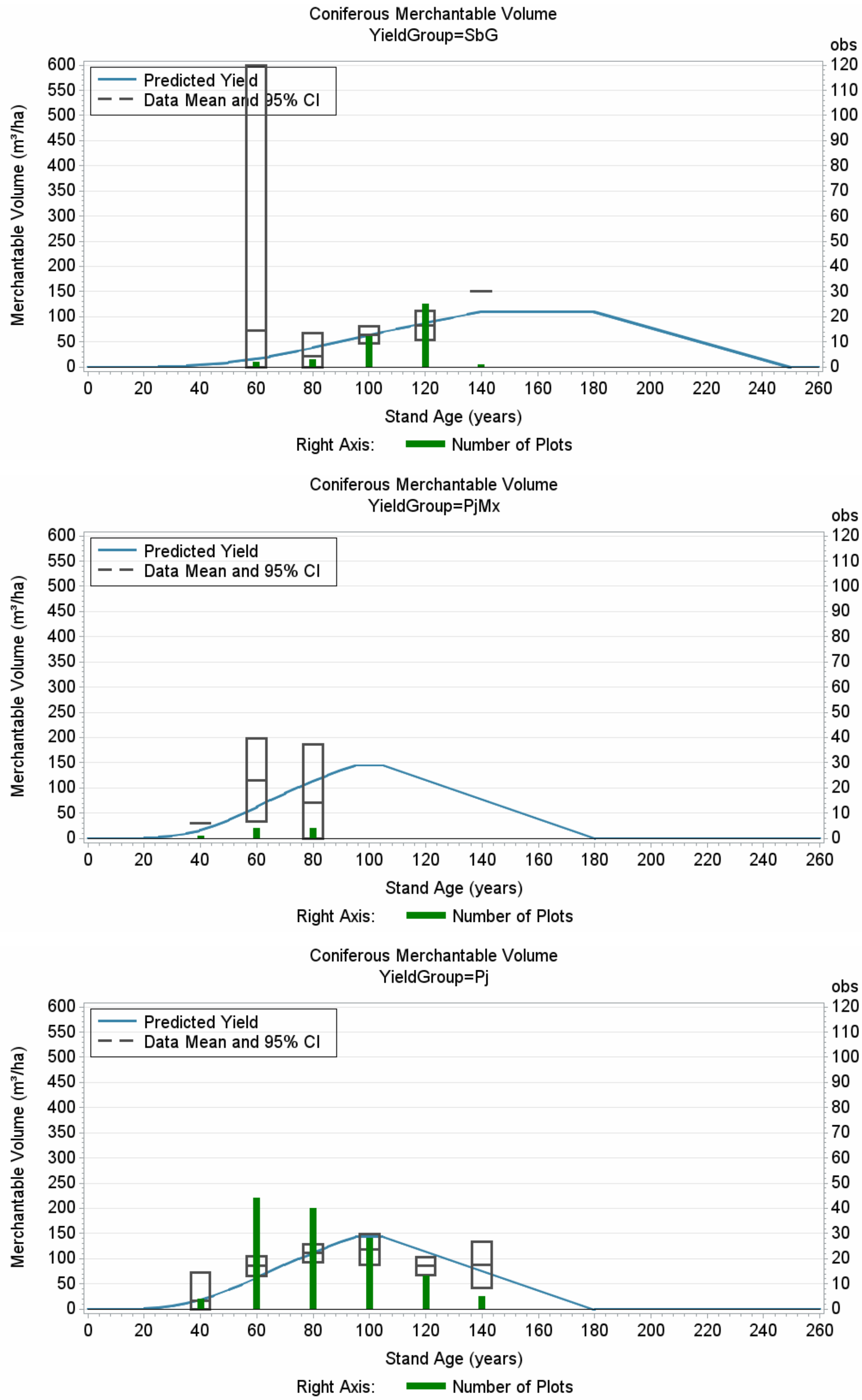


Figure 2-8. Final natural stand coniferous yield curves against 20-year plot averages.

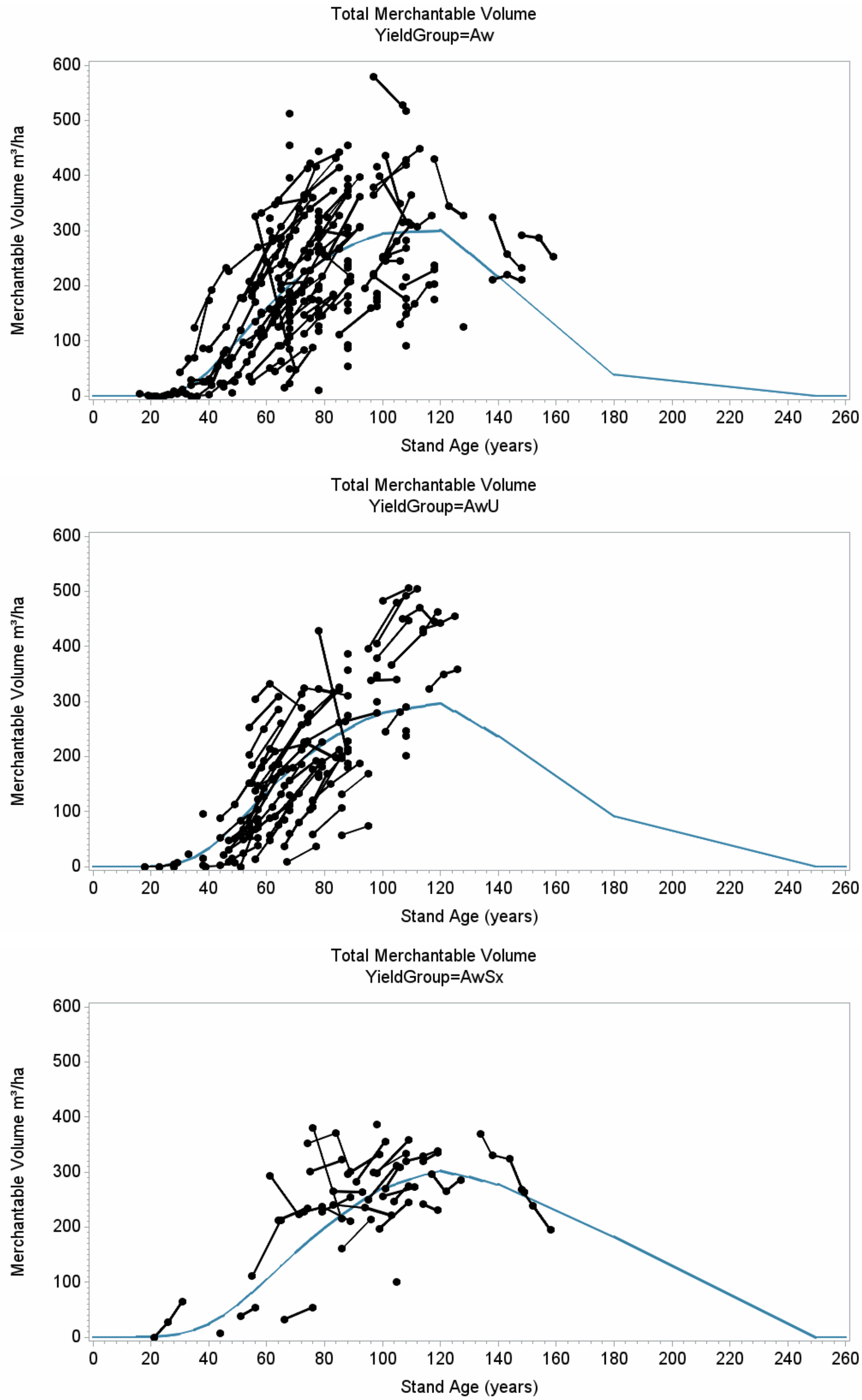


Figure 3-9. Natural stand total plot data against final natural stand yield curves.

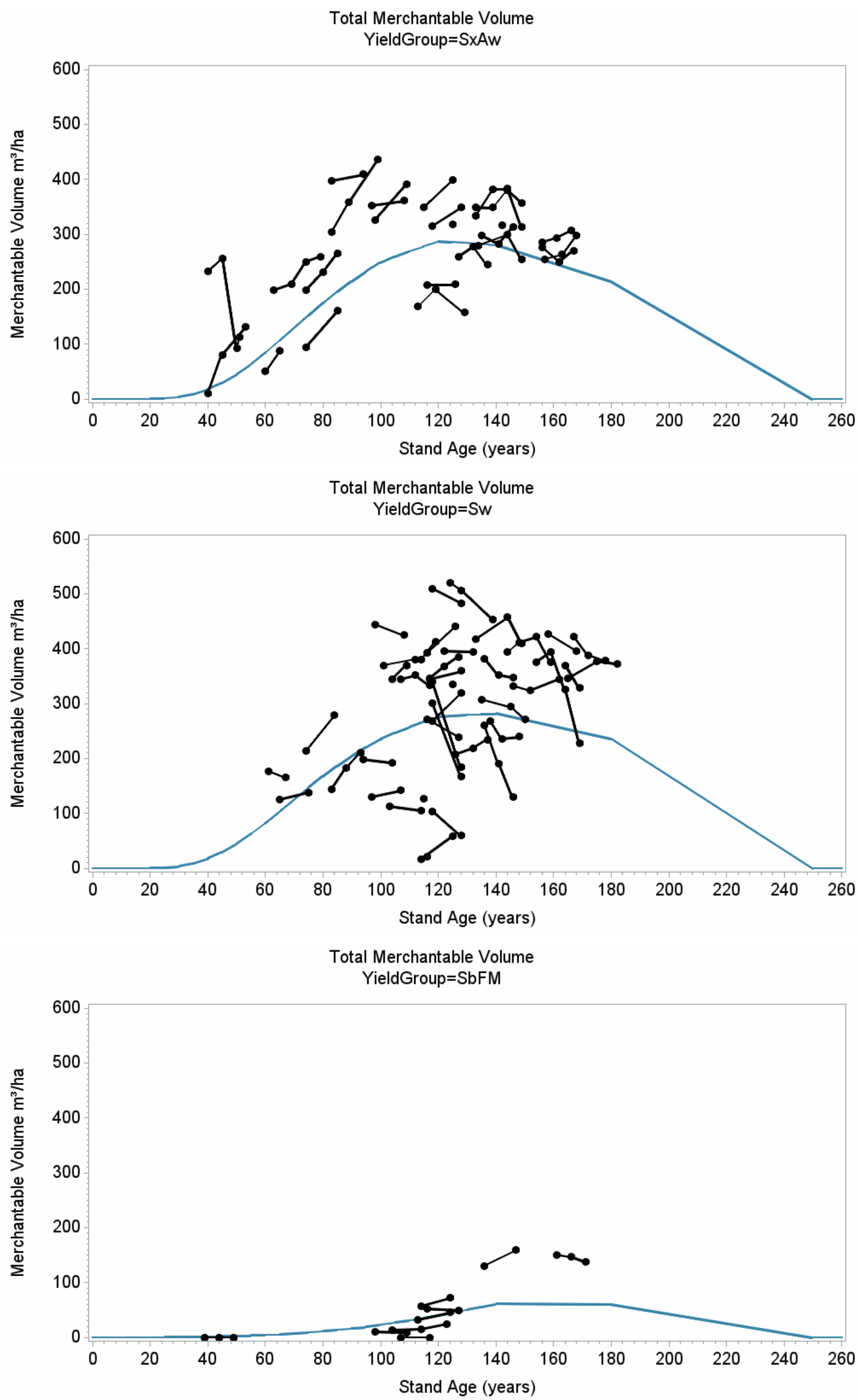


Figure 2-9. Natural stand total plot data against final natural stand yield curves.

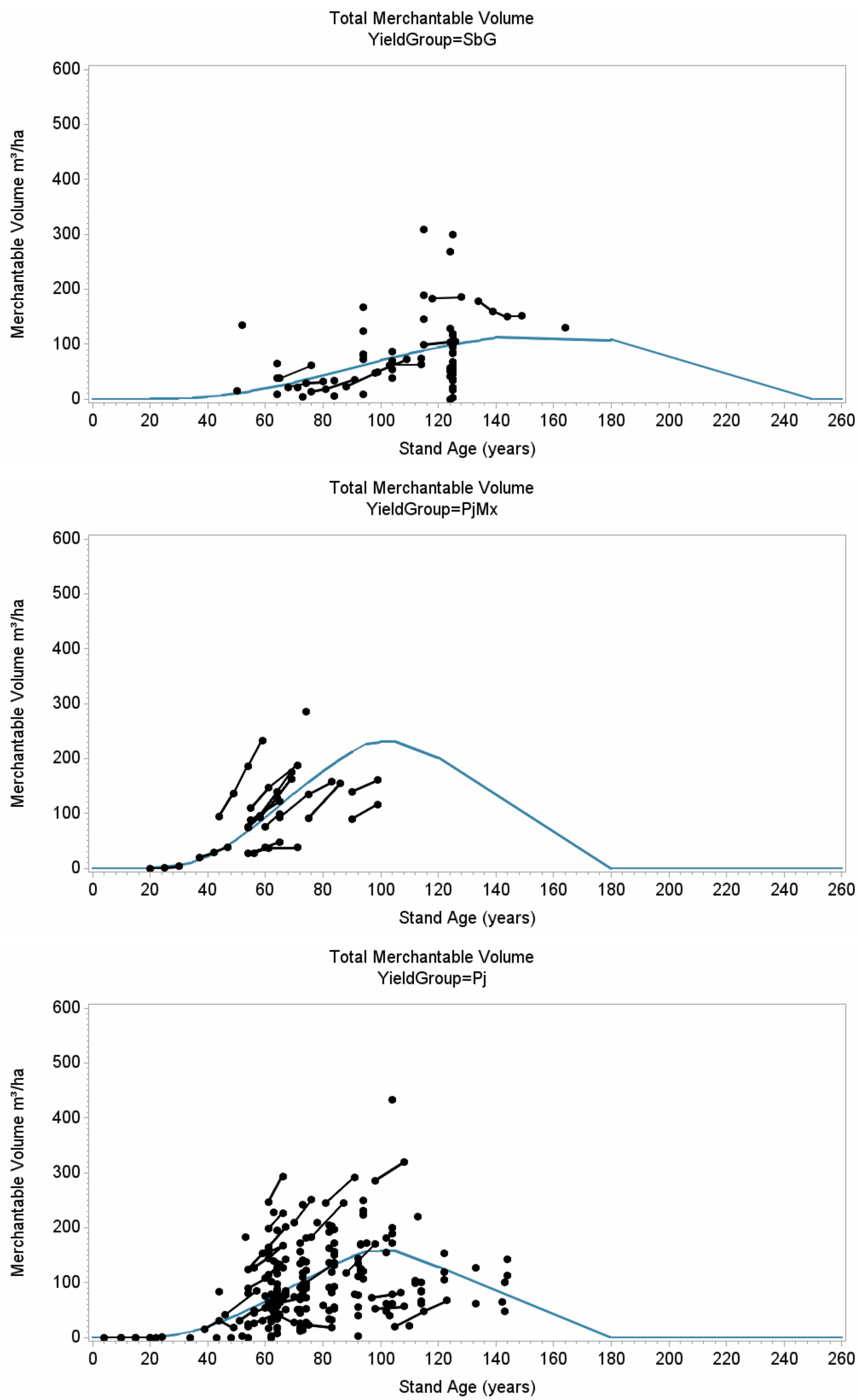
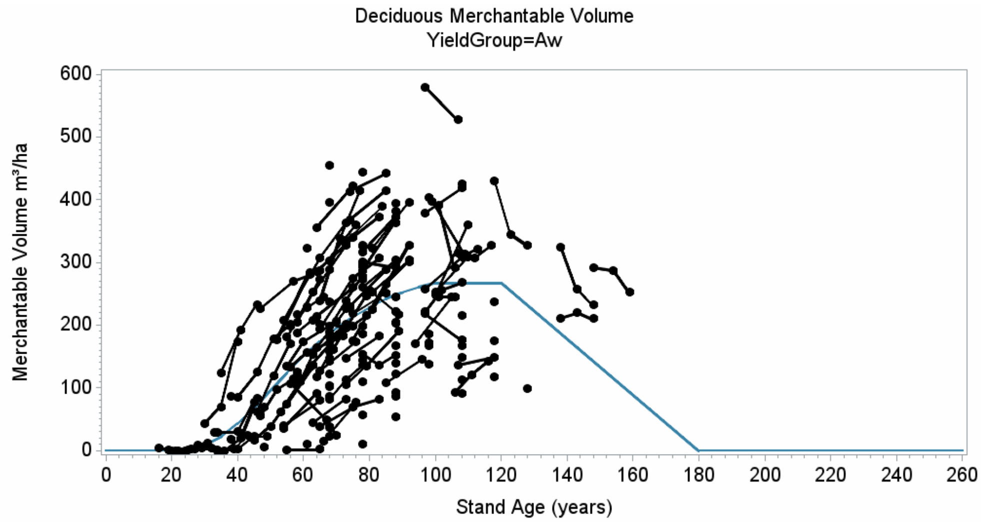
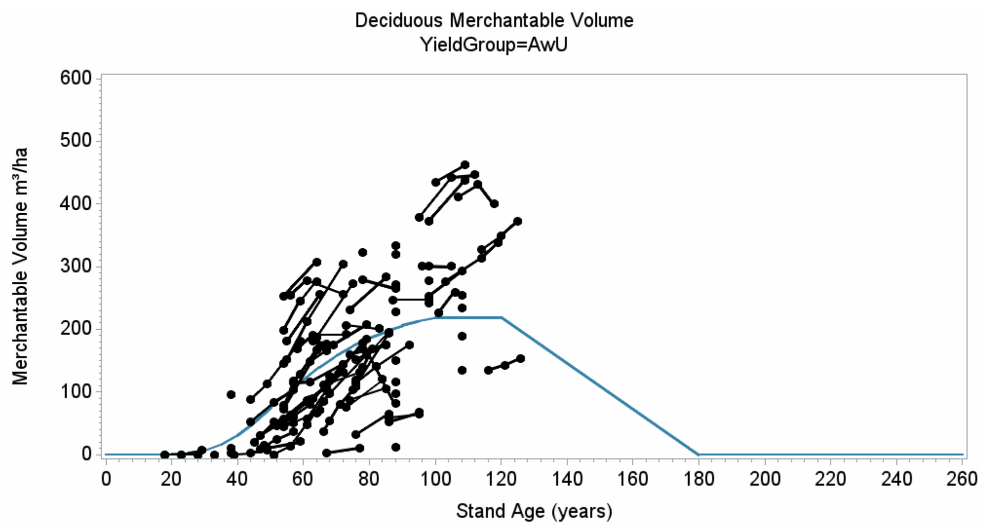


Figure 2-9. Natural stand total plot data against final natural stand yield curves.





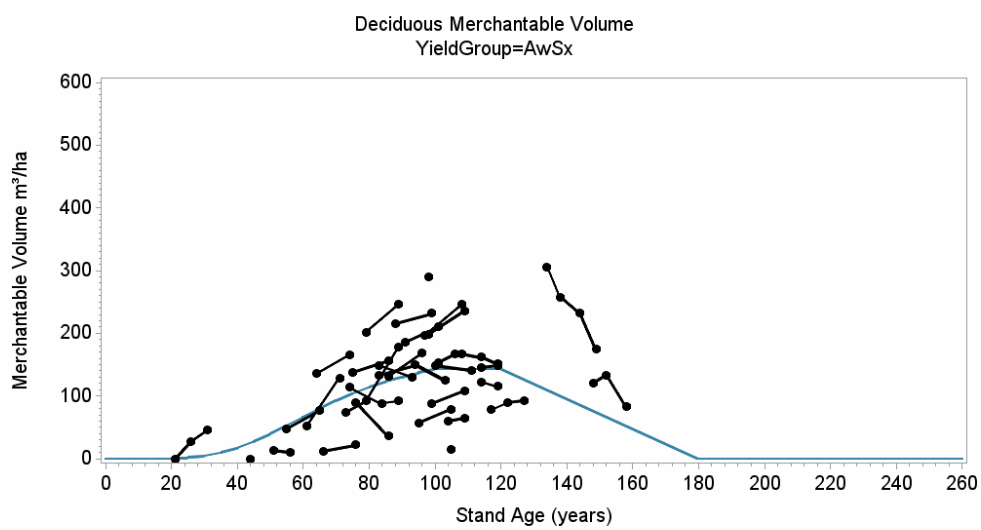


Figure 3-10. Natural stand deciduous plot data against final natural stand yield curves.

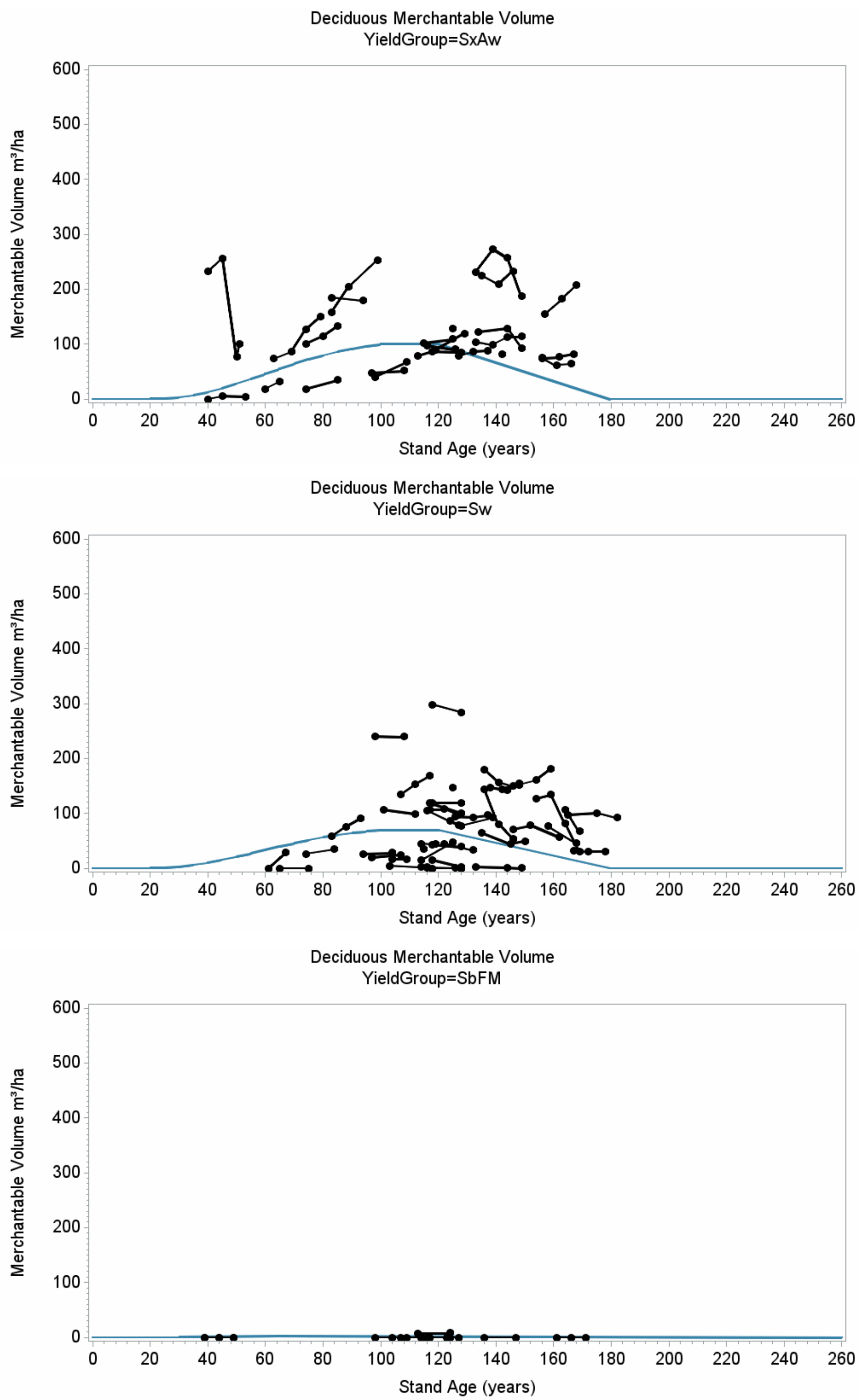


Figure 2-10. Natural stand deciduous plot data against final natural stand yield curves.

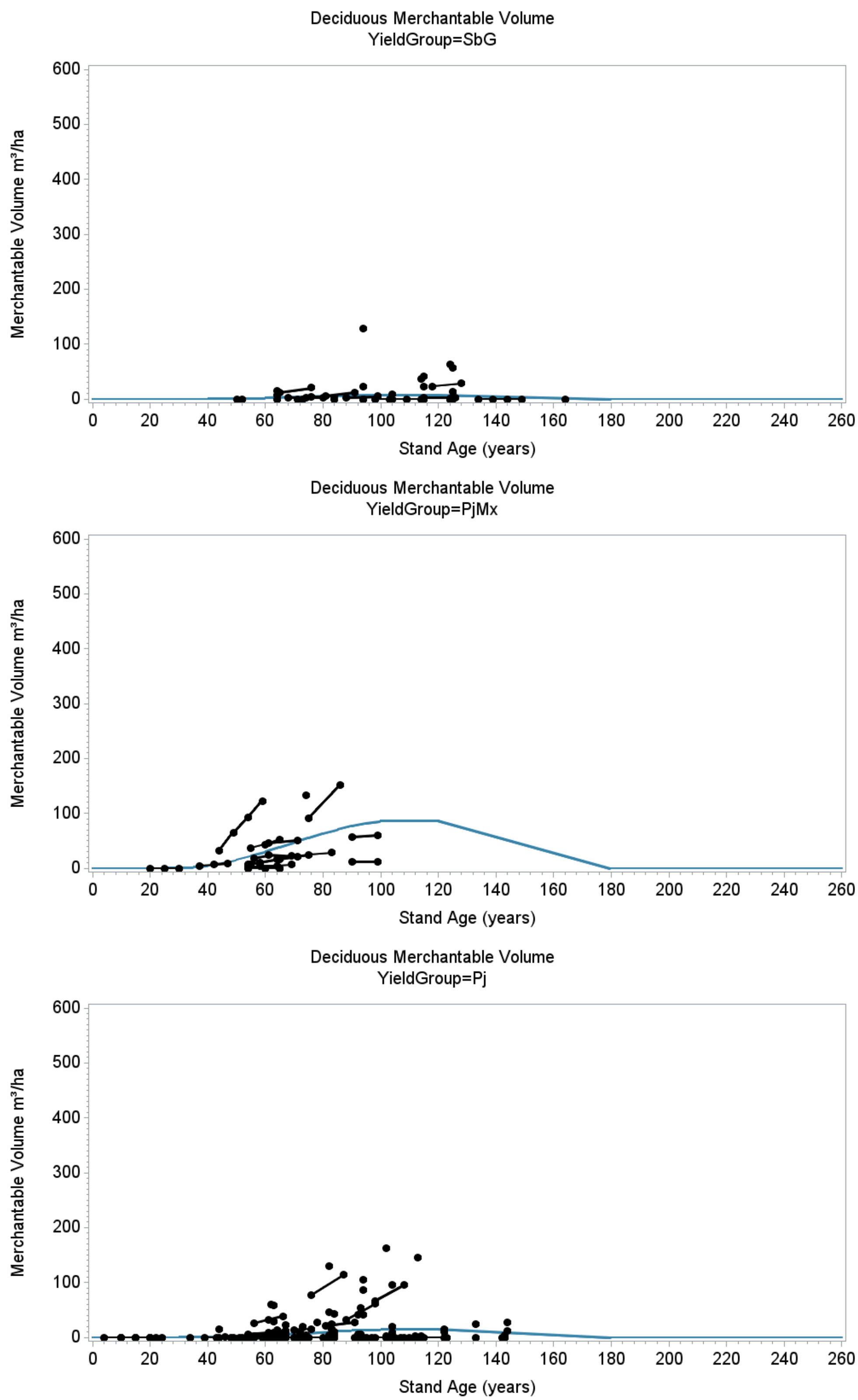


Figure 2-10. Natural stand deciduous plot data against final natural stand yield curves.

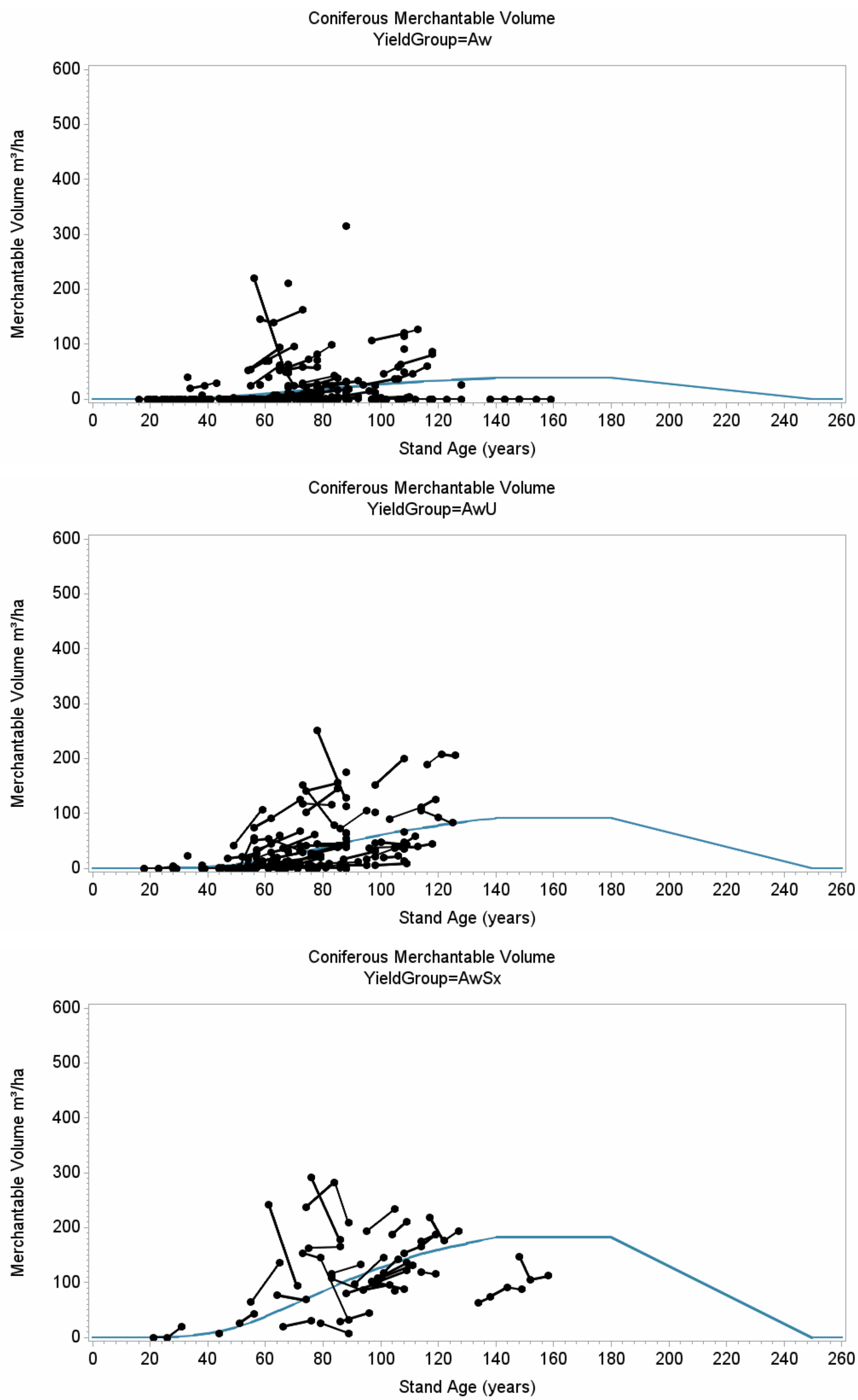


Figure 3-11. Natural stand coniferous plot data against final natural stand yield curves.

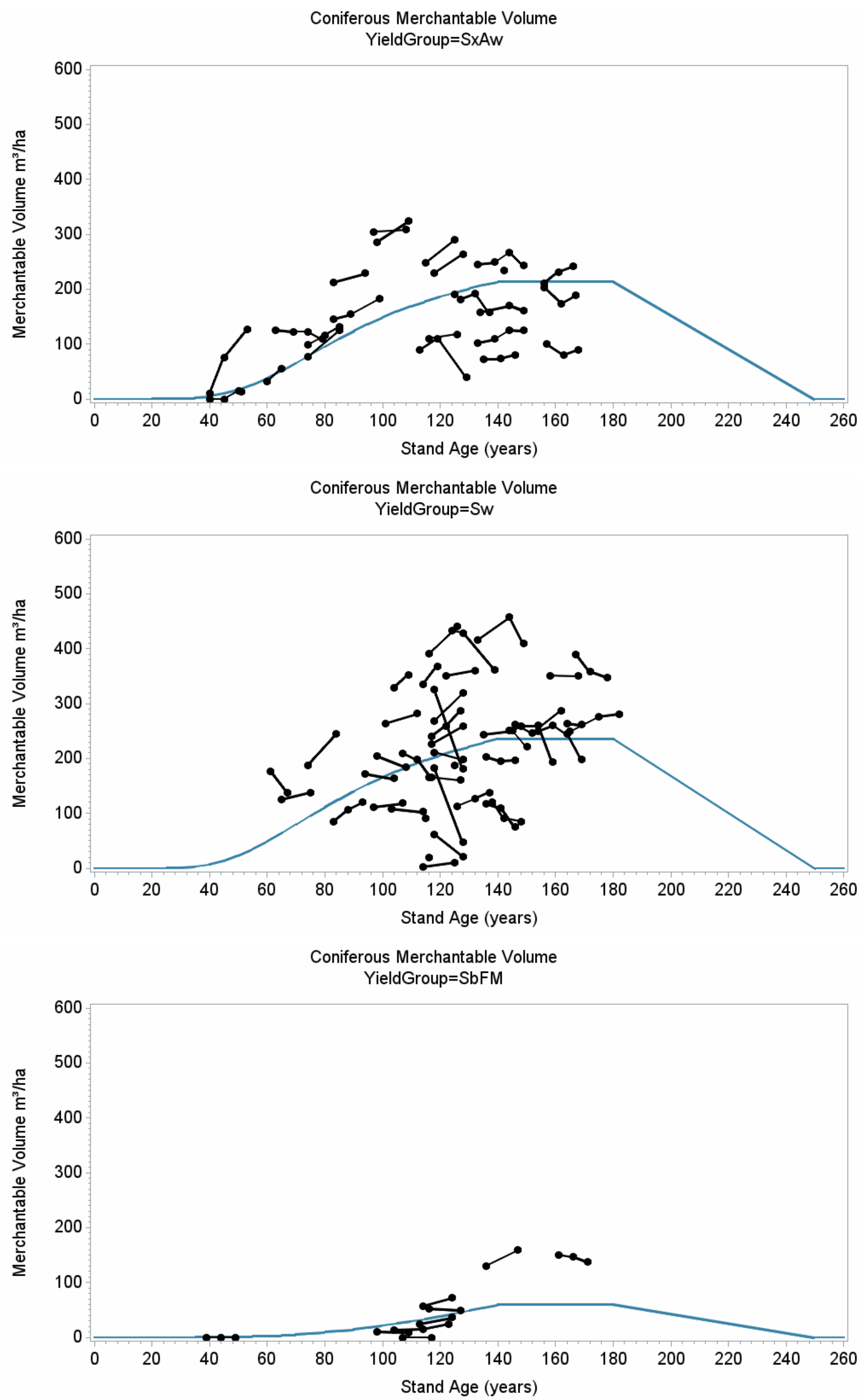


Figure 2-11. Natural stand coniferous plot data against final natural stand yield curves.

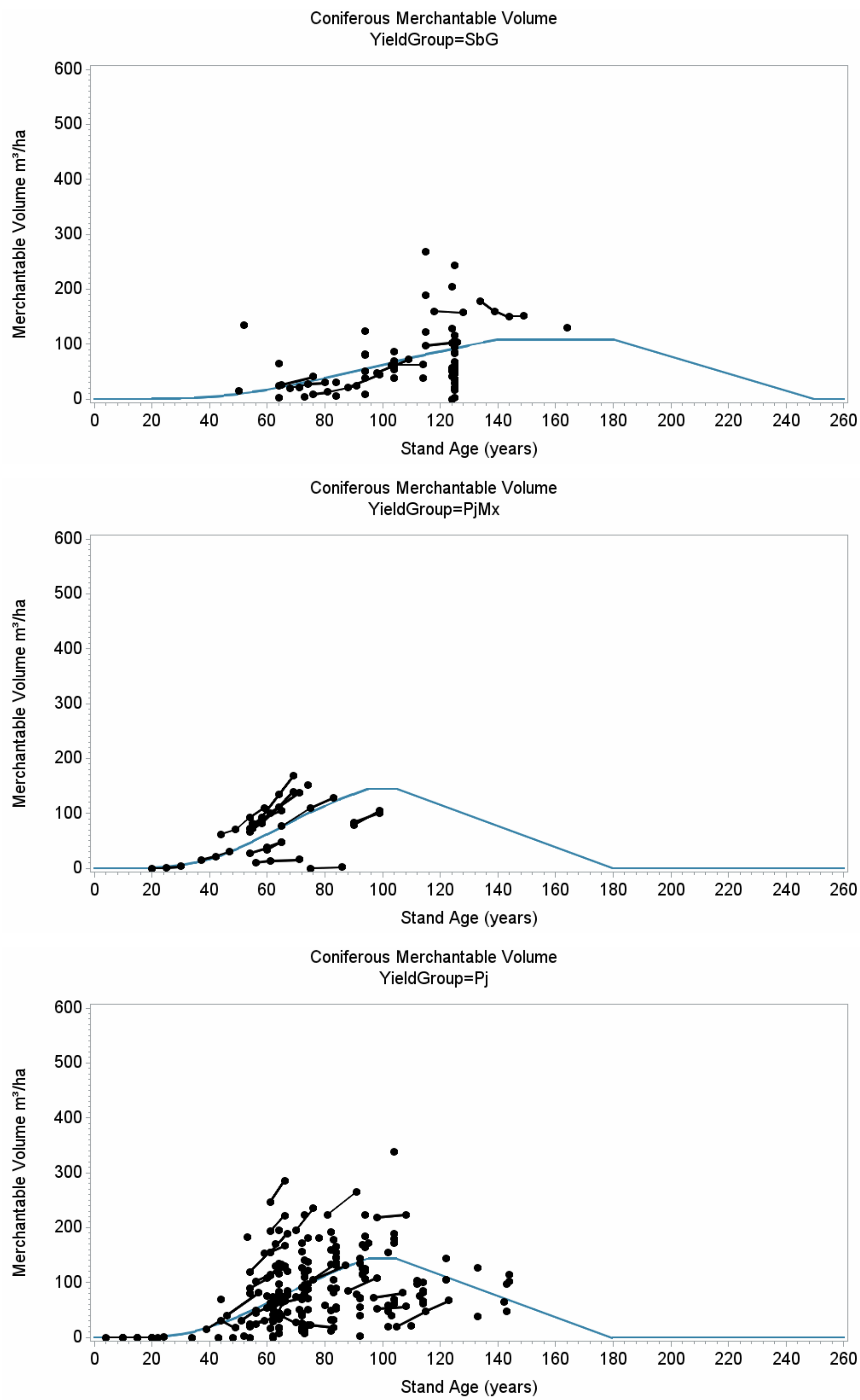


Figure 2-11. Natural stand coniferous plot data against final natural stand yield curves.

ALBERTA-PACIFIC FOREST INDUSTRIES INC.

4 Post-Performance Yield Curves (Group B)

Yield curves created to represent the population of openings with Regeneration Standard of Alberta performance surveys (yield curves 10-18).

4.1 Approach

After discussions with AESRD, an approach to development of post-performance yield curves was designed, with the objective of maintaining sampling unit linework from aerial performance surveys and stratification from photo-interpreted labels. Yield curve development was therefore at the SU level (scale), although in many cases there was only one SU per opening. The naming convention for this set of yield curves is as per the Regeneration Standard of Alberta in order to reflect the fact that yield stratification originates from aerial performance survey definitions. The GYPSY model was selected for yield projections to align with the RSA process of determining yields; a key adjustment to the use of GYPSY was that yield projections were modified to account for mortality at older ages.

4.2 Input Datasets

4.2.1 Source Data

Available RSA performance survey data from 763 openings were used to develop post-performance managed stand yield curves. Data had been assembled into a single RSA compiler for ease of import. A description of RSA data and the RSA compiler is provided in Section 2.6.4.

4.2.2 Yield Stratum Assignment

Yield strata were assigned at the sampling unit, rather than at the opening level. For aerial programs, yield stratum was obtained from the photo-interpreted "species class" (SP_CL) assignment. For non-photo programs, each SU was re-assigned to an equivalent yield stratum based on ground survey data. There were two key reasons for re-assignment:

- Ground-interpreted labels are sometimes inaccurate relative to observed ground data; and
- Ground-based labels are at a coarser resolution than aerial labels (e.g., HwPl and PlHw in aerial programs are combined as MxPl in non-photo programs).

For non-photo programs compiled densities from the GYPSY_INPUT table (RSA compiler) were used to assign a yield stratum based on proportion of density, following the rules for aerial stratum assignment outlined in the RSA survey manual (AESRD 2014b).

4.2.3 Data Exclusions

Fifteen non-photo surveys from pure deciduous stands were excluded from yield curve development. These surveys were undertaken by AESRD to test non-photo protocols in deciduous stands, but were not legislated surveys and selection was not random. Three openings with an SU flag of 1 (survey population deletion due to disturbance) were also removed (3 SUs, one in pure Hw and two in pure Sw). No other deletions were applied to the dataset, regardless of whether or not openings were spatially represented on the landbase, at the direction of AESRD. The total area and number of ground-sampled SUs by program type (aerial vs. non-photo) and yield stratum is presented in Table 4-1.

Table 4-1. Number of ground-sampled sampling units and associated area by program type and yield stratum.

Yield	Aerial		NonPhoto		Total	
Stratum	SUs	Area (ha)	SUs	Area (ha)	SUs	Area (ha)
Hw	67	696.9	23	420.5	90	1117.4
HwSx	99	1154.0	65	1057.6	164	2211.6
SwHw	81	1061.6	11	135.2	92	1196.8
Sw	73	1025.1	2	26.6	75	1051.7
SbHw	4	42.4	2	37.2	6	79.6
Sb	10	79.4	1	1.5	11	80.9
HwPl	5	37.8	3	42.3	8	80.1
PlHw	10	94.8	7	97.6	17	192.4
Pl	10	101.3	1	2.0	11	103.3
Total	359	4293.2	115	1820.5	474	6113.7

4.3 Data Preparation

Several edits to 2009 performance survey data were required in order to load these data into the existing RSA compiler. These edits included:

- Adding nil tally plots;
- Constructing photo interpretation and opening tables (not required in the 2009 submissions)
- Moving shrub percentages to the plot location table; and
- Making the minimum number of data edits possible to enable data loading within the compiler.

In the 2009 Millar Western RSA dataset, there were several incorrect opening numbers that were not corrected in the original data, but rather during submission of results into ARIS; the RSA compiler was edited to change these data to the correct opening number.

4.4 Data Compilation

Data from the RSA compiler were used for yield curve development. SU-level density, basal area, site index and age (stand and species-level) were obtained from the GYPSY_INPUT table. The methods used for compiling data are documented in the Regeneration Standard of Alberta (AESRD 2013)[17].

[17] Note that changes to sample selection protocols and compilation routines occurred in 2014, therefore the 2013 manual is specifically being referenced here.

4.5 Modelling

4.5.1 Growth Modelling Approach

The GYPSY model (Huang et al., 2009a and 2009b) was used for growth projections. Although the RSA compiler stored yield table outputs, these data are provided in 10-year increments which was unsuitable for timber supply analysis needs. Compiled RSA data were therefore re-projected using GYPSY to obtain 5-year outputs.

4.5.2 Model Inputs

SU-level inputs were taken from the RSA compiler's GYPSY_INPUT table. Inputs included stand age, species age, site index, density, percent stocking and, where available, basal area. While basal area was not collected for all programs, it was used when available (in order to maintain consistency with the original RSA model projections).

4.5.3 Model Outputs

The GYPSY model was projected to age 300 for all sampling units. Yield curves were generated from SU-level outputs as follows:

Aerial Programs

An average yield was generated for each aerial program by sampling stratum, employing the composite weighting approach developed for the RSA program (AESRD 2013) to roll individual projections to the program/sampling stratum level. Where sampling strata represented more than one yield stratum, e.g. a combined SbHw/SwHw sampling stratum, separate yield curves were created for each stratum with identical yields. The total population area (including all SUs, not just ground sampled SUs) was then assigned to each yield stratum within its respective program.

Non-Photo Programs

Each sampling unit had its own yield stratum assignment, yield projection, and area.

Averaging Across Programs

Yield curves were created by calculating area-weighted averages across all yield strata, combining program-level averaged yields from aerial programs and individual SU-level yields from non-photo programs.

4.5.4 Yield Adjustments

Yield adjustments were applied in a manner consistent with Natural and Intensive GYPSY-based curves:

- Deciduous volume (all yield strata): flat line deciduous volumes from 100 to 120 years, then implement a continuous decline in volume from ages 120 to 180, targeting zero deciduous volume at year 180.

- Coniferous volume (HwPl, PlHw and Pl yield strata): flat line coniferous volumes from 95 to 105 years, then implement a continuous decline in volume from ages 105 to 180, targeting zero coniferous volume at year 180.
- Coniferous volume (all other yield strata): flat line coniferous volumes from 140 to 180 years, then implement a continuous decline in volume from ages 180 to 250, targeting zero coniferous volume at year 250.

4.6 Results

4.6.1 Post-Performance Yield Curves

Figure 4-1 presents the unadjusted yield curves by yield stratum; grey represents total merchantable yield, blue represents coniferous merchantable yield and red represents deciduous merchantable yield. The persistence of yield accumulation at mature ages is pronounced in these curves. Also note the abundance of coniferous volume in the Hw stratum; this reflects the impact of current (RSA) density-based thresholds for yield stratum assignment as well as the inability of photo-interpreters to see small conifers.

Figure 4-2 presents the adjusted yield curves by yield stratum; grey represents total merchantable yield, blue represents coniferous merchantable yield and red represents deciduous merchantable yield. Older stand breakup is better reflected in these curves. For pine strata (HwPl, PlHw and Pl), maximum yields are reduced by 100-150 m^3/ha using these methods.

4.6.2 Comparison with Natural Stand Yield Curves

Post-performance yields are graphically compared to the 2015 natural stand yields in Figure 4-3. Post-performance yields exceed natural stand yields across all yield strata.

4.6.3 Final Yields

Final post-performance managed stand yield tables are provided in Appendix II.

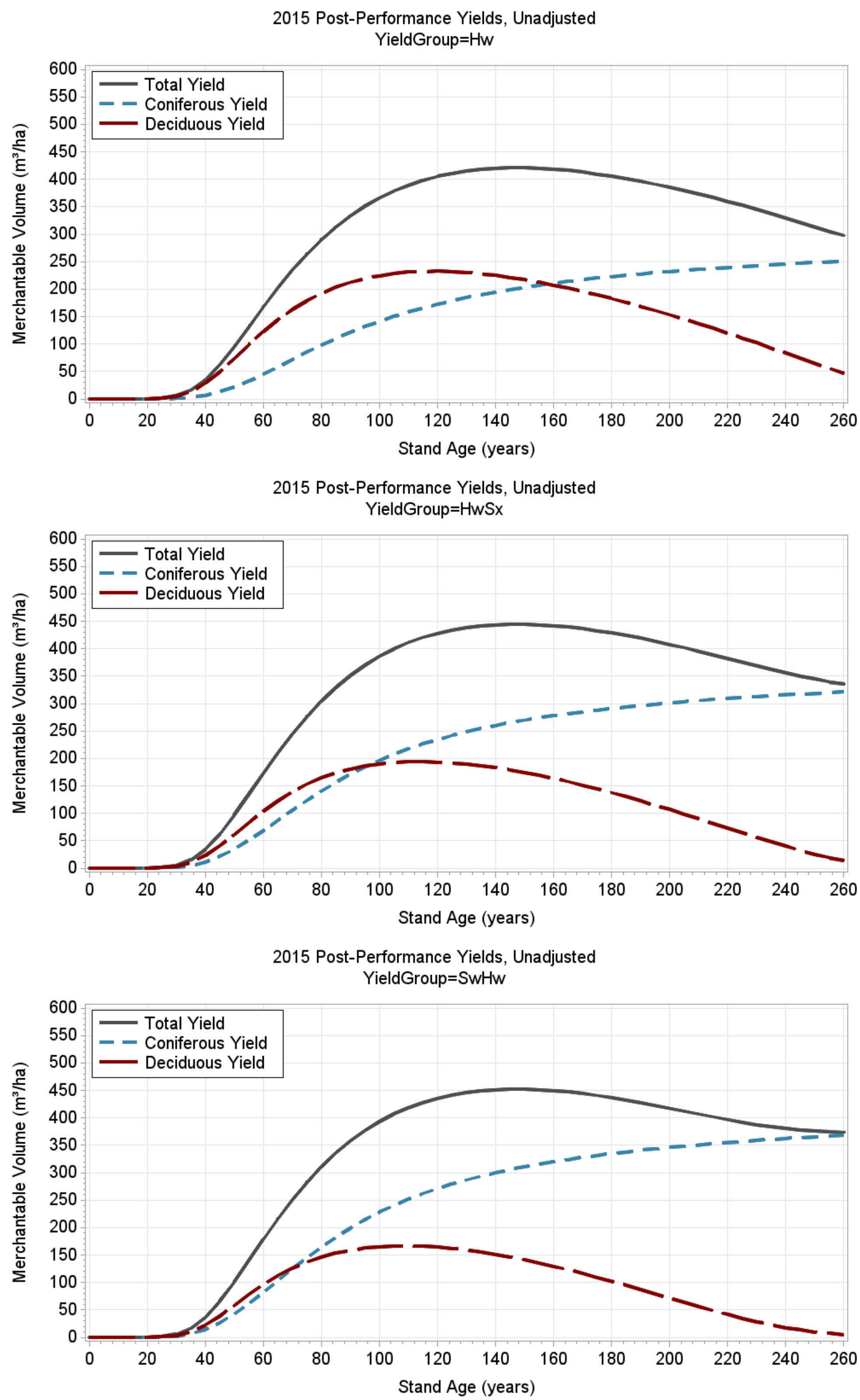


Figure 4-1. Post-performance yield curves, unadjusted.

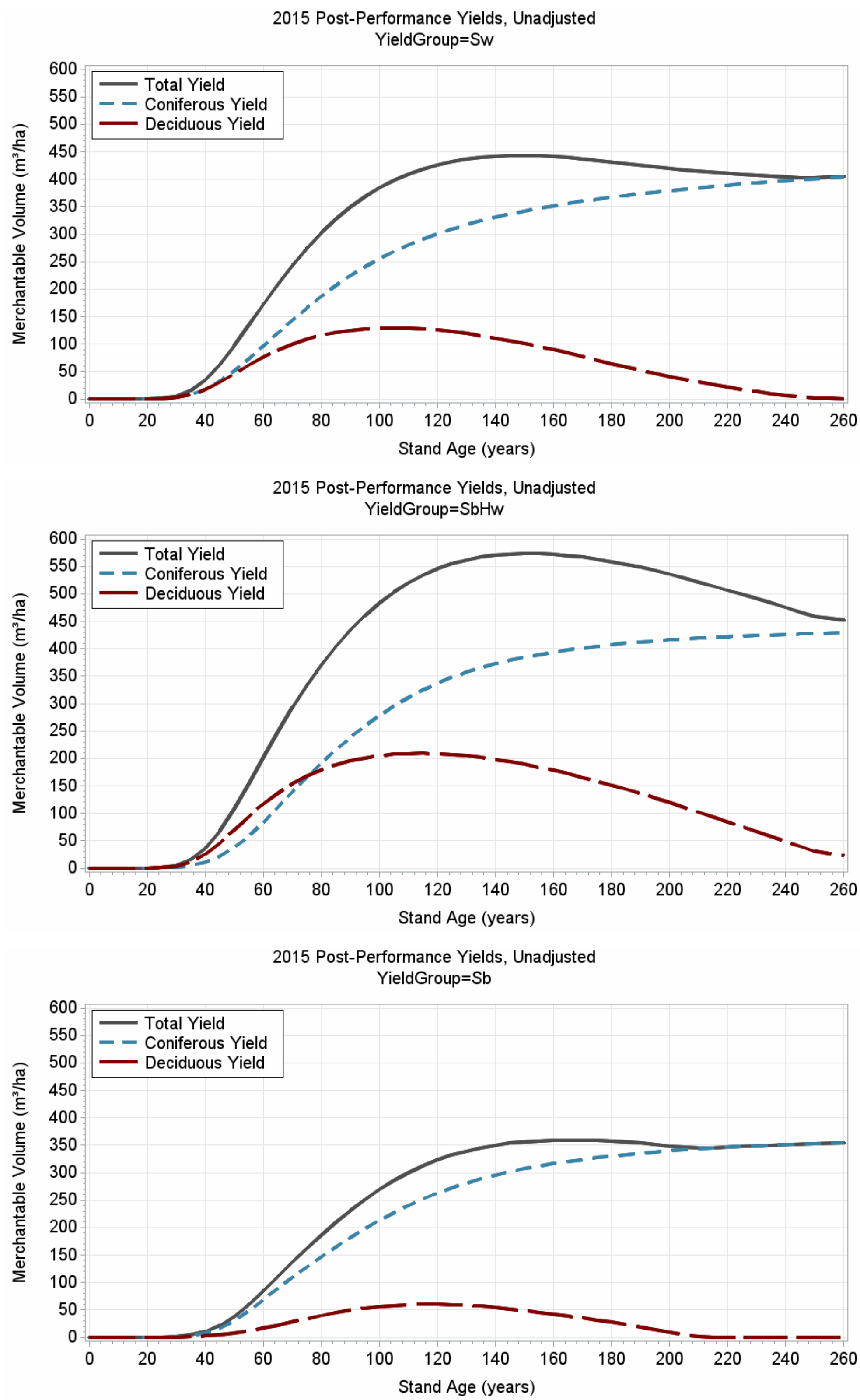


Figure 3-1. Post-performance yield curves, unadjusted.

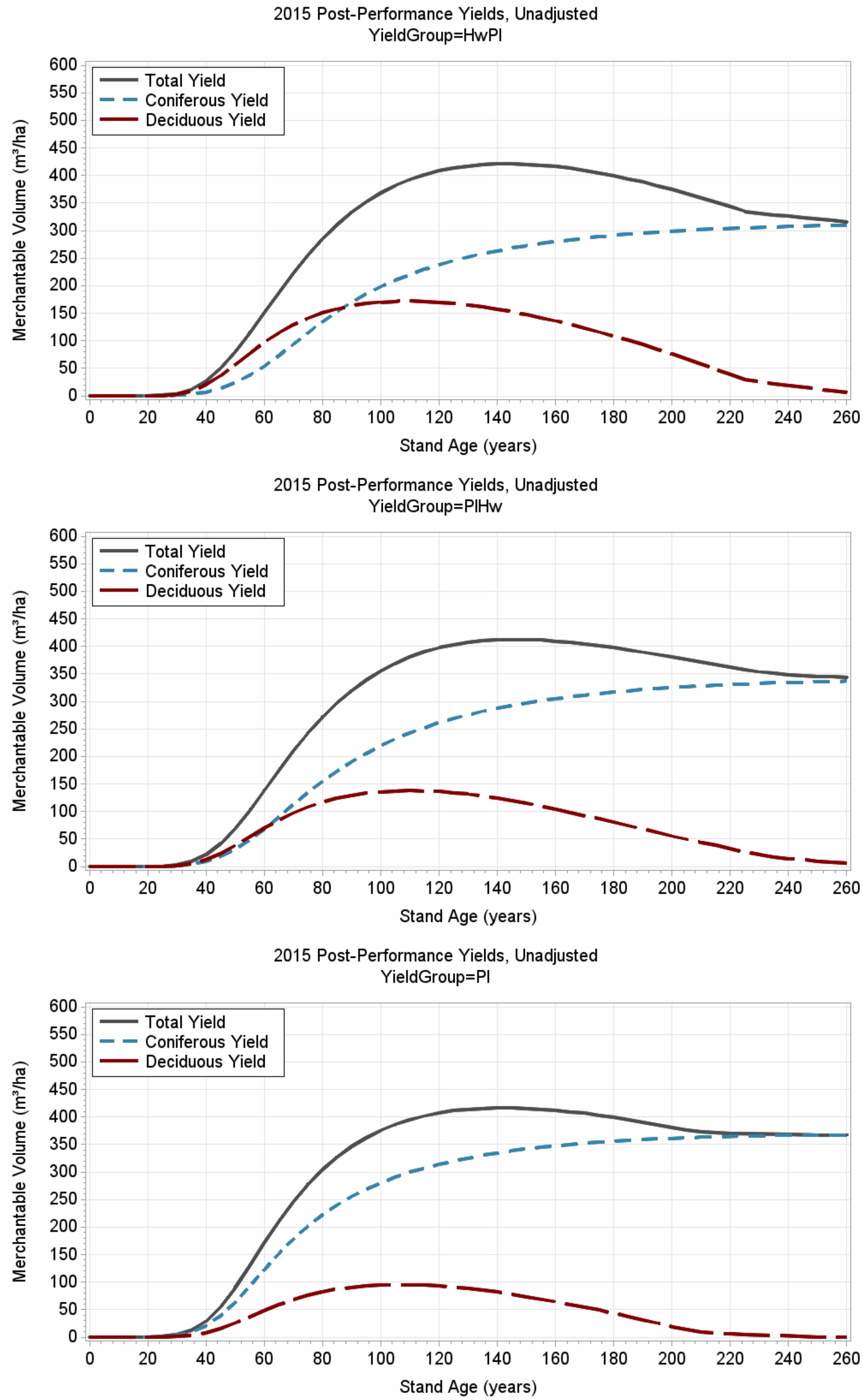


Figure 3-1. Post-performance yield curves, unadjusted.

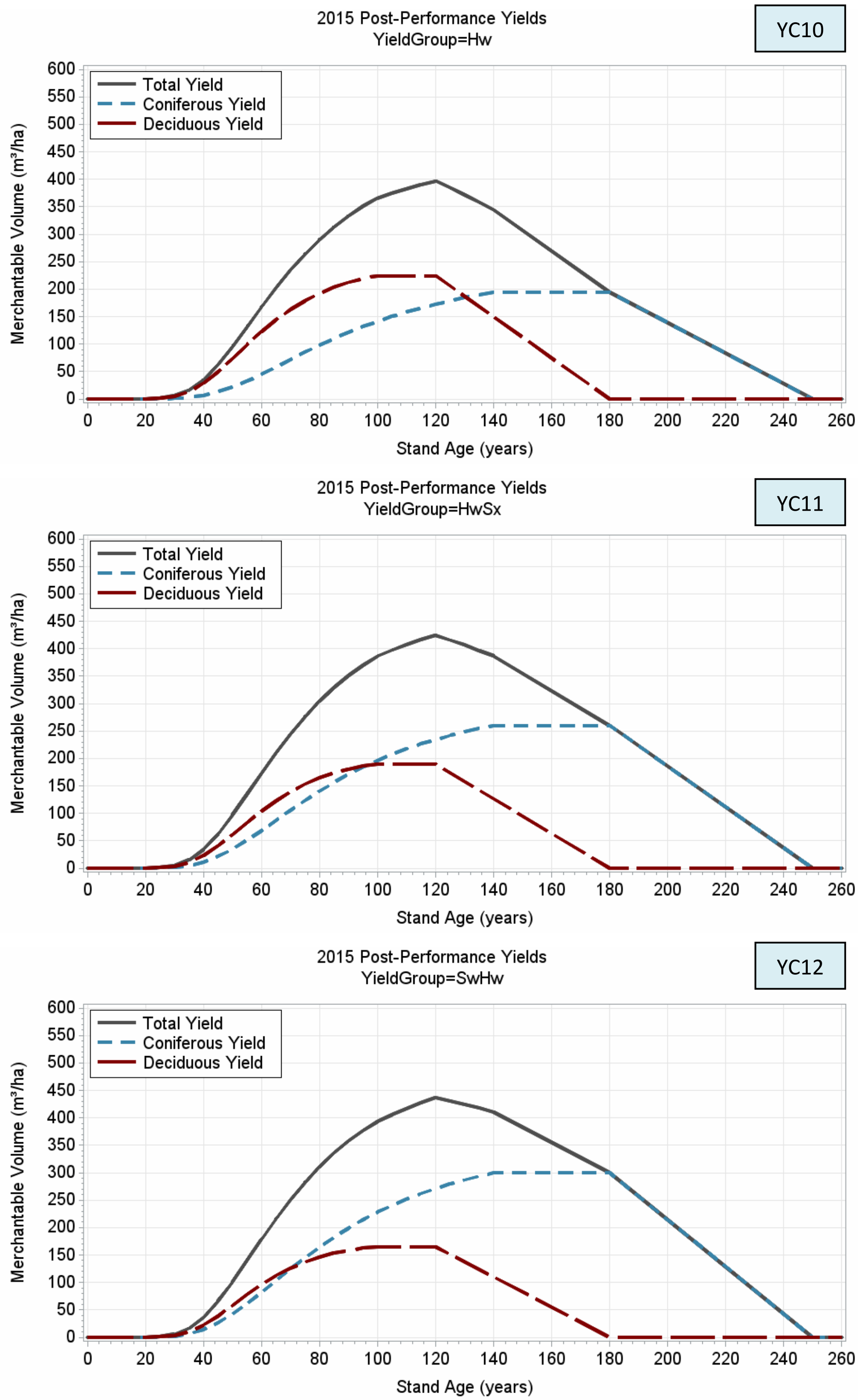
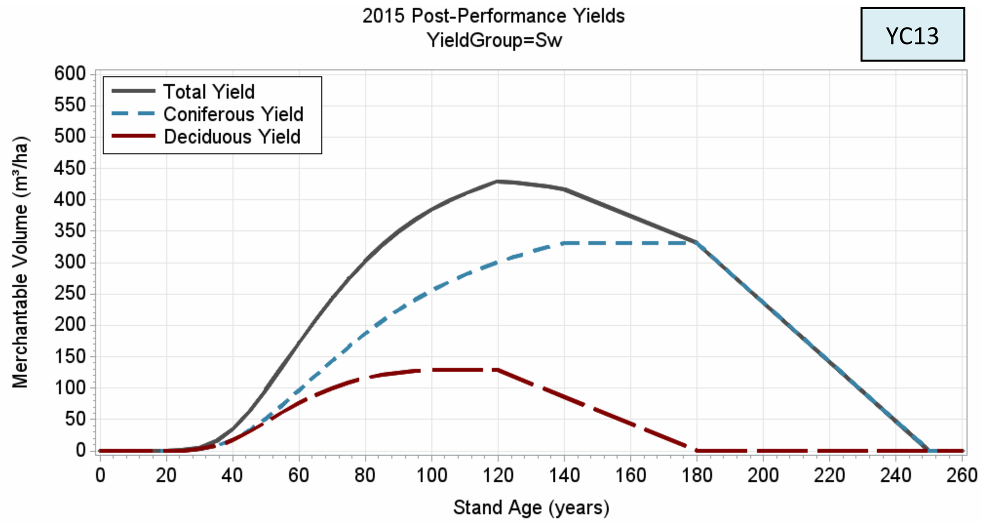
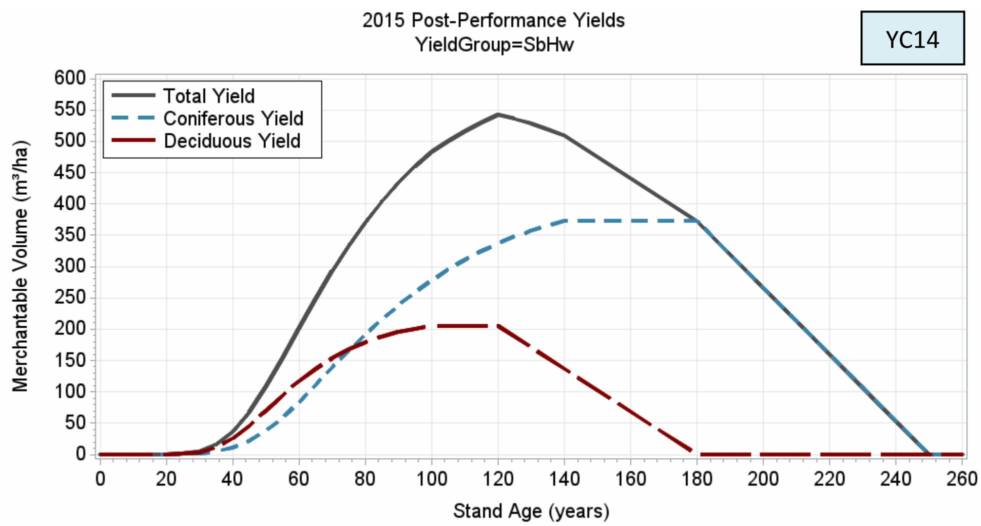


Figure 4-2. Final post-performance yield curves.





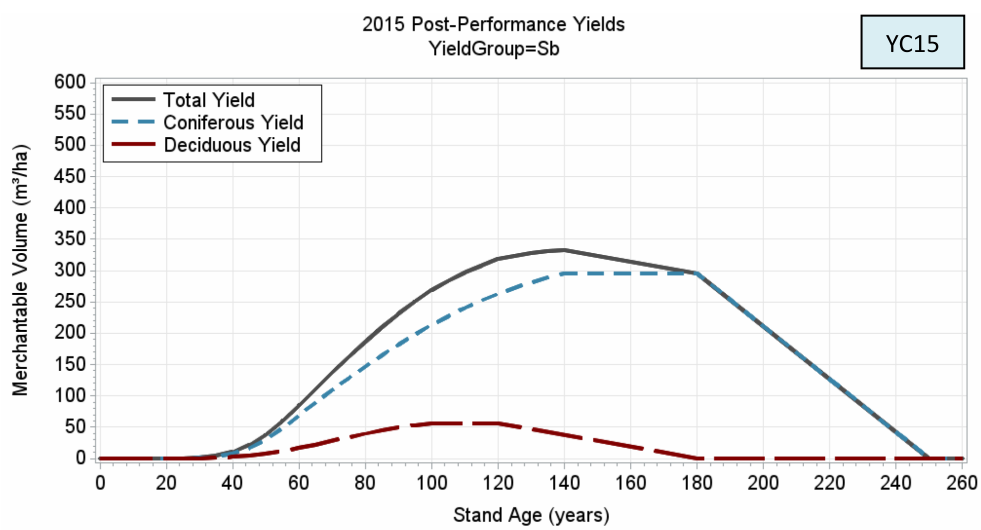


Figure 3-2. Final post-performance yield curves.

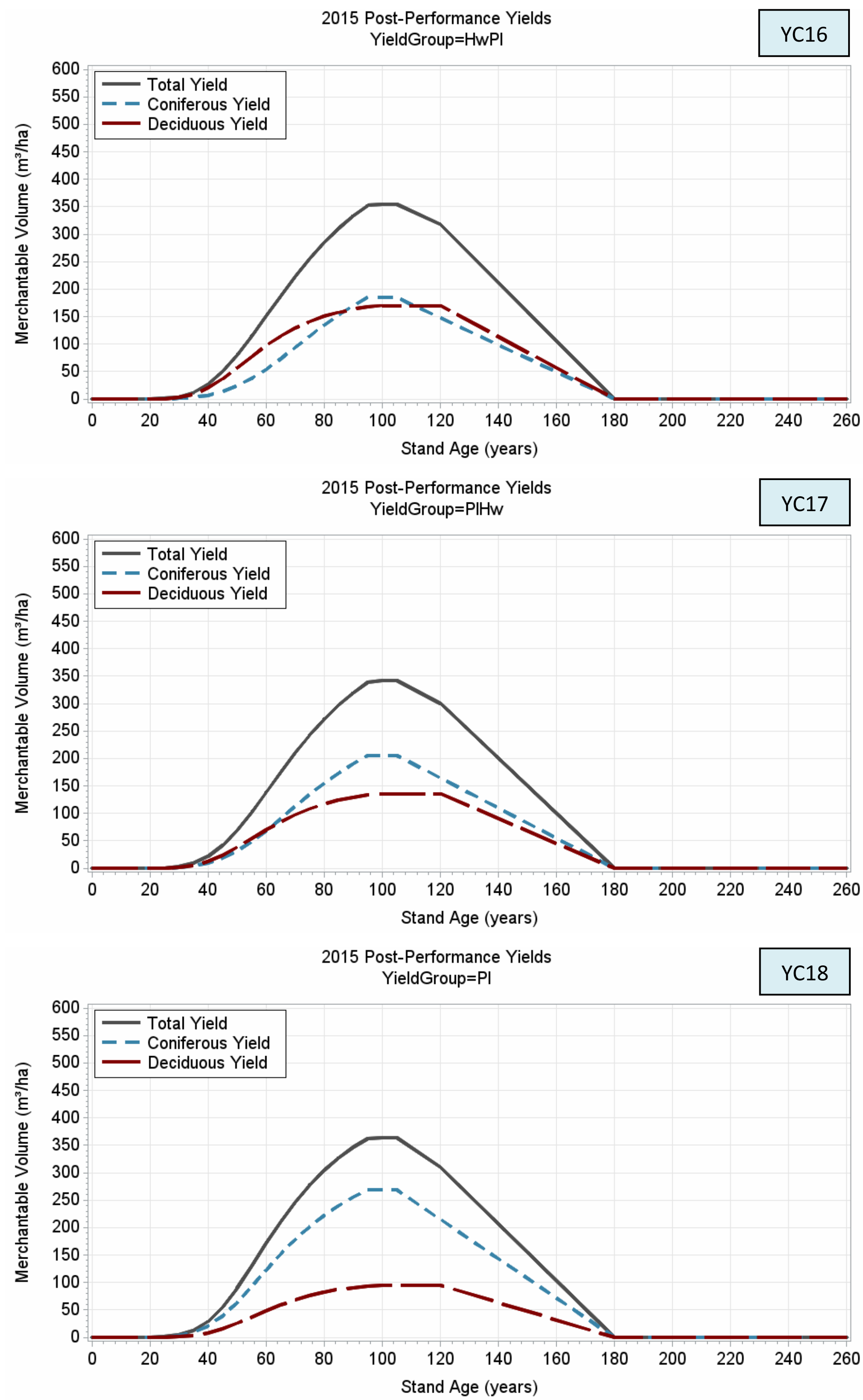


Figure 3-2. Final post-performance yield curves.

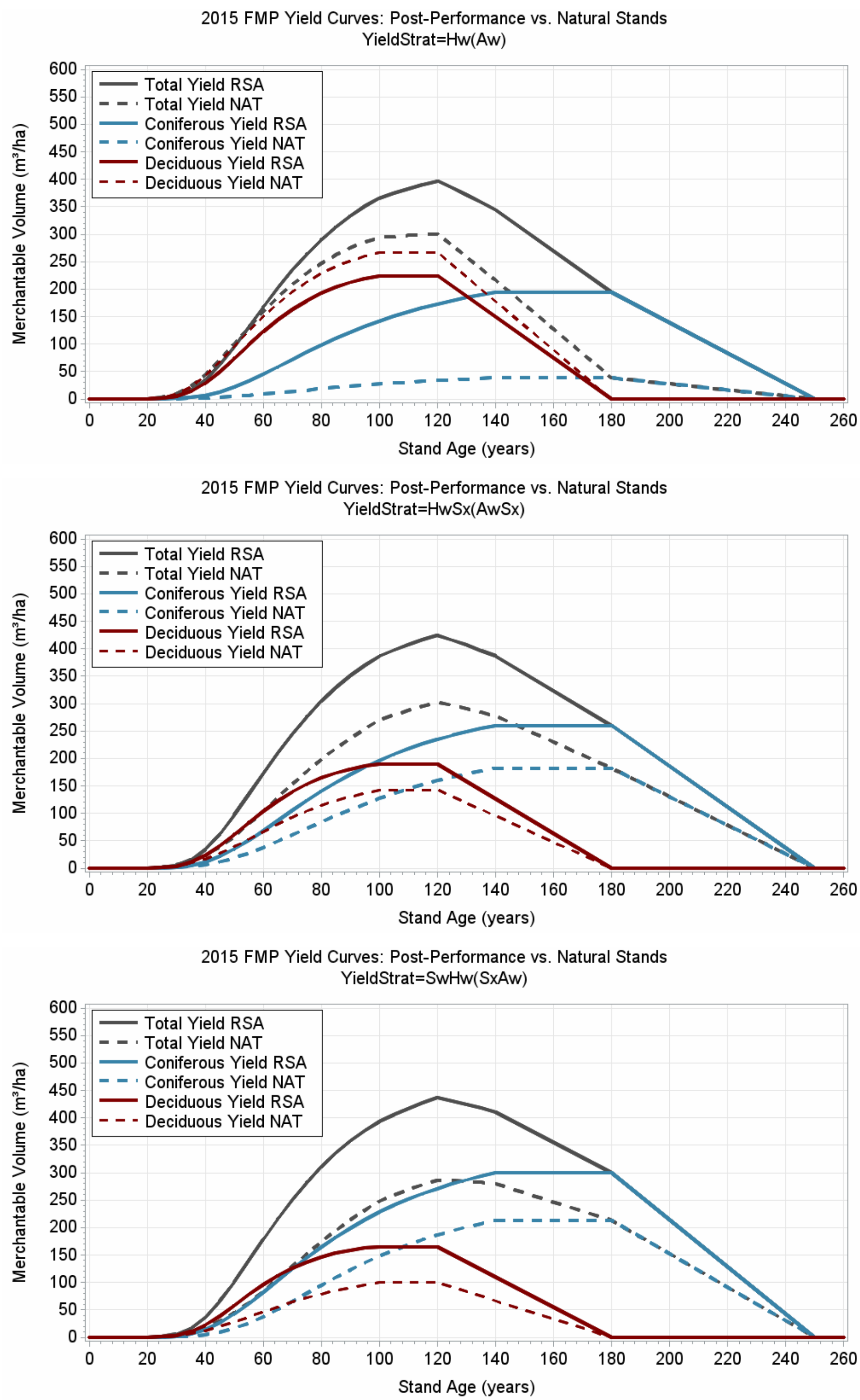


Figure 4-3. Comparison between post-performance and natural stand yield curves.

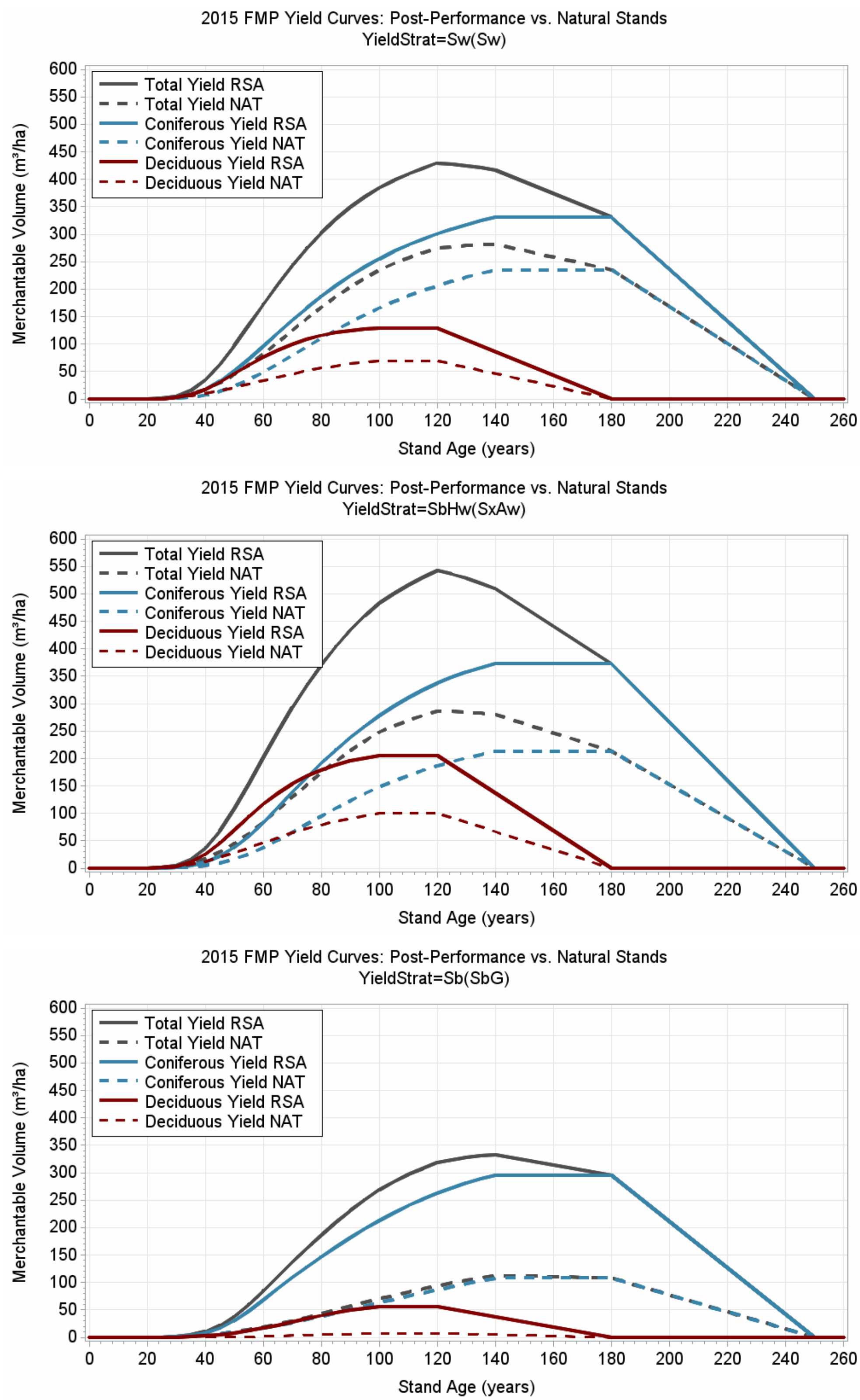
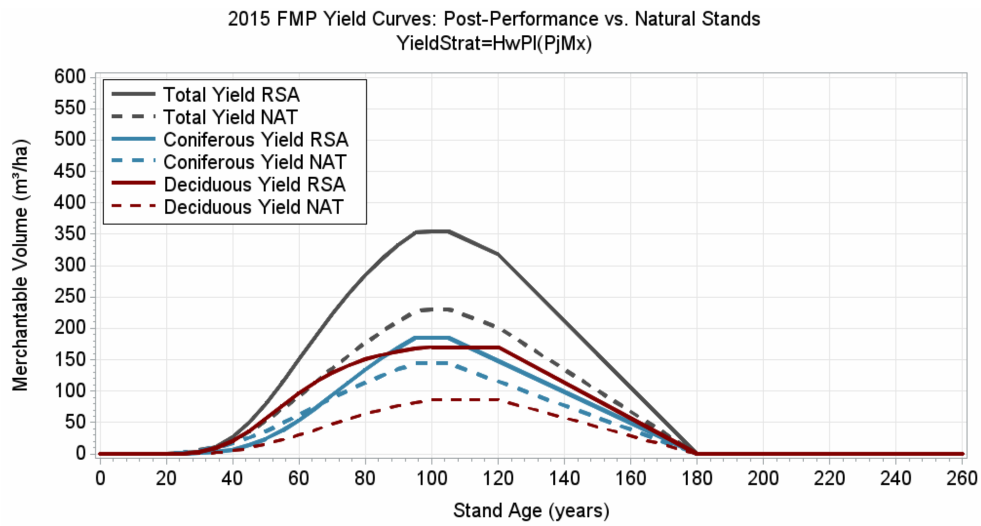
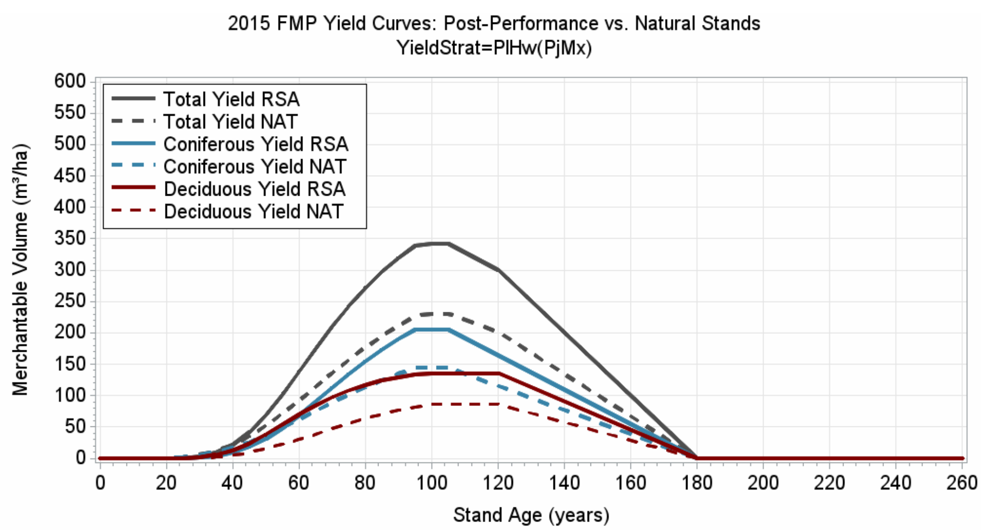


Figure 3-3. Comparison between post-performance and natural stand yield curves.





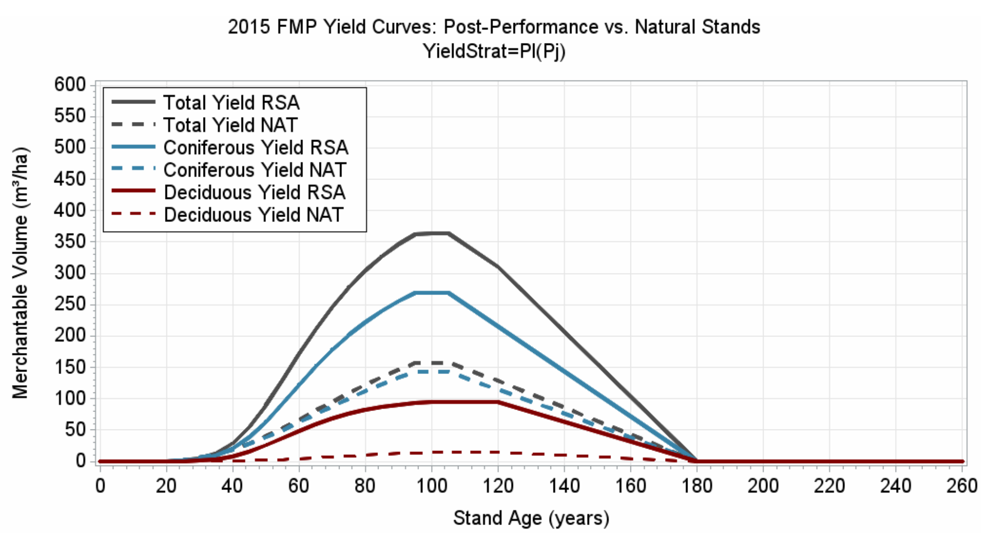


Figure 3-3. Comparison between post-performance and natural stand yield curves.

5 Intensive Management Yield Curves (Group C)

Coniferous and mixedwood yield curves developed to represent post-harvest quota holder cutblocks in the Alberta-Pacific FMA area (yield curves 19-21) plus natural stand yields for strata lacking sufficient data (yield curves 1 and 6-9).

5.1 Approach

Intensive management yield curves are required to represent yields for openings without an RSA performance survey (generally, openings too young to have a performance survey). Objectives for intensive management yield curves were to 1) create a set of yield curves specific to quota holders within the Alberta-Pacific FMA area that 2) reflected the potential scale (resolution) of silviculture practice for openings without a performance survey.

The GYPSY model was used to create yield curves for the AwSx, SxAw and Sw yield strata. Because GYPSY is a stand level model, all inputs were compiled and projected at the opening or SU level (i.e., TSP data were averaged across plots within stand, and RSA data were maintained at the SU level).

The Aw, SbFM, SbG, PjMx and Pj yield strata were assigned natural yields due to a lack of available data.

The following sections describe the development of yield curves 19-21; the full final set of yield curves is included in Appendix III.

5.2 Input Datasets

5.2.1 Source Data

Source data included all managed stand data. In order to increase the available sample size for managed stands, the RSA data used for post-performance yield curve development were re-assigned to yield strata at the opening level to mimic the rule set for assigning strata to blocks without a performance survey (see Section 5.2.2 for description of methods).

The population of available managed stand data is summarized in Table 5-1. Some of Alberta-Pacific`s permanent sample plots fall within quota holder openings, however, at the time of yield curve development, no PSPs could be definitively linked to intensive management quota holder openings, therefore no PSP data were included in intensive yield curve development. Four ATP installations were located within quota holder openings; however, since RSA performance survey data was available for these openings, the ATP installations were excluded from the intensive management dataset.

As such, three sources of data were used for yield curve development:

- RSA performance survey data;
- TSP data from the 2013 program in managed stands (2012 data collection focused on pure Aw openings); and
- Non-legislated RSA performance surveys collected in 2013 in FMU S14 (referred to as TSP-RSA data).

A description of these datasets is provided in Sections 2.6.3 through 2.6.5.

Table 5-1. Initial population of managed stand data.

Sampling Program	Number of Openings
ATP	49
PSP	53
RSA	763
TSP	44
TSP-RSA	11
Total	920

5.2.2 Yield Stratum Assignment

Yield strata were assigned to each opening based on ARIS declaration and, where required, silviculture treatment information (planting, seeding and/or leave for natural activities).A description of the rule set used to assign yield strata to existing managed stands is provided in Annex IV (ForCorp 2014).

5.2.3 Data Exclusions

The intensive management population of data was refined by applying the following deletions to the combined RSA, TSP and RSA-TSP datasets:

- Openings belonging to Alberta-Pacific (including test deciduous performance surveys established in Alberta-Pacific cutblocks by AESRD) and PSP plots with unknown ownership;
- Openings lacking spatial location information at the time of yield curve development;
- Openings lacking ARIS information at the time of yield curve development (primarily FRIAA blocks);
- Yield stratum was not one of: AwSx, SxAw or Sw;
- Four ATP installations established in quota holder stands (duplicates in RSA-surveyed SUs);
- RSA performance surveys with no ground survey data; and
- RSA aerial performance surveys with < 80% of the opening area selected for ground surveying (to ensure that SU data were representative at the opening level).

A summary of the initial and final number of openings by program is provided in Table 5-2, and the final number of openings by yield stratum is presented in Table 5-3.

Table 5-2. Reduction of data suitable for intensive management yield curves.

Number of Openings by Sampling Program	RSA	TSP	TSP-RSA	ATP	JPSP	PSP	Total
Initial Number of Openings	763	44	11	49	9	44	920
Albert Pacific or unknown ownership	239	37		45	9	36	366
ASRD RSA deciduous blocks	15						15
Duplicate samples in the same opening				4			4
No opening ID						3	3
No spatial information	21					5	26
No ARIS information	108						108
Not in target yield strata	5	5					10
RSA opening no ground survey	187						187
RSA opening with <80% ground sampled	6						6
Total Number of Openings Lost	581	42	0	49	9	44	725
Final Number of Eligible Openings	**182**	**2**	**11**	**0**	**0**	**0**	**195**

Table 5-3. Number of intensive management openings by yield stratum and data type.

Yield	Data Collection Program			Total
Stratum	RSA	TSP	TSP-RSA	
AwSx	21		4	25
SxAw	40		7	47
Sw	121	2		123
Total	**182**	**2**	**11**	**195**

5.3 Data Preparation

See Section 4.3 for details on RSA performance survey data preparation. For both the RSA and TSP-RSA datasets, no additional data preparation or compilation was required.

The TSP dataset was reviewed for missing or outlier information. Several minor data edits were applied to the TSP data during compilation; these edits are documented within the code included with this yield curve submission. The only additional change to the TSP dataset was to delete all larch data.

5.4 Data Compilation

GYPSY input data from the RSA compiler (both RSA and TSP-RSA databases) were used for intensive management yield curve development. SU-level density, basal area, stocking, site index and age (stand and species-level) were obtained from the GYPSY_INPUT tables. The methods used for compiling data are documented in the Regeneration Standard of Alberta (AESRD 2013).

Stand-level inputs were compiled for the TSP data separately. Data were compiled to align with the RSA survey manual methodology, with the exception of including birch in age calculations. The following Sections describe the methods used to compile GYPSY inputs for the TSP data.

5.4.1 Density

Density was calculated using species-level tree tallies from the TSP plots. Tallies were multiplied by the inverse of plot area to convert tallies to a stems per hectare basis. Density by species group was then calculated by summing across species and dividing by 3 (since there were 3 plots per stand).

5.4.2 Basal Area

Average basal area (basal area at breast height) was calculated by species as follows:

- Advance trees were excluded from average basal area calculations for both deciduous and coniferous species; and
- Average basal area was calculated separately for deciduous species that initiated following tending as opposed to those that initiated immediately after harvesting[18].

For coniferous species, the density/ha of stems ≥ 1.3 m in height, including advance growth, was multiplied by the average basal area to determine basal area per hectare. For deciduous species, basal area per hectare was calculated using:

- Average basal area of post-harvest stems multiplied by the stems/ha of post-harvest plus advance deciduous; plus
- Average basal area of post-tending stems multiplied by the stems/ha of post-tending deciduous.

Total basal area by species group was then calculated by summing across species.

5.4.3 Top Height

Top height was not calculated. Based on the RSA performance survey manual approach, site index and species age were used as inputs for GYPSY, from which top height was then derived by the model.

5.4.4 Stand Age

Stand age was calculated based on skid clearance year and month of survey in a manner similar to the RSA data compilation specifications:

Stand Age = Measurement Year + 1 – Clock Start Year

Where one year is added to all stand ages since surveys were performed after April 30.

5.4.5 Species Group Age

For TSP plots, only one age was collected per species group, according to the same selection rules as the RSA manual. All top height trees, including birch, were used to calculate average species group age (a minor deviation from the RSA performance survey protocols, where birch is not sampled). No exclusions based on total age were applied to the dataset. During 2013 TSP data collection, age was

[18] The use of post-harvest and post-tending data collection was targeted primarily at Alberta-Pacific cutblocks in order to correctly characterize the two cohorts that are created by manual tending, however, the protocols were applied to all openings sampled under this manual and thus compilation routines must reflect this difference.

destructively sampled at the root collar (10 cm above point of germination); this age was converted to total age as follows:

- No adjustment for deciduous species age since these are assumed to reach 10 cm in year 1;
- Added one year to all coniferous ages (except fir) under the assumption that these are primarily planted trees; and
- Add two years to fir ages since these are assumed to be natural ingress[19].

Stand level average age by species group was then calculated across all plots.

5.4.6 Site Index

Site index was calculated from height and total age for each sampled top height tree using GYPSY top height equations (Huang et al. 2009a). Deciduous and pine less than 8 years total age and spruce less than 10 years total age were excluded from site index calculations as recommended for GYPSY modelling. All birch were also excluded (GYPSY top height models are not recommended for use with birch). An average site index was then calculated for each TSP stand by species group. An area-weighted average site index by yield stratum and species group was used to fill in missing site index values; this area-weighted average was calculated based on the combined RSA, TSP-RSA and RSA datasets.

5.4.7 Stocking

Stocking was set to blank (missing) for all TSP data.

5.5 Modelling

5.5.1 Growth Modelling Approach

The GYPSY model (Huang et al., 2009a and 2009b) was used for model projections. Although the RSA compiler stored yield table outputs, these data are provided in 10-year increments which was unsuitable for timber supply analysis needs, therefore TSP, RSA and TSP-RSA data were all projected to obtain output yields in 5-year increments.

5.5.2 Model Inputs

For RSA and TSP-RSA data, SU-level inputs were taken from the RSA compiler's GYPSY_INPUT table. For TSP data, inputs were compiled as described in Section 5.4. Inputs included stand age, species age, site index, density, percent stocking (RSA and TSP-RSA data) and, where available, basal area (TSP, TSP-RSA and some RSA data). While basal area was not collected within all RSA survey programs, where it was collected it was used in order to maintain consistency with the original RSA model projections.

[19] Natural ingress of shade-tolerance fir assumed to take 2 years, on average, to reach 10 cm in height.

5.5.3 Model Outputs

The GYPSY model was run to age 300 for all SUs. Yield curves were generated by averaging across observations using weighting by opening and/or SU area (rather than creating program-level yields and then calculating area-weighted averaged across programs as for post-performance yield curves in Section 4.5.3). Simple area-weighted averages were used for two reasons:

1. Because the intensive management yield stratum assignment was different from the initial RSA label used for subsampling, and composite weights were specific to RSA sampling strata, these weights could not be used.
2. TSP programs sampled a smaller fraction of a large population, while RSA programs sampled a large fraction of a smaller population. Generating population-level results and then area-weighting the results based on population size would result in RSA data having a much smaller influence on the final yields relative to the number of samples.

Since both programs were selected randomly (or pseudo-randomly in the case of RSA surveys), an area-weighted average was considered the most appropriate method under these circumstances.

5.5.4 Yield Adjustments

Yield adjustments were applied in a manner consistent with other GYPSY-based curves:

- Deciduous volume: flat line deciduous volumes from 100 to 120 years, then implement a continuous decline in volume from ages 120 to 180, targeting zero deciduous volume at year 180.
- Coniferous volume: flat line coniferous volumes from 140 to 180 years, then implement a continuous decline in volume from ages 180 to 250, targeting zero coniferous volume at year 250.

5.5.5 Natural Curves

Natural stand yield curves (curves 1 and 6-9) were used to represent intensive management yields for the Aw, SbFM, SbG, PjMx and Pj yield strata.

5.6 Results

5.6.1 Intensive Management Yield Curves

Figure 5-1 presents the unadjusted yield curves by yield stratum; grey represents total merchantable yield, blue represents coniferous merchantable yield and red represents deciduous merchantable yield. The persistence of yield accumulation at mature ages is pronounced in these curves. Figure 5-2 presents the final (adjusted) yield curves by yield stratum; grey represents total merchantable yield, blue represents coniferous merchantable yield and red represents deciduous merchantable yield. Older stand breakup is better reflected using this methodology.

5.6.2 Comparison with Natural Stand Yield Curves

Intensive management stand yields are graphically compared to the 2015 natural stand yields in Figure 5-3. Yields are considerably higher than in natural stands.

5.6.3 Final Yields

Final intensive management yield tables are provided in Appendix III.

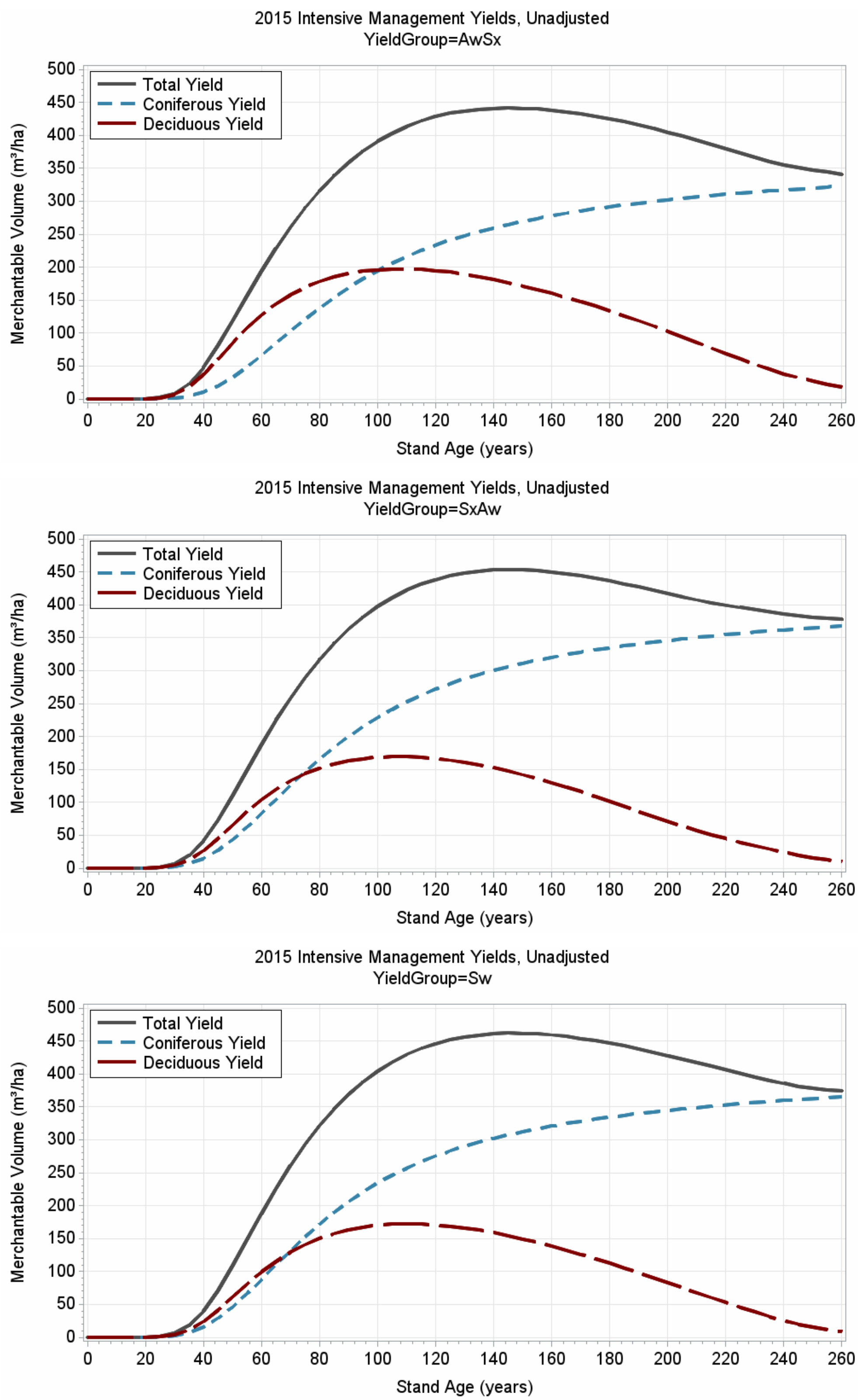


Figure 5-1. Intensive management yield curves 19-21, unadjusted.

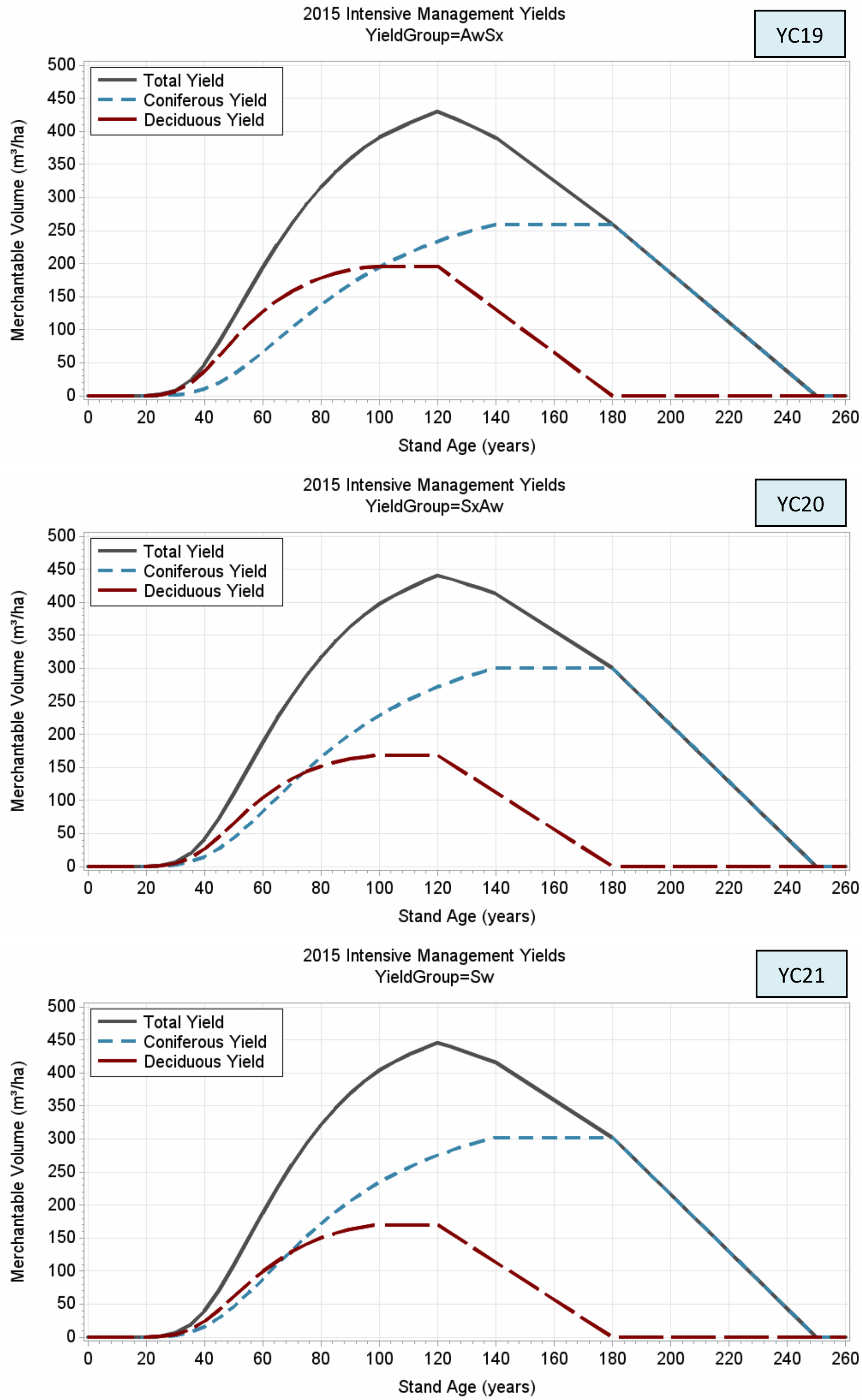


Figure 5-2. Intensive management yield curves 19-21, adjusted.

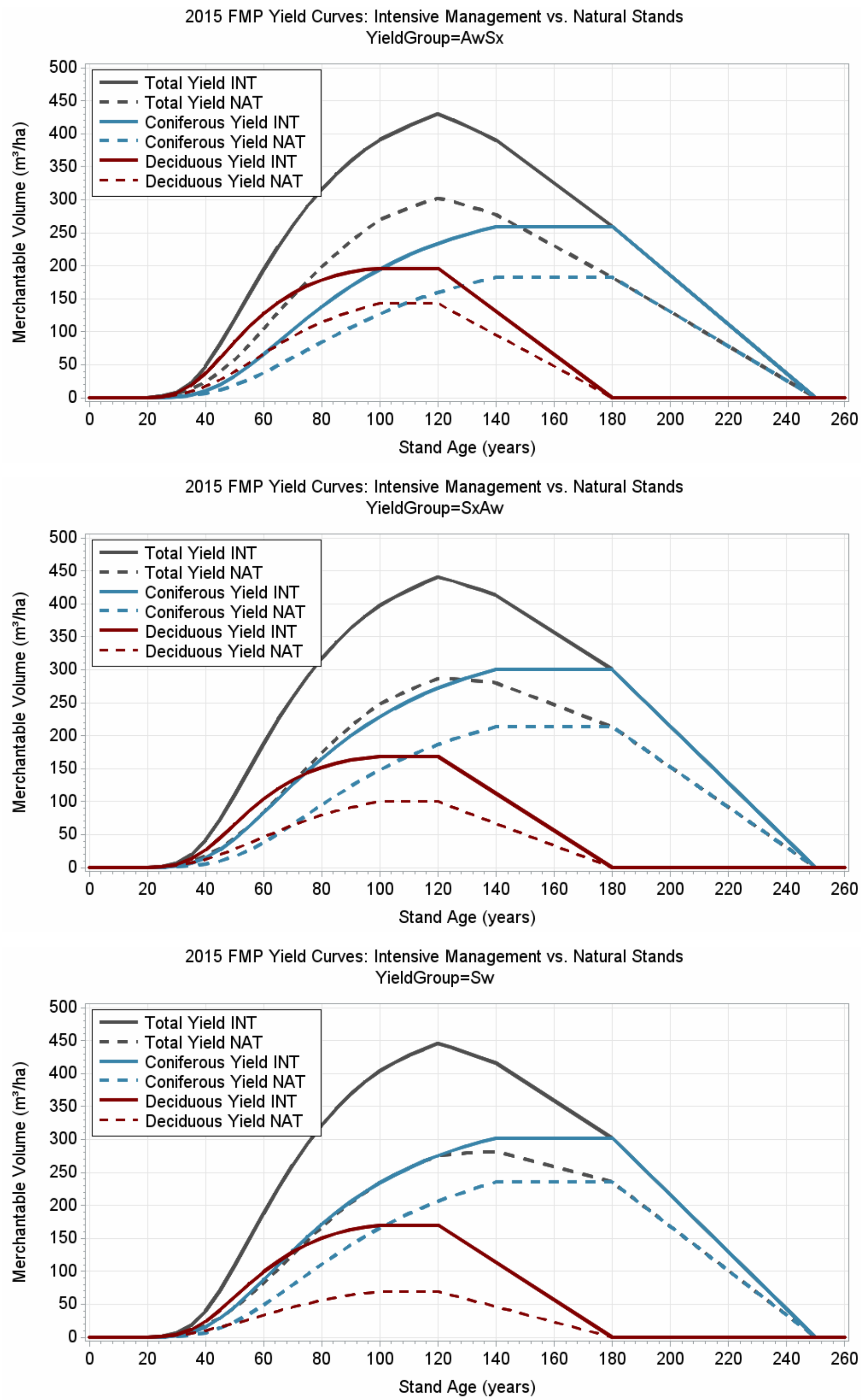


Figure 5-3. Comparison between intensive management yield curves 19-21 and natural stand yield curves 3-5.

6 Extensive Management Yield Curves (Group D)

Yield curves developed to represent Alberta-Pacific's post-harvest cutblocks (yield curves 22-25) plus natural stand yields for strata where the use of MGM was not approved (yield curves 7-9).

6.1 Approach

Extensive management yield curves were required to represent yields for Alberta-Pacific openings lacking an RSA performance survey. Objectives for extensive management yield curves were to 1) create a set of yield curves specific to Alberta-Pacific's silviculture practices that 2) reflected the scale (resolution) of silviculture for openings without a performance survey.

Alberta-Pacific's management regime involves manual tending at year 10-12, which results in:

- Multiple cohorts of deciduous species within the same opening; and
- Atypical size relationships between deciduous and coniferous species.

In order to create extensive management yield curves, use of the MGM model was required since GYPSY is not well suited to modelling multiple cohorts of the same species. MGM grows individual trees from a tree list, and competition from larger trees drives mortality functions within the model; as such, deciduous volumes would be better represented using this model. AESRD agreed to use MGM for creating extensive management yield curves for the Aw, AwSx, SxAw and Sw yield strata. Natural stand yields were assumed for the SbG, PjMx and Pj yield strata.

In terms of silviculture, the only difference between the AwSx and SxAw stratum is generally the proportion of the opening that is treated. As such, silviculture-based yield curves were created separately for planted and tended vs. no plant and no tended management regimes. These yield curves were subsequently combined with weights based on proportion of area tended in order to create AwSx and SxAw extensive management yield curves.

For GYPSY modelling, plot data were combined to create a single stand-level input. However, for MGM modelling, plot-level model inputs were used rather than stand-level inputs (where possible) since combining tree lists from different plots can result in unusual height and/or diameter distributions within a "tree list" or pseudo-stand. As such, TSP, ATP and PSP data were projected at the plot level (multiple plots within openings or SUs) while RSA data, which is comprised of small plots distributed across sampling units, was simulated at the SU level. Further discussion is provided in Section 6.4.4.

The following sections describe the development of silviculture-based yield curves and subsequent weighting to create final extensive management yield curves (yield curves 22-24); the full final set of extensive management yield curves is included in Appendix IV.

6.2 Input Datasets

6.2.1 Source Data

The available managed stand data are summarized in Table 6-1. As with extensive management yield curve development, in order to increase the available sample size for managed stands, the RSA data used for post-performance yield curve development were re-assigned to yield strata at the opening level to mimic the rule set for assigning strata to blocks without a performance survey (see Section 5.2.2 for description of methods).

Table 6-1. Initial population of managed stand data.

Sampling Program	Number of Openings
ATP	49
PSP	53
RSA	763
TSP	44
TSP-RSA	11
Total	920

6.2.2 Yield Stratum Assignment

Yield strata were assigned to each opening based on declaration and, where required, silviculture treatment information (planting, seeding and/or leave for natural activities). A description of the rule set used to assign yield strata to existing managed stands is provided in Annex IV (ForCorp 2014). AwSx and SxAw data (plots and/or sampling units) were further assigned to tended vs. untended based on spatial tending records; in the case of sampling units, at least 70% of the area had to be either tended or untended in order to make such an assignment (see Data Exclusions, Section 6.2.3, for number of deletions).

6.2.3 Data Exclusions

The extensive management population was identified by applying the following deletions to the combined managed stand dataset:

- Openings not belonging to Alberta-Pacific;
- Openings missing spatial location information at the time of yield curve development;
- Juvenile Permanent Sample Plots (plot size issues)[20];
- Samples not within the target yield strata (Aw, AwSx, SxAw or Sw);
- Mixedwood (AwSx or SxAw) samples from untended portions of openings[21];

[20] The Juvenile Permanent sample plot program is comprised of 9 plots established in managed stand in mid-2000; these plots are not described separately under available data since a minor issue with the data needs to be resolved in the field before these data are used.

- RSA performance surveys with no ground survey data;
- PSPs installations established in understorey protection openings;
- RSA-surveyed openings assigned to AwSx or SxAw yield strata, but where tending spatial boundaries did not align with sampling unit (SU) boundaries; and
- RSA aerial performance surveys with < 80% of the opening area selected for ground surveying (to ensure that SU data were representative at the opening level).

A summary of the initial and final number of openings by program is provided in Table 6-2, and the final number of openings by yield stratum is presented in Table 6-3.

All ATP installations were established within RSA-surveyed sampling units, and two PSPs were later performance surveyed; therefore some duplication of opening-level samples was present in these datasets. The total number of unique openings is also provided in a separate column in Table 6-3.

Duplicate samples are dealt with during the averaging process to ensure that those openings do not have an undue influence on the final yield curves.

Table 6-2. Reduction of data suitable for extensive management yield curves.

Number of Openings	Deletion Category
920	*Initial list of managed stand data*
559	Non-Alberta Pacific openings
3	No spatial information
9	JPSP plots
83	Not in target yield strata
5	Mixedwood, untended and unplanted only
124	RSA openings with no ground survey
5	Understory protection PSPs
6	AwSx or SxAw yield strata, tending not aligned with SU boundaries
3	RSA openings with < 80% of area selected for ground survey
123	Total number of eligible openings
103	Total number of unique openings[1]

[1]All ATP installations are within RSA sampling units, and 2 PSPs are in RSA-surveyed SUs.

Table 6-3. Number of extensive management openings by yield stratum and data type.

Yield	Data Collection Program					# of Openings	
Stratum	ATP	PSP	RSA	TSP	TSP-RSA	Total	Unique
Aw		7		20		27	27
AwSx	1		7	4		12	11
SxAw			6	7		13	13
Sw	18	4	49			71	52
Total	19	11	62	31	0	123	103

[21] Plots in untended portions of mixedwoods were later found to be mostly planted, which does not align with recent silviculture practices; as such the untended portion of mixedwoods was instead represented by pure aspen yields (which are untended and unplanted, and thus align better with current practice).

Table 6-4 shows the number of openings by silviculture stratum. Silviculture stratum is assigned by combining both the AwSx and SxAw stratum into a single mixedwood (MxSx) stratum, since all samples came from planted and tended portions the opening and had identical silviculture treatments.

Table 6-4. Number of extensive management openings by silviculture stratum and data type.

Silviculture	Data Collection Program					# of Openings	
Stratum	ATP	PSP	RSA	TSP	TSP-RSA	Total	Unique
Aw		7		20		27	27
MxSx-Tended	1		13	11		25	24
Sw	18	4	49			71	52
Total	19	11	62	31	0	123	103

6.3 Data Preparation

6.3.1 Deletions

All trees with "dead" or "missing" condition codes were removed from the PSP dataset. No other deletions were applied to the plot data. Because MGM simulates the dynamics between individual trees, larch was not deleted from any of the datasets, but was excluded from volume compilation in the model outputs (see Section 6.5.1).

6.3.2 Missing Diameters

No missing diameters were found in the managed stand datasets.

6.3.3 Missing Heights

Missing heights were replaced using one of two methods:

- For trees above 1.3 m in height, heights were predicted from DBH using juvenile height-diameter models developed using Alberta-Pacific ATP and TSP data (see Appendix VI); and
- For conifers under 1.3 m in height, heights were predicted using juvenile height distribution models developed using Alberta-Pacific ATP data (see Appendix VII).

Height predictions were needed primarily for RSA data, where only diameters were measured, and for ATP data, where heights were subsampled in situations with high densities (generally, deciduous species). Further discussion of the methods used for height predictions is provided in Section 6.4.4.

6.4 Data Compilation

6.4.1 Stand Age

Stand age was calculated based on skid clearance year and month of survey in a manner similar to the RSA data compilation specifications:

Stand Age = Measurement Year + 1 – Clock Start Year

Where one year is added to all data since surveys were implemented after April 30.

6.4.2 Natural Subregion

The 2005 natural subregion assignment was extracted from plot header data in all cases except for RSA performance survey data, where natural subregion was obtained from Alberta-Pacific silviculture records. Natural subregion was needed for growth modelling as the 1997 site index equations used by MGM are natural subregion-specific (see Section 6.5.1 for further details).

6.4.3 Site Index

The MGM model was originally built using the 1997 provincial site index equations (Huang et al. 1997), although there is an option to initiate the model using the newer GYPSY (Huang et al. 2009a) top height equations. The direction provided by AESRD was to use the 1997 SI-based version of the model, since that is the version currently being reviewed for government approval. However, using the 1997 equations to predict site index in managed stands was problematic:

- Site index predictions are not accurate for small or young trees;
- Site index predictions cannot be obtained for trees under 1.3 m in height.

As such, the GYPSY (Huang 2009a) equations were used to predict site index, although the 1997-enabled version of the model was still used for growth predictions (see Section 6.5.1).

Prior to calculating site index, any root collar ages (primarily in ATP and TSP data) were converted to total age as follows:

- No adjustment for deciduous species ages since these are assumed to reach 10 cm in year 1;
- Added one year to all coniferous ages (except fir) under the assumption that these are primarily planted trees; and
- Add two years to fir ages since these are natural ingress.

Site index was then calculated for each dataset as follows:

- RSA data: Site index was taken from the RSA compiler table GYPSY_INPUT.
- TSP data: Since one tree by species group was sampled per plot, site index was calculated for each sampled tree, excluding birch, and then averaged across all plots.
- ATP data: One site tree per species was sampled at each 100 m^2 top height plot. In order to select one tree per species group, the largest DBH tree was selected as follows: where both aspen and poplar were present, aspen was selected over poplar (birch was excluded); where both white spruce and fir were present, white spruce was selected over fir. Site index was calculated for each selected tree and averaged across all plots.
- PSP data: Site index data were only available for 2 out of 15 plots; in these cases, aspen was selected over poplar and birch were excluded; no coniferous species were present. For all other plots, the yield-stratum based average site index from natural stands was used to fill in missing values.

6.4.4 Tree Lists

The method and scale used for creating tree lists was specific to each data type. A description of the methodologies used is provided for each data collection program as follows:

RSA Data

RSA data were used to create SU-level tree lists. Individual plots were of insufficient size (10 m^2) for modelling separately: given the number and good spatial distribution of plots within sampling units, combining all plots to create an SU-level input was the logical choice. Only the detailed plots (those with subsampled diameters) were used to create tree lists, with the number of plots generally ranging from 8 to 16. Methods used for creating tree lists were as follows:

1. Determine tree factor for each measured tree ≥ 1.3 m in height.

Each measured tree (tree measured for DBH) was assigned a tree factor based on the sampling fraction (proportion of measured trees vs. tallied trees) by species group and plot size (10 m^2). The number of measured trees was obtained from RSA detailed plot measurement data, and the total tally of trees ≥ 1.3 m in height was obtained from detailed plot tree tallies for conifers and basic tallies for deciduous.

2. Estimate tree height for each measured tree ≥ 1.3 m in height.

Height was predicted for each measured tree using the juvenile stand height-diameter equations developed by R. Froese (Appendix VI) for the Alberta-Pacific FMA area.

3. Estimate tree height and tree factor for conifers under 1.3 m in height.

The number of conifers below 1.3 m in height was calculated from basic and detailed plot data by subtracting the total count of trees ≥ 1.3 m from the basic plot tally. A record was then created for each tree under 1.3 m in height. Height was assigned to each tree by drawing a pseudo-random value from a Weibull distribution, using parameters localized to stand condition, developed and described by R. Froese (Appendix VII).

4. Estimate total tree age based on site index.

Total age was estimated for each tree in the tree list using GYPSY site index equations and height, and iteratively solving for age.

5. Combine plots to create a single tree list and duplicate tree records as required.

Plots were combined into a single tree list, and tree factors were adjusted by dividing by the total number of plots. Each tree in the tree list was replicated until the tree factor was below 25 in order to ensure that mortality of a single tree in the list would not have an undue impact on volume estimates.

TSP Data

Averaging TSP data could result in unrealistic tree lists since there are generally too few plots to get a smooth height-diameter distribution. As such, each individual plot was modelled as a separate “stand”, and outputs were averaged following simulation. There were no nil tally plots in the TSPs to account for. Tree lists were created as follows:

1. Determine tree factor for all measured trees.

A subsample of up to 10 trees per species and type (advanced, post-harvest or post-tending for deciduous species and advanced vs. seedling for coniferous species), along with a total tally by species and type, was available for each plot. Each measured tree was assigned a tree factor based on the sampling fraction (proportion of measured vs. tallied trees) and plot size (100 m^2).

2. Estimate height for each measured tree.

No trees were missing values for height.

3. Estimate total tree age based on site index.

Total age was estimated for each tree in the tree list using GYPSY site index equations and height, and iteratively solving for age.

4. Combine plots to create a single tree list and duplicate tree records as required.

Plots were combined into a single tree list, and then tree factors were adjusted by dividing by the total number of plots (3 in all cases). Trees in the tree list were replicated until the tree factor was below 25.

ATP Data

All ATP100 data were used for tree list generation. Because plots are 100 m^2 in size, plot-level tree lists were also created (using the same rationale as for TSPs). Tree lists were created as follows:

1. Determine tree factor for all measured trees.

All trees inside each plot were measured; each was assigned a tree factor based on plot size (100 m^2).

2. Estimate height for each measured tree.

Missing heights were estimated using juvenile height-diameter equations as previously described in this Section; because other measured heights were also available within the plot, the ratio adjustment approach outlined by Huang et al. (2013) was implemented using the same methodology as described in Section 3.3.3 for natural stands.

3. Estimate total tree age based on site index.

Total age was estimated for each tree in the tree list using GYPSY site index equations and height, and iteratively solving for age.

4. Combine plots to create a single tree list and duplicate tree records as required.

Plots were combined into a single tree list, and tree factors were adjusted by dividing by the total number of plots in each SU. Trees in the tree list were replicated until the tree factor was below 25.

PSP Data

PSPs were compiled to generate a single tree list. Examination of PSP data showed that where multiple measurements existed, newer measurements showed a substantial increase in the number of trees, indicating that plots were actively undergoing recruitment. Since MGM does not currently simulate ingress, only the most recent measurement of each PSP was used for developing tree lists. Procedures for creating PSP tree lists followed a similar process to ATP data:

1. Determine tree factor for all measured trees.

All trees inside each plot were measured; each was assigned a tree factor based on plot size (main or sapling plot depending on tree size).

2. Estimate height for each measured tree.

Missing heights were estimated using juvenile height-diameter equations as previously described in this Section; because other measured heights were also available within the plot, the ratio adjustment approach outlined by Huang et al. (2013) was implemented using the same methodology as described in Section 3.3.3 for natural stands.

3. Estimate total tree age based on site index.

Total age was estimated for each tree in the tree list using GYPSY site index equations and height, and iteratively solving for age.

4. Duplicate tree records as required.

Trees in the tree list were replicated until the tree factor was below 25.

Final Number of Tree Lists

The final number of tree lists is presented in Table 6-5. Note that since multiple TSP and ATP tree lists were generated for each opening, and because separate tree lists were created for each SU in the RSA datasets, the number of tree lists is considerably higher than the original number of openings.

Table 6-5. Number of tree lists by silviculture stratum used for extensive management yields.

Silviculture	Data Collection Program				
Stratum	ATP	PSP	RSA	TSP	Total
Aw		7		60	67
MxSx-Tended	3		15	33	51
Sw	66	4	59		129
Total	69	11	74	93	247

6.4.5 Gap Area Loss

A gap area loss factor was required to reflect the expected area in gaps at maturity. This input is necessary to ensure that competitive effects are correctly modelled within MGM. Work undertaken by Jensen (2014) outlined a methodology for calculating the percent area of gaps in natural stands; this methodology was applied to Alberta-Pacific's FMA area (see Appendix VIII) using LiDAR data. Results from mature natural stands are presented in Table 6-6.

Table 6-6. Natural stand gap area loss by yield stratum.

Yield Stratum	Gap Area Loss (% Area in Gaps)
Aw	20.26
AwSx	25.15
SxAw	29.29
Sw	30.46

Gap area loss increases as the coniferous component (based on overstorey species composition) increases, likely due to the clumped distribution of conifers. For extensive management yield curve development, gap area loss was set to 20.26% for all four extensive management yield strata, since planted spruce in managed stands is expected to have a regular rather than a clumpy distribution and exhibit the same gap area loss as pure deciduous stands.

6.4.6 Replication

Regardless of each stem's tree factor (the number of trees/ha that each stem in the tree list represents), a minimum of 30 trees was targeted for each tree list. With too few trees in the list, the mortality of a single tree could cause sharp "jumps" in density and/or volumes. Where less than 30 trees were present in a tree list, a replication factor was calculated as:

Replicate = ROUNDUP (30/number of trees)

This replication factor was used internally by MGM to replicate the tree list during growth modelling, with an associated reduction in individual tree factors.

6.5 Modelling

6.5.1 Growth Modelling Approach

The MGM model (Bokalo et al. 2013) was used for model projections. MGM was initialized using tree lists based on plot data rather than simulating tree lists from summary data, which is also an option in MGM. Within MGM, model settings were set for all stands as follows:

- Minimum DBH = 13.67 cm[22], top diameter = 10 cm, stump height = 0.3 m and minimum log length = 3.66 m[23];
- Species to be used in summaries: Aw, Bw, Pb, Fb, Pj, Sb, Sw[24];
- Volume Loss for decay, waste and breakage = 0%;
- Default settings for site index, number of years to 1.3 m height, and maximum density adjustments were not changed;
- "Allow ingrowth" turned off; and
- "MA Flag" (stand breakup mortality adjustments for trees >4 cm DBH) turned on.

At the direction of AESRD, the "use 2008 provincial site index functions" option was turned off, since the current version of MGM being considered for government approval is based on the 1997 provincial site index equations.

6.5.2 Model Inputs

Model inputs included:

- Tree lists for each stand, including species, DBH, height, tree factor and age.
- Batch processing lists, including stand age, natural subregion, gap area loss and a replicate factor.

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[22] Using the MGM diameter tool, the minimum DBH for a 15 cm stump tree in the Central Mixedwoods natural subregion is as follows: Aw=13.67 cm, Pj=13.16 cm, Sb=13.67 cm and Sw=13.51. Using 13.67 cm as a minimum DBH is conservative with respect to estimation of merchantable volume.

[23] A custom version of the MGM model was provided by Mike Bokalo, which contains only one modification: compiled merchantable volumes include only trees with a minimum log length of 3.66 m.

[24] While all trees regardless of species are grown within MGM, only the "species to be used in summaries" are included in stand-level summary outputs (density, volume, etc.).

Excel macros provided by Dr. Mike Bokalo (UofA) were used to generate tree lists in the necessary MGM formats for batch processing. An Excel-based batch processor was also provided to access the MGM model files for simulating multiple plots.

6.5.3 Model Outputs

Stands were grown in 1-year increments to 300 years of age. Compiled outputs from MGM included merchantable coniferous and deciduous yields for each plot. Because MGM does not "backwards project", output yields commenced at the year of measurement; since all stands were < 20 year of age at time of measurement, zero merchantable volume was assumed for these ages. These outputs were then averaged using weighting by area divided by the number of observations (tree lists). Areas were determined as follows:

- Aw and Sw strata: SU area (RSA and ATP data) or opening area (TSP and PSP data).
- MxSx strata: SU area (RSA and ATP data) or total tended/untended area by opening[25].

Initial averaged curves showed a lack of smoothness, particularly for the pure Aw yield stratum, therefore a 3-parameter regression approach was used to fit a curve to output yields, applying area-based weighting as described above.

6.5.4 Using Silviculture Curves to Create Extensive Management Curves

The average yields created in Section 6.5.3 are based on silviculture strata, not extensive management yield strata. Extensive management yield curves were created as follows:

- Aw: 100% silviculture Aw
- AwSx: 35% MxSx-Tended + 65% silviculture Aw
- SxAw: 60% MxSx-Tended + 40% silviculture Aw
- Sw: 100% silviculture Sw

Surveys and sample plots established in untended areas were temporally restricted to an early population of blocks that were planted to conifer, a practice that was implemented for only a 5-6 year span. Therefore, rather than using the untended silviculture curve to represent the second component of mixedwood stands, the pure Aw curve was used.

6.5.5 Yield Adjustments

No adjustments were made to the extensive management yield curves to account for mortality at older ages. Mortality simulated by MGM using the "MA flag" option (mortality adjustment for trees > 4 cm DBH) provided satisfactory results without adjustment.

[25] Tended/untended areas were determined by intersecting tending shapefiles with an opening shapefile extracted from Alberta-Pacific's TFM system.

6.5.6 Natural Curves

Natural stand yield curves (curves 7-9) were used to represent extensive management yields for the SbG, PjMx and Pj yield strata.

6.6 Results

6.6.1 Silviculture-Based Yield Curves

Silviculture-based yield curves are presented in Figure 6-1. Both the straight averaging and regression-based approaches are shown. There is very good correspondence between the two curve sets, with the regression-based approach providing smoother curves.

6.6.2 Extensive Management Yield Curves

Extensive management yield curves 22-25 are presented in Figure 6-2.

6.6.3 Comparison with Natural Stand Yield Curves

A comparison between the extensive management and natural stand yield curves is presented in Figure 6-3. Yields are comparable except that deciduous volumes accumulate earlier than in natural stands, which is likely a reflection of the difference between using skid clearance date and inventory year for calculating stand age. Deciduous volumes are lower in SxAw stands due to the increased influence of manual tending; smaller deciduous trees are modelled as suffering from increased mortality due to competition by coniferous species. Coniferous volumes are higher in pure Sw stands (relative to natural yields) which is likely a result of both stand age differences (skid clearance vs. inventory age) and the model accounting for silviculture practices (site preparation and earlier regeneration via planting).

6.6.4 Final Yields

Extensive management yield tables are provided in Appendix IV.

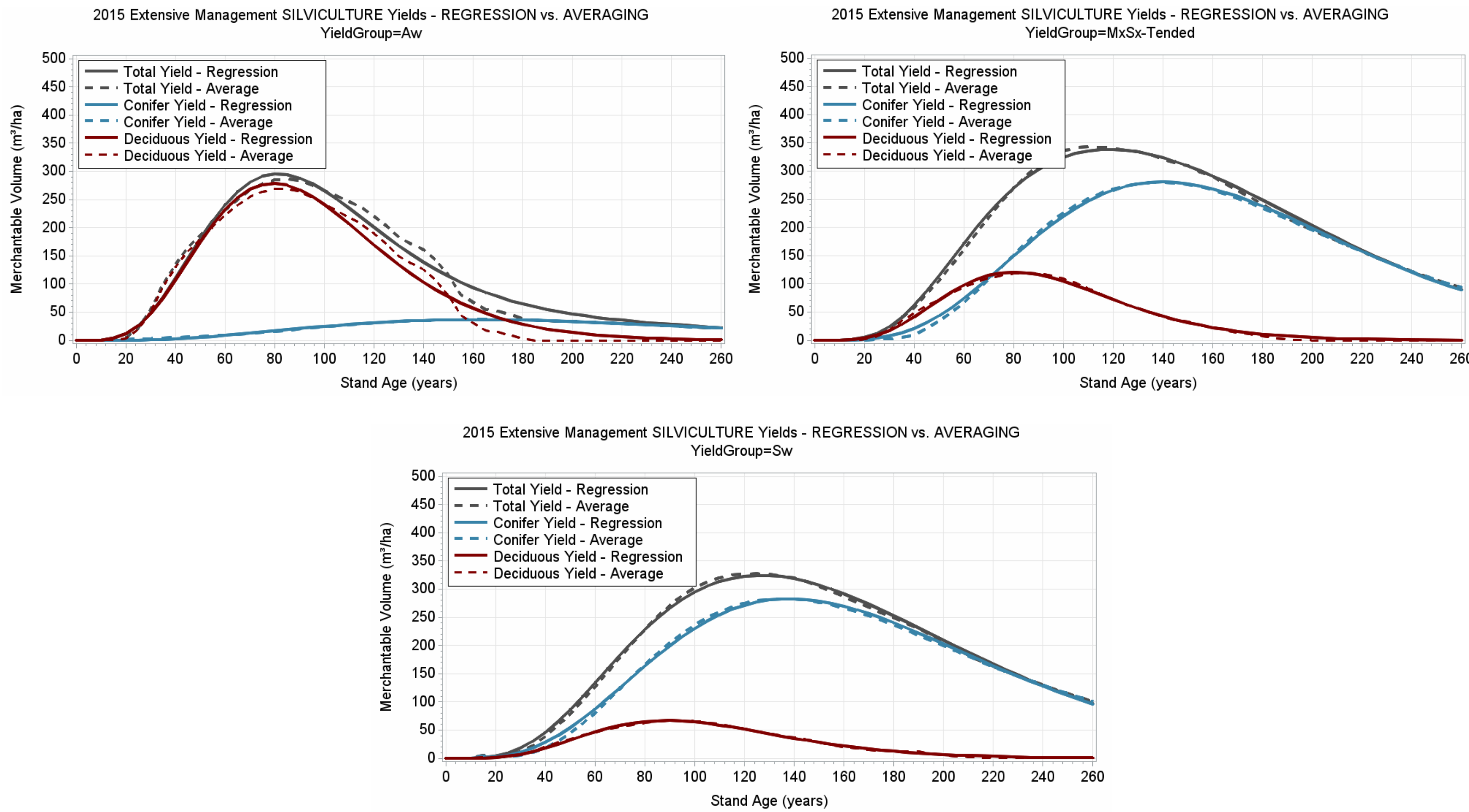

Figure 6-1. Silviculture-based yield curves showing averaging vs regression-based approaches.

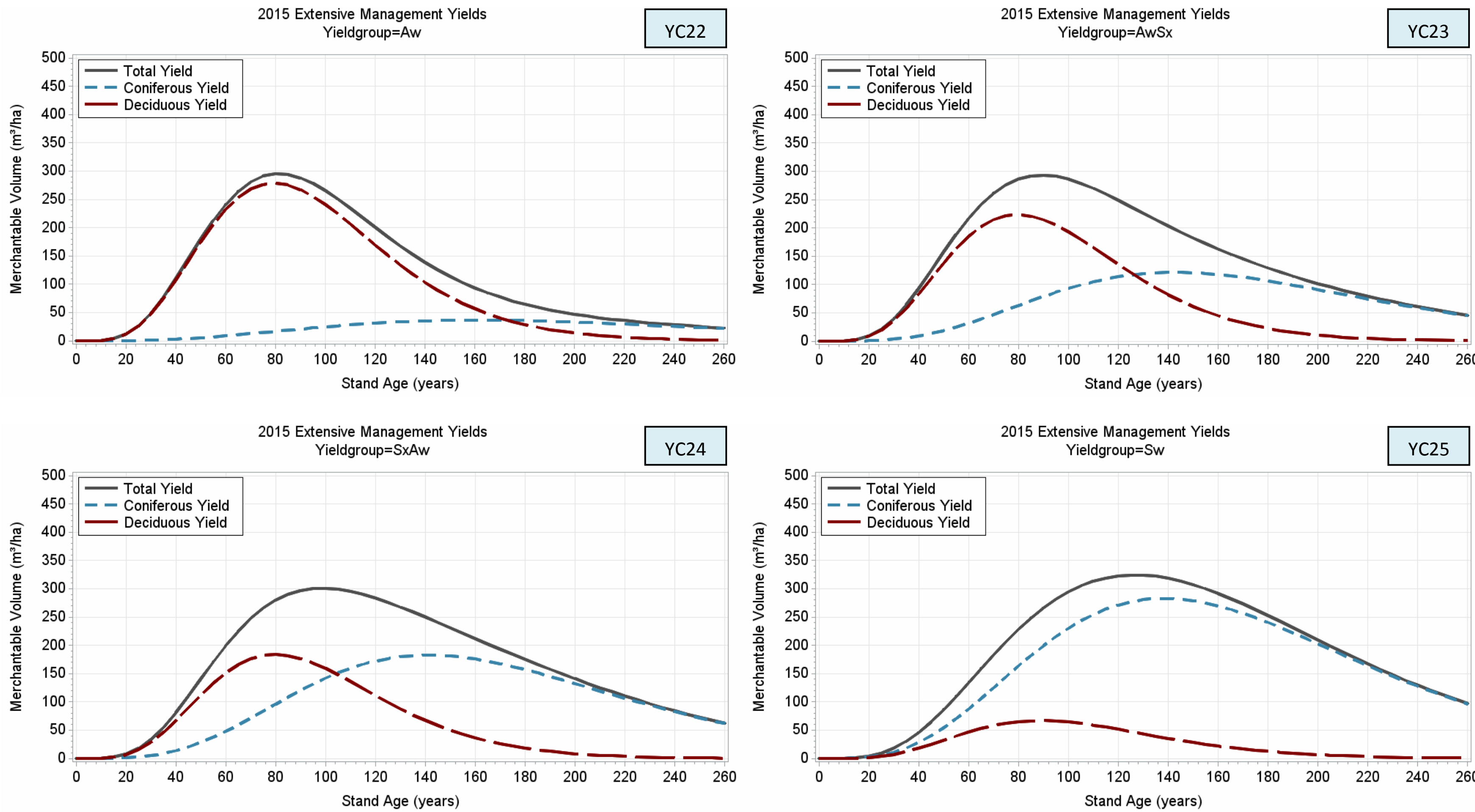

Figure 6-2. Extensive management yield curves 22-25.

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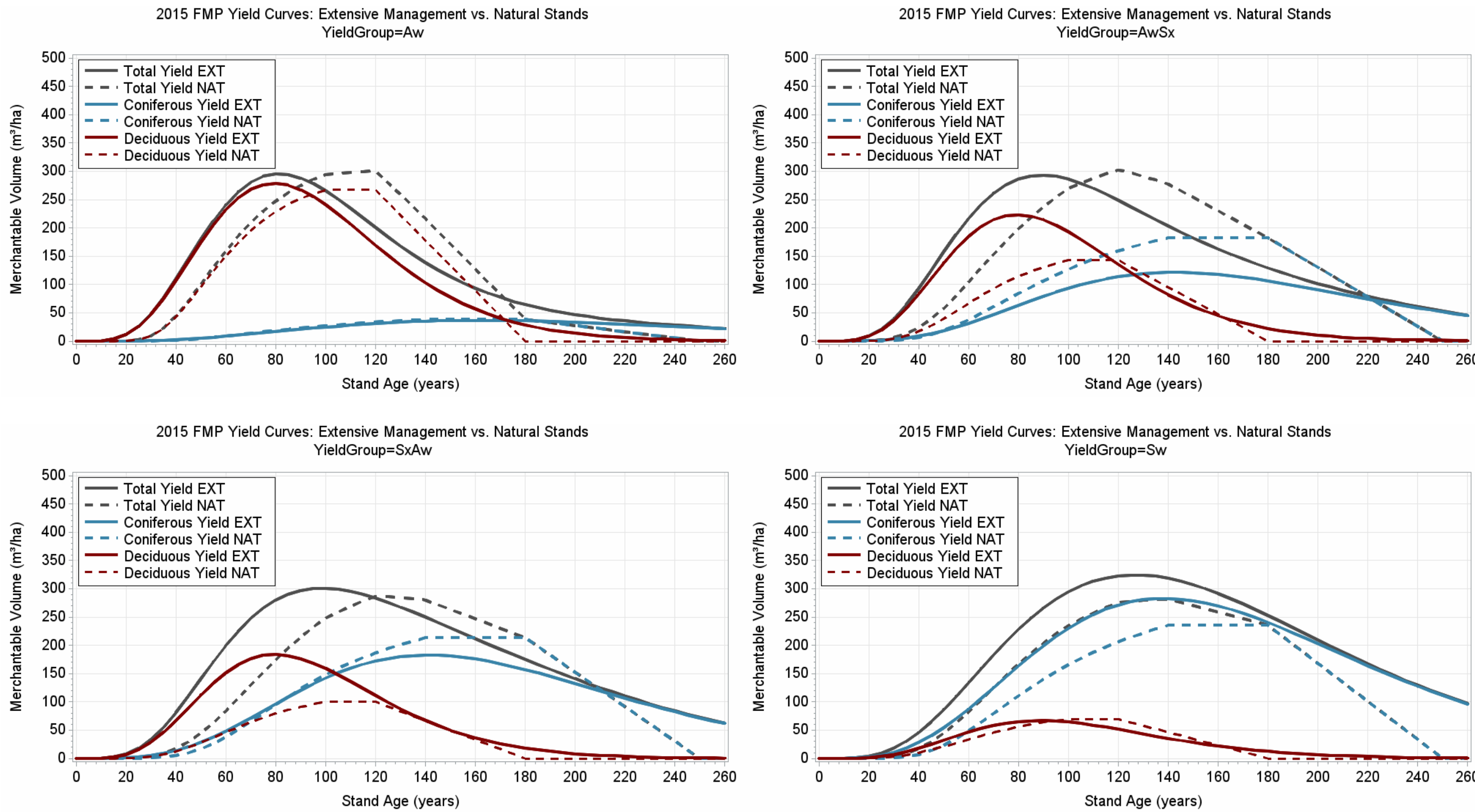

Figure 6-3. Comparison between extensive management yield curves 22-25 and natural stand yield curves 1, 3, 4, and 5.

7 Understorey Protection Yield Curves (Group E)

Yield curves created to represent high effort understorey protection (strip cut) openings in the Alberta-Pacific FMA area (yield curves 26- 27).

7.1 Approach

The approach to development of understorey protection yield curves was constrained in part by the availability of approved growth models. Alberta-Pacific obtained agreement from AESRD to use the non-spatial version of the MGM model for yield curve development, but not to use MGM with the adjacency module (which simulates effects of shading from adjacent strata on tree growth). As such, Alberta-Pacific chose to model the individual strata within understorey protection openings separately:

- Extensive (MGM) Aw yield curves were used to represent growth in harvest area areas (e.g., extraction trails, roads, landings and backlines); and
- An understorey protection white spruce yield curve was developed using MGM to represent released white spruce in reach and buffer areas.

Yields for these two strata were combined using different proportions of protected areas to create two understorey protection yield curves: $AwSw^{UP}$ and $SwAw^{UP}$. These yield curves are analogous to the AwSx and SxAw managed stand (intensive and extensive management) yield strata.

7.2 Input Datasets

7.2.1 Source Data

All PSPs defined as natural origin in the Alberta-Pacific database were included in the preliminary set of plot data, as described in Section 3.2.1. Within this dataset, all plots with tree measurements were selected as follows:

- Yield stratum (as defined in Section 3.2.2) = Aw or AwU; and
- Contains at least 600 stems per hectare of white spruce ≥ 2m in height[26].

A total of 39 plots (73 measurements) met the criteria listed above.

7.2.2 Yield Stratum Assignment

Yield stratum assignments used in selecting plot data were as defined in Section 3.2.2 for natural stands.

[26] Two metres is the minimum operational height used for identifying stands suitable for high intensity understorey protection. Stands with smaller trees but suitable densities may still be protected, but due to the smaller size of these trees they will be assumed to form part of the "new" cohort and will be placed on an extensive management AwSx or SxAw yield trajectory.

7.2.3 Data Exclusions

One plot (three measurements) was deleted because the plot contained a high proportion of larch, which would not have been selected for understorey protection in an operational setting and was thus not representative of the target population.

7.3 Data Preparation

This section refers specifically to the methods of compiling data for creating the retention Sw yield curve. For information on data preparation for the extensive Aw yield curve, see Section 6.3.

7.3.1 Deletions

The initial set of plots represented natural stands eligible for understorey protection. In order to simulate the impacts of overstorey removal during understorey protection, all deciduous trees were deleted from the dataset. While some buffer trees are normally retained during understorey protection, 1) very few trees are retained, therefore these trees generally don't compete with the released spruce for light resources and 2) without using the semi-spatial version of MGM, the model would assume a uniform distribution of trees which would result in an inaccurate depiction of the competitive effect of these trees.

All fir trees were also removed from the dataset since fir tends to die quickly following understorey protection due to the dramatic shift in environmental conditions, which would likely not be adequately modelled by MGM.

7.3.2 Missing Diameters

Processed data were obtained from natural stand yield curve output files; see Section 3.3.2 for a description of the methods used to fill in missing diameters.

7.3.3 Missing Heights

Processed data were obtained from natural stand yield curve output files; see Section 3.3.3 for a description of the methods used to fill in missing heights.

7.4 Data Compilation

This section refers specifically to the methods of compiling data for creating the retention Sw yield curve. For information on the methods used to compile data for the extensive Aw yield curve, see Section 6.4.

7.4.1 Stand Age

Stand age was reset to 0 at time of "overstorey removal".

7.4.2 Natural Subregion

The 2005 natural subregion was obtained from the Alberta-Pacific PSP database. Natural subregion was needed for growth modelling since the 1997 site index equations used by MGM are natural subregion-specific (see Section 7.5.1).

7.4.3 Site Index

Site index estimates for white spruce and black spruce were obtained from the natural stand PSPs in pure Sw stands to establish a conservative estimate of the site index of released spruce. As such, a site index of 17.37 m was used for white spruce, and a site index of 11.06 m was used for black spruce trees.

7.4.4 Tree Lists

Tree lists were created for each PSP plot/measurement as described in Section 6.4.4. A key difference from extensive management yield curve development was that ages were calculated by iteratively solving for age using the 1997 provincial site index equations for white and black spruce (Huang et al. 1997a and 1997b), because trees were generally of appropriate size for using these site index equations. Tree lists contained species, height, diameter at breast height, tree factor and age.

7.4.5 Gap Area Loss

A gap area loss factor was required to reflect the expected spatial patterning (and thus competitive effect) of spruce following release. From a successional perspective, spruce understories grow into the overstorey as deciduous canopies break up over time. As such, the spatial patterning of mature white spruce stands is likely the best estimate of spatial patterning of released Sw. A gap area loss of 30.46, calculated for natural white spruce stands (see Appendix VIII), was applied to all plots.

7.4.6 Replication

Sufficient trees were present in each tree list, therefore replication was set = 1 for all tree lists (see Section 6.4.6 for information on tree list replication requirements).

7.5 Modelling

7.5.1 Growth Modelling Approach

The MGM model (Bokalo et al. 2013) was used for model projections. MGM was initialized using tree lists created from plot data as described in Section 7.4. Model settings were as outlined in Section 6.5.1.

7.5.2 Model Inputs

Model inputs included:

- Tree lists for each stand, including species, DBH, height, tree factor and age.
- Batch processing lists, including stand age, natural subregion, gap area loss and a replicate factor.

Excel macros provided by Mike Bokalo were used to generate tree lists in the necessary MGM formats for batch processing. An Excel-based batch processor was also provided to access the MGM model files for simulating multiple plots.

7.5.3 Model Outputs

Stands were grown in 1-year increments to 300 years of age. Compiled outputs from MGM included merchantable coniferous and deciduous yields for each plot. All yield projections commenced at year zero (year of overstorey removal). Outputs were averaged by plot across measurements, then across all plots, to create a "retention Sw" yield curve. The resulting yield curve did not require additional smoothing via a regression-based approach.

7.5.4 Yield Adjustments

Understorey protection yield curves were created by proportionally combining the Sw Retention area yield curve with the extensive Aw yield curve as follows:

- $AwSw^{UP}$: 40% retention Sw + 60% extensive Aw
- $SwAw^{UP}$: 60% retention Sw + 40% extensive Aw

These proportions reflect an expected average condition based on Alberta-Pacific's silviculture decision rules, which indicate the following minima for declaring understorey protection blocks to yield strata:

- $AwSw^{UP}$: ≥ 30% area in retention; and
- $SwAw^{UP}$: ≥ 50% area in retention.

No additional adjustments for stand mortality were required.

7.6 Results

7.6.1 Retention Area Yield Curve

The retention Sw yield curve is presented in Figure 7-1. Note the presence of merchantable coniferous volumes at stand age zero (year of overstorey removal). Also note that there is no deciduous volume, therefore coniferous and total volume is the same.

7.6.2 Understorey Protection Yield Curves

The final understorey protection yield curves, creating by combining the retention Sw and extensive Aw yield curves, are shown in Figure 7-2. Note the early accumulation of coniferous volume resulting from release of residual conifers.

7.6.3 Comparison with Natural Stand Yield Curves

A comparison between understorey protection and natural stand yield curves is provided in Figure 7-3 and Figure 7-4. Deciduous yields are similar to natural stands, except that deciduous volume accumulation occurs earlier.

7.6.4 Comparison with Managed Stand Yield Curves

Figure 7-5 to Figure 7-8 illustrate the difference between understorey protection and intensive and extensive management yield curves. The magnitude of coniferous (and, for AwSx, deciduous) volume is less in understorey protection relative to intensive management. Understorey protection and extensive management curves are very similar, with the key difference being the timing of coniferous volume accumulation.

7.6.5 Final Yields

Final understorey protection yield tables are provided in Appendix V.

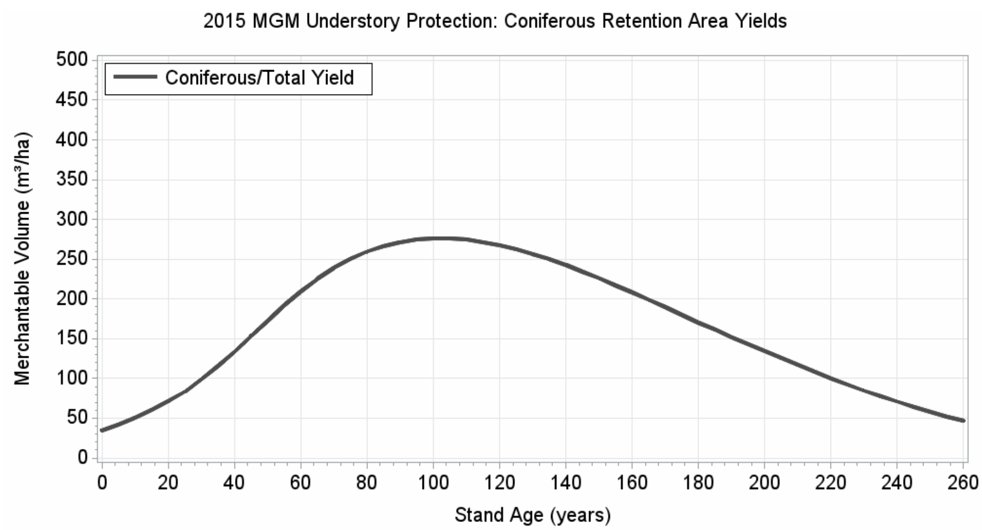

Figure 7-1. Retention Sw yield curve.

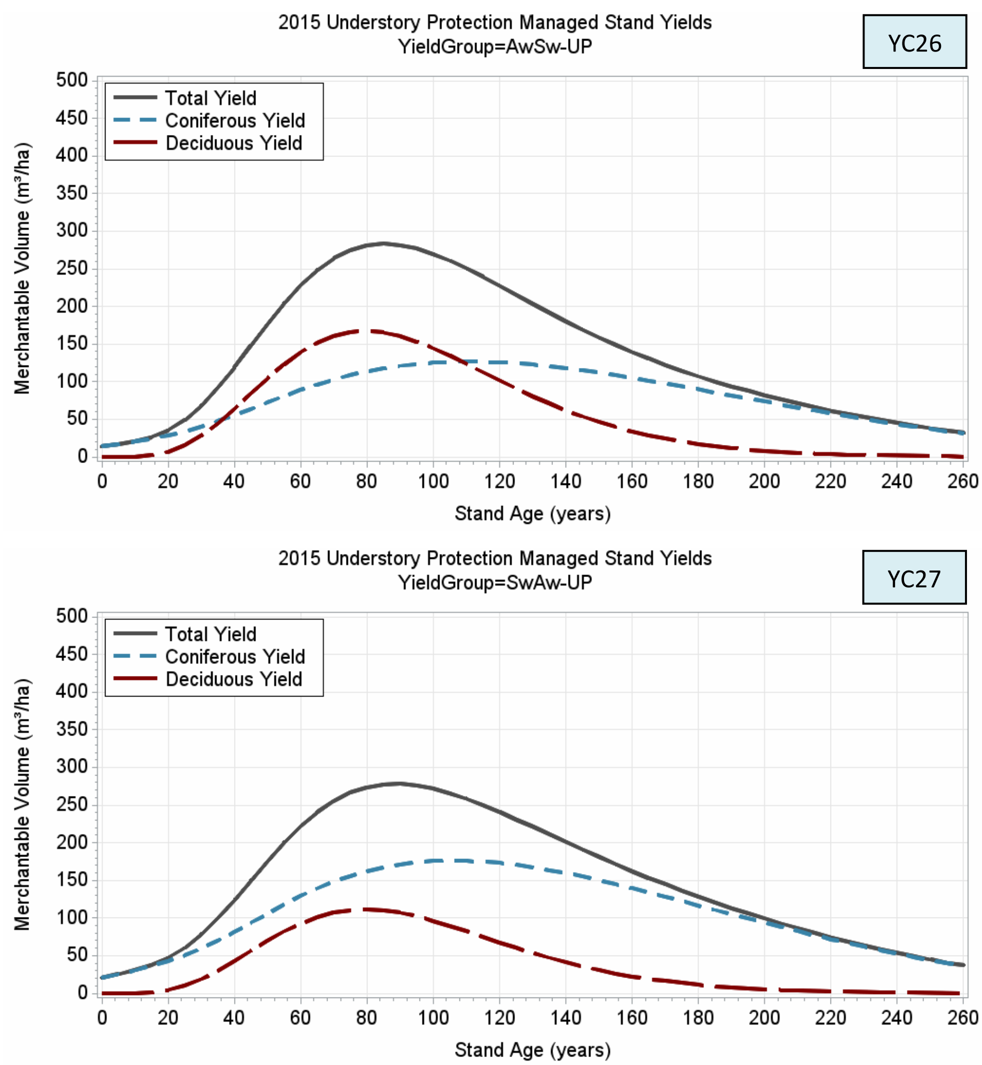

Figure 7-2. Understorey protection yield curves.

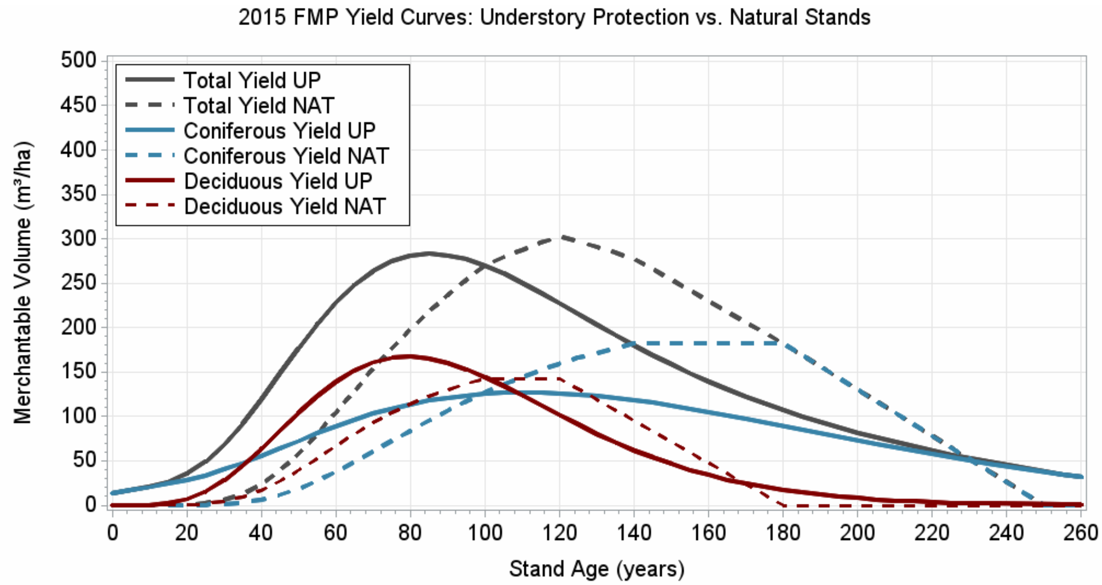

Figure 7-3. Comparison between understorey protection AwSw^{UP} and natural stand AwSx yield curves.

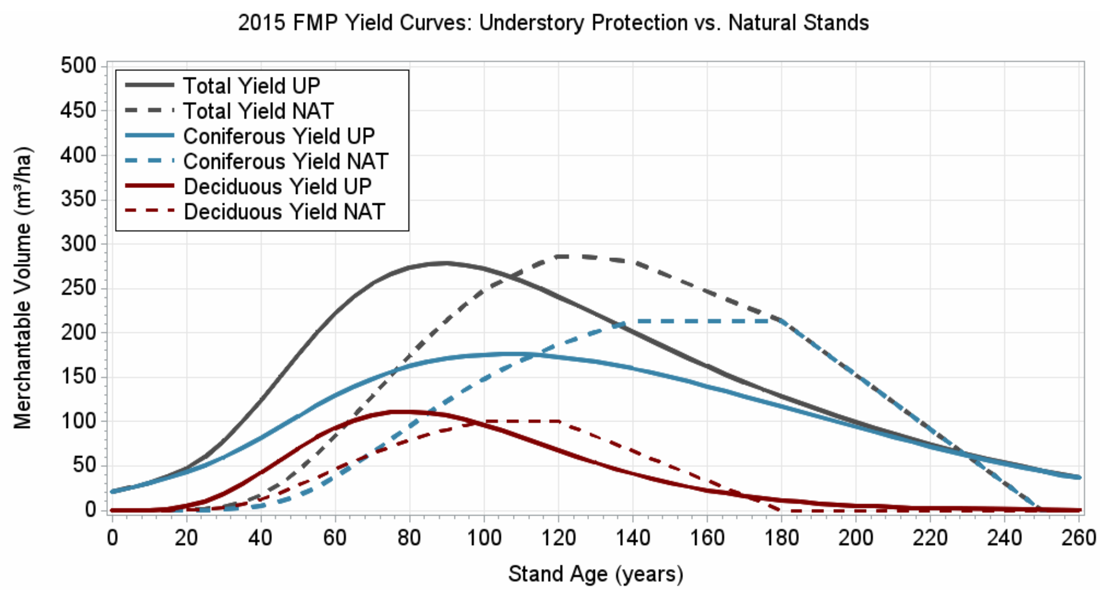

Figure 7-4. Comparison between understorey protection SwAw^{UP} and natural stand SxAw yield curves.

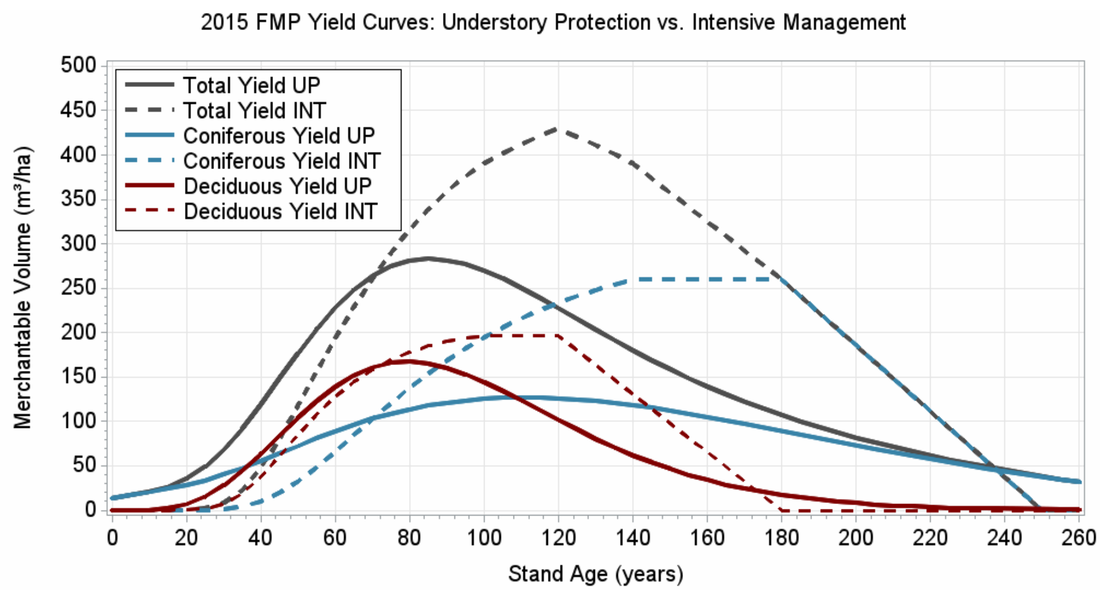

Figure 7-5. Comparison between understorey protection AwSw^UP and intensive management AwSx yield curves.

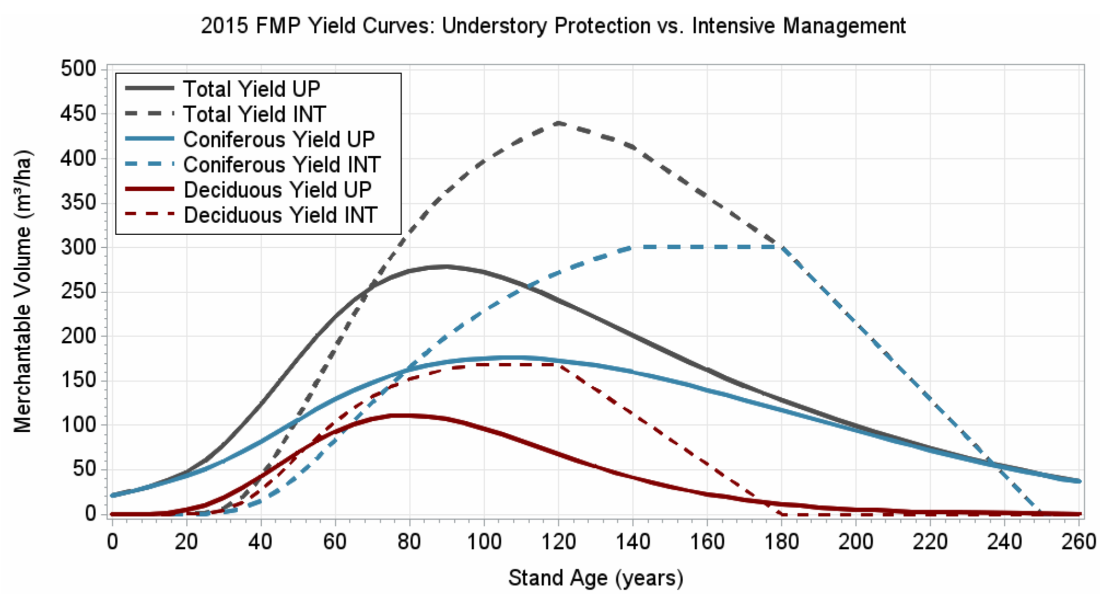

Figure 7-6. Comparison between understorey protection SwAw^UP and intensive management SxAw yield curves.

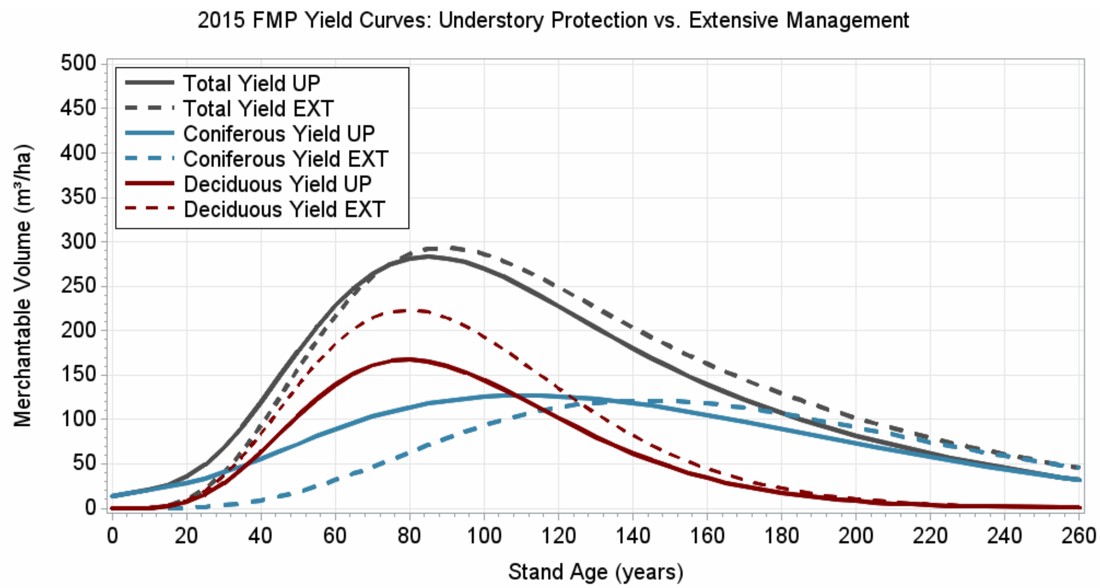

Figure 7-7. Comparison between understorey protection AwSw[UP] and extensive management AwSx yield curves.

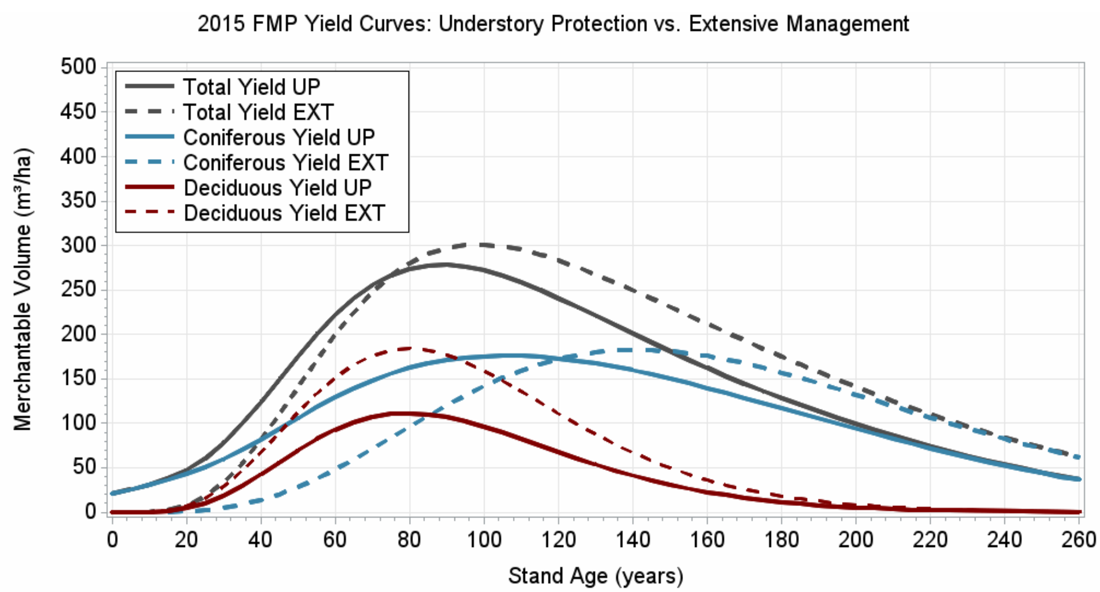

Figure 7-8. Comparison between understorey protection SwAw[UP] and extensive management SxAw yield curves.

8 Additional Analysis

8.1 Area Weighted Yield Curves

Area-weighted yield curves were created at the broad cover group level, using natural stand yield curves and natural stand (standing timber) landbase areas. The PjMx (pine mixedwood) stratum was separated into deciduous-leading and coniferous-leading areas, in order to contribute to the area weighted averages for both broad cover groups. A summary of net landbase areas is provided in Table 8-1. Area weighted yield curves are presented in Appendix IX.

Table 8-1. Natural stand net landbase areas used to create area weighted yield curves.

Alberta-Pacific Yield Stratum	AESRD Yield Stratum	Broad Cover Group	Area (ha)
Aw	Hw	D	503,118
AwU	Hw	D	371,207
AwSx	HwSx	DC	82,550
SxAw	SwHw, SbHw	CD	66,905
Sw	Sw	C	172,065
SbFM	Sb	C	32,443
SbG	Sb	C	68,649
PjMx	HwPl	DC	25,927
	PlHw	CD	20,235
Pj	Pl	C	270,783
Total			1,613,881

8.2 Piece Size Curves

Piece size curves were created based on natural stand GYPSY yield projections. The same set of plots used in natural stand yield curve development (see Section 3.2.1) was used for piece size curve development.

Merchantable density and merchantable volume were obtained from GYPSY model projections by species group, and then summed across species groups to create estimates for deciduous and coniferous species types (see Section 3.5). An average merchantable density and merchantable volume were calculated for each PSP where multiple measurements existed. Piece size was then calculated as m^3/tree (dividing merchantable volume by merchantable density).

In order to create a continuous smooth response surface that characterized the average trend in piece size as a function of stand age, individual models were fit for coniferous and deciduous species by yield stratum.

First, the data were cleaned to remove implausible observations and obvious errors. Two specific issues were common to most yield strata. The first was unusually large piece size estimates at the beginning of the time series available for certain stands, which fell rapidly towards zero, before rising more predictably for the remainder of the series. This appears to be an artifact of the GYPSY model; in some cases (usually stands with low site index and low volume) the estimates of density are very low and hence piece size is unexpectedly large, despite low overall volumes. These anomalies were removed by searching for rapidly declining piece size with increasing age at stand age below 35 years (150 years for SbFM conifer), and setting these values to zero.

The second case was implausibly large piece size as stands age. This also appears to be an artifact of the model, which seems to decrease in density faster than volume in certain stands. Again, this usually occurs in stands with low site index and low initial volume. These anomalies were removed by searching for unusual cases, and removing the entire series for that species type only (i.e., conifer or deciduous).

The relationship between piece size and stand age was then modeled using a non-parametric local regression-fitting technique, known as the "LOESS" (LOcal regrESSion; see http://cran.r-project.org/doc/contrib/Fox-Companion/appendix-nonparametric-regression.pdf). This method is preferred to least-squares approaches because the form of the response surface does not need to be specified in advance, and there are no "parametric" assumptions (such as independence, constant variance, etc.).

Piece size curves are presented in Appendix X.

8.3 MAI Targets

As per the current Regeneration Standard of Alberta (AESRD 2014b):

"Development of MAI standards is a mandatory component of the forest management planning process. Once developed and approved, the MAI standards will apply to all timber disposition operations covered by the Forest Management Plan (FMP). Should multiple Timber Supply Analyses (TSA) be included in the FMP (i.e., a TSA run for each FMU within a FMA), then the MAI standards shall reflect each TSA ... The number of MAI standards shall reflect the number of regenerated yield strata assumed in the FMP to a minimum of the Base 10 strata, as outlined in the Forest Management Planning Standard."

Since Alberta-Pacific's timber supply was analyzed by FMU, culmination mean annual increment (MAI) targets were developed specific to each FMU. MAI targets were selected as follows:

- Aw and AwU yield strata are managed for deciduous yield, and therefore deciduous culmination was used to select MAI targets.
- All coniferous and mixedwood strata are managed primarily for coniferous yield, and therefore for coniferous culmination was used to select MAI targets.
- Understory protection stands are managed for coniferous volume, however, because coniferous volume is present at year of harvest, coniferous volume culminates at year 10 and declines thereafter. As such, the minimum harvest age used for timber supply (100 years) was used for setting MAI targets for both strata.

Culmination MAIs for each yield curve are presented in Table 8-2. Note that post-performance culmination MAIs are not included, since they are not relevant to setting targets for future cutblocks.

Table 8-2. Culmination mean annual increments by stand group and yield curve.

Stand Group	Yield Curve	Culmination Type	Culmination Age	Culm. MAI (m^3/ha/y) Dec	Con	Tot
Natural	1 Aw	Deciduous	80	2.86	0.24	3.09
	2 AwU	Deciduous	80	2.33	0.47	2.80
	3 AwSx	Coniferous	120	1.19	1.33	2.52
	4 SxAw	Coniferous	120	0.83	1.55	2.39
	5 Sw	Coniferous	120	0.58	1.72	2.29
	6 SbFM	Coniferous	140	0.01	0.43	0.43
	7 SbG	Coniferous	140	0.03	0.78	0.81
	8 PjMx	Coniferous	90	0.85	1.50	2.35
	9 Pj	Coniferous	90	0.14	1.48	1.62
Intensive	19 AwSx	Coniferous	110	1.78	1.96	3.75
	20 SxAw	Coniferous	110	1.53	2.30	3.83
	21 Sw	Coniferous	100	1.70	2.34	4.04
Extensive	22 Aw	Deciduous	60	3.87	0.14	4.02
	23 AwSx	Coniferous	110	1.50	0.95	2.46
	24 SxAw	Coniferous	110	1.24	1.45	2.69
	25 Sw	Coniferous	110	0.54	2.31	2.85
Understory	26 $AwSw^{UP}$	Coniferous	100	1.45	1.25	2.70
Protection	27 $SwAw^{UP}$	Coniferous	100	0.96	1.76	2.72

Table 8-3 shows the transitions from natural to managed stands, and the associated culmination MAIs by yield curve type. Natural stand culmination MAIs are shown where managed stand yields are taken from natural stand yield curves (Aw and SbFM for intensive stands, and SbG, PjMx and Pj for extensive stands). Note that the only stand type that transitions in terms of species composition is the AwU stratum, which is re-assigned in the timber supply analysis to one of Aw, $AwSw^{UP}$ or $SwAw^{UP}$ yield curves following harvest.

Table 8-3. Natural stand culmination MAI, transitions to managed stand yield curves, and associated managed stand MAIs.

Natural Yield Stratum	AESRD Stratum	Culm. MAI (m^3/ha/y) Dec	Con	Managed Yield Stratum	AESRD Stratum	Culmination MAI by Yield Curve(m^3/ha/y) Natural[1] Dec	Con	Intensive Dec	Con	Extensive Dec	Con	Understory Dec	Con
Aw	Hw	2.86	0.24	Aw	Hw	2.86	0.24	-	-	3.87	0.14	-	-
AwU	Hw	2.33	0.47	Aw	Hw	2.86	0.24	-	-	3.87	0.14	-	-
				$AwSw^{UP}$	HwSx	-	-	-	-	-	-	1.45	1.25
				$SwAw^{UP}$	SwHw	-	-	-	-	-	-	0.96	1.76
AwSx	HwSx	1.19	1.33	AwSx	HwSx	-	-	1.78	1.96	1.50	0.95	-	-
SxAw	SwHw, SbHw	0.83	1.55	SxAw	SwHw, SbHw	-	-	1.53	2.30	1.24	1.45	-	-
Sw	Sw	0.58	1.72	Sw	Sw	-	-	1.70	2.34	0.54	2.31	-	-
SbFM	Sb	0.01	0.43	SbFM	Sb	0.01	0.43	-	-	-	-	-	-
SbG	Sb	0.03	0.78	SbG	Sb	0.03	0.78	-	-	-	-	-	-
PjMx	HwPl, PlHw	0.85	1.50	PjMx	HwPl, PlHw	0.85	1.50	-	-	-	-	-	-
Pj	Pl	0.14	1.48	Pj	PlHw	0.14	1.48	-	-	-	-	-	-

[1]Managed stand yields taken from natural stand yield curves.

MAI targets are provided for Alberta-Pacific and quota holders, separately, in Table 8-4. Note that SbFM targets are only applicable to FMUs L3 and A14 where one quota holder intend to harvest fair and medium TPR black spruce.

Table 8-4. Culmination MAI targets by FMU.

		Culmination MAI (m^3/ha/y)			
Yield	AESRD	Al-Pac		Quota Holder	
Stratum	Stratum	Dec	Con	Dec	Con
Aw	Hw	3.87	0.14	2.86	0.24
AwSw^{UP}	HwSx	1.45	1.25	*n/a*	*n/a*
SwAw^{UP}	SwHw	0.96	1.76	*n/a*	*n/a*
AwSx	HwSx	1.50	0.95	1.78	1.96
SxAw	SbHw	1.24	1.45	1.53	2.30
	SwHw	1.24	1.45	1.53	2.30
Sw	Sw	0.54	2.31	1.70	2.34
SbFM	Sb	*n/a*	*n/a*	0.01	0.43
SbG	Sb	0.03	0.78	0.03	0.78
PjMx	HwPl	0.85	1.50	0.85	1.50
	PlHw	0.85	1.50	0.85	1.50
Pj	Pl	0.14	1.48	0.14	1.48

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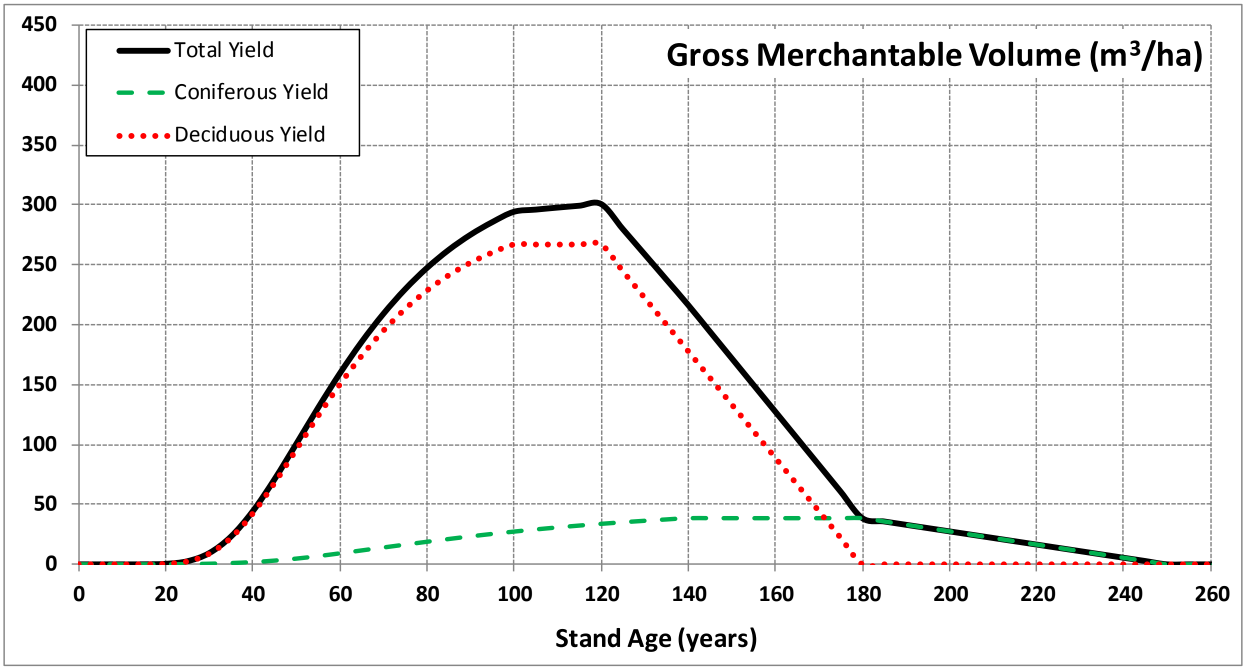
Appendix I – Natural Stand Yield Tables

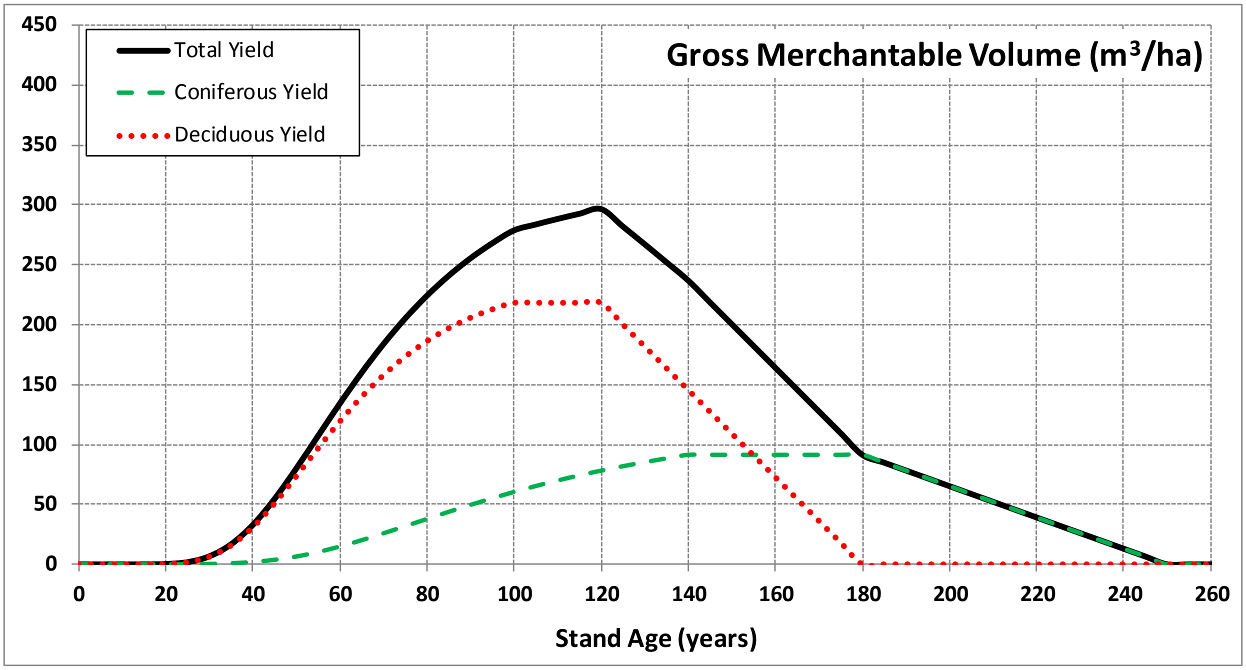
ALBERTA-PACIFIC FOREST INDUSTRIES INC.

YIELD STRATUM:	Aw	TYPE	Deciduous	YC1



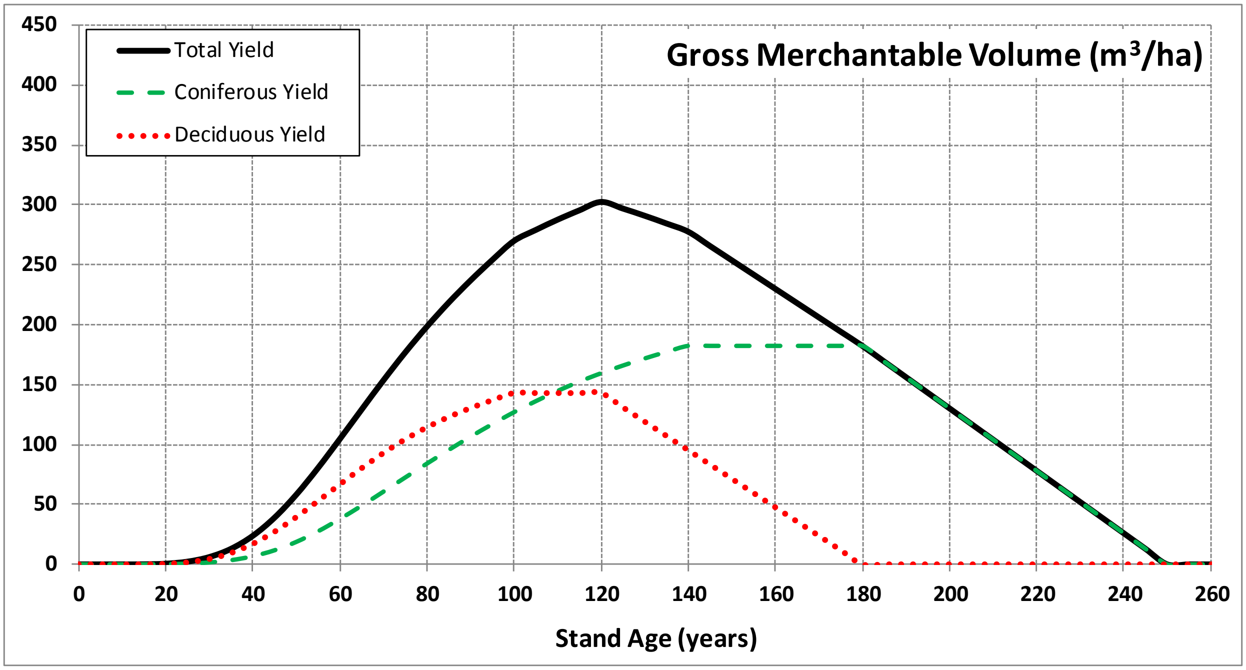
Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.4	0.1	0.4	0.02	0.00	0.02
30	8.8	0.5	9.3	0.29	0.02	0.31
40	42.4	1.9	44.3	1.06	0.05	1.11
50	95.7	4.8	100.5	1.91	0.10	2.01
60	150.1	9.2	159.3	2.50	0.15	2.65
70	195.0	14.1	209.1	2.79	0.20	2.99
80	228.5	18.8	247.3	2.86	0.24	3.09
90	251.8	23.3	275.1	2.80	0.26	3.06
100	266.9	27.3	294.3	2.67	0.27	2.94
110	266.9	30.8	297.8	2.43	0.28	2.71
120	266.9	33.8	300.8	2.22	0.28	2.51
130	222.5	36.4	258.8	1.71	0.28	1.99
140	178.0	38.5	216.5	1.27	0.28	1.55
150	133.5	38.5	172.0	0.89	0.26	1.15
160	89.0	38.5	127.5	0.56	0.24	0.80
170	44.5	38.5	83.0	0.26	0.23	0.49
180	0.0	38.5	38.5	0.00	0.21	0.21
190	0.0	33.0	33.0	0.00	0.17	0.17
200	0.0	27.5	27.5	0.00	0.14	0.14
210	0.0	22.0	22.0	0.00	0.10	0.10
220	0.0	16.5	16.5	0.00	0.08	0.08
230	0.0	11.0	11.0	0.00	0.05	0.05
240	0.0	5.5	5.5	0.00	0.02	0.02
250	0.0	0.0	0.0	0.00	0.00	0.00

YIELD STRATUM:	AwU	TYPE	Deciduous	YC2



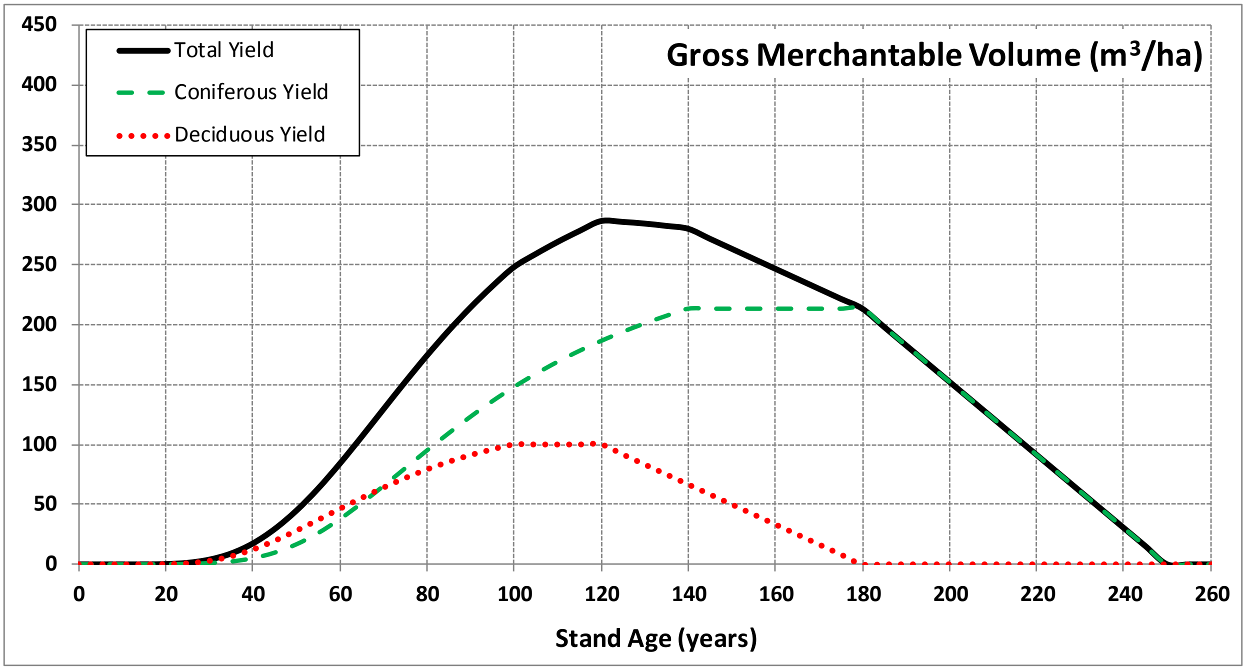
Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.3	0.0	0.3	0.01	0.00	0.01
30	6.3	0.3	6.6	0.21	0.01	0.22
40	30.8	2.0	32.8	0.77	0.05	0.82
50	73.4	6.5	80.0	1.47	0.13	1.60
60	119.3	14.9	134.2	1.99	0.25	2.24
70	157.8	25.9	183.7	2.25	0.37	2.62
80	186.3	37.9	224.2	2.33	0.47	2.80
90	205.8	49.6	255.4	2.29	0.55	2.84
100	218.3	60.4	278.7	2.18	0.60	2.79
110	218.3	70.0	288.3	1.98	0.64	2.62
120	218.3	78.2	296.5	1.82	0.65	2.47
130	181.9	85.3	267.2	1.40	0.66	2.06
140	145.5	91.4	236.9	1.04	0.65	1.69
150	109.2	91.4	200.6	0.73	0.61	1.34
160	72.8	91.4	164.2	0.45	0.57	1.03
170	36.4	91.4	127.8	0.21	0.54	0.75
180	0.0	91.4	91.4	0.00	0.51	0.51
190	0.0	78.3	78.3	0.00	0.41	0.41
200	0.0	65.3	65.3	0.00	0.33	0.33
210	0.0	52.2	52.2	0.00	0.25	0.25
220	0.0	39.2	39.2	0.00	0.18	0.18
230	0.0	26.1	26.1	0.00	0.11	0.11
240	0.0	13.1	13.1	0.00	0.05	0.05
250	0.0	0.0	0.0	0.00	0.00	0.00

YIELD STRATUM: **AwSx** **TYPE** **Coniferous** **YC3**



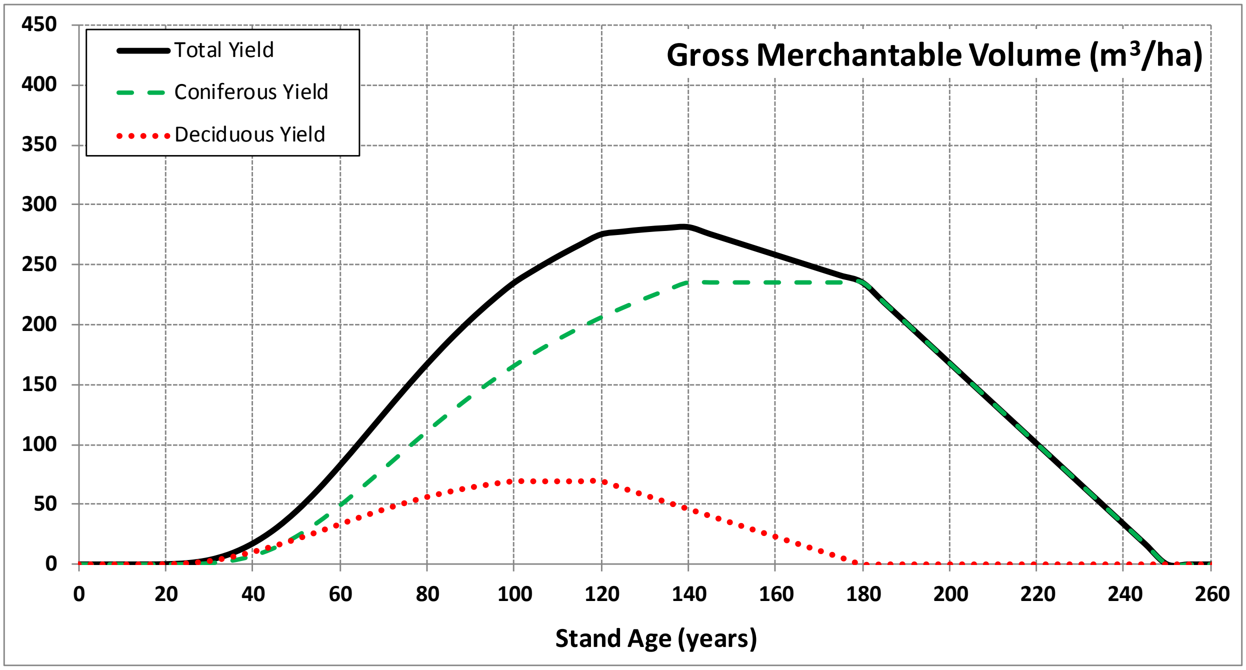
Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.4	0.2	0.5	0.02	0.01	0.03
30	4.5	1.6	6.1	0.15	0.05	0.20
40	17.0	6.7	23.8	0.43	0.17	0.59
50	39.4	18.7	58.1	0.79	0.37	1.16
60	66.7	37.8	104.5	1.11	0.63	1.74
70	92.9	60.6	153.5	1.33	0.87	2.19
80	114.3	84.1	198.4	1.43	1.05	2.48
90	130.4	106.5	236.9	1.45	1.18	2.63
100	143.0	127.0	269.9	1.43	1.27	2.70
110	143.0	144.7	287.7	1.30	1.32	2.62
120	143.0	159.5	302.5	1.19	1.33	2.52
130	119.1	171.8	291.0	0.92	1.32	2.24
140	95.3	182.4	277.7	0.68	1.30	1.98
150	71.5	182.4	253.8	0.48	1.22	1.69
160	47.7	182.4	230.0	0.30	1.14	1.44
170	23.8	182.4	206.2	0.14	1.07	1.21
180	0.0	182.4	182.4	0.00	1.01	1.01
190	0.0	156.3	156.3	0.00	0.82	0.82
200	0.0	130.3	130.3	0.00	0.65	0.65
210	0.0	104.2	104.2	0.00	0.50	0.50
220	0.0	78.2	78.2	0.00	0.36	0.36
230	0.0	52.1	52.1	0.00	0.23	0.23
240	0.0	26.1	26.1	0.00	0.11	0.11
250	0.0	0.0	0.0	0.00	0.00	0.00

YIELD STRATUM:	SxAw	TYPE	Coniferous	YC4



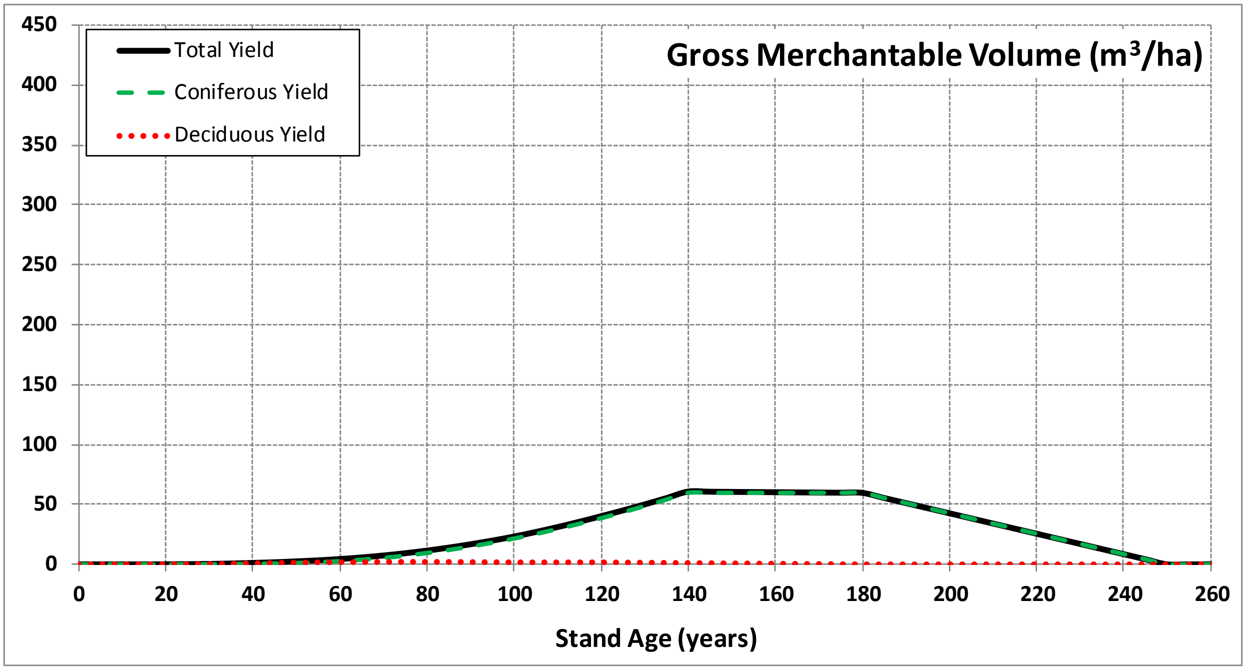
Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.2	0.1	0.2	0.01	0.00	0.01
30	2.9	1.0	3.9	0.10	0.03	0.13
40	12.3	5.1	17.4	0.31	0.13	0.43
50	28.1	16.7	44.7	0.56	0.33	0.89
60	46.3	37.7	84.0	0.77	0.63	1.40
70	64.0	65.4	129.4	0.91	0.93	1.85
80	79.2	95.0	174.2	0.99	1.19	2.18
90	91.2	123.2	214.4	1.01	1.37	2.38
100	100.0	148.1	248.1	1.00	1.48	2.48
110	100.0	169.0	269.1	0.91	1.54	2.45
120	100.0	186.5	286.5	0.83	1.55	2.39
130	83.4	201.1	284.4	0.64	1.55	2.19
140	66.7	213.4	280.1	0.48	1.52	2.00
150	50.0	213.4	263.4	0.33	1.42	1.76
160	33.3	213.4	246.7	0.21	1.33	1.54
170	16.7	213.4	230.0	0.10	1.26	1.35
180	0.0	213.4	213.4	0.00	1.19	1.19
190	0.0	182.9	182.9	0.00	0.96	0.96
200	0.0	152.4	152.4	0.00	0.76	0.76
210	0.0	121.9	121.9	0.00	0.58	0.58
220	0.0	91.4	91.4	0.00	0.42	0.42
230	0.0	61.0	61.0	0.00	0.27	0.27
240	0.0	30.5	30.5	0.00	0.13	0.13
250	0.0	0.0	0.0	0.00	0.00	0.00

YIELD STRATUM:	Sw	TYPE	Coniferous	YC5



Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.2	0.0	0.2	0.01	0.00	0.01
30	2.7	0.9	3.7	0.09	0.03	0.12
40	10.4	7.1	17.4	0.26	0.18	0.44
50	21.0	23.2	44.3	0.42	0.46	0.89
60	33.4	49.0	82.4	0.56	0.82	1.37
70	45.7	79.6	125.2	0.65	1.14	1.79
80	56.2	110.8	167.0	0.70	1.39	2.09
90	64.1	140.0	204.1	0.71	1.56	2.27
100	69.3	165.7	235.0	0.69	1.66	2.35
110	69.3	187.6	256.9	0.63	1.71	2.34
120	69.3	206.1	275.4	0.58	1.72	2.29
130	57.8	221.8	279.5	0.44	1.71	2.15
140	46.2	235.3	281.5	0.33	1.68	2.01
150	34.7	235.3	270.0	0.23	1.57	1.80
160	23.1	235.3	258.4	0.14	1.47	1.62
170	11.6	235.3	246.9	0.07	1.38	1.45
180	0.0	235.3	235.3	0.00	1.31	1.31
190	0.0	201.7	201.7	0.00	1.06	1.06
200	0.0	168.1	168.1	0.00	0.84	0.84
210	0.0	134.5	134.5	0.00	0.64	0.64
220	0.0	100.8	100.8	0.00	0.46	0.46
230	0.0	67.2	67.2	0.00	0.29	0.29
240	0.0	33.6	33.6	0.00	0.14	0.14
250	0.0	0.0	0.0	0.00	0.00	0.00

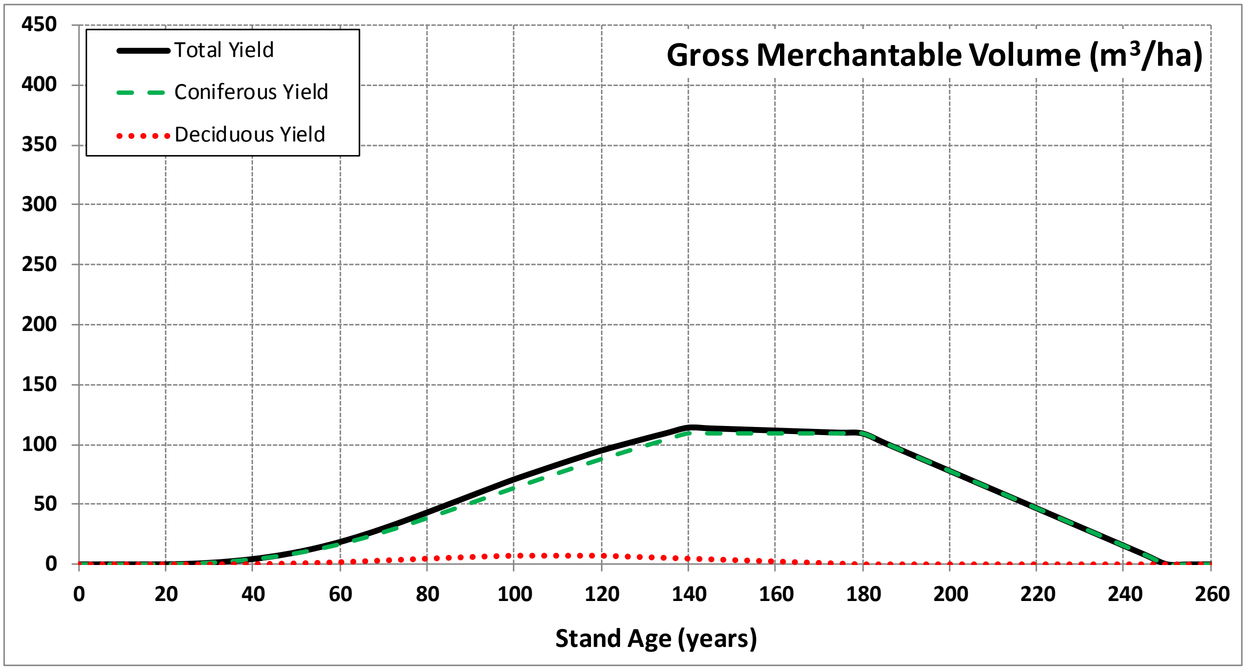
YIELD STRATUM:	SbFM	TYPE	Coniferous	YC6



Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.1	0.0	0.1	0.00	0.00	0.00
30	0.3	0.1	0.4	0.01	0.00	0.01
40	0.8	0.4	1.2	0.02	0.01	0.03
50	1.4	1.1	2.5	0.03	0.02	0.05
60	1.8	2.6	4.4	0.03	0.04	0.07
70	2.0	5.4	7.4	0.03	0.08	0.11
80	2.0	9.5	11.5	0.03	0.12	0.14
90	1.9	14.9	16.8	0.02	0.17	0.19
100	1.6	21.6	23.2	0.02	0.22	0.23
110	1.6	29.5	31.1	0.01	0.27	0.28
120	1.6	38.6	40.2	0.01	0.32	0.33
130	1.4	48.7	50.0	0.01	0.37	0.38
140	1.1	59.7	60.7	0.01	0.43	0.43
150	0.8	59.7	60.5	0.01	0.40	0.40
160	0.5	59.7	60.2	0.00	0.37	0.38
170	0.3	59.7	59.9	0.00	0.35	0.35
180	0.0	59.7	59.7	0.00	0.33	0.33
190	0.0	51.1	51.1	0.00	0.27	0.27
200	0.0	42.6	42.6	0.00	0.21	0.21
210	0.0	34.1	34.1	0.00	0.16	0.16
220	0.0	25.6	25.6	0.00	0.12	0.12
230	0.0	17.0	17.0	0.00	0.07	0.07
240	0.0	8.5	8.5	0.00	0.04	0.04
250	0.0	0.0	0.0	0.00	0.00	0.00

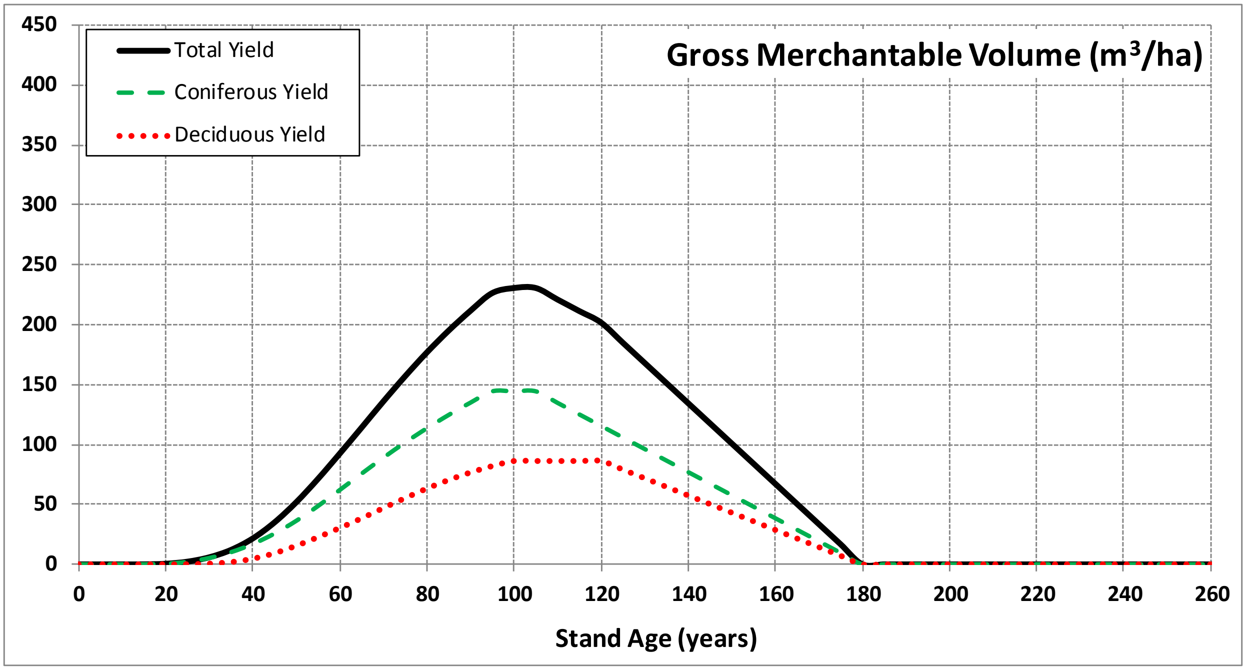
ALBERTA-PACIFIC FOREST INDUSTRIES INC.

YIELD STRATUM: SbG TYPE Coniferous YC7



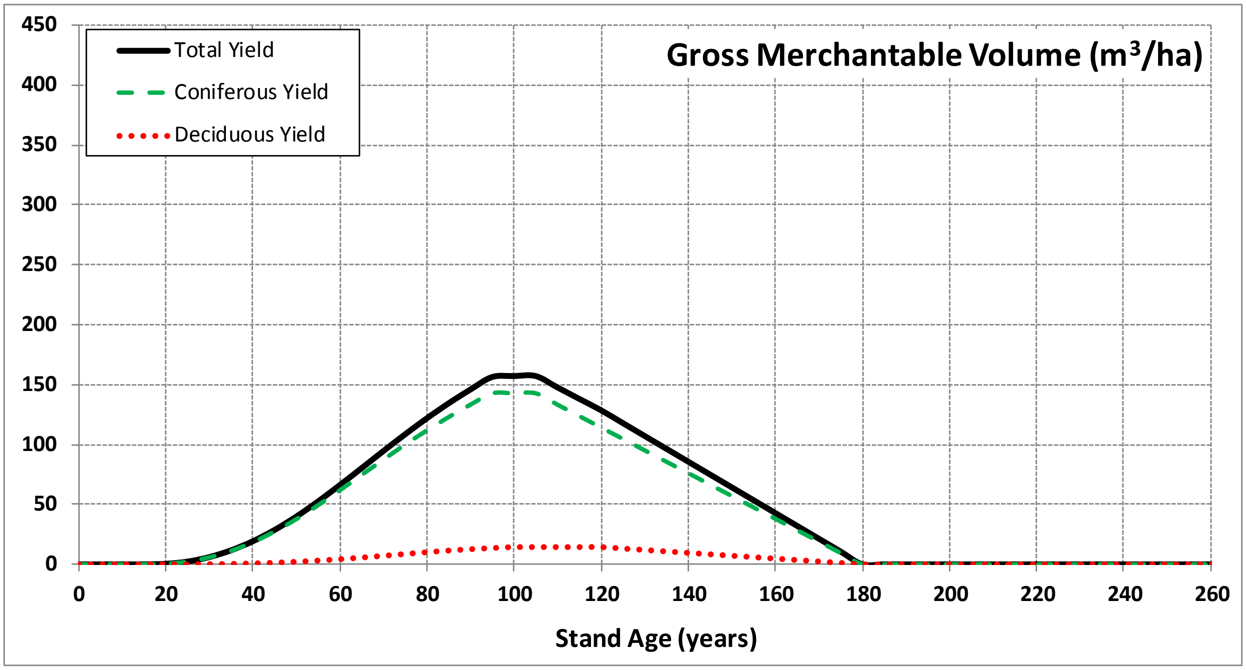
Stand Age	Merchantable Volume (m^3/ha) Deciduous	Merchantable Volume (m^3/ha) Coniferous	Merchantable Volume (m^3/ha) Total	Mean Annual Increment (m^3/ha/year) Deciduous	Mean Annual Increment (m^3/ha/year) Coniferous	Mean Annual Increment (m^3/ha/year) Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.0	0.1	0.1	0.00	0.00	0.00
30	0.0	1.2	1.3	0.00	0.04	0.04
40	0.2	4.2	4.4	0.01	0.11	0.11
50	0.8	9.3	10.0	0.02	0.19	0.20
60	1.8	16.8	18.6	0.03	0.28	0.31
70	3.2	26.8	30.0	0.05	0.38	0.43
80	4.7	38.5	43.2	0.06	0.48	0.54
90	6.1	51.0	57.1	0.07	0.57	0.63
100	7.2	63.7	70.9	0.07	0.64	0.71
110	7.2	76.0	83.2	0.07	0.69	0.76
120	7.2	87.7	94.9	0.06	0.73	0.79
130	6.0	98.8	104.8	0.05	0.76	0.81
140	4.8	109.3	114.1	0.03	0.78	0.81
150	3.6	109.3	112.9	0.02	0.73	0.75
160	2.4	109.3	111.7	0.01	0.68	0.70
170	1.2	109.3	110.5	0.01	0.64	0.65
180	0.0	109.3	109.3	0.00	0.61	0.61
190	0.0	93.7	93.7	0.00	0.49	0.49
200	0.0	78.1	78.1	0.00	0.39	0.39
210	0.0	62.5	62.5	0.00	0.30	0.30
220	0.0	46.8	46.8	0.00	0.21	0.21
230	0.0	31.2	31.2	0.00	0.14	0.14
240	0.0	15.6	15.6	0.00	0.07	0.07
250	0.0	0.0	0.0	0.00	0.00	0.00

YIELD STRATUM:	PjMx	TYPE	Coniferous	YC8



Stand Age	Merchantable Volume (m^3/ha) Deciduous	Merchantable Volume (m^3/ha) Coniferous	Merchantable Volume (m^3/ha) Total	Mean Annual Increment (m^3/ha/year) Deciduous	Mean Annual Increment (m^3/ha/year) Coniferous	Mean Annual Increment (m^3/ha/year) Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.0	0.5	0.5	0.00	0.02	0.03
30	0.6	5.3	5.9	0.02	0.18	0.20
40	4.7	16.9	21.6	0.12	0.42	0.54
50	15.5	36.3	51.9	0.31	0.73	1.04
60	30.4	62.1	92.5	0.51	1.03	1.54
70	47.0	89.0	136.0	0.67	1.27	1.94
80	63.3	113.6	176.9	0.79	1.42	2.21
90	76.7	135.0	211.6	0.85	1.50	2.35
100	86.2	144.4	230.7	0.86	1.44	2.31
110	86.2	134.8	221.0	0.78	1.23	2.01
120	86.2	115.5	201.8	0.72	0.96	1.68
130	71.9	96.3	168.2	0.55	0.74	1.29
140	57.5	77.0	134.5	0.41	0.55	0.96
150	43.1	57.8	100.9	0.29	0.39	0.67
160	28.7	38.5	67.3	0.18	0.24	0.42
170	14.4	19.3	33.6	0.08	0.11	0.20
180	0.0	0.0	0.0	0.00	0.00	0.00
190	0.0	0.0	0.0	0.00	0.00	0.00
200	0.0	0.0	0.0	0.00	0.00	0.00
210	0.0	0.0	0.0	0.00	0.00	0.00
220	0.0	0.0	0.0	0.00	0.00	0.00
230	0.0	0.0	0.0	0.00	0.00	0.00
240	0.0	0.0	0.0	0.00	0.00	0.00
250	0.0	0.0	0.0	0.00	0.00	0.00

YIELD STRATUM:	Pj	TYPE	Coniferous	YC9

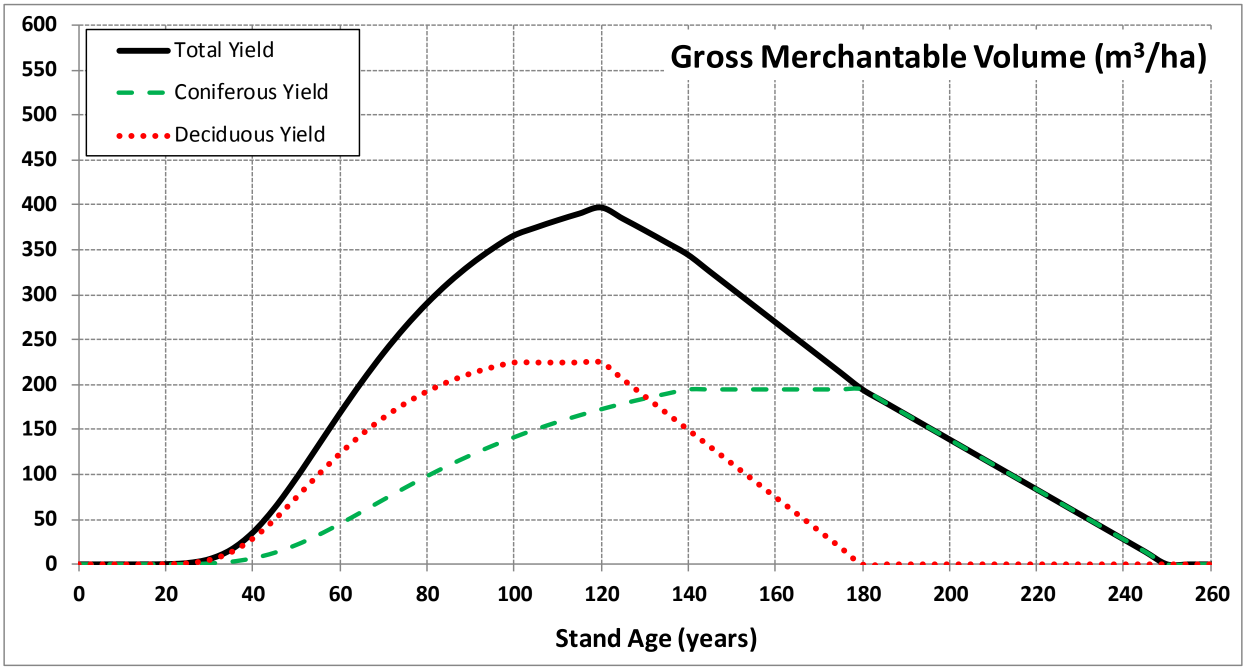


Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.0	0.4	0.5	0.00	0.02	0.02
30	0.2	5.8	6.0	0.01	0.19	0.20
40	0.8	18.5	19.2	0.02	0.46	0.48
50	2.2	37.7	39.9	0.04	0.75	0.80
60	4.3	61.8	66.1	0.07	1.03	1.10
70	7.1	87.4	94.5	0.10	1.25	1.35
80	10.1	111.8	121.9	0.13	1.40	1.52
90	12.7	133.3	145.9	0.14	1.48	1.62
100	14.4	142.8	157.1	0.14	1.43	1.57
110	14.4	133.2	147.6	0.13	1.21	1.34
120	14.4	114.2	128.6	0.12	0.95	1.07
130	12.0	95.2	107.2	0.09	0.73	0.82
140	9.6	76.1	85.7	0.07	0.54	0.61
150	7.2	57.1	64.3	0.05	0.38	0.43
160	4.8	38.1	42.9	0.03	0.24	0.27
170	2.4	19.0	21.4	0.01	0.11	0.13
180	0.0	0.0	0.0	0.00	0.00	0.00
190	0.0	0.0	0.0	0.00	0.00	0.00
200	0.0	0.0	0.0	0.00	0.00	0.00
210	0.0	0.0	0.0	0.00	0.00	0.00
220	0.0	0.0	0.0	0.00	0.00	0.00
230	0.0	0.0	0.0	0.00	0.00	0.00
240	0.0	0.0	0.0	0.00	0.00	0.00
250	0.0	0.0	0.0	0.00	0.00	0.00

Appendix II – Post-Performance Yield Tables

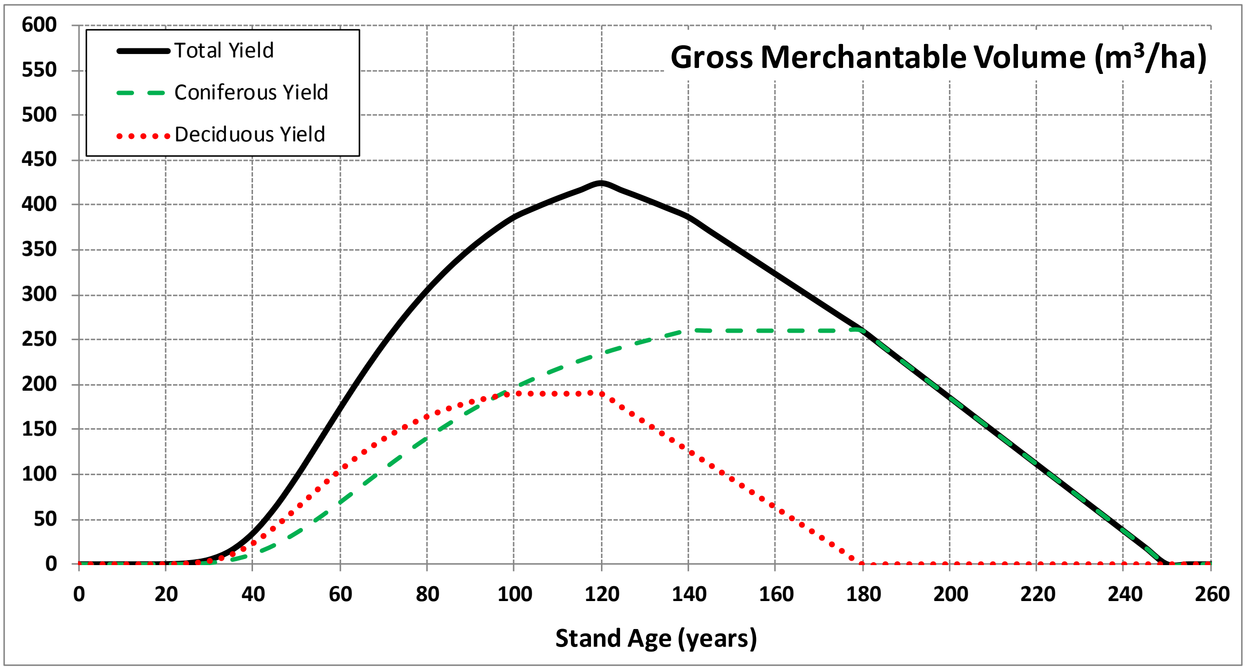
ALBERTA-PACIFIC FOREST INDUSTRIES INC.

YIELD STRATUM: Hw **TYPE** Deciduous **YC10**



Stand Age	Merchantable Volume (m³/ha)			Mean Annual Increment (m³/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.2	0.1	0.3	0.01	0.00	0.01
30	4.8	1.0	5.8	0.16	0.03	0.19
40	28.6	6.7	35.3	0.72	0.17	0.88
50	74.3	21.6	95.9	1.49	0.43	1.92
60	123.1	45.0	168.1	2.05	0.75	2.80
70	163.1	71.9	235.0	2.33	1.03	3.36
80	192.3	98.1	290.4	2.40	1.23	3.63
90	212.2	121.4	333.6	2.36	1.35	3.71
100	224.6	141.4	366.0	2.25	1.41	3.66
110	224.6	158.3	382.9	2.04	1.44	3.48
120	224.6	172.6	397.2	1.87	1.44	3.31
130	187.2	184.5	371.7	1.44	1.42	2.86
140	149.7	194.7	344.4	1.07	1.39	2.46
150	112.3	194.7	307.0	0.75	1.30	2.05
160	74.9	194.7	269.5	0.47	1.22	1.68
170	37.4	194.7	232.1	0.22	1.15	1.37
180	0.0	194.7	194.7	0.00	1.08	1.08
190	0.0	166.9	166.9	0.00	0.88	0.88
200	0.0	139.1	139.1	0.00	0.70	0.70
210	0.0	111.2	111.2	0.00	0.53	0.53
220	0.0	83.4	83.4	0.00	0.38	0.38
230	0.0	55.6	55.6	0.00	0.24	0.24
240	0.0	27.8	27.8	0.00	0.12	0.12
250	0.0	0.0	0.0	0.00	0.00	0.00

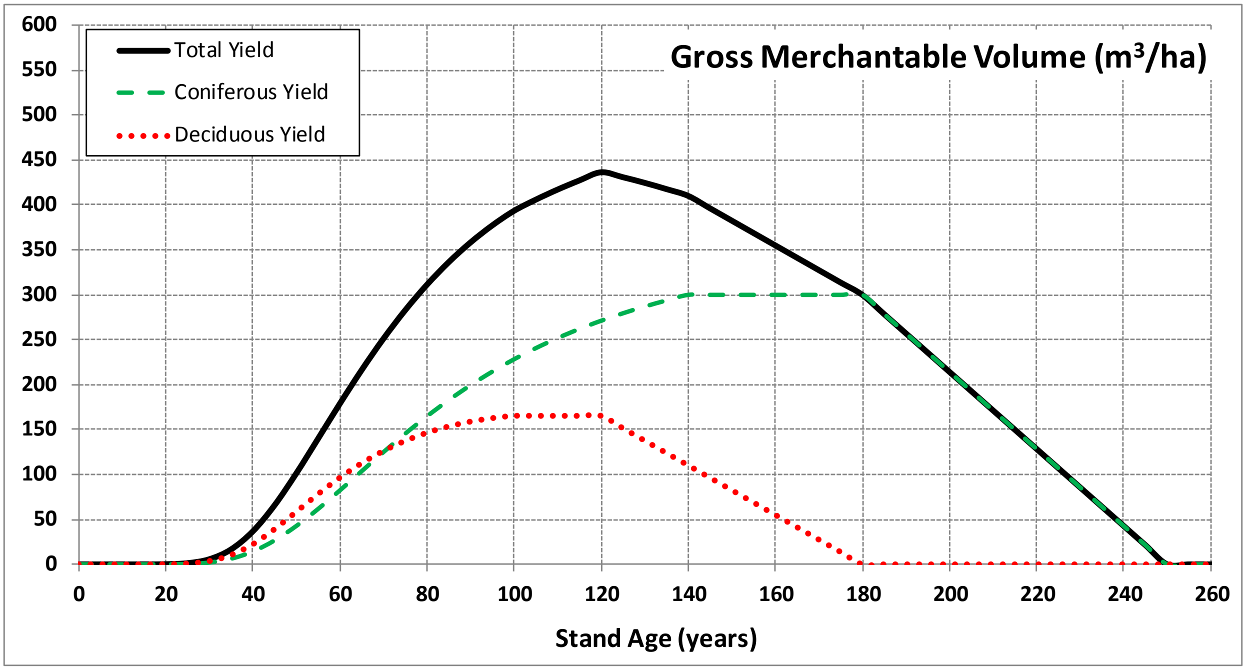
YIELD STRATUM:	HwSx	TYPE	Coniferous	YC11



Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.1	0.0	0.2	0.01	0.00	0.01
30	3.6	1.5	5.1	0.12	0.05	0.17
40	23.1	11.2	34.3	0.58	0.28	0.86
50	61.9	34.8	96.7	1.24	0.70	1.93
60	104.4	68.7	173.0	1.74	1.14	2.88
70	139.3	105.6	244.9	1.99	1.51	3.50
80	164.3	140.5	304.8	2.05	1.76	3.81
90	180.6	171.0	351.5	2.01	1.90	3.91
100	189.9	196.5	386.4	1.90	1.96	3.86
110	189.9	217.4	407.4	1.73	1.98	3.70
120	189.9	234.5	424.4	1.58	1.95	3.54
130	158.3	248.5	406.8	1.22	1.91	3.13
140	126.6	260.1	386.7	0.90	1.86	2.76
150	95.0	260.1	355.0	0.63	1.73	2.37
160	63.3	260.1	323.4	0.40	1.63	2.02
170	31.7	260.1	291.7	0.19	1.53	1.72
180	0.0	260.1	260.1	0.00	1.44	1.44
190	0.0	222.9	222.9	0.00	1.17	1.17
200	0.0	185.8	185.8	0.00	0.93	0.93
210	0.0	148.6	148.6	0.00	0.71	0.71
220	0.0	111.5	111.5	0.00	0.51	0.51
230	0.0	74.3	74.3	0.00	0.32	0.32
240	0.0	37.2	37.2	0.00	0.15	0.15
250	0.0	0.0	0.0	0.00	0.00	0.00

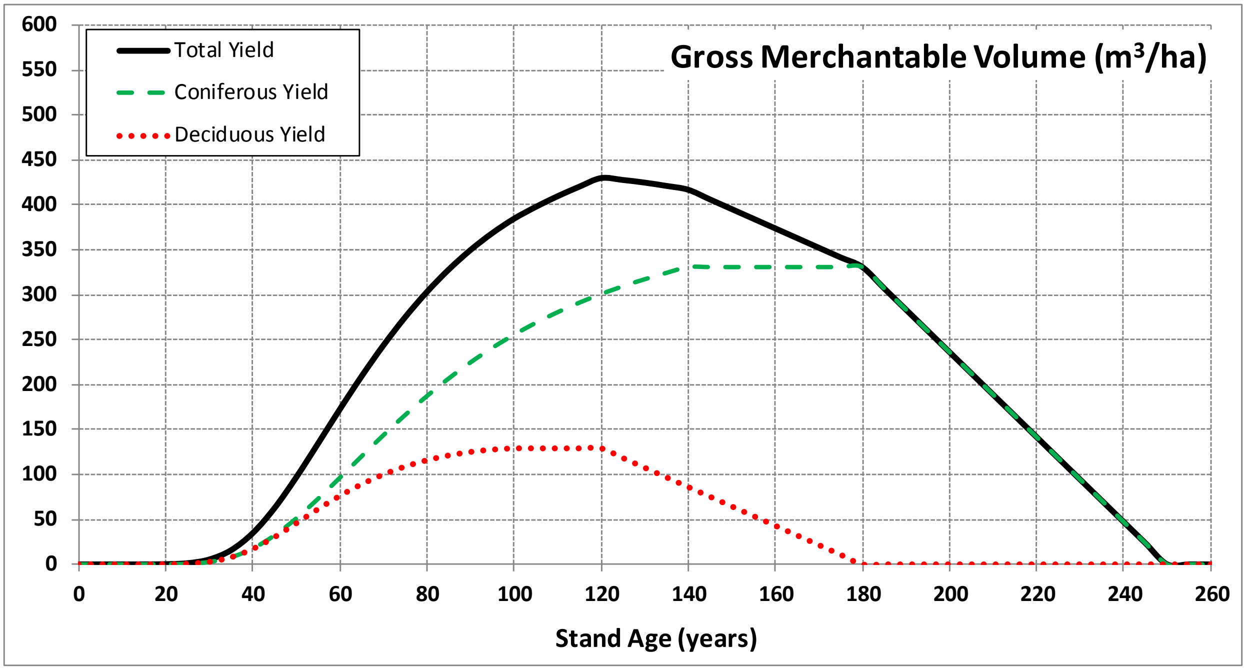
ALBERTA-PACIFIC FOREST INDUSTRIES INC.

YIELD STRATUM: SwHw TYPE Coniferous YC12



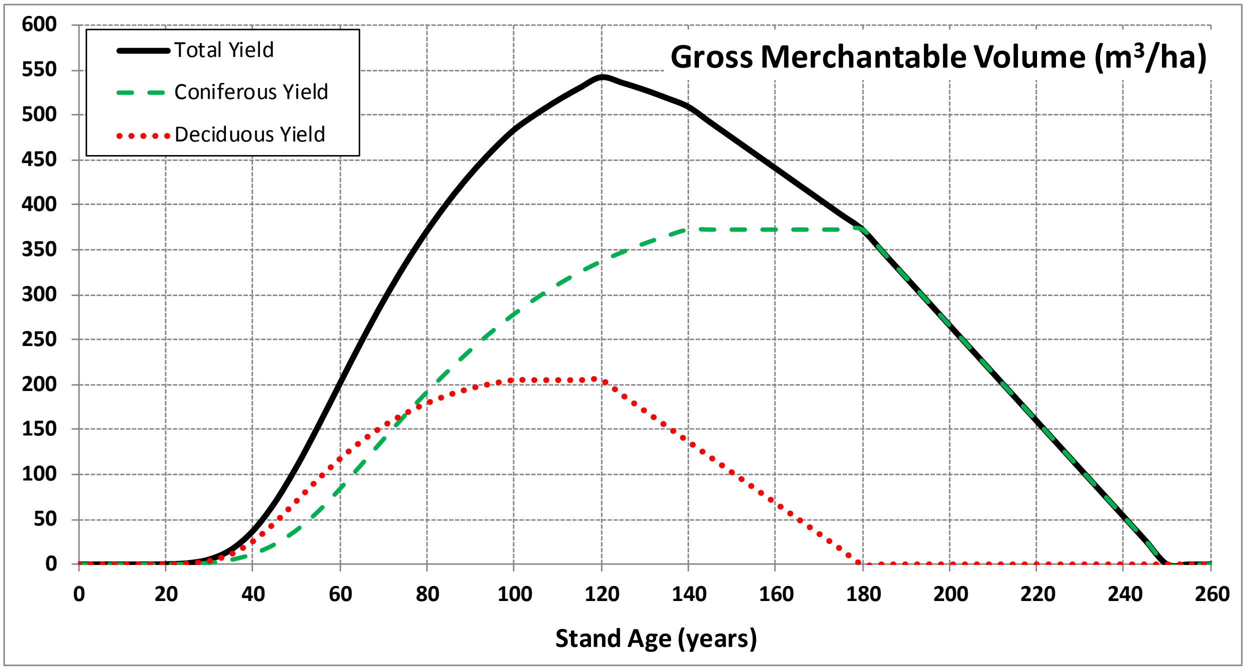
Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.1	0.1	0.2	0.01	0.00	0.01
30	3.6	2.0	5.6	0.12	0.07	0.19
40	22.3	14.3	36.6	0.56	0.36	0.92
50	58.5	42.7	101.2	1.17	0.85	2.02
60	96.5	82.2	178.7	1.61	1.37	2.98
70	126.2	124.8	251.0	1.80	1.78	3.59
80	146.4	164.7	311.1	1.83	2.06	3.89
90	158.9	199.3	358.2	1.77	2.21	3.98
100	165.3	228.2	393.4	1.65	2.28	3.93
110	165.3	251.8	417.1	1.50	2.29	3.79
120	165.3	271.1	436.3	1.38	2.26	3.64
130	137.7	286.9	424.6	1.06	2.21	3.27
140	110.2	299.9	410.1	0.79	2.14	2.93
150	82.6	299.9	382.5	0.55	2.00	2.55
160	55.1	299.9	355.0	0.34	1.87	2.22
170	27.5	299.9	327.4	0.16	1.76	1.93
180	0.0	299.9	299.9	0.00	1.67	1.67
190	0.0	257.1	257.1	0.00	1.35	1.35
200	0.0	214.2	214.2	0.00	1.07	1.07
210	0.0	171.4	171.4	0.00	0.82	0.82
220	0.0	128.5	128.5	0.00	0.58	0.58
230	0.0	85.7	85.7	0.00	0.37	0.37
240	0.0	42.8	42.8	0.00	0.18	0.18
250	0.0	0.0	0.0	0.00	0.00	0.00

YIELD STRATUM:	Sw	TYPE	Coniferous	YC13



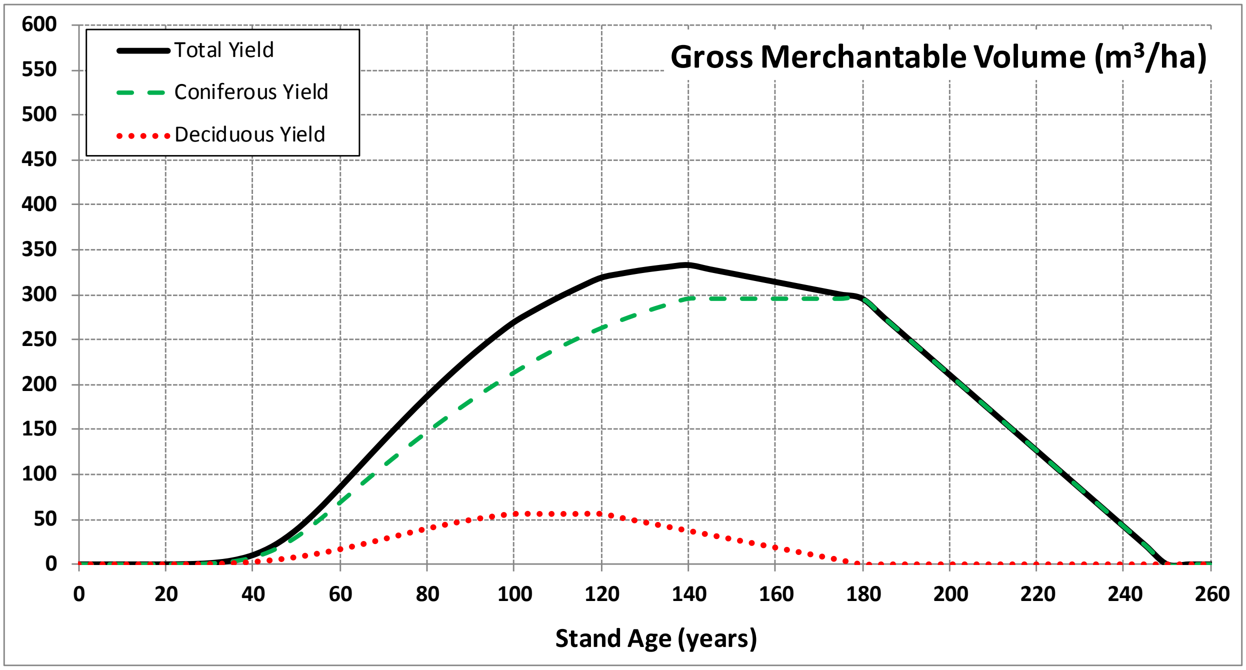
Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.1	0.1	0.2	0.01	0.01	0.01
30	2.8	2.6	5.4	0.09	0.09	0.18
40	17.1	17.6	34.7	0.43	0.44	0.87
50	45.7	51.2	96.9	0.91	1.02	1.94
60	76.2	96.3	172.5	1.27	1.61	2.88
70	100.0	143.7	243.6	1.43	2.05	3.48
80	115.9	187.3	303.1	1.45	2.34	3.79
90	125.1	224.7	349.8	1.39	2.50	3.89
100	129.1	255.5	384.6	1.29	2.56	3.85
110	129.1	280.6	409.6	1.17	2.55	3.72
120	129.1	300.8	429.9	1.08	2.51	3.58
130	107.6	317.3	424.8	0.83	2.44	3.27
140	86.1	330.8	416.9	0.61	2.36	2.98
150	64.5	330.8	395.4	0.43	2.21	2.64
160	43.0	330.8	373.9	0.27	2.07	2.34
170	21.5	330.8	352.3	0.13	1.95	2.07
180	0.0	330.8	330.8	0.00	1.84	1.84
190	0.0	283.6	283.6	0.00	1.49	1.49
200	0.0	236.3	236.3	0.00	1.18	1.18
210	0.0	189.1	189.1	0.00	0.90	0.90
220	0.0	141.8	141.8	0.00	0.64	0.64
230	0.0	94.5	94.5	0.00	0.41	0.41
240	0.0	47.3	47.3	0.00	0.20	0.20
250	0.0	0.0	0.0	0.00	0.00	0.00

YIELD STRATUM:	SbHw	TYPE	Coniferous	YC14



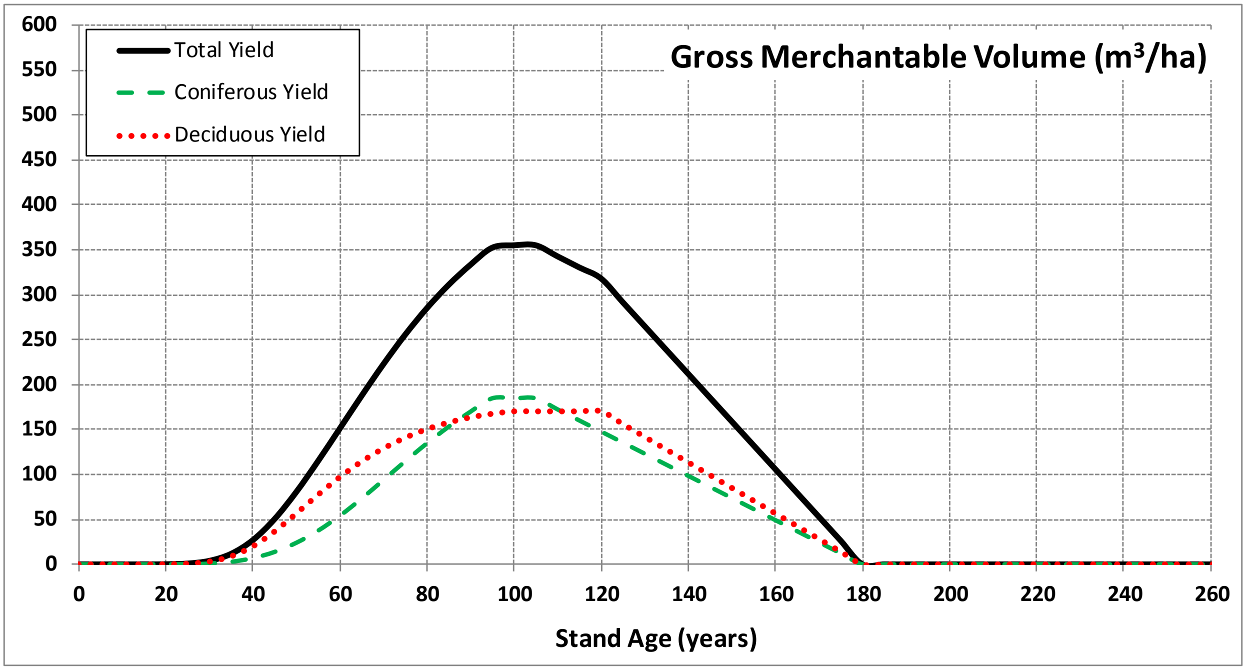
Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.1	0.1	0.2	0.01	0.00	0.01
30	3.7	1.7	5.5	0.12	0.06	0.18
40	25.5	11.5	36.9	0.64	0.29	0.92
50	70.1	37.9	108.0	1.40	0.76	2.16
60	117.3	83.8	201.1	1.95	1.40	3.35
70	153.9	139.0	292.9	2.20	1.99	4.18
80	179.3	191.7	370.9	2.24	2.40	4.64
90	195.7	238.4	434.1	2.17	2.65	4.82
100	205.1	278.4	483.5	2.05	2.78	4.83
110	205.1	311.2	516.3	1.86	2.83	4.69
120	205.1	337.1	542.1	1.71	2.81	4.52
130	170.9	357.1	528.0	1.31	2.75	4.06
140	136.7	372.5	509.2	0.98	2.66	3.64
150	102.5	372.5	475.1	0.68	2.48	3.17
160	68.4	372.5	440.9	0.43	2.33	2.76
170	34.2	372.5	406.7	0.20	2.19	2.39
180	0.0	372.5	372.5	0.00	2.07	2.07
190	0.0	319.3	319.3	0.00	1.68	1.68
200	0.0	266.1	266.1	0.00	1.33	1.33
210	0.0	212.9	212.9	0.00	1.01	1.01
220	0.0	159.7	159.7	0.00	0.73	0.73
230	0.0	106.4	106.4	0.00	0.46	0.46
240	0.0	53.2	53.2	0.00	0.22	0.22
250	0.0	0.0	0.0	0.00	0.00	0.00

YIELD STRATUM: Sb TYPE Coniferous YC15



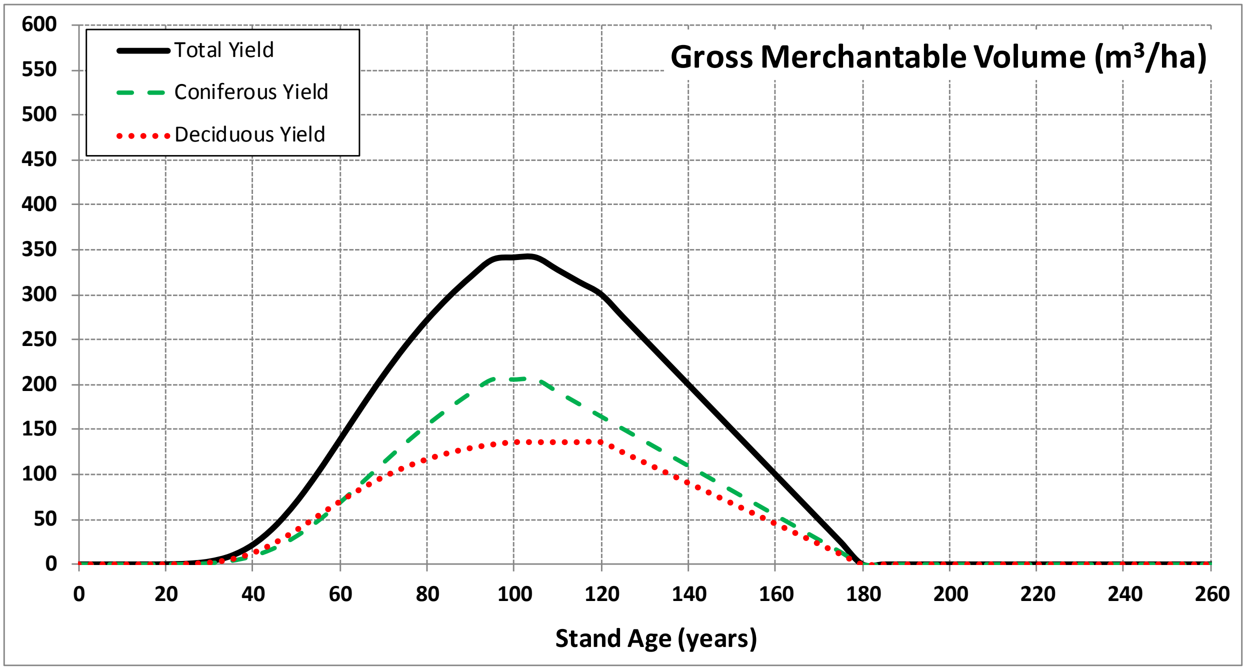
Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.0	0.0	0.0	0.00	0.00	0.00
30	0.4	0.9	1.3	0.01	0.03	0.04
40	2.7	7.6	10.2	0.07	0.19	0.26
50	8.1	30.3	38.4	0.16	0.61	0.77
60	16.8	68.6	85.3	0.28	1.14	1.42
70	28.0	109.2	137.3	0.40	1.56	1.96
80	39.7	147.1	186.8	0.50	1.84	2.33
90	49.4	182.0	231.4	0.55	2.02	2.57
100	56.1	213.4	269.5	0.56	2.13	2.70
110	56.1	240.4	296.5	0.51	2.19	2.70
120	56.1	262.8	319.0	0.47	2.19	2.66
130	46.8	281.0	327.8	0.36	2.16	2.52
140	37.4	295.6	333.1	0.27	2.11	2.38
150	28.1	295.6	323.7	0.19	1.97	2.16
160	18.7	295.6	314.3	0.12	1.85	1.96
170	9.4	295.6	305.0	0.06	1.74	1.79
180	0.0	295.6	295.6	0.00	1.64	1.64
190	0.0	253.4	253.4	0.00	1.33	1.33
200	0.0	211.2	211.2	0.00	1.06	1.06
210	0.0	168.9	168.9	0.00	0.80	0.80
220	0.0	126.7	126.7	0.00	0.58	0.58
230	0.0	84.5	84.5	0.00	0.37	0.37
240	0.0	42.2	42.2	0.00	0.18	0.18
250	0.0	0.0	0.0	0.00	0.00	0.00

YIELD STRATUM:	HwPl	TYPE	Coniferous	YC16



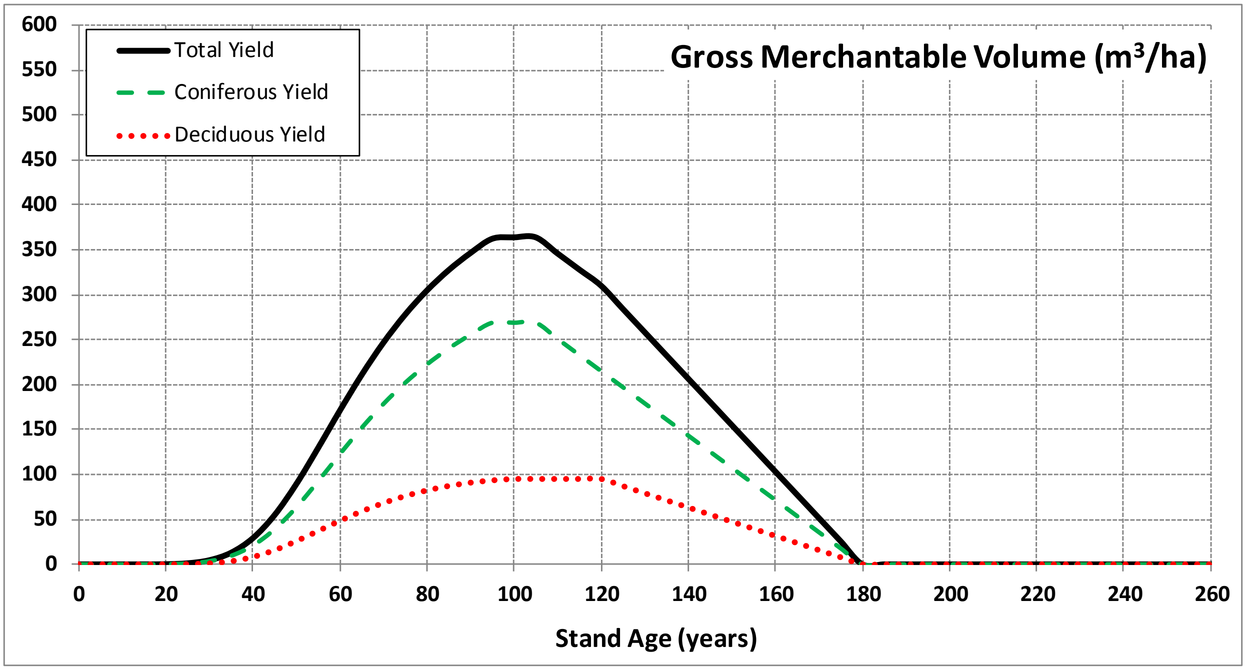
Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.1	0.0	0.1	0.01	0.00	0.01
30	3.0	0.8	3.9	0.10	0.03	0.13
40	20.0	6.9	26.8	0.50	0.17	0.67
50	56.5	24.0	80.5	1.13	0.48	1.61
60	97.1	54.0	151.1	1.62	0.90	2.52
70	128.9	93.8	222.7	1.84	1.34	3.18
80	150.4	134.7	285.1	1.88	1.68	3.56
90	163.5	169.9	333.4	1.82	1.89	3.70
100	170.3	184.8	355.1	1.70	1.85	3.55
110	170.3	172.5	342.7	1.55	1.57	3.12
120	170.3	147.8	318.1	1.42	1.23	2.65
130	141.9	123.2	265.1	1.09	0.95	2.04
140	113.5	98.6	212.1	0.81	0.70	1.51
150	85.1	73.9	159.1	0.57	0.49	1.06
160	56.8	49.3	106.0	0.35	0.31	0.66
170	28.4	24.6	53.0	0.17	0.14	0.31
180	0.0	0.0	0.0	0.00	0.00	0.00
190	0.0	0.0	0.0	0.00	0.00	0.00
200	0.0	0.0	0.0	0.00	0.00	0.00
210	0.0	0.0	0.0	0.00	0.00	0.00
220	0.0	0.0	0.0	0.00	0.00	0.00
230	0.0	0.0	0.0	0.00	0.00	0.00
240	0.0	0.0	0.0	0.00	0.00	0.00
250	0.0	0.0	0.0	0.00	0.00	0.00

YIELD STRATUM:	PlHw	TYPE	Coniferous	YC17



Stand Age	Merchantable Volume (m^3/ha) Deciduous	Merchantable Volume (m^3/ha) Coniferous	Merchantable Volume (m^3/ha) Total	Mean Annual Increment (m^3/ha/year) Deciduous	Mean Annual Increment (m^3/ha/year) Coniferous	Mean Annual Increment (m^3/ha/year) Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.1	0.0	0.1	0.00	0.00	0.01
30	1.9	1.3	3.2	0.06	0.04	0.11
40	12.6	9.2	21.8	0.32	0.23	0.54
50	38.0	31.2	69.2	0.76	0.62	1.38
60	69.8	68.5	138.3	1.16	1.14	2.30
70	97.3	112.9	210.1	1.39	1.61	3.00
80	116.9	154.8	271.8	1.46	1.94	3.40
90	129.4	190.4	319.8	1.44	2.12	3.55
100	136.0	205.7	341.6	1.36	2.06	3.42
110	136.0	192.0	327.9	1.24	1.75	2.98
120	136.0	164.5	300.5	1.13	1.37	2.50
130	113.3	137.1	250.4	0.87	1.05	1.93
140	90.6	109.7	200.3	0.65	0.78	1.43
150	68.0	82.3	150.3	0.45	0.55	1.00
160	45.3	54.8	100.2	0.28	0.34	0.63
170	22.7	27.4	50.1	0.13	0.16	0.29
180	0.0	0.0	0.0	0.00	0.00	0.00
190	0.0	0.0	0.0	0.00	0.00	0.00
200	0.0	0.0	0.0	0.00	0.00	0.00
210	0.0	0.0	0.0	0.00	0.00	0.00
220	0.0	0.0	0.0	0.00	0.00	0.00
230	0.0	0.0	0.0	0.00	0.00	0.00
240	0.0	0.0	0.0	0.00	0.00	0.00
250	0.0	0.0	0.0	0.00	0.00	0.00

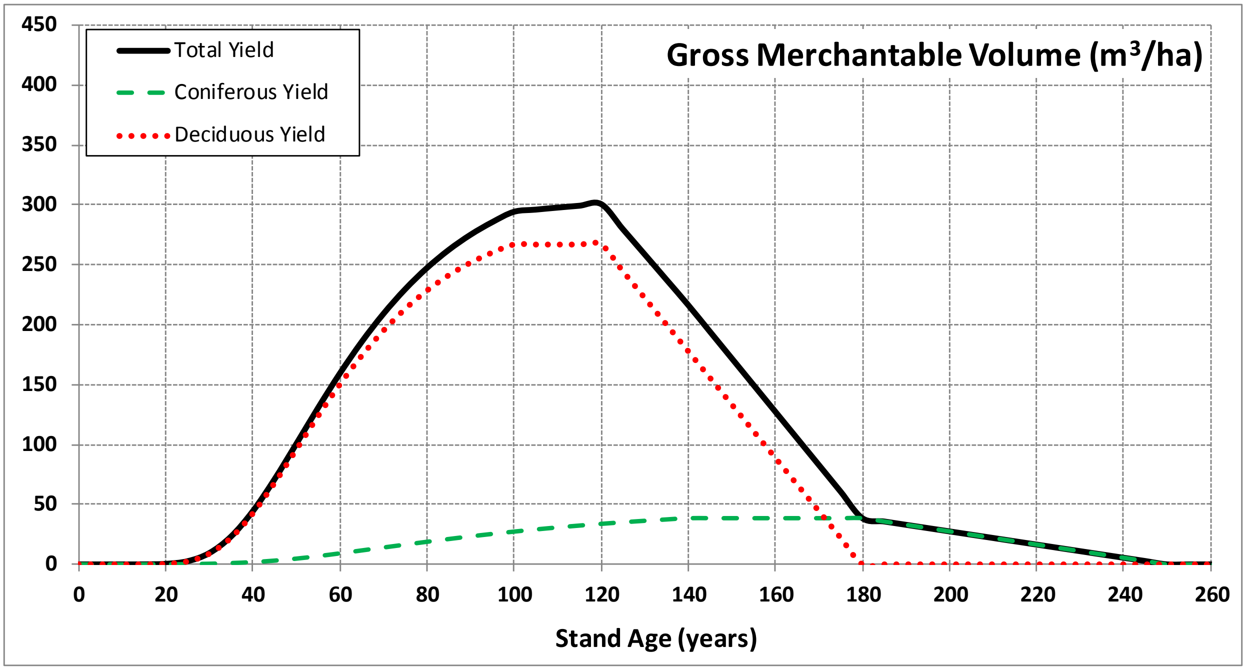
YIELD STRATUM:	Pl	TYPE	Coniferous	YC18



Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.0	0.2	0.2	0.00	0.01	0.01
30	1.1	3.5	4.6	0.04	0.12	0.15
40	8.2	20.8	29.0	0.20	0.52	0.73
50	25.8	63.4	89.2	0.52	1.27	1.78
60	48.4	122.6	171.0	0.81	2.04	2.85
70	68.2	178.4	246.6	0.97	2.55	3.52
80	82.3	222.5	304.7	1.03	2.78	3.81
90	90.9	255.6	346.5	1.01	2.84	3.85
100	95.0	268.9	363.9	0.95	2.69	3.64
110	95.0	251.0	346.0	0.86	2.28	3.15
120	95.0	215.1	310.1	0.79	1.79	2.58
130	79.2	179.3	258.4	0.61	1.38	1.99
140	63.4	143.4	206.8	0.45	1.02	1.48
150	47.5	107.6	155.1	0.32	0.72	1.03
160	31.7	71.7	103.4	0.20	0.45	0.65
170	15.8	35.9	51.7	0.09	0.21	0.30
180	0.0	0.0	0.0	0.00	0.00	0.00
190	0.0	0.0	0.0	0.00	0.00	0.00
200	0.0	0.0	0.0	0.00	0.00	0.00
210	0.0	0.0	0.0	0.00	0.00	0.00
220	0.0	0.0	0.0	0.00	0.00	0.00
230	0.0	0.0	0.0	0.00	0.00	0.00
240	0.0	0.0	0.0	0.00	0.00	0.00
250	0.0	0.0	0.0	0.00	0.00	0.00

Appendix III – Intensive Management Yield Tables

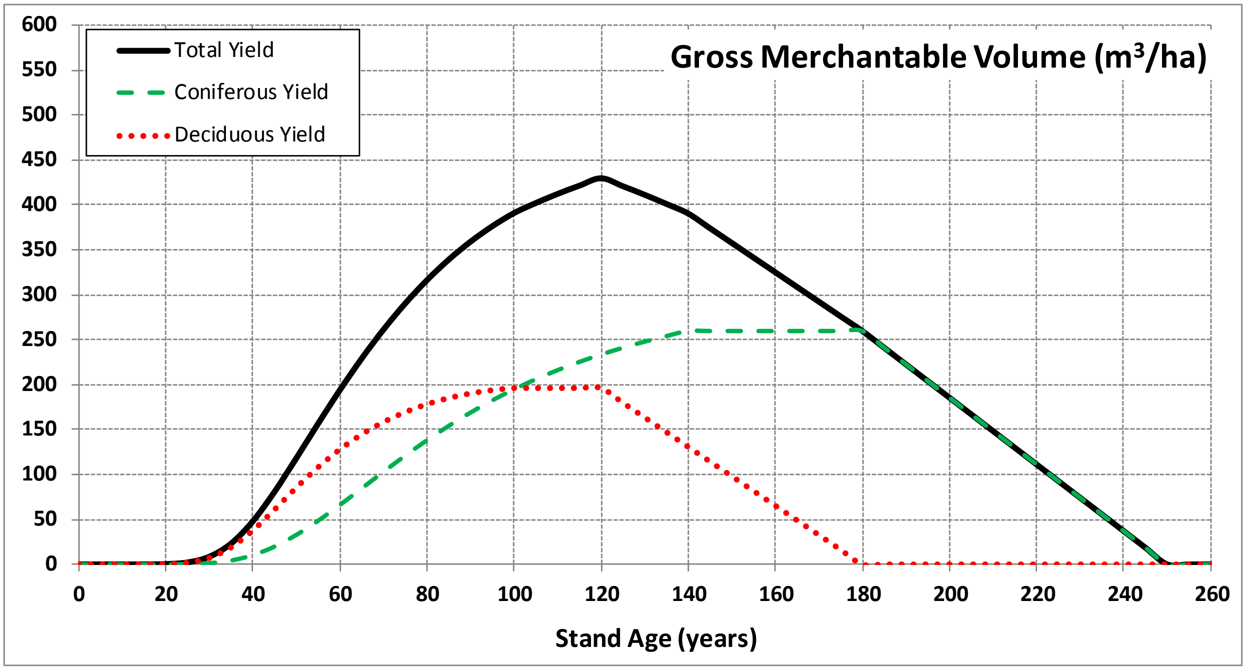
YIELD STRATUM:	Aw	TYPE	Deciduous	YC1



Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.4	0.1	0.4	0.02	0.00	0.02
30	8.8	0.5	9.3	0.29	0.02	0.31
40	42.4	1.9	44.3	1.06	0.05	1.11
50	95.7	4.8	100.5	1.91	0.10	2.01
60	150.1	9.2	159.3	2.50	0.15	2.65
70	195.0	14.1	209.1	2.79	0.20	2.99
80	228.5	18.8	247.3	2.86	0.24	3.09
90	251.8	23.3	275.1	2.80	0.26	3.06
100	266.9	27.3	294.3	2.67	0.27	2.94
110	266.9	30.8	297.8	2.43	0.28	2.71
120	266.9	33.8	300.8	2.22	0.28	2.51
130	222.5	36.4	258.8	1.71	0.28	1.99
140	178.0	38.5	216.5	1.27	0.28	1.55
150	133.5	38.5	172.0	0.89	0.26	1.15
160	89.0	38.5	127.5	0.56	0.24	0.80
170	44.5	38.5	83.0	0.26	0.23	0.49
180	0.0	38.5	38.5	0.00	0.21	0.21
190	0.0	33.0	33.0	0.00	0.17	0.17
200	0.0	27.5	27.5	0.00	0.14	0.14
210	0.0	22.0	22.0	0.00	0.10	0.10
220	0.0	16.5	16.5	0.00	0.08	0.08
230	0.0	11.0	11.0	0.00	0.05	0.05
240	0.0	5.5	5.5	0.00	0.02	0.02
250	0.0	0.0	0.0	0.00	0.00	0.00

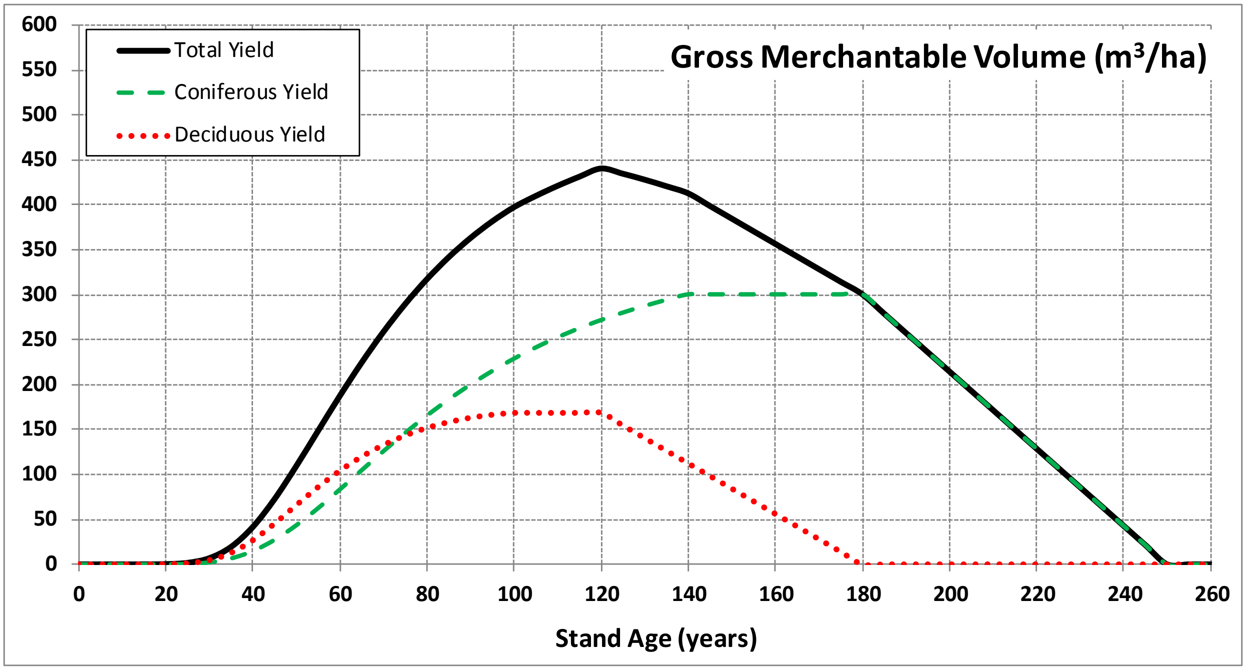
ALBERTA-PACIFIC FOREST INDUSTRIES INC.

YIELD STRATUM: AwSxINT TYPE Coniferous YC19



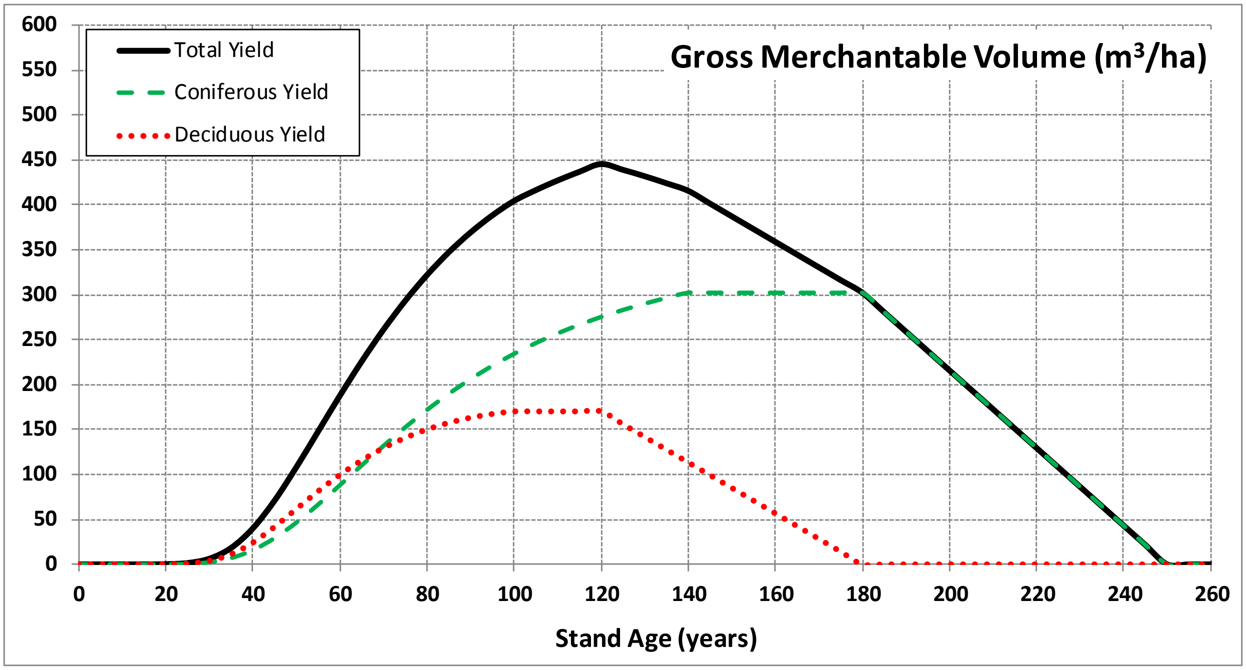
Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.3	0.0	0.3	0.02	0.00	0.02
30	7.1	1.3	8.4	0.24	0.04	0.28
40	37.6	10.2	47.8	0.94	0.26	1.19
50	85.3	32.8	118.0	1.71	0.66	2.36
60	127.8	66.0	193.8	2.13	1.10	3.23
70	158.2	102.9	261.1	2.26	1.47	3.73
80	178.2	138.0	316.2	2.23	1.73	3.95
90	190.2	168.8	359.0	2.11	1.88	3.99
100	196.1	194.8	390.9	1.96	1.95	3.91
110	196.1	216.1	412.2	1.78	1.96	3.75
120	196.1	233.5	429.7	1.63	1.95	3.58
130	163.4	247.8	411.3	1.26	1.91	3.16
140	130.8	259.7	390.4	0.93	1.85	2.79
150	98.1	259.7	357.7	0.65	1.73	2.38
160	65.4	259.7	325.1	0.41	1.62	2.03
170	32.7	259.7	292.4	0.19	1.53	1.72
180	0.0	259.7	259.7	0.00	1.44	1.44
190	0.0	222.6	222.6	0.00	1.17	1.17
200	0.0	185.5	185.5	0.00	0.93	0.93
210	0.0	148.4	148.4	0.00	0.71	0.71
220	0.0	111.3	111.3	0.00	0.51	0.51
230	0.0	74.2	74.2	0.00	0.32	0.32
240	0.0	37.1	37.1	0.00	0.15	0.15
250	0.0	0.0	0.0	0.00	0.00	0.00

YIELD STRATUM:	SxAwINT	TYPE	Coniferous	YC20



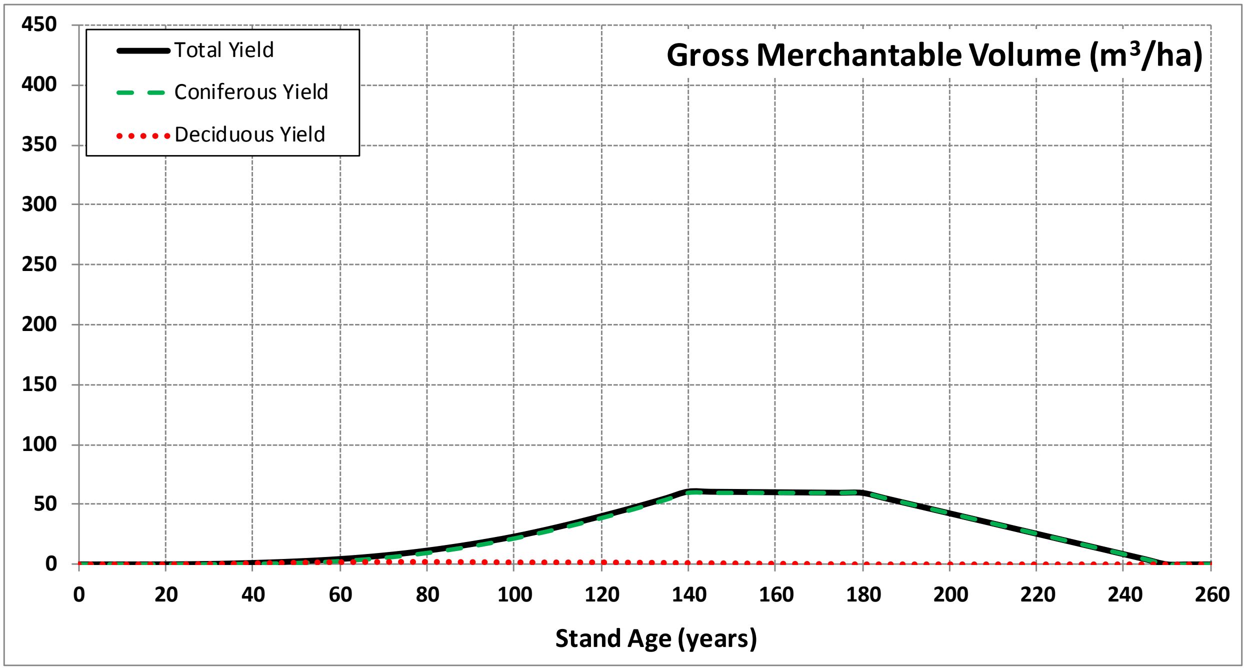
Stand	Merchantable Volume (m³/ha)			Mean Annual Increment (m³/ha/year)		
Age	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.2	0.1	0.2	0.01	0.00	0.01
30	4.6	2.2	6.8	0.15	0.07	0.23
40	26.7	14.8	41.5	0.67	0.37	1.04
50	65.9	43.5	109.3	1.32	0.87	2.19
60	104.1	83.3	187.4	1.74	1.39	3.12
70	132.8	125.9	258.6	1.90	1.80	3.69
80	151.8	165.6	317.3	1.90	2.07	3.97
90	163.1	200.0	363.2	1.81	2.22	4.04
100	168.6	228.9	397.5	1.69	2.29	3.98
110	168.6	252.7	421.2	1.53	2.30	3.83
120	168.6	271.9	440.5	1.40	2.27	3.67
130	140.5	287.6	428.1	1.08	2.21	3.29
140	112.4	300.5	412.9	0.80	2.15	2.95
150	84.3	300.5	384.8	0.56	2.00	2.57
160	56.2	300.5	356.7	0.35	1.88	2.23
170	28.1	300.5	328.6	0.17	1.77	1.93
180	0.0	300.5	300.5	0.00	1.67	1.67
190	0.0	257.6	257.6	0.00	1.36	1.36
200	0.0	214.6	214.6	0.00	1.07	1.07
210	0.0	171.7	171.7	0.00	0.82	0.82
220	0.0	128.8	128.8	0.00	0.59	0.59
230	0.0	85.9	85.9	0.00	0.37	0.37
240	0.0	42.9	42.9	0.00	0.18	0.18
250	0.0	0.0	0.0	0.00	0.00	0.00

YIELD STRATUM:	SwINT	TYPE	Coniferous	YC21



Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.1	0.1	0.2	0.01	0.00	0.01
30	3.9	2.3	6.2	0.13	0.08	0.21
40	24.1	15.8	39.9	0.60	0.39	1.00
50	61.5	46.4	107.9	1.23	0.93	2.16
60	99.5	88.0	187.6	1.66	1.47	3.13
70	129.3	131.7	261.0	1.85	1.88	3.73
80	150.1	171.8	321.9	1.88	2.15	4.02
90	163.2	206.1	369.2	1.81	2.29	4.10
100	170.2	234.2	404.4	1.70	2.34	4.04
110	170.2	257.0	427.2	1.55	2.34	3.88
120	170.2	275.3	445.5	1.42	2.29	3.71
130	141.8	290.1	431.9	1.09	2.23	3.32
140	113.5	302.2	415.7	0.81	2.16	2.97
150	85.1	302.2	387.3	0.57	2.01	2.58
160	56.7	302.2	359.0	0.35	1.89	2.24
170	28.4	302.2	330.6	0.17	1.78	1.94
180	0.0	302.2	302.2	0.00	1.68	1.68
190	0.0	259.1	259.1	0.00	1.36	1.36
200	0.0	215.9	215.9	0.00	1.08	1.08
210	0.0	172.7	172.7	0.00	0.82	0.82
220	0.0	129.5	129.5	0.00	0.59	0.59
230	0.0	86.4	86.4	0.00	0.38	0.38
240	0.0	43.2	43.2	0.00	0.18	0.18
250	0.0	0.0	0.0	0.00	0.00	0.00

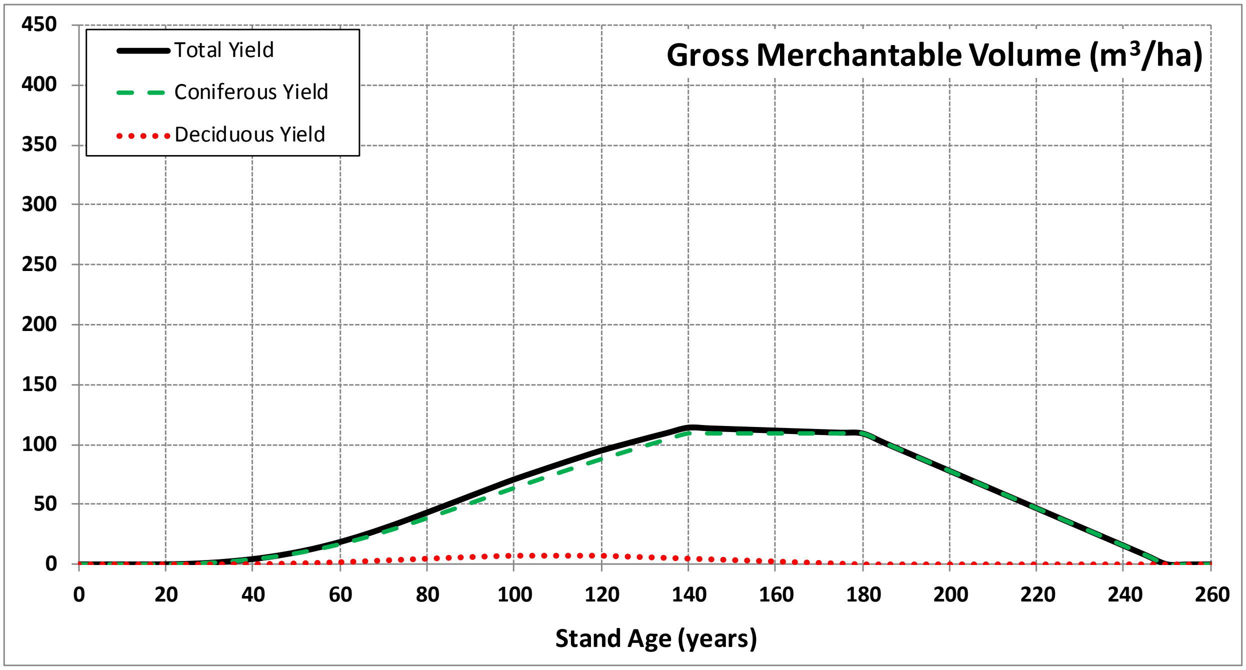
YIELD STRATUM:	SbFM	TYPE	Coniferous	YC6



Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.1	0.0	0.1	0.00	0.00	0.00
30	0.3	0.1	0.4	0.01	0.00	0.01
40	0.8	0.4	1.2	0.02	0.01	0.03
50	1.4	1.1	2.5	0.03	0.02	0.05
60	1.8	2.6	4.4	0.03	0.04	0.07
70	2.0	5.4	7.4	0.03	0.08	0.11
80	2.0	9.5	11.5	0.03	0.12	0.14
90	1.9	14.9	16.8	0.02	0.17	0.19
100	1.6	21.6	23.2	0.02	0.22	0.23
110	1.6	29.5	31.1	0.01	0.27	0.28
120	1.6	38.6	40.2	0.01	0.32	0.33
130	1.4	48.7	50.0	0.01	0.37	0.38
140	1.1	59.7	60.7	0.01	0.43	0.43
150	0.8	59.7	60.5	0.01	0.40	0.40
160	0.5	59.7	60.2	0.00	0.37	0.38
170	0.3	59.7	59.9	0.00	0.35	0.35
180	0.0	59.7	59.7	0.00	0.33	0.33
190	0.0	51.1	51.1	0.00	0.27	0.27
200	0.0	42.6	42.6	0.00	0.21	0.21
210	0.0	34.1	34.1	0.00	0.16	0.16
220	0.0	25.6	25.6	0.00	0.12	0.12
230	0.0	17.0	17.0	0.00	0.07	0.07
240	0.0	8.5	8.5	0.00	0.04	0.04
250	0.0	0.0	0.0	0.00	0.00	0.00

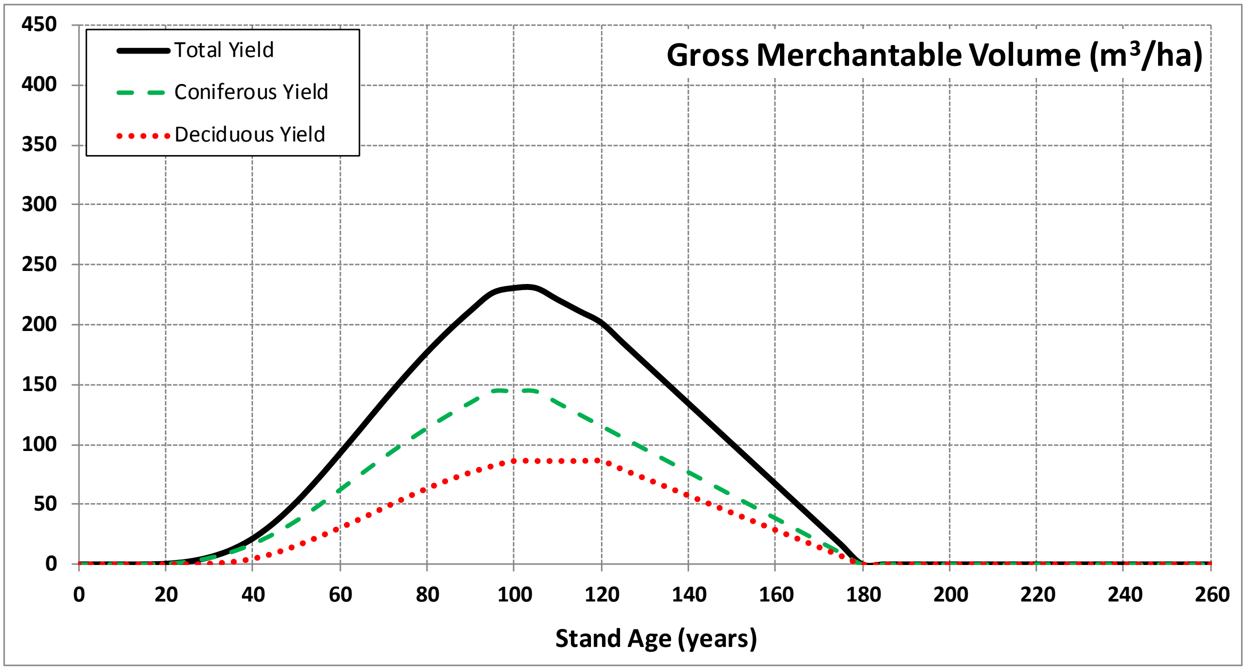
ALBERTA-PACIFIC FOREST INDUSTRIES INC.

YIELD STRATUM: SbG **TYPE Coniferous** **YC7**



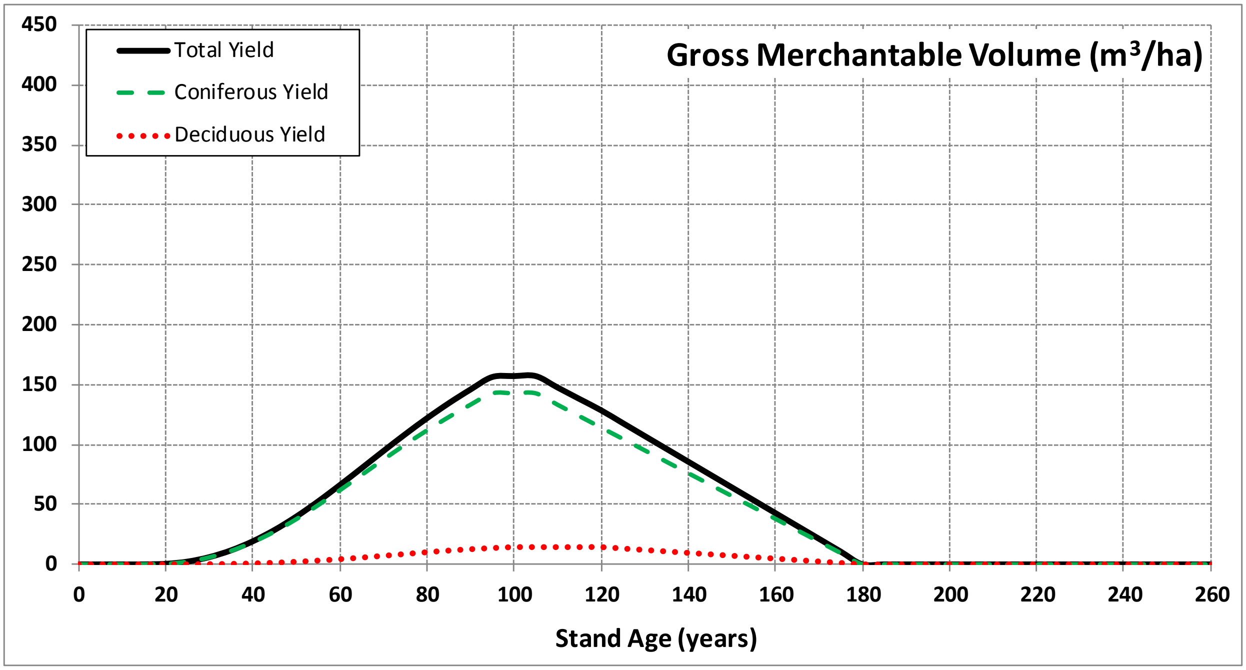
Stand	Merchantable Volume (m³/ha)			Mean Annual Increment (m³/ha/year)		
Age	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.0	0.1	0.1	0.00	0.00	0.00
30	0.0	1.2	1.3	0.00	0.04	0.04
40	0.2	4.2	4.4	0.01	0.11	0.11
50	0.8	9.3	10.0	0.02	0.19	0.20
60	1.8	16.8	18.6	0.03	0.28	0.31
70	3.2	26.8	30.0	0.05	0.38	0.43
80	4.7	38.5	43.2	0.06	0.48	0.54
90	6.1	51.0	57.1	0.07	0.57	0.63
100	7.2	63.7	70.9	0.07	0.64	0.71
110	7.2	76.0	83.2	0.07	0.69	0.76
120	7.2	87.7	94.9	0.06	0.73	0.79
130	6.0	98.8	104.8	0.05	0.76	0.81
140	4.8	109.3	114.1	0.03	0.78	0.81
150	3.6	109.3	112.9	0.02	0.73	0.75
160	2.4	109.3	111.7	0.01	0.68	0.70
170	1.2	109.3	110.5	0.01	0.64	0.65
180	0.0	109.3	109.3	0.00	0.61	0.61
190	0.0	93.7	93.7	0.00	0.49	0.49
200	0.0	78.1	78.1	0.00	0.39	0.39
210	0.0	62.5	62.5	0.00	0.30	0.30
220	0.0	46.8	46.8	0.00	0.21	0.21
230	0.0	31.2	31.2	0.00	0.14	0.14
240	0.0	15.6	15.6	0.00	0.07	0.07
250	0.0	0.0	0.0	0.00	0.00	0.00

YIELD STRATUM:	PjMx	TYPE	Coniferous	YC8



Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.0	0.5	0.5	0.00	0.02	0.03
30	0.6	5.3	5.9	0.02	0.18	0.20
40	4.7	16.9	21.6	0.12	0.42	0.54
50	15.5	36.3	51.9	0.31	0.73	1.04
60	30.4	62.1	92.5	0.51	1.03	1.54
70	47.0	89.0	136.0	0.67	1.27	1.94
80	63.3	113.6	176.9	0.79	1.42	2.21
90	76.7	135.0	211.6	0.85	1.50	2.35
100	86.2	144.4	230.7	0.86	1.44	2.31
110	86.2	134.8	221.0	0.78	1.23	2.01
120	86.2	115.5	201.8	0.72	0.96	1.68
130	71.9	96.3	168.2	0.55	0.74	1.29
140	57.5	77.0	134.5	0.41	0.55	0.96
150	43.1	57.8	100.9	0.29	0.39	0.67
160	28.7	38.5	67.3	0.18	0.24	0.42
170	14.4	19.3	33.6	0.08	0.11	0.20
180	0.0	0.0	0.0	0.00	0.00	0.00
190	0.0	0.0	0.0	0.00	0.00	0.00
200	0.0	0.0	0.0	0.00	0.00	0.00
210	0.0	0.0	0.0	0.00	0.00	0.00
220	0.0	0.0	0.0	0.00	0.00	0.00
230	0.0	0.0	0.0	0.00	0.00	0.00
240	0.0	0.0	0.0	0.00	0.00	0.00
250	0.0	0.0	0.0	0.00	0.00	0.00

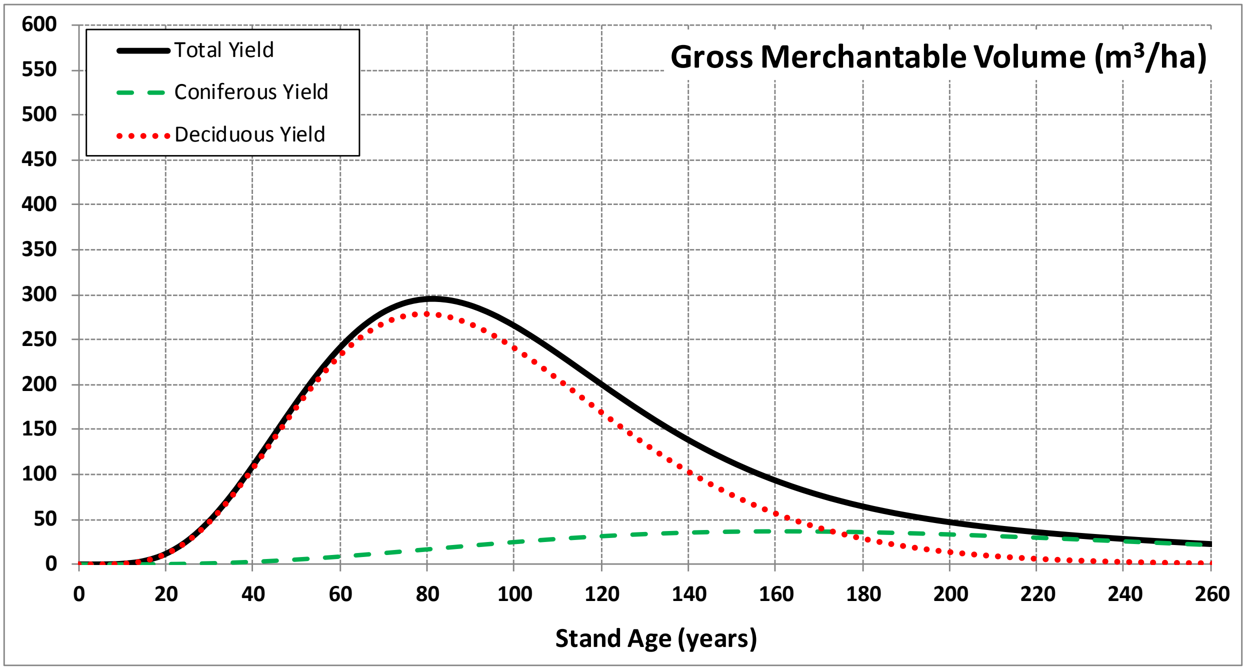
YIELD STRATUM:	Pj	TYPE	Coniferous	YC9



Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.0	0.4	0.5	0.00	0.02	0.02
30	0.2	5.8	6.0	0.01	0.19	0.20
40	0.8	18.5	19.2	0.02	0.46	0.48
50	2.2	37.7	39.9	0.04	0.75	0.80
60	4.3	61.8	66.1	0.07	1.03	1.10
70	7.1	87.4	94.5	0.10	1.25	1.35
80	10.1	111.8	121.9	0.13	1.40	1.52
90	12.7	133.3	145.9	0.14	1.48	1.62
100	14.4	142.8	157.1	0.14	1.43	1.57
110	14.4	133.2	147.6	0.13	1.21	1.34
120	14.4	114.2	128.6	0.12	0.95	1.07
130	12.0	95.2	107.2	0.09	0.73	0.82
140	9.6	76.1	85.7	0.07	0.54	0.61
150	7.2	57.1	64.3	0.05	0.38	0.43
160	4.8	38.1	42.9	0.03	0.24	0.27
170	2.4	19.0	21.4	0.01	0.11	0.13
180	0.0	0.0	0.0	0.00	0.00	0.00
190	0.0	0.0	0.0	0.00	0.00	0.00
200	0.0	0.0	0.0	0.00	0.00	0.00
210	0.0	0.0	0.0	0.00	0.00	0.00
220	0.0	0.0	0.0	0.00	0.00	0.00
230	0.0	0.0	0.0	0.00	0.00	0.00
240	0.0	0.0	0.0	0.00	0.00	0.00
250	0.0	0.0	0.0	0.00	0.00	0.00

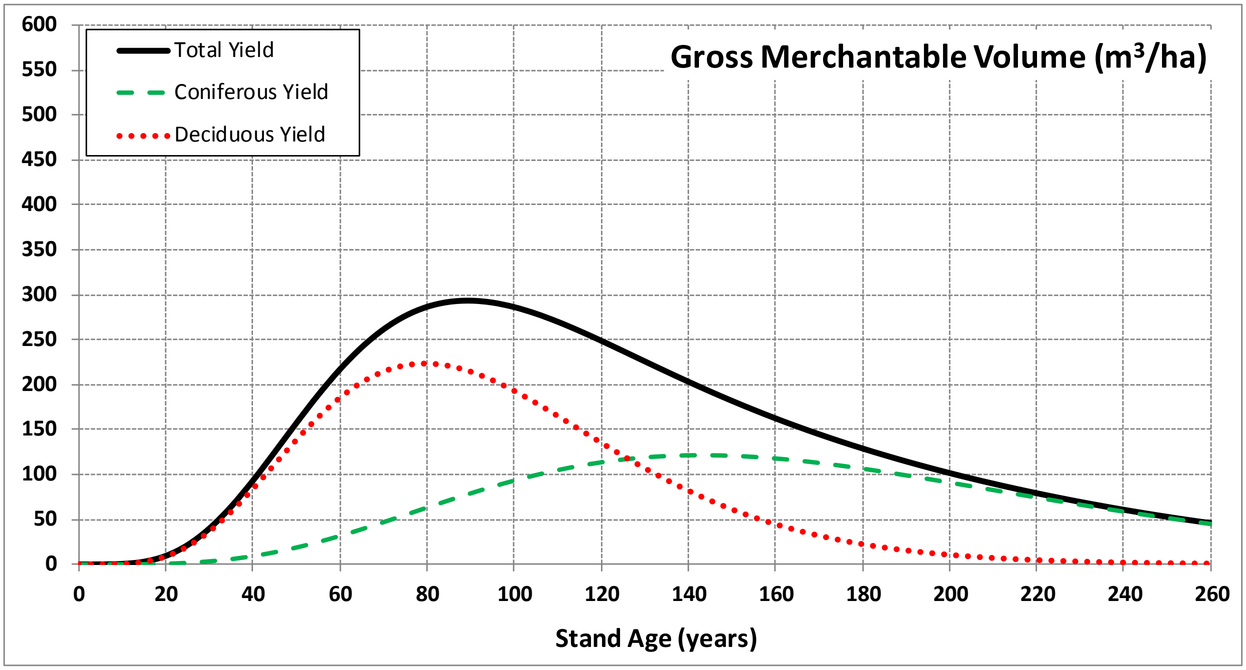
Appendix IV – Extensive Management Yield Tables

YIELD STRATUM:	AwEXT	TYPE	Deciduous	YC22



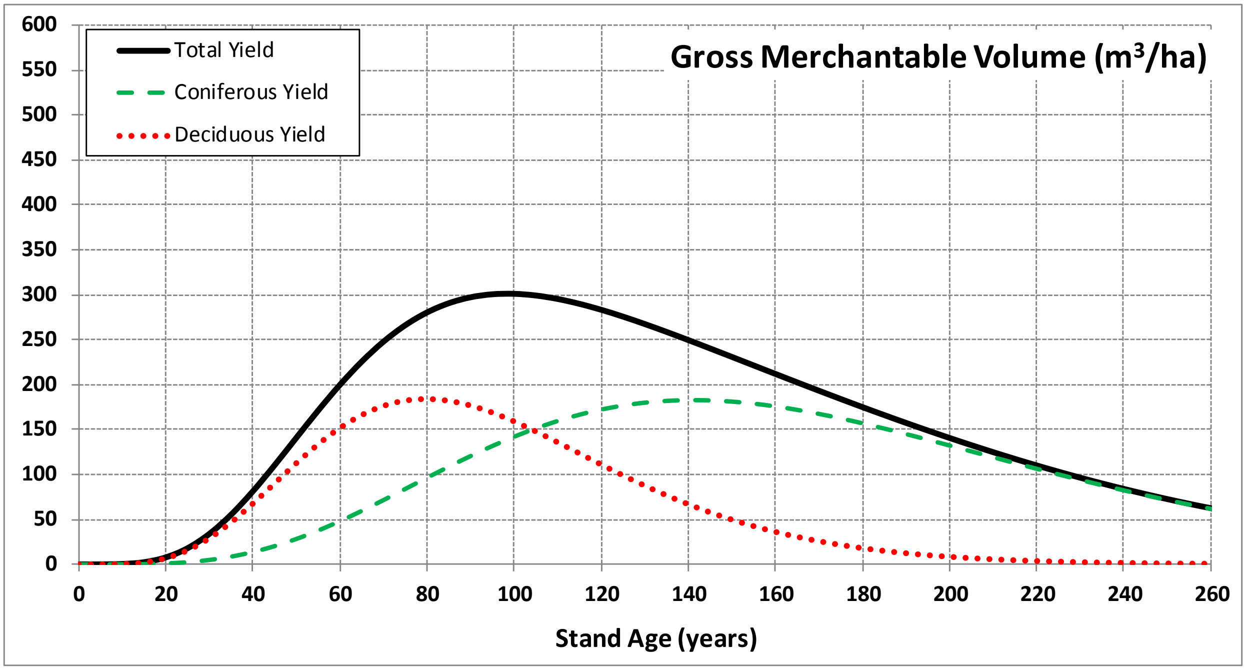
Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.6	0.0	0.7	0.06	0.00	0.07
20	11.4	0.3	11.7	0.57	0.01	0.58
30	46.9	1.1	48.1	1.56	0.04	1.60
40	106.6	2.8	109.4	2.66	0.07	2.73
50	174.5	5.3	179.8	3.49	0.11	3.60
60	232.3	8.6	240.9	3.87	0.14	4.02
70	268.1	12.5	280.6	3.83	0.18	4.01
80	278.6	16.6	295.3	3.48	0.21	3.69
90	267.4	20.8	288.2	2.97	0.23	3.20
100	241.0	24.8	265.7	2.41	0.25	2.66
110	206.3	28.3	234.6	1.88	0.26	2.13
120	169.4	31.3	200.7	1.41	0.26	1.67
130	134.3	33.6	167.9	1.03	0.26	1.29
140	103.3	35.3	138.6	0.74	0.25	0.99
150	77.4	36.3	113.7	0.52	0.24	0.76
160	56.7	36.7	93.4	0.35	0.23	0.58
170	40.7	36.5	77.2	0.24	0.21	0.45
180	28.7	35.8	64.6	0.16	0.20	0.36
190	20.0	34.7	54.7	0.11	0.18	0.29
200	13.7	33.3	46.9	0.07	0.17	0.23
210	9.2	31.6	40.8	0.04	0.15	0.19
220	6.2	29.7	35.9	0.03	0.13	0.16
230	4.1	27.7	31.8	0.02	0.12	0.14
240	2.7	25.6	28.3	0.01	0.11	0.12
250	1.7	23.5	25.3	0.01	0.09	0.10

YIELD STRATUM:	AwSxEXT	TYPE	Coniferous	YC23



Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.5	0.0	0.5	0.05	0.00	0.05
20	8.6	0.7	9.3	0.43	0.03	0.47
30	36.4	3.3	39.7	1.21	0.11	1.32
40	83.7	9.1	92.9	2.09	0.23	2.32
50	138.3	18.7	157.0	2.77	0.37	3.14
60	185.2	31.6	216.8	3.09	0.53	3.61
70	214.5	46.9	261.4	3.06	0.67	3.73
80	223.4	63.1	286.5	2.79	0.79	3.58
90	214.5	78.9	293.4	2.38	0.88	3.26
100	193.2	93.1	286.3	1.93	0.93	2.86
110	165.2	104.8	270.1	1.50	0.95	2.46
120	135.4	113.5	248.9	1.13	0.95	2.07
130	107.0	119.0	226.0	0.82	0.92	1.74
140	82.1	121.3	203.4	0.59	0.87	1.45
150	61.3	120.8	182.1	0.41	0.81	1.21
160	44.7	117.8	162.6	0.28	0.74	1.02
170	32.0	112.9	144.9	0.19	0.66	0.85
180	22.5	106.5	129.0	0.12	0.59	0.72
190	15.6	99.1	114.6	0.08	0.52	0.60
200	10.6	91.0	101.6	0.05	0.46	0.51
210	7.1	82.7	89.9	0.03	0.39	0.43
220	4.8	74.4	79.2	0.02	0.34	0.36
230	3.1	66.4	69.5	0.01	0.29	0.30
240	2.0	58.7	60.8	0.01	0.24	0.25
250	1.3	51.6	52.9	0.01	0.21	0.21

YIELD STRATUM:	SxAwEXT	TYPE	Coniferous	YC24



Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.3	0.1	0.4	0.03	0.01	0.04
20	6.7	1.0	7.7	0.33	0.05	0.38
30	28.9	4.9	33.7	0.96	0.16	1.12
40	67.4	13.7	81.1	1.69	0.34	2.03
50	112.5	28.2	140.7	2.25	0.56	2.81
60	151.6	48.0	199.6	2.53	0.80	3.33
70	176.3	71.4	247.7	2.52	1.02	3.54
80	183.9	96.3	280.3	2.30	1.20	3.50
90	176.7	120.4	297.2	1.96	1.34	3.30
100	159.1	142.0	301.1	1.59	1.42	3.01
110	135.9	159.5	295.4	1.24	1.45	2.69
120	111.1	172.2	283.3	0.93	1.44	2.36
130	87.6	179.9	267.5	0.67	1.38	2.06
140	66.9	182.7	249.6	0.48	1.31	1.78
150	49.8	181.1	230.9	0.33	1.21	1.54
160	36.2	175.8	212.0	0.23	1.10	1.32
170	25.8	167.5	193.3	0.15	0.99	1.14
180	18.0	157.0	175.0	0.10	0.87	0.97
190	12.4	145.1	157.5	0.07	0.76	0.83
200	8.4	132.3	140.7	0.04	0.66	0.70
210	5.6	119.3	124.9	0.03	0.57	0.59
220	3.7	106.4	110.1	0.02	0.48	0.50
230	2.4	94.0	96.5	0.01	0.41	0.42
240	1.6	82.4	84.0	0.01	0.34	0.35
250	1.0	71.6	72.7	0.00	0.29	0.29

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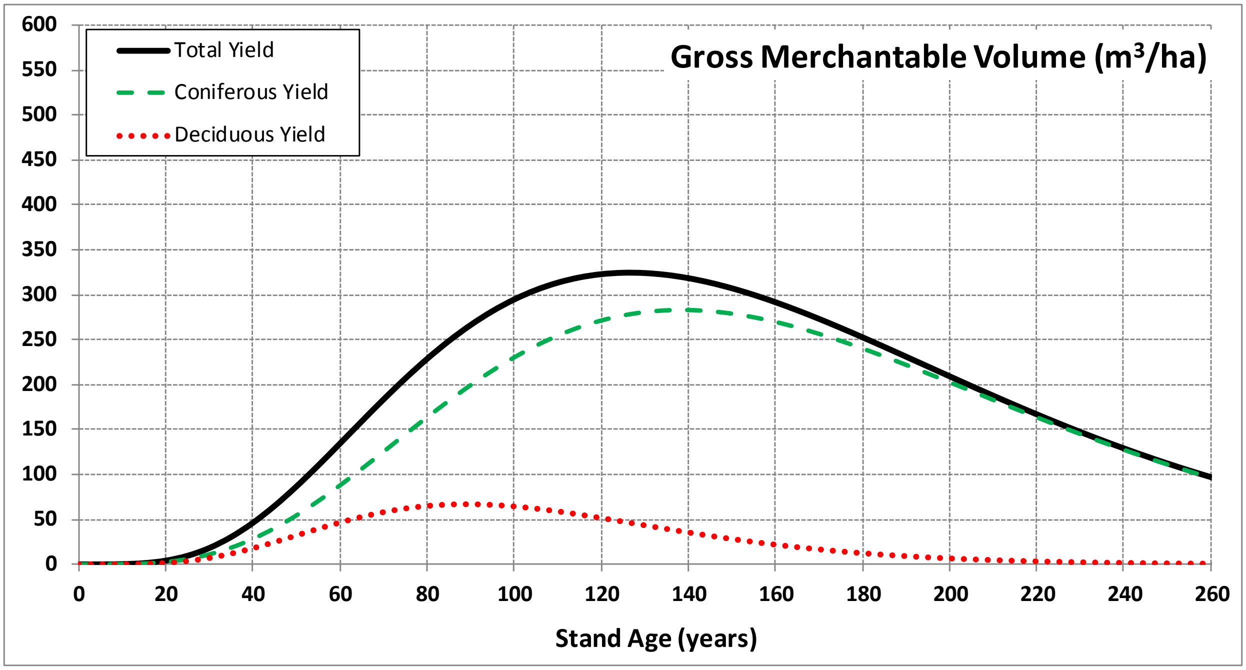
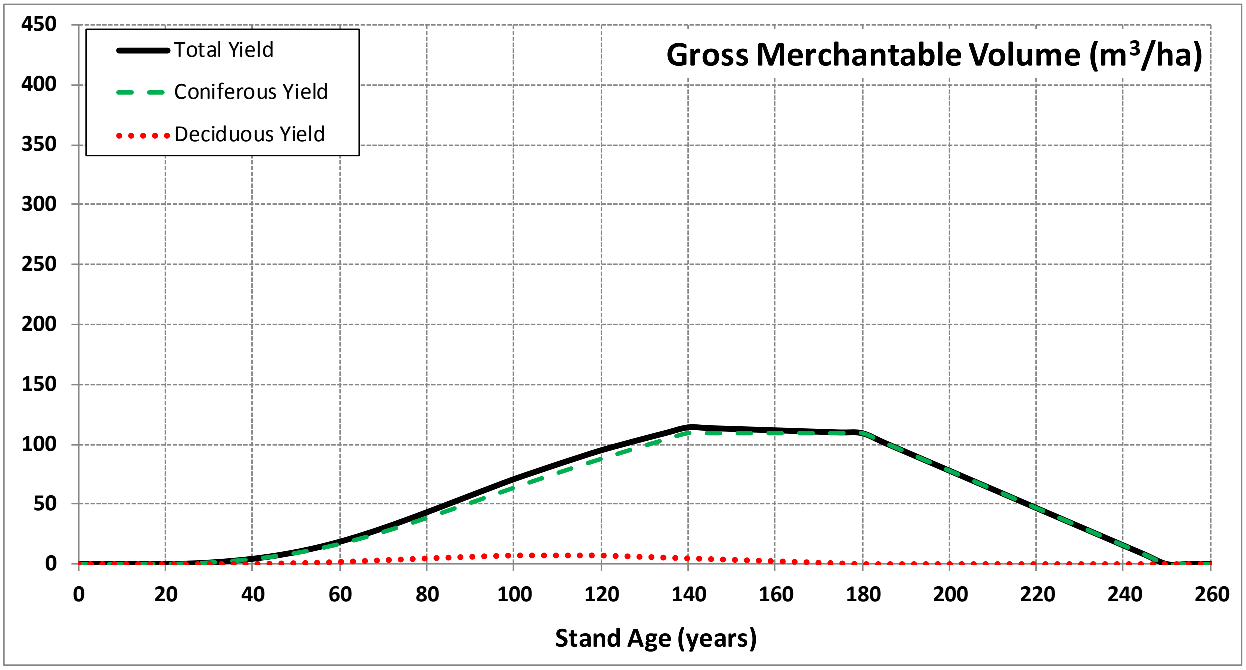
YIELD STRATUM: SwEXT TYPE Coniferous YC25



Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.1	0.2	0.2	0.01	0.02	0.02
20	1.5	2.6	4.1	0.07	0.13	0.20
30	7.1	11.1	18.1	0.24	0.37	0.60
40	17.9	28.2	46.1	0.45	0.71	1.15
50	32.1	54.4	86.5	0.64	1.09	1.73
60	46.5	87.7	134.3	0.78	1.46	2.24
70	58.1	125.3	183.3	0.83	1.79	2.62
80	65.0	163.5	228.5	0.81	2.04	2.86
90	66.9	199.3	266.2	0.74	2.21	2.96
100	64.5	230.2	294.7	0.64	2.30	2.95
110	59.0	254.5	313.4	**0.54**	**2.31**	**2.85**
120	51.6	271.3	322.9	0.43	2.26	2.69
130	43.5	280.7	324.2	0.33	2.16	2.49
140	35.5	283.0	318.5	0.25	2.02	2.28
150	28.2	279.0	307.3	0.19	1.86	2.05
160	21.9	269.9	291.8	0.14	1.69	1.82
170	16.7	256.6	273.3	0.10	1.51	1.61
180	12.5	240.3	252.8	0.07	1.34	1.40
190	9.2	222.1	231.2	0.05	1.17	1.22
200	6.6	202.7	209.4	0.03	1.01	1.05
210	4.7	183.1	187.8	0.02	0.87	0.89
220	3.3	163.7	167.1	0.02	0.74	0.76
230	2.3	145.1	147.4	0.01	0.63	0.64
240	1.6	127.5	129.2	0.01	0.53	0.54
250	1.1	111.3	112.4	0.00	0.45	0.45

YIELD STRATUM:	SbG	TYPE	Coniferous	YC7



Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.0	0.1	0.1	0.00	0.00	0.00
30	0.0	1.2	1.3	0.00	0.04	0.04
40	0.2	4.2	4.4	0.01	0.11	0.11
50	0.8	9.3	10.0	0.02	0.19	0.20
60	1.8	16.8	18.6	0.03	0.28	0.31
70	3.2	26.8	30.0	0.05	0.38	0.43
80	4.7	38.5	43.2	0.06	0.48	0.54
90	6.1	51.0	57.1	0.07	0.57	0.63
100	7.2	63.7	70.9	0.07	0.64	0.71
110	7.2	76.0	83.2	0.07	0.69	0.76
120	7.2	87.7	94.9	0.06	0.73	0.79
130	6.0	98.8	104.8	0.05	0.76	0.81
140	4.8	109.3	114.1	0.03	0.78	0.81
150	3.6	109.3	112.9	0.02	0.73	0.75
160	2.4	109.3	111.7	0.01	0.68	0.70
170	1.2	109.3	110.5	0.01	0.64	0.65
180	0.0	109.3	109.3	0.00	0.61	0.61
190	0.0	93.7	93.7	0.00	0.49	0.49
200	0.0	78.1	78.1	0.00	0.39	0.39
210	0.0	62.5	62.5	0.00	0.30	0.30
220	0.0	46.8	46.8	0.00	0.21	0.21
230	0.0	31.2	31.2	0.00	0.14	0.14
240	0.0	15.6	15.6	0.00	0.07	0.07
250	0.0	0.0	0.0	0.00	0.00	0.00

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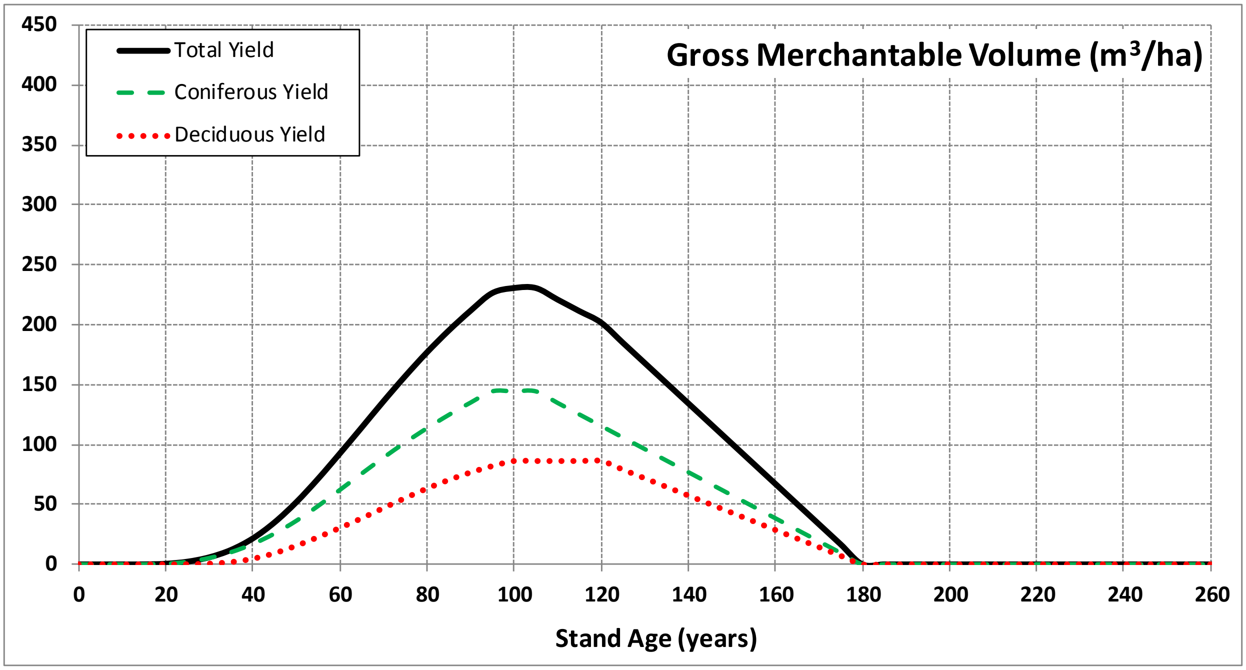
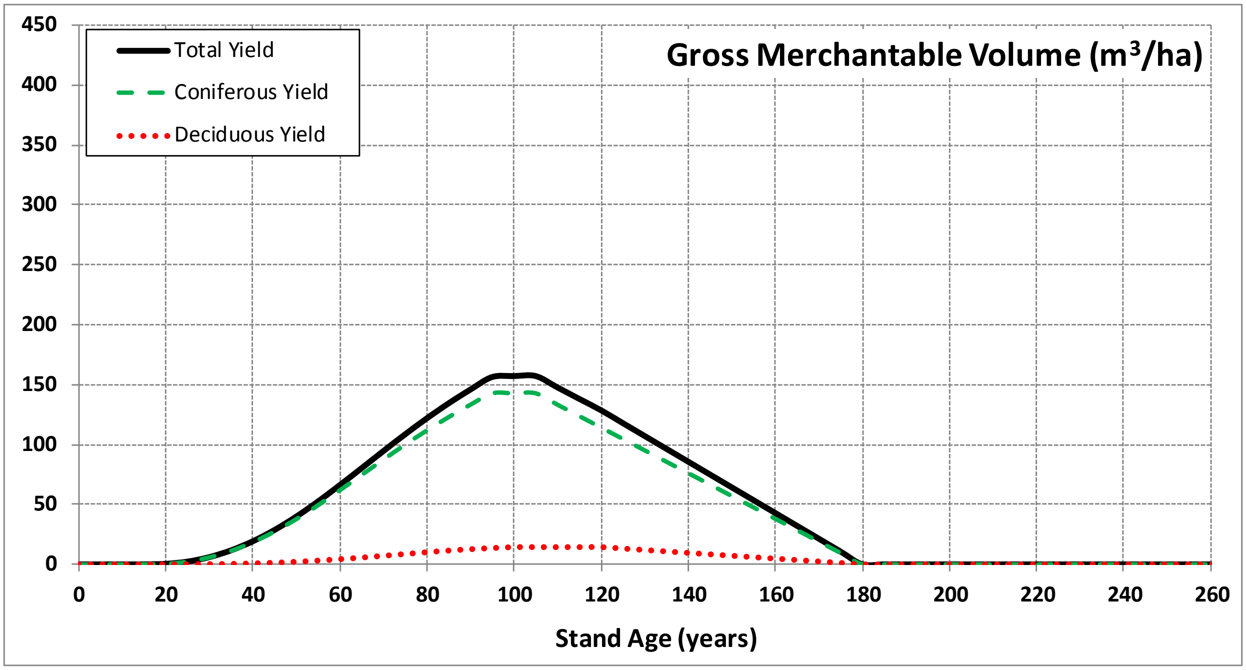
YIELD STRATUM: PjMx TYPE Coniferous YC8



Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.0	0.5	0.5	0.00	0.02	0.03
30	0.6	5.3	5.9	0.02	0.18	0.20
40	4.7	16.9	21.6	0.12	0.42	0.54
50	15.5	36.3	51.9	0.31	0.73	1.04
60	30.4	62.1	92.5	0.51	1.03	1.54
70	47.0	89.0	136.0	0.67	1.27	1.94
80	63.3	113.6	176.9	0.79	1.42	2.21
90	76.7	135.0	211.6	0.85	1.50	2.35
100	86.2	144.4	230.7	0.86	1.44	2.31
110	86.2	134.8	221.0	0.78	1.23	2.01
120	86.2	115.5	201.8	0.72	0.96	1.68
130	71.9	96.3	168.2	0.55	0.74	1.29
140	57.5	77.0	134.5	0.41	0.55	0.96
150	43.1	57.8	100.9	0.29	0.39	0.67
160	28.7	38.5	67.3	0.18	0.24	0.42
170	14.4	19.3	33.6	0.08	0.11	0.20
180	0.0	0.0	0.0	0.00	0.00	0.00
190	0.0	0.0	0.0	0.00	0.00	0.00
200	0.0	0.0	0.0	0.00	0.00	0.00
210	0.0	0.0	0.0	0.00	0.00	0.00
220	0.0	0.0	0.0	0.00	0.00	0.00
230	0.0	0.0	0.0	0.00	0.00	0.00
240	0.0	0.0	0.0	0.00	0.00	0.00
250	0.0	0.0	0.0	0.00	0.00	0.00

YIELD STRATUM:	Pj	TYPE	Coniferous	YC9



Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.0	0.4	0.5	0.00	0.02	0.02
30	0.2	5.8	6.0	0.01	0.19	0.20
40	0.8	18.5	19.2	0.02	0.46	0.48
50	2.2	37.7	39.9	0.04	0.75	0.80
60	4.3	61.8	66.1	0.07	1.03	1.10
70	7.1	87.4	94.5	0.10	1.25	1.35
80	10.1	111.8	121.9	0.13	1.40	1.52
90	12.7	133.3	145.9	0.14	1.48	1.62
100	14.4	142.8	157.1	0.14	1.43	1.57
110	14.4	133.2	147.6	0.13	1.21	1.34
120	14.4	114.2	128.6	0.12	0.95	1.07
130	12.0	95.2	107.2	0.09	0.73	0.82
140	9.6	76.1	85.7	0.07	0.54	0.61
150	7.2	57.1	64.3	0.05	0.38	0.43
160	4.8	38.1	42.9	0.03	0.24	0.27
170	2.4	19.0	21.4	0.01	0.11	0.13
180	0.0	0.0	0.0	0.00	0.00	0.00
190	0.0	0.0	0.0	0.00	0.00	0.00
200	0.0	0.0	0.0	0.00	0.00	0.00
210	0.0	0.0	0.0	0.00	0.00	0.00
220	0.0	0.0	0.0	0.00	0.00	0.00
230	0.0	0.0	0.0	0.00	0.00	0.00
240	0.0	0.0	0.0	0.00	0.00	0.00
250	0.0	0.0	0.0	0.00	0.00	0.00

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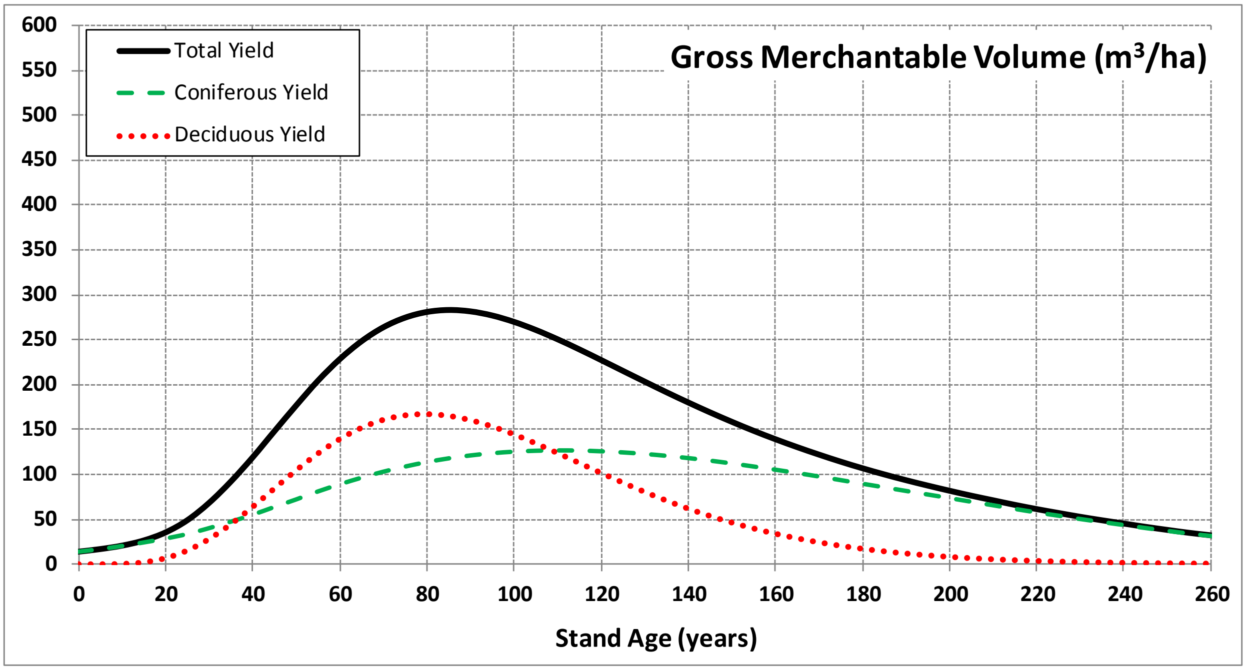
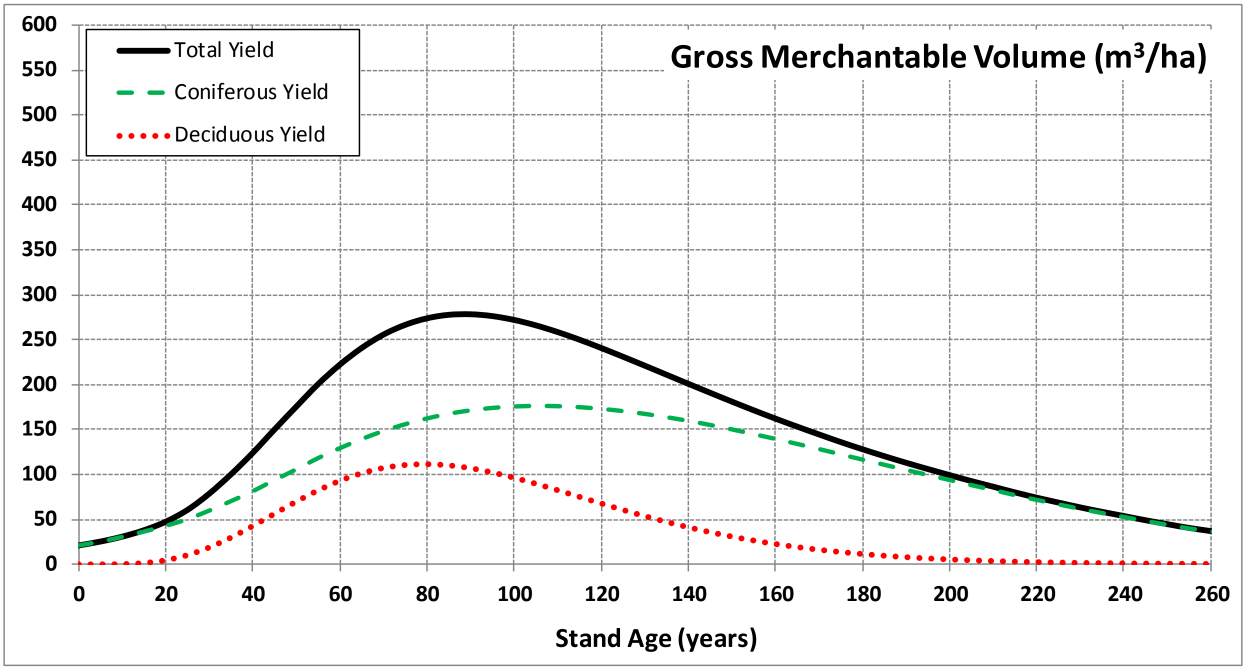
Appendix V – Understorey Protection Yield Tables

YIELD STRATUM:	AwSw-UP	TYPE	Coniferous	YC26



Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.4	20.4	20.7	0.04	2.04	2.07
20	6.8	28.7	35.5	0.34	1.43	1.77
30	28.2	40.2	68.4	0.94	1.34	2.28
40	64.0	55.2	119.1	1.60	1.38	2.98
50	104.7	72.2	176.9	2.09	1.44	3.54
60	139.4	89.1	228.4	2.32	1.48	3.81
70	160.8	103.1	263.9	2.30	1.47	3.77
80	167.2	113.8	281.0	2.09	1.42	3.51
90	160.4	121.2	281.6	1.78	1.35	3.13
100	144.6	125.4	269.9	1.45	1.25	2.70
110	123.8	126.8	250.6	1.13	1.15	2.28
120	101.6	125.8	227.4	0.85	1.05	1.90
130	80.6	122.9	203.4	0.62	0.95	1.56
140	62.0	118.2	180.2	0.44	0.84	1.29
150	46.4	112.3	158.7	0.31	0.75	1.06
160	34.0	105.3	139.3	0.21	0.66	0.87
170	24.4	97.8	122.2	0.14	0.58	0.72
180	17.2	89.7	106.9	0.10	0.50	0.59
190	12.0	81.7	93.6	0.06	0.43	0.49
200	8.2	73.7	81.9	0.04	0.37	0.41
210	5.5	65.7	71.3	0.03	0.31	0.34
220	3.7	57.7	61.5	0.02	0.26	0.28
230	2.5	50.4	52.9	0.01	0.22	0.23
240	1.6	43.7	45.3	0.01	0.18	0.19
250	1.0	37.2	38.3	0.00	0.15	0.15

YIELD STRATUM:	SwAw-UP	TYPE	Coniferous	YC27



Stand Age	Merchantable Volume (m^3/ha) Deciduous	Coniferous	Total	Mean Annual Increment (m^3/ha/year) Deciduous	Coniferous	Total
10	0.3	30.5	30.8	0.03	3.05	3.08
20	4.5	42.8	47.4	0.23	2.14	2.37
30	18.8	59.8	78.6	0.63	1.99	2.62
40	42.6	81.4	124.0	1.07	2.03	3.10
50	69.8	105.7	175.5	1.40	2.11	3.51
60	92.9	129.3	222.2	1.55	2.15	3.70
70	107.2	148.4	255.6	1.53	2.12	3.65
80	111.5	162.3	273.8	1.39	2.03	3.42
90	107.0	171.4	278.3	1.19	1.90	3.09
100	96.4	175.7	272.0	0.96	1.76	2.72
110	82.5	176.0	258.5	0.75	1.60	2.35
120	67.8	173.1	240.8	0.56	1.44	2.01
130	53.7	167.5	221.2	0.41	1.29	1.70
140	41.3	159.7	201.0	0.30	1.14	1.44
150	30.9	150.2	181.2	0.21	1.00	1.21
160	22.7	139.6	162.3	0.14	0.87	1.01
170	16.3	128.4	144.7	0.10	0.76	0.85
180	11.5	116.6	128.1	0.06	0.65	0.71
190	8.0	105.1	113.1	0.04	0.55	0.60
200	5.5	93.9	99.4	0.03	0.47	0.50
210	3.7	82.8	86.5	0.02	0.39	0.41
220	2.5	71.8	74.3	0.01	0.33	0.34
230	1.6	61.8	63.4	0.01	0.27	0.28
240	1.1	52.8	53.8	0.00	0.22	0.22
250	0.7	44.1	44.8	0.00	0.18	0.18

Appendix VI – Juvenile Height-Diameter Modelling

MEMO

To: Gitte Grover, Alberta-Pacific Forest Industries Inc.

From: Robert Froese[1]

Cc: Katrina Froese

Date: 15 December 2013

Re: Height-Diameter Models for Alberta-Pacific Regenerated Stand Data

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PURPOSE

This memo presents analysis and results from a project to develop of height-diameter models for regenerated stand data for the Alberta-Pacific Forest Management Agreement (FMA) area.

SUMMARY

Results from the development of height-diameter equations fit to data from regenerated stands in the Al-Pac FMA area are presented. A non-linear mixed-effects modelling framework was used to calibrate a Chapman-Richards function for seven individual species (aspen, white birch, poplar, balsam fir, jack pine, white spruce and black spruce). There was evidence of significant difference in the shape of the equation for aspen, birch, pine, and poplar in tended vs. untended stands. There was evidence of a significant interaction between stand history (tended vs. untended) and tree origin (seedling vs. advance) that affected the shape of the equation for white and black spruce. Coefficient estimates are provided for default equations for each species, and alternatives that include stand history and tree origin, for those species where these factors were significant.

DISCUSSION

Background

The goal of this project was to develop empirical height-diameter functions using data from regenerated (post-harvest) stands within Al-Pac's FMA area in Alberta. The stated intent was that these curves would be used to replace missing individual-tree height values in plot data, which will subsequently be used to initialize growth models for yield forecasting.

Summary of the Model Development Data

Two data sets were made available for model development: data from the TSP program and the ATP program. Data were available from measurement years 2010-2013 for the ATP program

[1] Associate Professor, School of Forest Resources and Environmental Science, Michigan Tech University; PhD, Forest Biometrics, University of Idaho.

and 2012-2013 for the TSP program. For the ATP program, data were from 100 m^2 (ATP100) and 400 m^2 (ATP400) plots; the design is such that a 100 m^2 plot is nested within the 400 m^2 plot and the nested trees are flagged so they may be distinguished. ATP and PSP plots were classified into tended vs. untended stands based on information provided by Katrina Froese.

Data from all trees were used in this analysis, but subsets were used where necessary to investigate potential predictor variables that were restricted to individual data sets. For example, DBH is available on all trees above 1.3 m in height in the ATP100 data set, and thus metrics of local inventory could be derived (e.g., basal area per hectare).

Once cleaned to remove apparent outliers and trees that did not have both DBH and HT measurements available the data set comprised about 14,700 trees. Of these, most (70%) were from the ATP100 data set. The most common species was AW, with 6,400 observations, followed by BW, SW, PJ, and PB each with 1,500-2,000 observations. Sufficient data were available to develop specific equations for every species in the data set, with the exception of LT, which was very poorly represented. For additional detail, a cross-tabular summary of the model development data is included in the Appendix to this memo (Table 4 and Table 5).

Issues and Approach

The overall approach used was to fit a species-specific height-diameter regression model following precedent in the published literature, especially examples from the boreal forest and involving data from Alberta. Particularly relevant is the recent report by Huang et al. (2013) who present a very comprehensive analysis and set of height-diameter models for major Alberta tree species. This work differs from the present analysis in that it uses natural and mature stand data, from across the range of forest conditions and types in Alberta; here the objective is to develop specific models for the Al-Pac FMA area for young, regenerating stands. Other relevant papers include a recent analysis for tree species in the Acadian region (Rijal et al. 2012), equations for boreal species in Ontario (Peng et al. 2001; Sharma et al. 2004), and an earlier analysis for white spruce in Alberta (Huang et al. 2000).

The consensus in all of the prior studies referenced here is that height-diameter relationships are modelled well using intrinsically non-linear functions. Huang et al. (2013) conclude that the superior base model for hardwood species is the Chapman-Richards (C-R) function:

[1] $$HT = 1.30 + b_1[1 - exp(-b_2DBH)]^{b_3}$$

where HT = tree height, DBH is diameter at breast height, and $b_1 - b_3$ are species-specific parameters to be estimated. Other authors (e.g., Peng et al. 2001) conclude that the quality of fit of the Chapman-Richards is nearly indistinguishable from alternatives. Thus, in this work, the C-R function was assumed to be sufficiently flexible for all species.

A notable feature of the C-R is that the parameter b_1 serves as the asymptote of the height-diameter relationship, and is usually estimated simultaneously with the other parameters using non-linear regression. In the Al-Pac data, however, the range of diameter and height is restricted relative to the potential in a mature forest population; the 95th percentile height and diameter across all species are just 7.7 m and 6.7 cm, respectively. Thus, there is effectively no information in the data about the realistic likely asymptote of the height-diameter relationship. The asymptote can still be estimated, but unrealistically low values are produced and these are problematic for two reasons. First, the unrealistic asymptote produces biased height predictions at the upper end of the diameter distribution in the calibration data, and second, extrapolation beyond the range of the data is even more severely unrealistic.

To remedy the issue of unrealistic asymptotes, values were fixed instead of estimated from the calibration data. To ensure the asymptotes were reasonable the specific values were set equal to those in Huang et al's (2013) study, which is based on an extensive data set, including large/tall trees, from Alberta. Values that those authors estimated for the Central Mixedwood region were used, and these replace the parameter b_1 with a constant, *a*, in the fitted model:

[2] $$HT = 1.30 + a[1 - exp(-b_2 DBH)]^{b_3}$$

A further issue is that the model development data are fundamentally grouped; several trees are measured in the same plot, and several plots are installed in the same stand. To account for the dependency that this creates a mixed models strategy was employed, where the C-R function was fit including random effects at the group level.

[3] $$HT = 1.30 + a[1 - exp(-(b_2 + u_2)DBH)]^{b_3 + u_3}$$

where u_2 and u_3 are assumed to follow independent Gaussian distributions with mean zero and standard deviation σ_2 and σ_3, estimated from the data. A nested random effect (plot within stand) was not included because clustering was principally at the stand level; the differences due to cluster were principally due to stand differences, not plot differences within stands.

To apply the model to a new population, the random effects are assumed to be zero for the new population (i.e., $u_2 = u_3 = 0$) and the model simplifies to [2]. Methods are available to estimate the random effect for populations to which the model might be applied, if appropriate data are available, and can improve precision. For further information, see the approach employed by Huang et al. (2013).

All analyses were completed in the R environment for statistical computing (R Core Team 2013). The C-R function was estimated using the non-linear mixed effects function `nlme()` included in the package 'nlme' (see http://cran.mtu.edu/web/packages/nlme/nlme.pdf).

Results

The decision to specify asymptotes by species proved essential to developing credible models. For example, consider the function for aspen illustrated in Figure 1. The difference in the mean function within the range of the data is relatively small, but the difference beyond the range of the data is substantial. These results are for seedling origin trees only, which dominate the data set. For all species, the asymptotes from Huang et al. (2013) appear reasonable, and have little apparent effect on the shape of the response function within the range of the Al-Pac data.

For some species there were distinct differences between trees of different origin. For example, for jack pine, there was a cluster of atypically large-diameter trees that were coded as advance that clearly had a different height/diameter relationship than the vast majority of the data set (Figure 2). Similar, but less obvious, trends were apparent for trembling aspen, paper birch, and balsam poplar. These four species are shade-intolerant and thus it seems plausible that advance trees are either (1) artifacts of unusual conditions, or (2) residual, formerly suppressed trees.

These trees would be better represented by regional, natural stand models published by Huang et al. (2013) than by models fit to the Al-Pac data. For this analysis, advance trees for these four species were not considered further. For white spruce, black spruce, and balsam fir, advance trees were common, spread across the diameter distribution, and well represented by models fit to all data, and were thus retained for the fitting of local models.

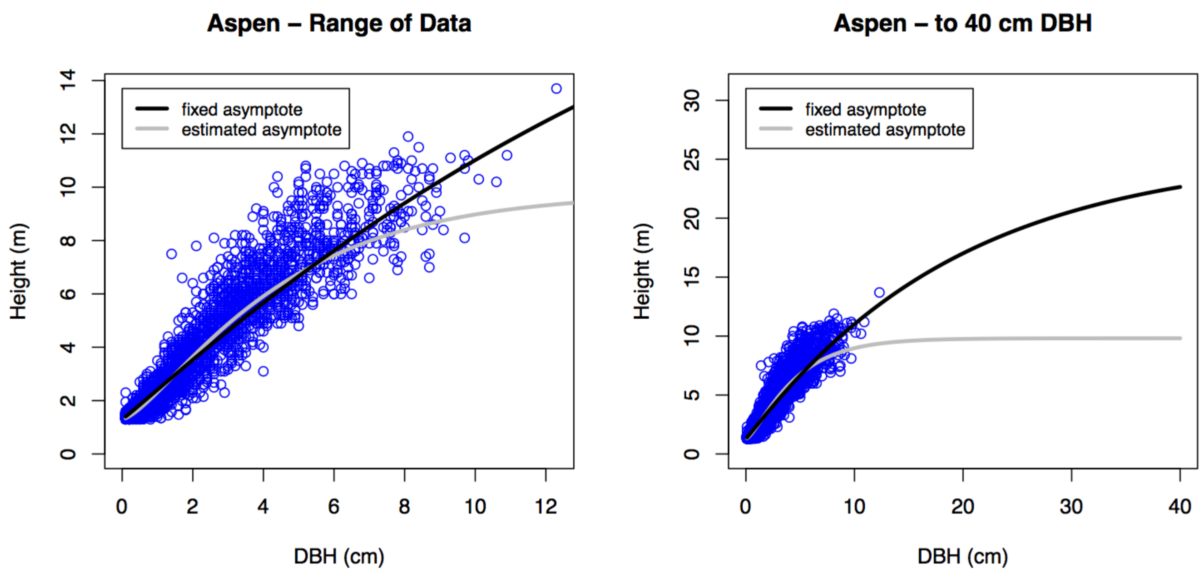

Figure 1. Scatterplot for trembling aspen illustrating the difference in height-diameter function when an explicit asymptote is assumed.

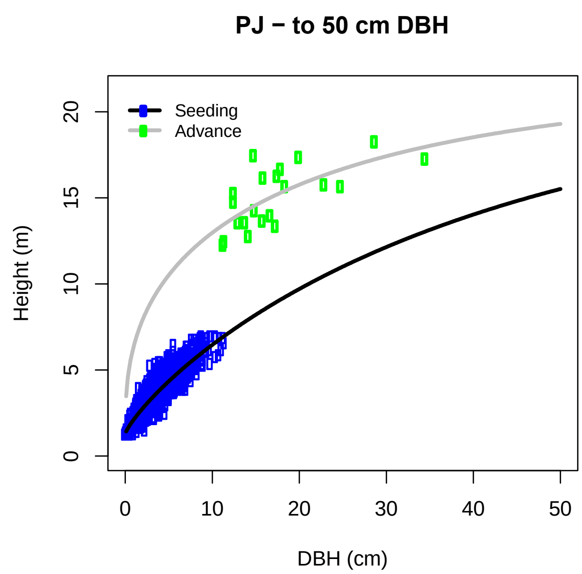

Figure 2. Scatterplot showing the distribution of jack pine in the fitting data by origin and the initial height-diameter functions.

Final coefficients for the species-specific models are given in Table 1. In all cases the coefficient estimates are statistically different from zero (α=0.05). Furthermore, in all cases the model including both fixed and random effects was also statistically superior to the non-linear least squares model that included fixed-effects only (α=0.05).

Table 1. Coefficient estimates and test statistics for use with equation [2].

Species	**n**§	**a**†	**Estimates**		**for** b_2		**for** b_3	
			b_2	b_3	**std. err.**	**p-value**	**std. err.**	**p-value**
AW	6,349	24.2731	0.055153	1.042926	0.001907	< 0.001	0.018449	< 0.001
BW	2,217	19.7369	0.046906	0.905730	0.002863	< 0.001	0.020145	< 0.001
PB	1,546	27.1012	0.044114	0.952908	0.003413	< 0.001	0.035597	< 0.001
FB	154	36.3526	0.022127	1.088331	0.002744	< 0.001	0.056432	< 0.001
PJ	1,691	20.2435	0.025506	0.885771	0.001772	< 0.001	0.027688	< 0.001
SB	846	36.9007	0.025021	1.145938	0.002218	< 0.001	0.040933	< 0.001
SW	1,745	35.5340	0.022103	1.123417	0.001400	< 0.001	0.026011	< 0.001

† asymptotes from Huang et al. (2013)

§ for FB, SB, and SW the fitting data include all trees, and for the other species include seedling origin only

A scatterplot that illustrates the fitted function using equation [2] (fixed-effects only) and equation [3] (fixed and random effects) for trembling aspen is shown in Figure 3. Figures for other species are included in the appendix (Figure 6 through Figure 11). The results show that including the random effect in the model has only a small influence on the population-level prediction (i.e., when the random effects $u_2 = u_3 = 0$), which should increase confidence in the approach.

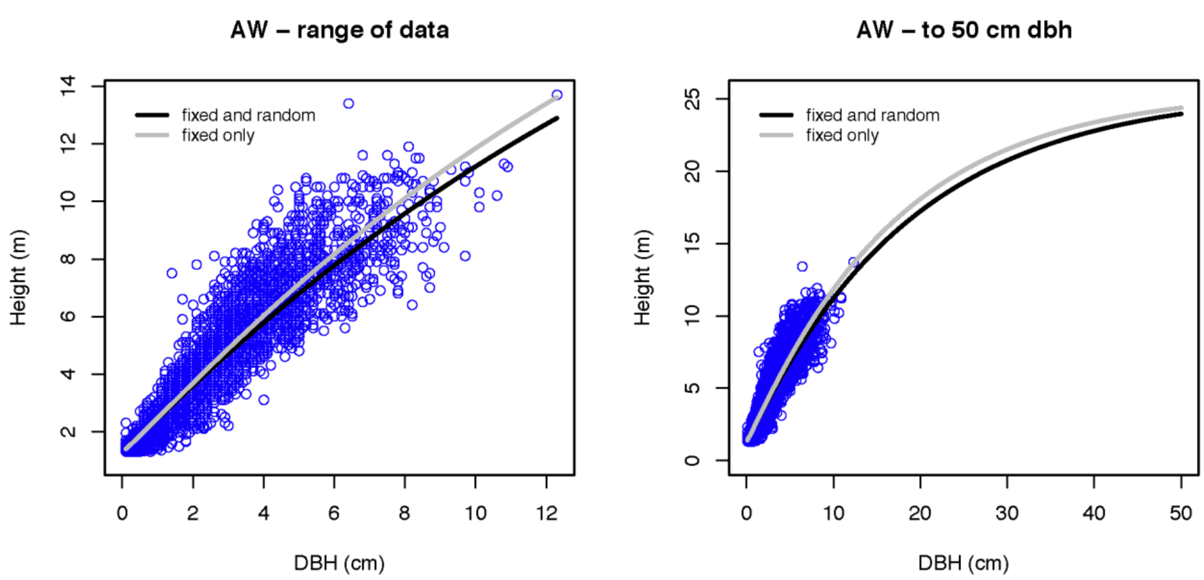

Figure 3. Fitted height-diameter function using fixed and random effects, and fixed effects only, for trembling aspen.

In addition to DBH there were other potential predictor variables available or derivable from the Al-Pac data. These include stand history and tree origin, which are factor variables, and stand density and basal area, which are continuous variables. Stand history is a binary variable that indicates whether stands had been tended or untended[2]. Tree origin is defined differently in the TSP, ATP100, and ATP400 data sets, but can be simplified into a binary variable that indicates if a tree originated pre-harvest (i.e., "advance") or post-harvest (i.e., "seedling"). Stand density and occupancy (trees/ha and basal area/ha respectively) could only be derived directly for the ATP100 data set, because all trees 1.3 m in height or greater have been tallied and their DBH measured. TSP densities were not available at the time of analysis.

In published works, other factors have been introduced into the Chapman-Richards function by making the asymptote parameter (b_1) or the rate parameter (b_2) a function of those variables; for example, Sharma and Zhang (2004) replaced b_2 in equation [1] with a function of stand density (SD):

[4] $$b_2 = c_1 SD^{c_2}$$

and solved for the additional coefficients using non-linear regression. In this analysis, since assumed values were used for the asymptote to condition the model, any modifications to include other effects were made to the b_2 parameter.

Analysis revealed stronger effects of plot history (tended vs. untended) than tree origin (advance vs. seedling) on the height-diameter relationship, for all species, with the exception of white spruce, black spruce, and balsam fir. For white and black spruce there was a statistically significant interaction between these two variables, and a model including both was fit. For balsam fir, there was no statistical effect of either treatment or origin, so the recommended model for this species is the default, Equation [3].

For trembling aspen, paper birch, jack pine, and balsam poplar, the model including treatment takes the form:

[5] $$HT = 1.30 + a[1 - exp(-(c_1 I_1 + c_2 I_2)DBH)]^{b_3 + u_3}$$

where I_1 = 1 and I_2 = 0 if the stand is tended, and I_1 = 0 and I_2 = 1 if the stand is untended. Note the random effect is included only for the b_3 term, because results showed that the additional fixed effects captured some of the grouping structure in the fitting data. Coefficient estimates are given in Table 2. For all four species the estimates are statistically different from zero (α=0.05). Furthermore, in all cases the model including treatment (Equation [5]) was statistically superior to the default model (Equation [3]; Table 1) (α=0.05).

[2] As per Katrina Froese pers comm.: In the TSP data, individual trees are assigned as tended and untended. However, the objective of this work is to create an equation that could be applied to performance survey data, which classifies trees as seedling or advance only. The only information we have on tending from performance surveys is at the sampling unit level. As such, this memo focused on modelling stand level equations.

Table 2. Coefficient estimates and test statistics for use with equation [5]. The values for a are in Table 1.

Species	Estimates			for c_1		for c_2		for b_3	
	c_1	c_2	b_3	std. err.	p-val	std. err.	p-val	std. err.	p-val
AW	0.050955	0.058248	1.045843	0.000747	< 0.001	0.000795	< 0.001	0.011131	< 0.001
BW	0.045229	0.053252	0.926561	0.001221	< 0.001	0.001395	< 0.001	0.014829	< 0.001
PB	0.037843	0.041554	0.932703	0.001258	< 0.001	0.001395	< 0.001	0.018959	< 0.001
PJ	0.020394	0.022717	0.833001	0.000807	< 0.001	0.001025	< 0.001	0.014879	< 0.001

Scatterplots that illustrate the fitted function using equation [5] for trembling aspen are shown in Figure 4. Scatterplots for the other three species are included in the appendix (Figure 12 through Figure 14). For all four species the effect of treatment is small, but statistically significant, revealing that trees in tended stands have less taper (are shorter for a given DBH).

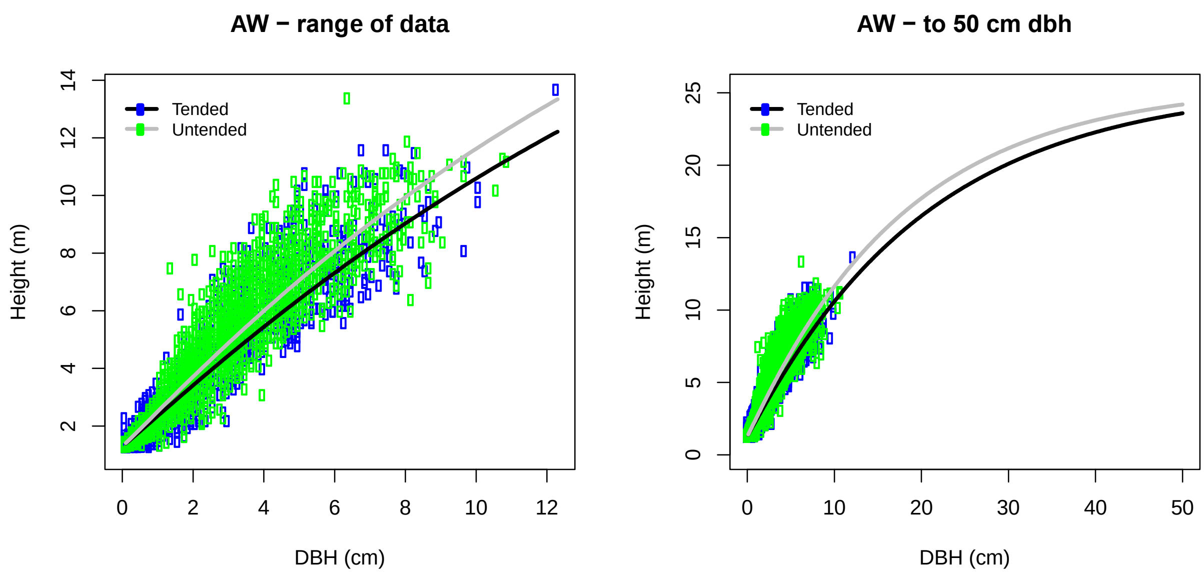

Figure 4. Fitted height-diameter function by treatment class, for trembling aspen.

For white spruce and black spruce, the model including both treatment and origin takes the form:

[6] $$HT = 1.30 + a[1 - exp(-(d_1 I_1 + d_2 I_2 + d_3 I_3 + d_4 I_4)DBH)]^{b_3 + u_3}$$

where:

I_1	I_2	I_3	I_4	Classification
1	0	0	0	Seedling, Tended
0	1	0	0	Advance, Tended
0	0	1	0	Advance, Untended
0	0	0	1	Seedling Untended

Note the random effect is included only for the b_3 term, because results showed that the additional fixed effects captured some of the grouping structure in the fitting data. Coefficient estimates are given in Table 3. For both species the estimates are statistically different from zero (α=0.05) and the model including the interaction (Equation [6]) was statistically superior to the model including treatment alone (Equation [5]) and the simple model (Equation [3]) (α=0.05).

Table 3. Coefficient estimates and test statistics for use with equation [5]. The values for *a* are the same as in Table 1.

Species	Estimates									
	d_1		d_2		d_3		d_4		b_3	
SB	0.0239552		0.0287032		0.0298559		0.0248345		1.1863302	
SW	0.0190165		0.0230889		0.0254196		0.0213897		1.1004934	
	std. err.	**p-val**	**std. err.**	**p-val**	**std. err.**	**p-val**	**std. err.**	**p-val**	**std. err.**	**p-val**
SB	0.001024	< 0.001	0.000798	< 0.001	0.002438	< 0.001	0.001258	< 0.001	0.02219	< 0.001
SW	0.000684	< 0.001	0.000522	< 0.001	0.001106	< 0.001	0.000690	< 0.001	0.01624	< 0.001

Scatterplots that illustrate the fitted function using equation [6] for both white spruce and black spruce is shown in Figure 5. The effect of treatment and origin is small, but statistically significant, and the two factors interact, meaning the treatment (plot history) effect depends on tree origin, and *vice versa*. Trees of seedling origin in untended stands and trees of advance origin in tended stands have the least taper, and trees of seedling origin in tended stands and trees of advance origin in untended stands have the least taper. For black spruce, the height-diameter equations for latter are essentially coincident (Figure 5).

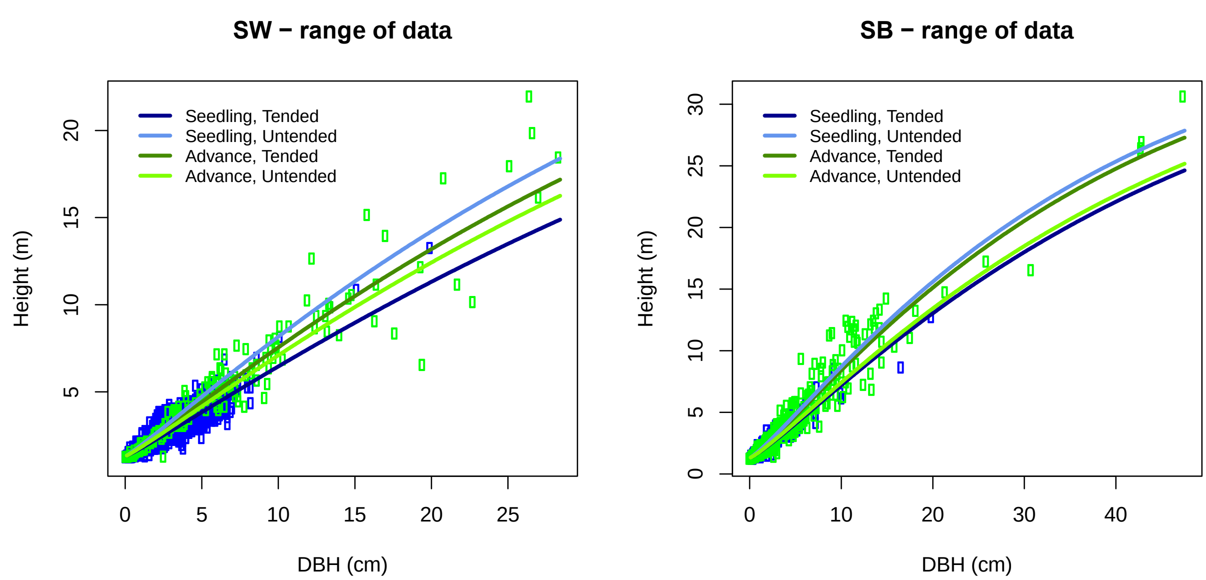

Figure 5. Scatterplots overlain with fitted height-diameter models that include plot treatment and tree origin as additional predictors.

Some exploratory analysis using tree density (trees/hectare) and stocking (basal area/hectare) was undertaken using the ATP100 data. Again, this analysis is restricted to the ATP100 data because these data have DBH measured for every tree ≥1.3 m in height within the plot, allowing calculation of both density and basal area. These results suggested there may be a significant density effect; however, the effect may be a consequence of plot history or correlated with tree origin, confounding the results. The potential effect was similar in magnitude to that observed for treatment (e.g., Figure 4).

Since treatment and origin were available for all of the data, these predictors were favoured. However, if there is interest in exploring the stocking effect further this is possible with the available data.

ACTION

Please test these models and share any feedback you may have. I encourage any questions or requests for clarification.

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APPENDIX

Table 4. Summary of available fitting data by species, origin, and data set.

Species		AW	BW	PB	FB	LT	PJ	SB	SW	TOTAL
Advance	ATP100	40	4	22	1	4	15	328	75	525
Advance	ATP400	0	0	1	0	0	6	16	10	39
Advance	TSP	12	9	59	0	9	0	21	73	176
Advance	**SUBTOTAL**	**52**	**13**	**82**	**1**	**13**	**21**	**365**	**158**	**740**
Seedling	ATP1	4,572	1,038	53	9	1,038	1,084	361	1,010	9,823
Seedling	ATP4	22	0	0	0	0	418	87	293	843
Seedling	TSP	1,755	508	19	1	508	189	33	284	3,287
Seedling	**SUBTOTAL**	**6,349**	**1,546**	**72**	**10**	**1,546**	**1,691**	**481**	**1,587**	**13,953**
TOTAL		6,401	2,265	1,559	154	11	1,712	846	1,745	14,693

Table 5. Summary of available fitting data by species, tending, origin, and data set.

Species			AW	BW	PB	FB	LT	PJ	SB	SW	TOTAL
Tended	Advance	ATP100	26	32	4	22	1	3	254	70	412
Tended	Advance	ATP400	0	6	0	1	0	3	15	1	26
Tended	Advance	TSP	0	2	0	20	0	0	10	27	59
Tended	Advance	**SUBTOT**	**26**	**40**	**4**	**43**	**1**	**6**	**279**	**98**	**497**
Tended	Seedling	ATP100	3,735	1,391	991	53	9	684	321	942	8,126
Tended	Seedling	ATP400	6	23	0	0	0	229	87	252	597
Tended	Seedling	TSP	712	153	119	2	1	83	26	208	1,304
Tended	Seedling	**SUBTOT**	**4,453**	**1,567**	**1,110**	**55**	**10**	**996**	**434**	**1,402**	**10,027**
Tended	**SUBTOTAL**		**4,479**	**1,607**	**1,114**	**98**	**11**	**1,002**	**713**	**1,500**	**10,524**
Untended	Advance	ATP100	14	8	0	0	0	12	74	5	113
Untended	Advance	ATP400	0	0	0	0	0	3	1	9	13
Untended	Advance	TSP	12	0	9	39	0	0	11	46	117
Untended	Advance	**SUBTOT**	**26**	**8**	**9**	**39**	**0**	**15**	**86**	**60**	**243**
Untended	Seedling	ATP100	837	305	47	0	0	400	40	68	1,697
Untended	Seedling	ATP400	16	0	0	0	0	189	0	41	246
Untended	Seedling	TSP	1,043	345	389	17	0	106	7	76	1,983
Untended	Seedling	**SUBTOT**	**1,896**	**650**	**436**	**17**	**0**	**695**	**47**	**185**	**3,926**
Untended	**SUBTOTAL**		**1,922**	**658**	**445**	**56**	**0**	**710**	**133**	**245**	**4,169**
TOTAL			**6,401**	**2,265**	**1,559**	**154**	**11**	**1,712**	**846**	**1,745**	**14,693**

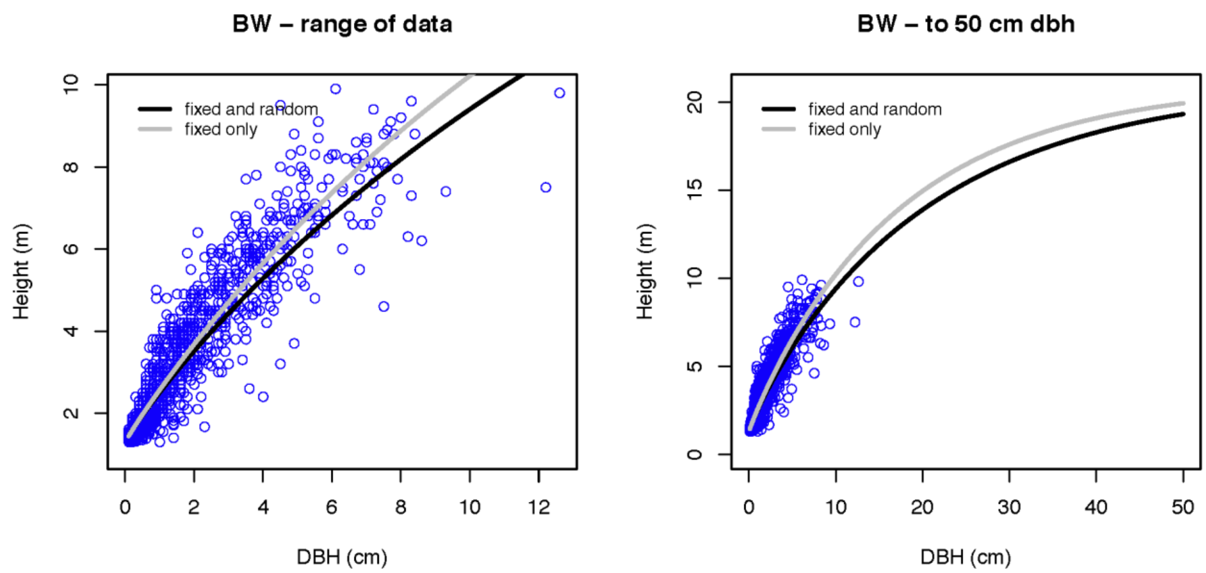

Figure 6. Fitted height-diameter function using fixed and random effects, and fixed effects only, for paper birch.

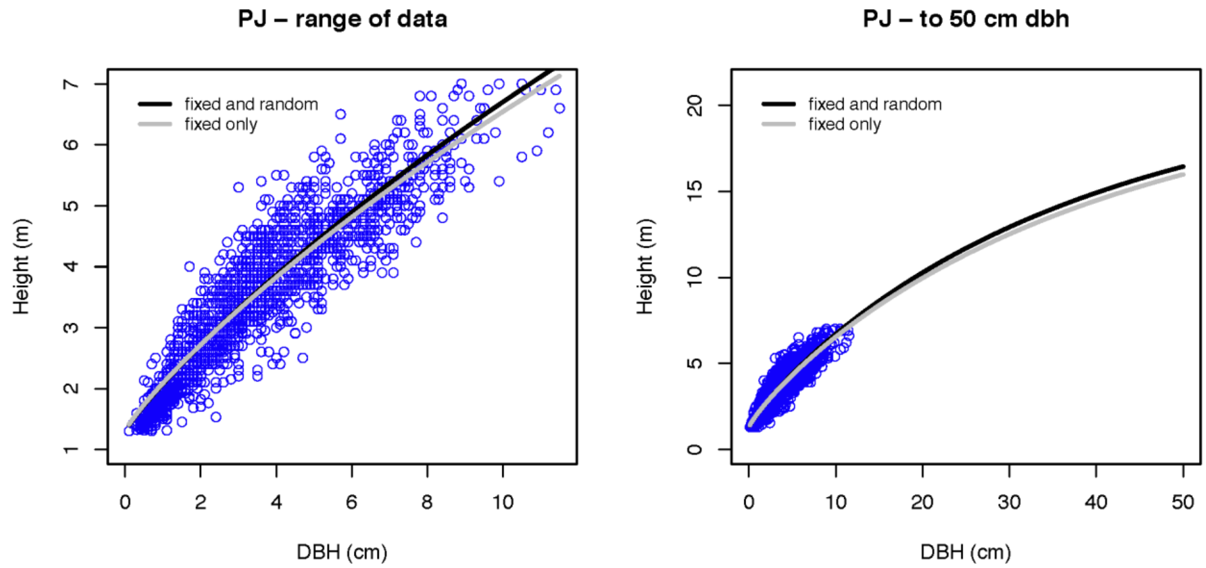

Figure 7. Fitted height-diameter function using fixed and random effects, and fixed effects only, for jack pine.

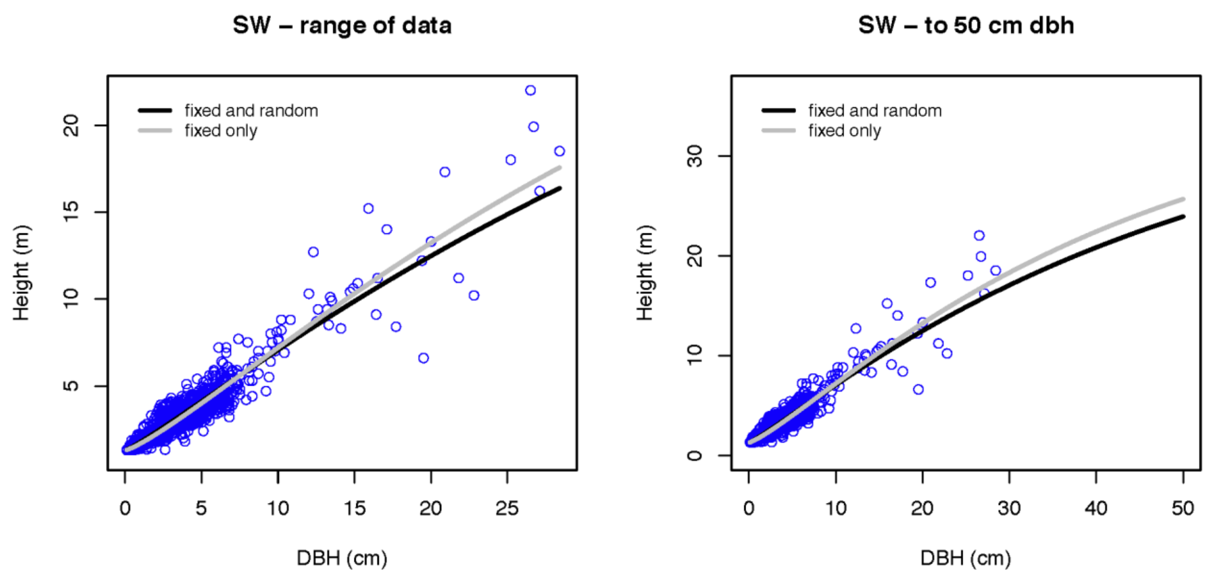

Figure 8. Fitted height-diameter function using fixed and random effects, and fixed effects only, for white spruce.

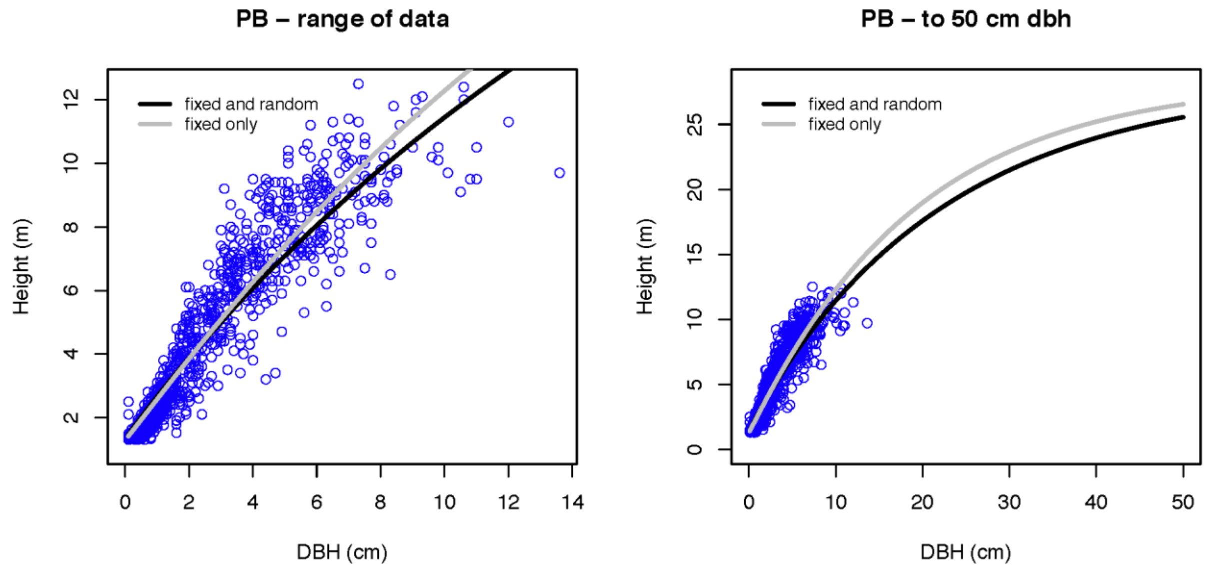

Figure 9. Fitted height-diameter function using fixed and random effects, and fixed effects only, for balsam poplar.

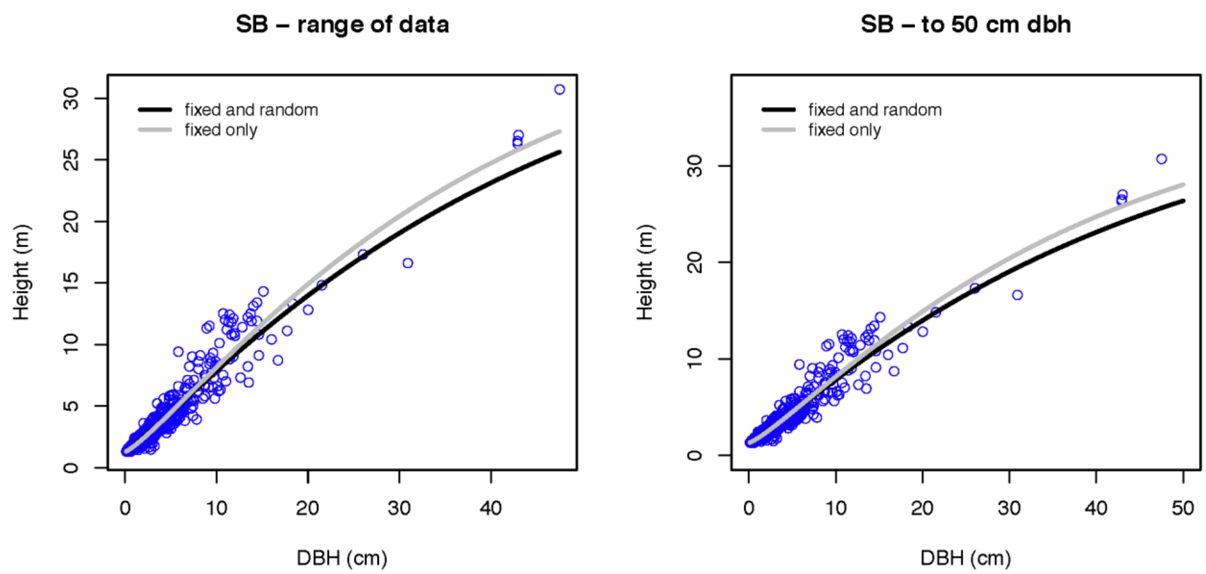

Figure 10. Fitted height-diameter function using fixed and random effects, and fixed effects only, for black spruce.

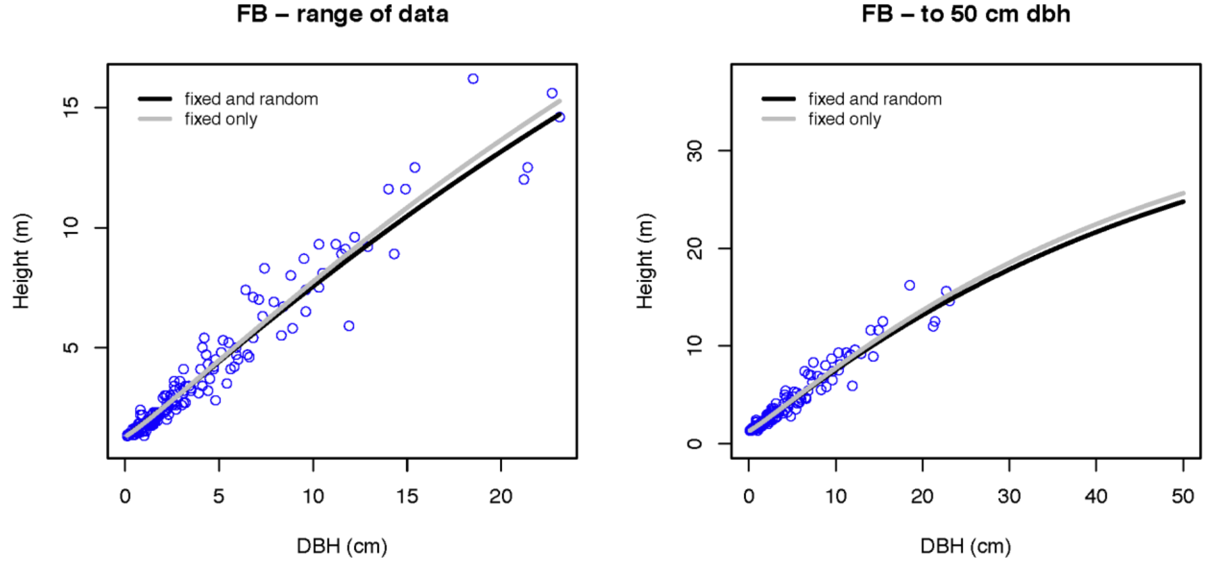

Figure 11. Fitted height-diameter function using fixed and random effects, and fixed effects only, for balsam fir.

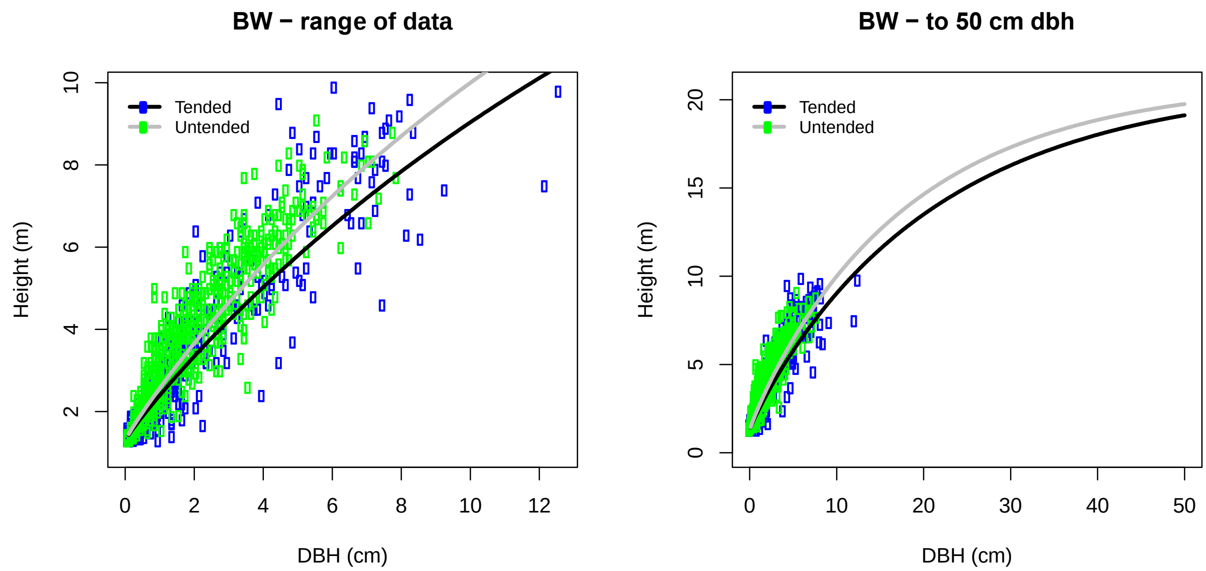

Figure 12. Fitted height-diameter function by treatment class, for paper birch.

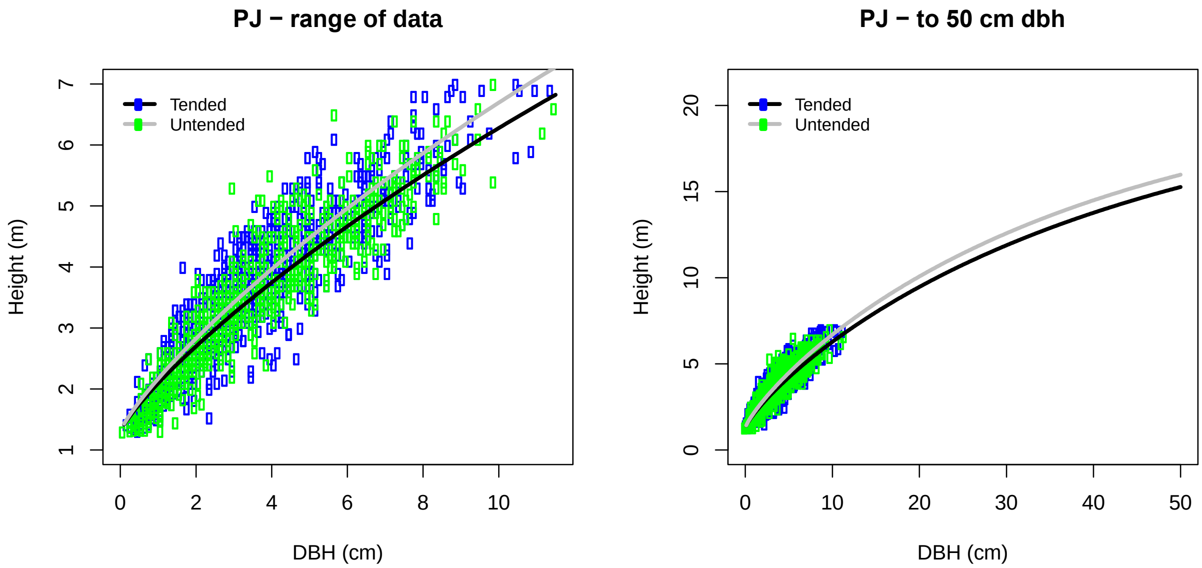

Figure 13. Fitted height-diameter function by treatment class, for jack pine.

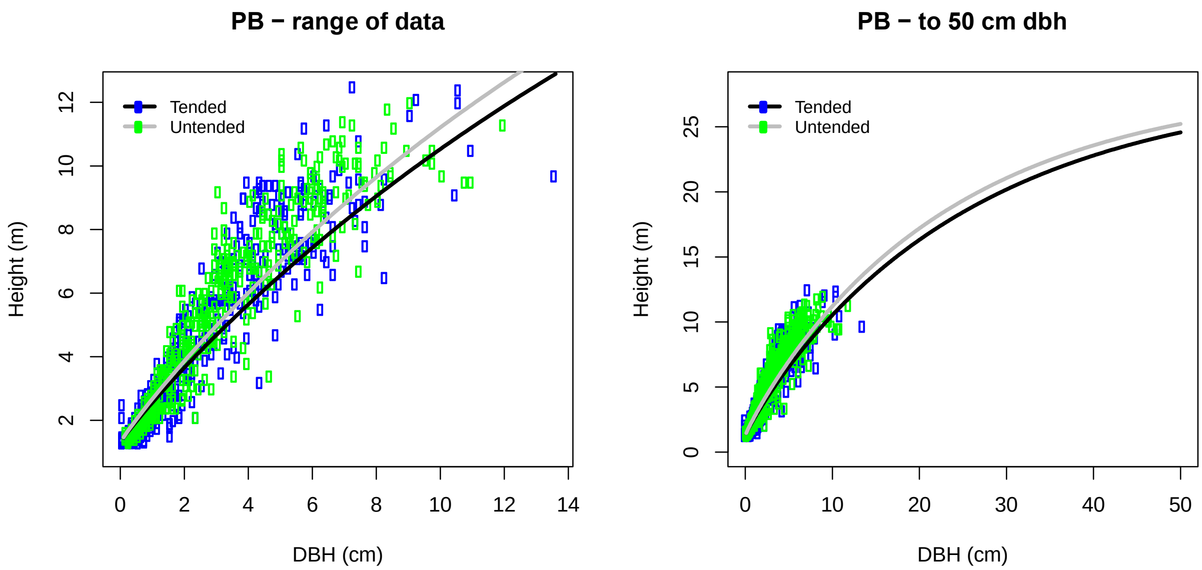

Figure 14. Fitted height-diameter function by treatment class, for balsam poplar.

Appendix VII – Juvenile Height Distribution Modelling

MEMO

To: Gitte Grover, Alberta-Pacific Forest Industries Inc.

From: Robert Froese[1]

Cc: Katrina Froese

Date: 07 January 2014

Re: Conifer Height Distribution Models for Alberta-Pacific Regenerated Stand Data

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PURPOSE

This memo presents analysis and results from a task to develop height distribution models for conifer species using regenerated stand data for the Alberta-Pacific Forest Management Agreement (FMA) area.

SUMMARY

Empirical height distribution models were constructed for Al-Pac's FMA area in Alberta to allow the generation of inferred heights for trees, known to be between 0.3 and 1.3 m in height, but without direct height measurements. The models were based upon data from 43 ATP installations (PSPs) and were constructed for three species groups: pine, black spruce, and white spruce. A parameter-prediction approach was used to localize the parameters of a Weibull probability density fit to each PSP. The resulting predictive models are able to closely reproduce the fitted Weibull density. To use the models to generate height predictions for individual trees two steps will be required. First, the Weibull parameters are predicted for the target stand or plot, as a function of trees per hectare and quadratic mean diameter. Second, random Weibull values (heights) are generated using routines in common statistical software packages.

DISCUSSION

<u>Background</u>

The goal of this task was to develop empirical height distribution models for conifer species, using data from regenerated (post-harvest) stands within Al-Pac's FMA area in Alberta. The stated intent was that these models would be used to generate inferred individual-tree height values for conifers in Regeneration Standard of Alberta (RSA) performance survey plot data that

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[1] Associate Professor, School of Forest Resources and Environmental Science, Michigan Tech University; PhD, Forest Biometrics, University of Idaho.

are < 1.3 m in height. These would subsequently be used to initialize growth models for yield forecasting. These models are to be applied only to Alberta-Pacific cutblocks; i.e. only blocks managed without the use of herbicide and thus comprised of mixed hardwood-softwood species.

Summary of the Model Development Data

Data from the ATP program, from measurement years 2010-2013, were used for model development. Only data from 100 m^2 (ATP100) plots were used, but these included the ATP100 plot nested within the 400 m^2 (ATP400) plots where available. Plots were classified into tended vs. untended stands based on information provided by Katrina Froese. Several plots were excluded because they were in Quota Holder (herbicided) blocks, again per instructions from Katrina Froese. Stands that were pure hardwood were also excluded since the intent was to generate models for conifer species groups only.

Table 1. Summary of the ATP100 PSP data for model development.

PSP	No. Plots	STPH†	HTPH	TENDED	No. of trees by species group			
					AW	PJ	SB	SW
725	4	1,375	8,775	TRUE	236	0	0	87
726	3	1,200	5,933	TRUE	112	0	0	38
727	4	1,450	16,075	FALSE	529	0	0	63
728	4	2,200	2,125	TRUE	85	0	87	43
729	4	1,375	2,925	TRUE	117	1	11	63
730	4	850	5,725	TRUE	188	0	1	63
731	4	2,100	12,100	TRUE	484	0	0	99
732	4	1,275	2,450	FALSE	98	50	0	0
734	3	1,300	0	FALSE	0	5	29	17
735	3	3,833	4,100	TRUE	123	6	140	30
736	3	1,833	6,133	TRUE	184	0	0	67
737	3	1,900	3,700	TRUE	111	0	0	64
738	3	733	6,300	TRUE	189	7	1	29
740	3	1,767	5,933	TRUE	178	25	0	40
741	4	3,300	2,525	TRUE	101	20	52	2
742	3	3,767	5,500	TRUE	165	119	57	5
743	4	2,600	4,025	TRUE	161	84	49	21
744	4	2,300	5,325	TRUE	153	74	143	26
745	3	1,233	7,800	TRUE	194	16	5	51
746	3	1,267	7,700	TRUE	186	7	33	4
747	4	1,925	7,075	FALSE	219	93	0	0
748	3	800	7,667	TRUE	137	23	42	5
749	4	800	10,725	TRUE	271	0	0	40
750	4	1,625	4,700	TRUE	112	0	35	60
751	3	1,433	16,367	TRUE	297	0	0	73
752	4	900	7,950	TRUE	214	41	97	18
753	4	3,400	1,425	FALSE	57	134	28	0
754	3	1,567	3,967	FALSE	45	19	44	5
755	4	2,275	11,175	TRUE	329	1	1	154
756	4	3,825	1,275	TRUE	51	84	135	0
757	4	4,725	5,300	TRUE	212	185	74	0
758	3	3,633	5,967	TRUE	179	103	44	3
759	3	1,133	7,467	TRUE	224	17	34	3
761	3	3,200	6,000	TRUE	72	60	127	1

762	3	2,900	0	FALSE	0	67	102	0
763	4	1,800	1,700	FALSE	68	93	26	4
PSP	**No. Plots**	**STPH**[†]	**HTPH**	**TENDED**	**No. of trees by species group**			
					AW	**PJ**	**SB**	**SW**
764	3	1,800	700	FALSE	21	51	41	0
765	4	1,175	15,250	TRUE	284	0	0	64
767	3	400	1,767	TRUE	53	0	0	17
768	3	1,233	1,533	TRUE	46	0	0	44
769	4	100	11,950	FALSE	165	0	0	5
770	3	1,600	17,567	TRUE	253	0	0	59

[†]STPH = softwood trees per hectare; HTPH = hardwood trees per hectare.

Sample data were available from 42 ATP installations (PSPs) (Table 1). Potential predictor variables include tending, and others that were derived from the fitting data. These were derived from conifer species only and include stand density (trees per hectare), quadratic mean DBH, and top height. Top height was calculated for each ATP installation as the arithmetic mean of the height of the seedling-origin conifer with the largest DBH from each ATP plot, by species group.

Tending was not used as a predictor variable since tending occurred only two years prior to survey, and likely did not affect the height distribution of conifers in such a short period of time. Hardwood trees per hectare was considered as a predictor variable, but was not implemented since in post-tending stands, densities are not reflective of the original competitive environment of these conifers for the first 12 years of stand growth[2]. Since the majority of Alberta-Pacific's mixedwood stands are growing in a similar competitive environment (e.g. relatively high density of deciduous with conifer species), no effort was made to include hardwood presence as a predictor variable in modelling.

Table 2. Summary of species groups and available model fitting data in the ATP100 data set.

Group	Species	No. trees
1 (AW)	Trembling aspen, paper birch, and balsam poplar	6,903
2 (PJ)	Jack pine and tamarack	1,385
3 (SB)	Black spruce	1,438
4 (SW)	White spruce and balsam fir	1,367
TOTAL	**All species**	**11,093**

Trees were grouped into species-specific classes that match the class definitions in the Reforestation Standard of Alberta Performance Survey Standard (Table 2). Once the fitting data were cleaned the data set comprised about 11,100 trees. The most common species group was the hardwoods, with about 6,900 trees, followed by the three conifer groups each with about 1,400 trees.

Issues and Approach

The planned approach was to characterize the height distribution of individual species groups using the Weibull probability distribution fit to the ATP100 data. Then, heights of trees in the RSA data can be inferred by generating random values from the Weibull distribution. The

[2] K.L. Froese, pers.comm., December 2013.

Weibull is very flexible and has been commonly used for modelling height and diameter distributions in forest systems (Burkhart and Tomé 2012). The probability density function (PDF) takes the form:

$$f(x;\lambda,k) = \frac{k}{\lambda}\left(\frac{x}{\lambda}\right)^{k-1} e^{-\left(\frac{x}{\lambda}\right)^{k}}$$

where *k* is the *shape* parameter, λ is the *scale* parameter, and *x* is the variable (i.e., height) assumed to follow a Weibull distribution. Scale affects the spread of the distribution, and shape affects the skew. For shape values > 1 the distribution is bell-shaped and the skew increases as the shape coefficient declines until, for values < 1, the distribution is "inverse-J" shaped (Figure 1). The distribution is bounded such that ($0 \leq x \leq \infty$). In older stands, where there may be few if any small trees, it may be more appropriate to use the 3-parameter Weibull, which makes the lower threshold a parameter to be estimated, instead of explicitly setting the lower bound to zero.

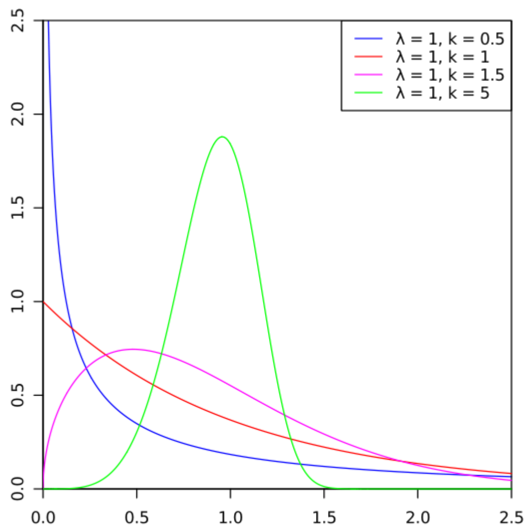

Figure 1. Examples of the Weibull using different values for the shape parameter. Reproduced from *http://en.wikipedia.org/wiki/File:Weibull_PDF.svg*

The Weibull can be localized at the stand (or plot) level by modelling the parameters using linear regression, to account for the effect of local stand attributes on the shape and scale of the height distribution. This is a common and accepted approach, known as "parameter prediction" (Burkhart and Tomé 2012). For example, using multiple linear regression, the parameters can be expressed as:

$$\hat{k} = b_0 + b_1x_1 + \cdots + b_jx_j$$

$$\hat{\lambda} = c_0 + c_1x_1 + \cdots + cx_j$$

where $b_0 - b_j$ and $c_0 - c_j$ are parameters to be estimated and $x_1 - x_j$ are the predictor variables. In such equation systems the error terms across the equations may be correlated, and greater statistical power can be realized using the seemingly unrelated regression approach (SUR; Kmenta 1986).

To apply the distribution to generate values, first the chosen predictor variables are derived for the stand of interest. These are then used to predict the local Weibull parameters. Finally, random values are drawn from the Weibull distribution, using the localized parameters, and assigned to the individual inventory trees. Common statistical software packages have built-in functions to create pseudo-random Weibull values.

Random values generated from the Weibull will span the entire range (i.e., from 0 to infinity), but this does not limit the ability to generate heights for a subset of the range. Some computer algorithms may be able to do this directly, by limiting the portion of the distribution of interest. An approach is to simply reject any values that are known to be false. In other words, since the intent is to apply the model only for trees that are known to have heights between 0.3 and 1.3 m, if a random value is generated that falls outside of this range, it can be discarded, and a new value generated.

All analyses were completed in the R environment for statistical computing (R Core Team 2013). The parameters of the Weibull distribution were estimated via constrained optimization of the likelihood equation using the `nlminb()` function. Regression coefficients for the equations to predict Weibull parameters were estimated using `systemfit()` in the package 'systemfit' (Henningsen and Hamann 2007).

<u>Results</u>

Parameters of the Weibull distribution were estimated uniquely for each stand and conifer species group. Histograms that show the empirical height distribution overlain by the corresponding fitted Weibull distribution are included in the Appendix. In most cases the fitted Weibull was a very close approximation to the empirical distribution; this reflects the inherent flexibility of the Weibull as well as the consistencies in the ATP data. The height distribution for most ATP installations spans a similar range and is right-skewed.

The Weibull is very flexible and can be fit to stands with as few as two sample trees. When sample sizes are small, however, it is likely that the resulting Weibull parameters for a given PSP reflect increasing amounts of sampling error, in addition to the true distribution of heights. These are subsequently modeled using regression (the "parameter prediction") and the increasing error can cause the models to be unstable. To reduce this influence only ATP installations with 10 or more sample trees were used to develop the final set of parameter prediction equations.

Table 3. Summary of the predictor variables available to model the Weibull parameter.

Predictor Variable	Description
TPH	Trees per hectare for the species group of interest
PropTPH	The proportion of TPH below 1.3 m in height, species group of interest
ConifTPH	Trees per hectare for all conifer species combined
QMD	Quadratic mean diameter for the species group of interest
TOPHT	Top height for the species of interest, using seedling origin only
TENDED	Binary variable indicating if past tending was done on the stand

Equations were developed to predict the Weibull shape and scale parameters for each species group using multiple linear regression. The intended application is to generate inferred height for trees in RSA data; therefore, the predictor variables used in the height model had to be constrained to the set that could be derived for both the application data (RSA) and the fitting data (ATP100). A list of these predictors is shown in Table 3. Forward-stepwise and backward-stepwise algorithms were used to identify the set of predictors that were superior, based on AIC, for each parameter (scale and shape). The final coefficients were estimated using SUR and only those that were statistically significant were retained (α=0.05). The best subset of predictors and estimated coefficients are shown in Table 4.

Table 4. Coefficients and fit statistics for equations to predict the Weibull parameters.

Species Group	No. ATP Installs	Weibull Parameter	Regression Coefficient				Adj. R^2	RMSE
			Intercept	ConTPH†	PropTPH	QMD		
2 (PJ)	20	*k*	3.035613	-	-4.019042	-	0.7605	0.3303
		λ	1.361447	-	-2.308858	0.592733	0.9039	0.2459
3 (SB)	22	*k*	2.180160	-0.146074	-	-	0.2337	0.4391
		λ	2.654215	-0.061672	-2.174955	0.182491	0.9403	0.1929
4 (SW)	25	*k*	2.55083	0	-1.447576	0	0.2465	0.4055
		λ	1.850598	0	-2.046707	0.373798	0.9037	0.1912

†Note: ConTPH was scaled (divided by 1,000) before model fitting, and needs to be scaled before application.

The results reveal that the shape parameter becomes smaller (has greater skew) with increasing proportion of TPH below breast height or increasing total conifer TPH. This is intuitive, as it reflects an "earlier" stage in stand development. The Adjusted R^2 values for the shape parameter are low, but this is not surprising since the shape is a complex function of within and among-species group distributions that are the result of many biological and geophysical factors (e.g., regeneration success, planting, microsite, etc.) as well as chance. Regardless, height distribution is far more affected by the scale than the shape parameter, and the low R^2 is not problematic.

The results also show the scale parameter increases (the distribution is wider) with decreasing proportion of TPH below breast height and increasing QMD. Again, this is intuitive, as these predictor variables are likely very close proxies for the spread of the height distribution. The parameter prediction models for the scale parameter have a very good fit, with R^2 values exceeding 0.9 for all three species groups. This is not surprising, as the predictors are close proxies for spread. The close correspondence between fitted Weibull distributions and predicted distributions (see Appendix), despite variability in observed spread, is evidence that the close fit is due to predictive power, not overfitting.

Examples that show the distribution across the range of conditions observed in the ATP data are shown in Figure 2. However, caution should be taken in applying any model outside of the range of the fitting data (i.e., the range of the predictors in the ATP data set). In the ATP data the observed QMD values were between 1-5 cm, most stands had values for proportion of TPH below 1.3 m in the range 0.1-0.5, and the total conifer density ranged from about 400-4,000 TPH. If the models are used to predict height distributions for stands with predictor values outside of these ranges, there is no guarantee the results will be credible.

There may be cases where all trees are under 1.3 m in height, in which case QMD is zero (a condition not encountered in the ATP data). A solution is to examine how the parameter prediction equations behave when they are extrapolated, and compare this against expected conditions in the context of stand dynamics. *Ad hoc* testing shows that the equations for all three species groups and are robust to extrapolation, though the spruces are more so than pine. The Weibull distribution requires that the shape and scale parameters are both greater than zero. Thus, the simplest rule to bound the models against error in extrapolation is to set the minimum shape parameter to 0.5 and the minimum scale parameter to 0.1. At these values the resulting height distribution is a sharp inverse-J and 95% of the probability is below 1.3 m in height. This is a credible distribution for very young stands where the proportion of TPH below 1.3 m is close to 1.0 and the QMD is correspondingly small, if not zero.

This rule is effective in practice. For both spruce groups (species group 3 and 4) a combination of predictors that generates values for scale and shape less than 0.5 and 0.1, respectively, is nearly impossible. Because the fitting data for pine includes somewhat more developed stand conditions, the fitted values are less robust to extrapolation. However, the proposed rule (bounding shape and scale to 0.5 and 0.1) is effective at generating credible distributions.

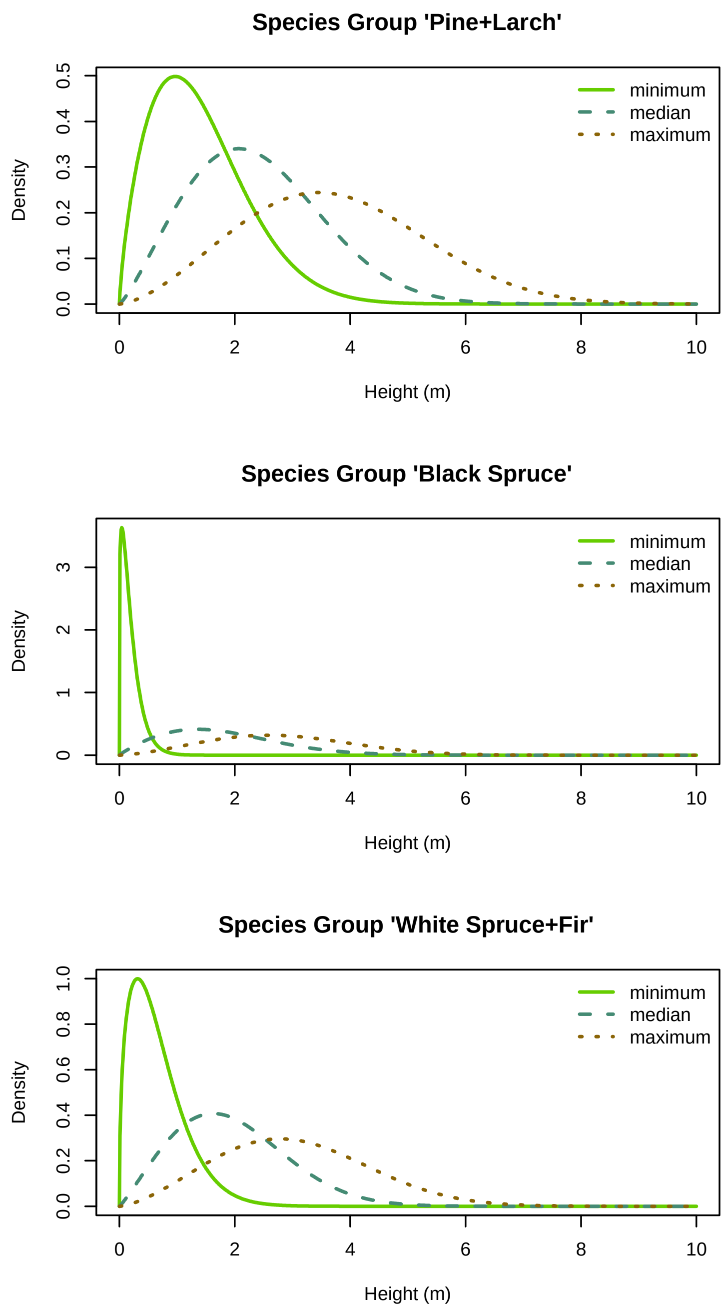

Figure 2. Examples of predicted Weibull densities for arbitrary values of stand/plot conditions. "Minimum" values use the smallest QMD, smallest conifer TPH, and smallest percentage of trees greater than 1.3 m in height observed in the ATP data. "Median" and "maximum" follow logically.

ACTION

Please test these models and share any feedback you may have. I encourage any questions or requests for clarification.

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Henningsen, A. and J.D. Hamann. 2007. systemfit: A Package for Estimating Systems of Simultaneous Equations in R. Journal of Statistical Software 23(4), 1-40. URL http://www.jstatsoft.org/v23/i04/ (last accessed 01 January 2014).

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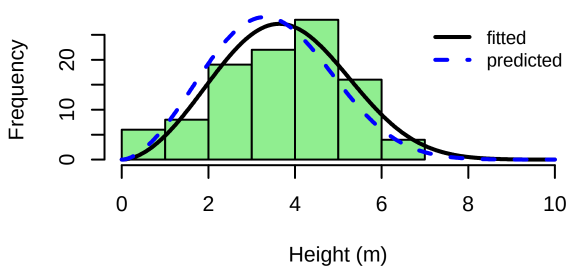
APPENDIX

PSP 758 'Pine+Larch'



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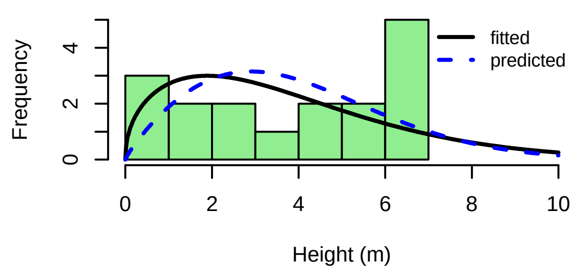

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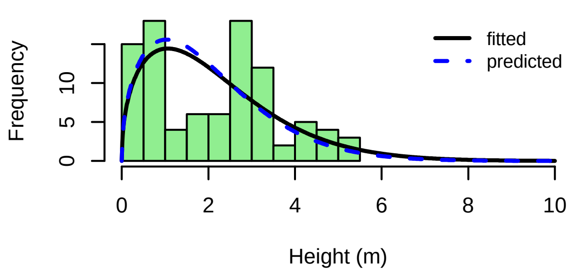

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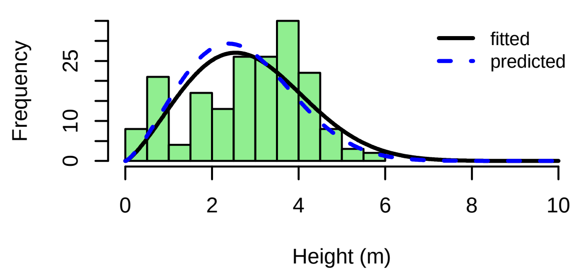

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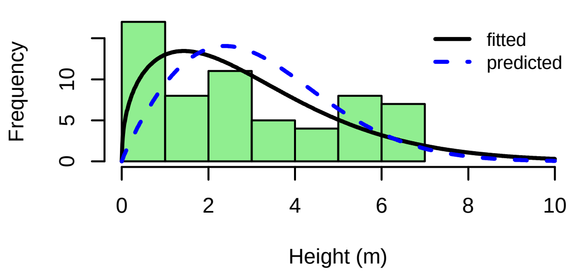

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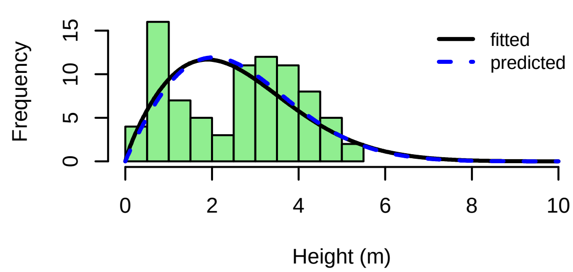

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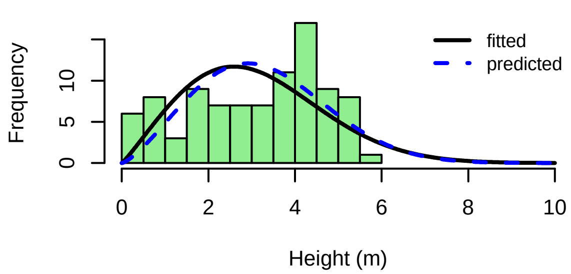

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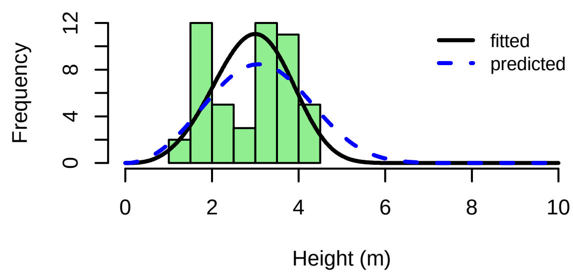

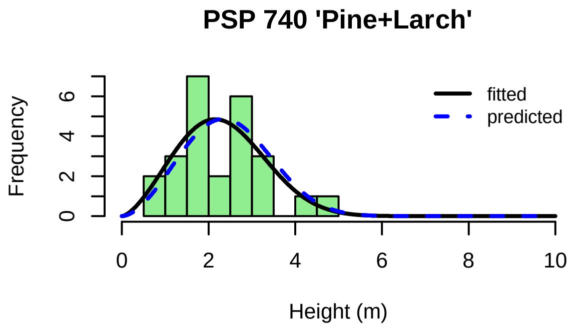
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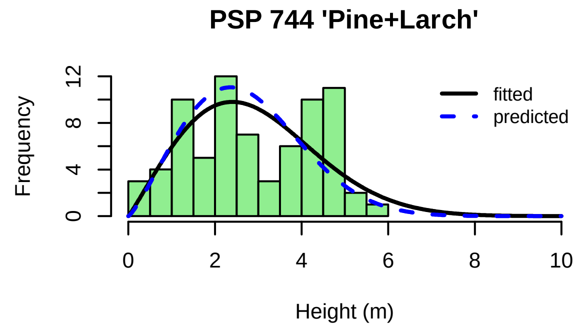
fitted
predicted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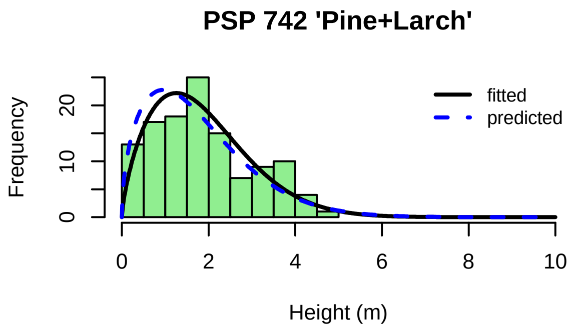
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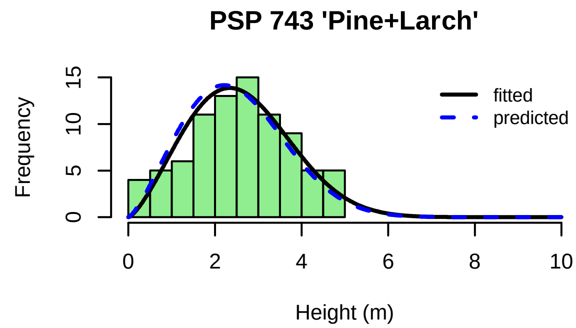
Height (m)
fitted
predicted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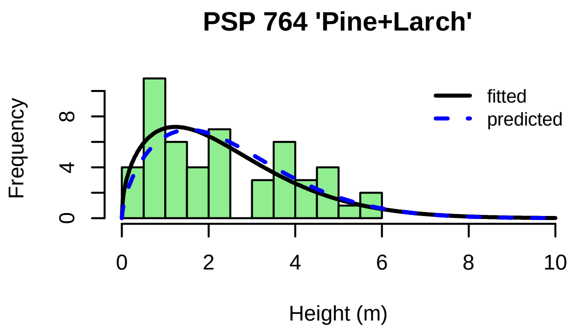
Frequency
Height (m)
fitted
predicted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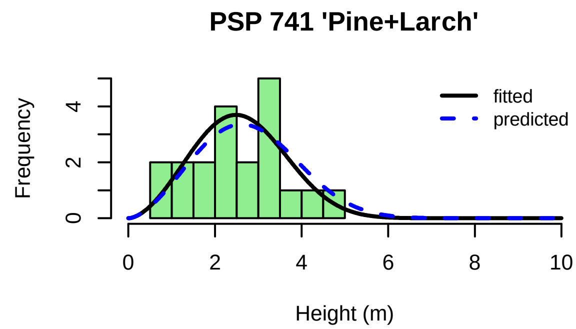
Frequency
Height (m)
fitted
predicted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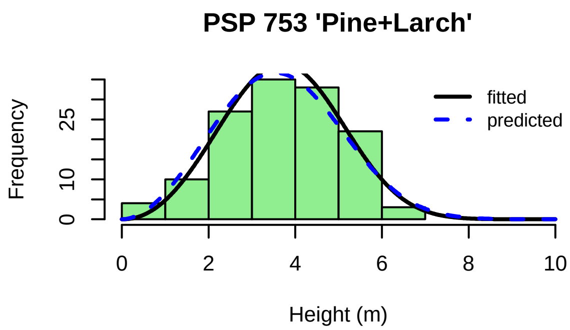
predicted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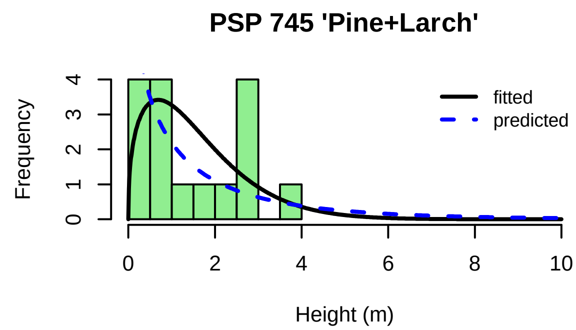
predicted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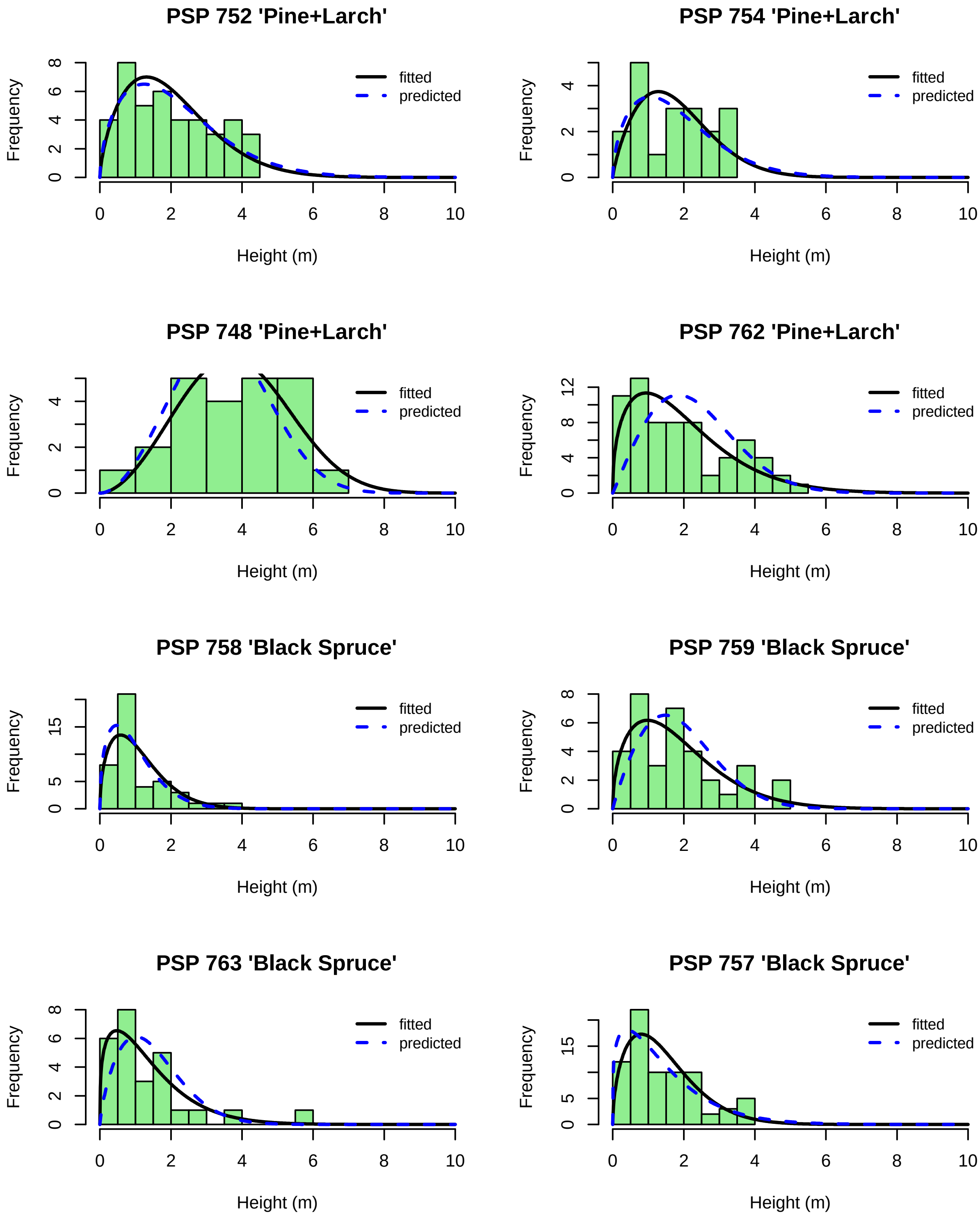
fitted
predicted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PSP 754 'Pine+Larch'
PSP 748 'Pine+Larch'
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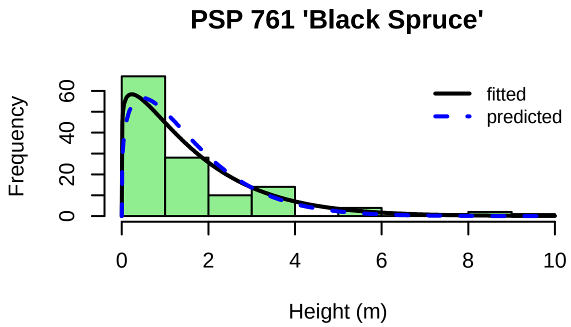
PSP 759 'Black Spruce'
PSP 763 'Black Spruce'
PSP 757 'Black Spruce'
Frequency
Height (m)
fitted
predicted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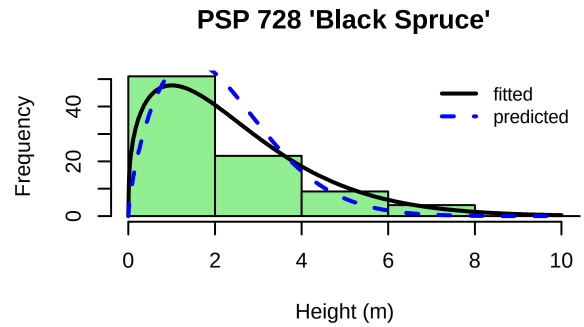
Height (m)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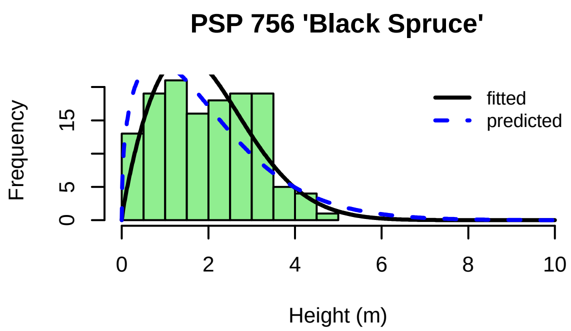
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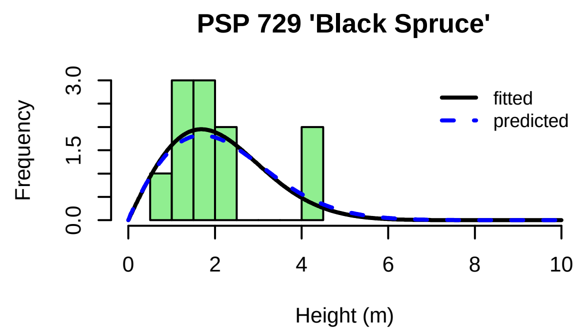
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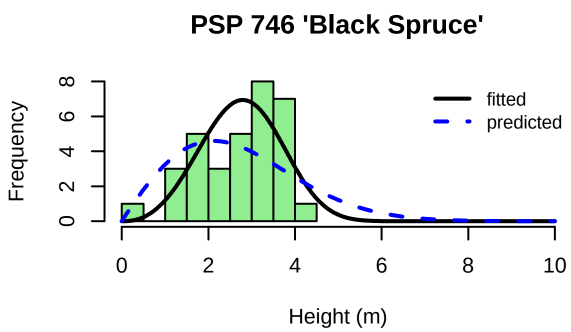
Height (m)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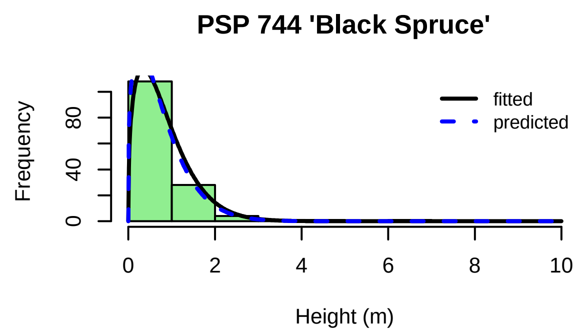
Height (m)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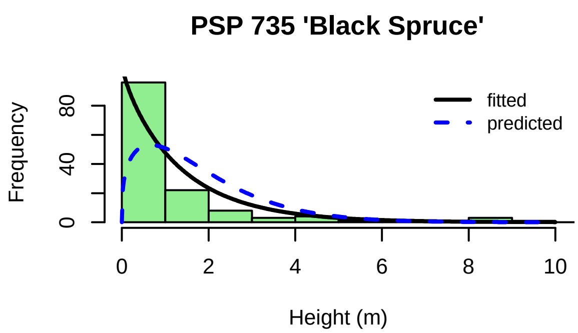
Height (m)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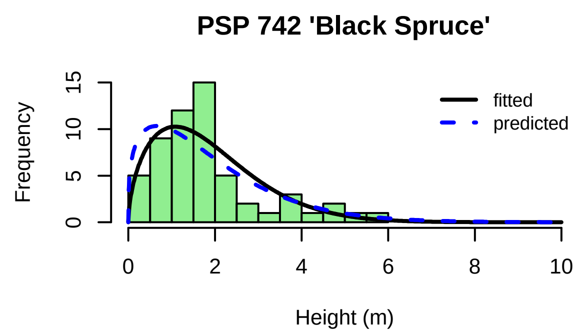
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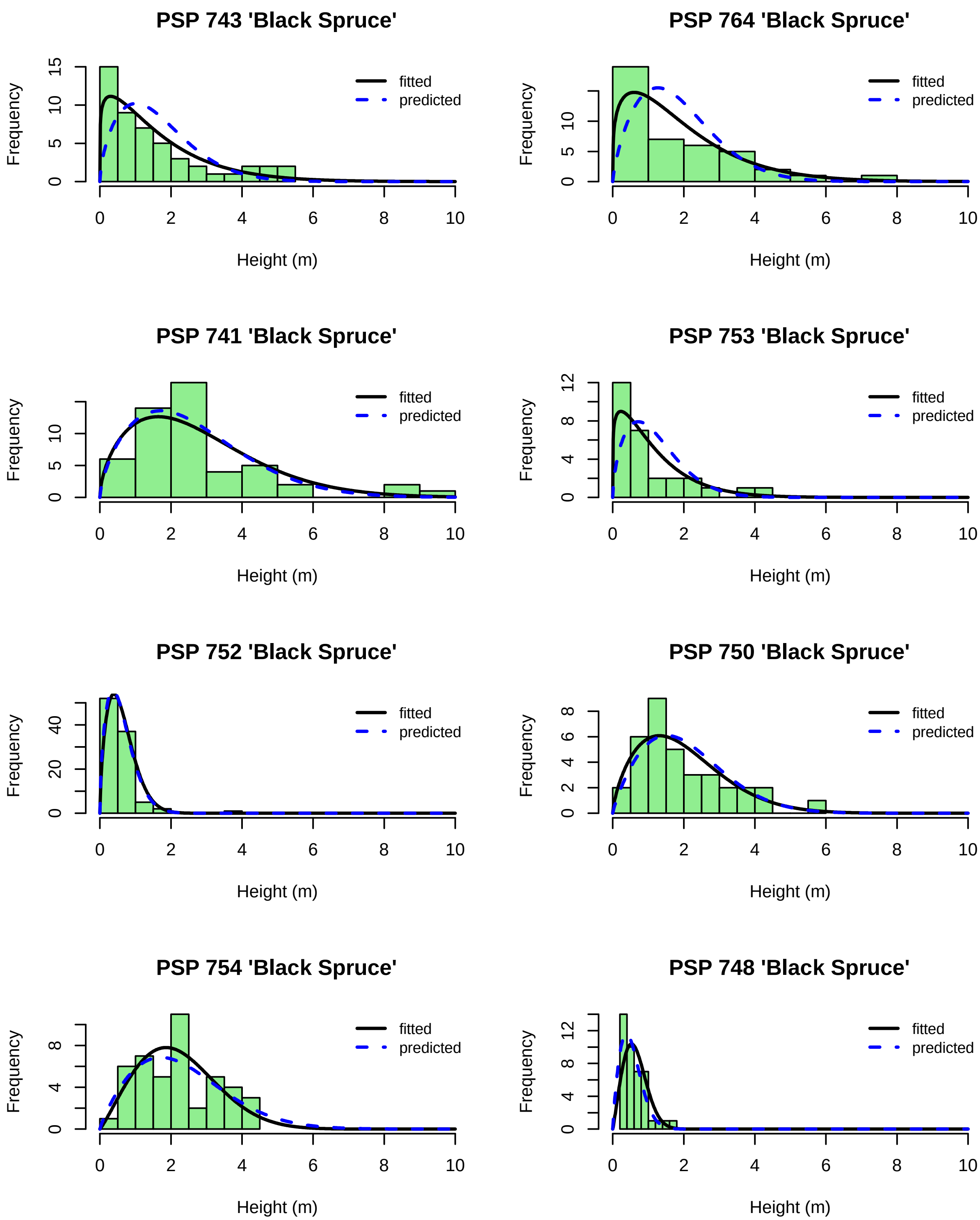
fitted
predicted
0
2
4
6
8
10
Height (m)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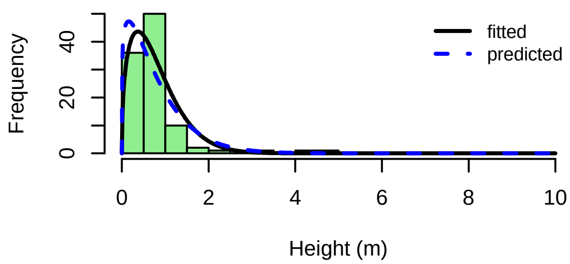
PSP 764 'Black Spruce'
PSP 741 'Black Spruce'
PSP 753 'Black Spruce'
PSP 752 'Black Spruce'
PSP 750 'Black Spruce'
PSP 754 'Black Spruce'
PSP 748 'Black Spruce'
fitted
predicted
Frequency
Height (m)

PSP 762 'Black Spruce'



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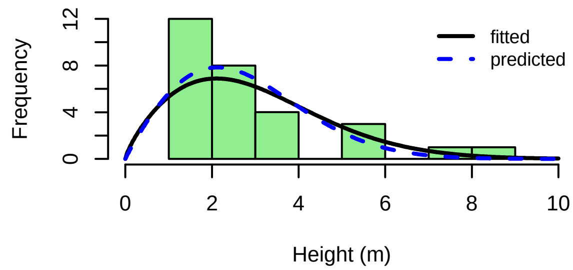

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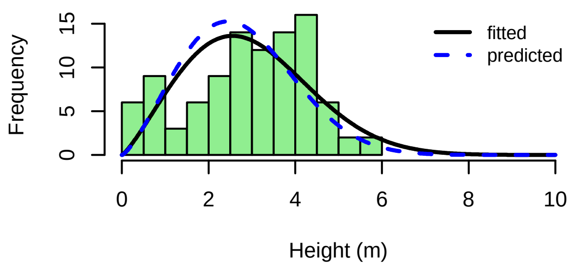

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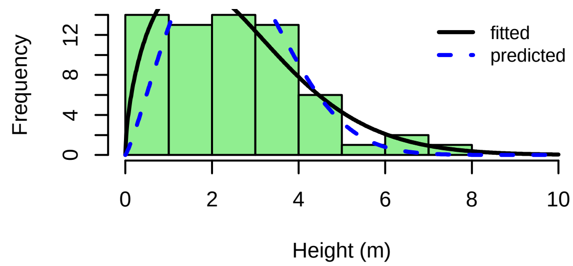

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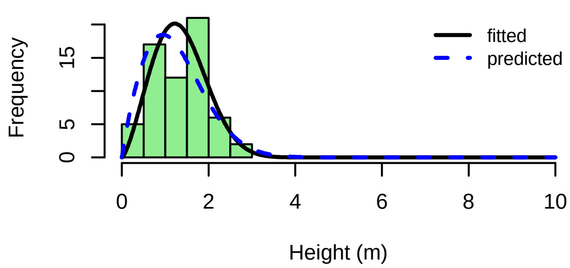

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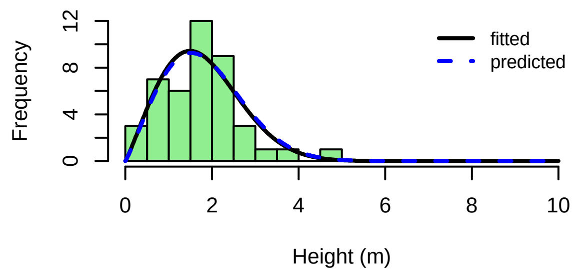

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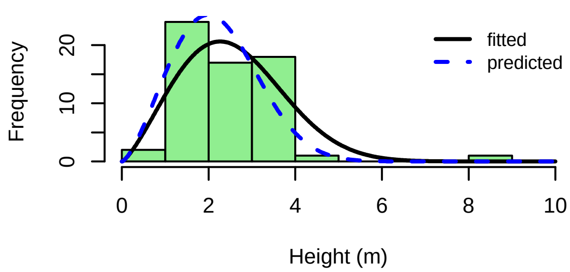

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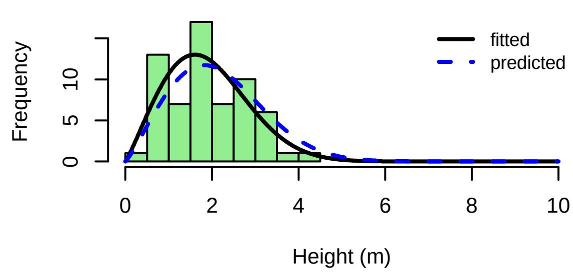

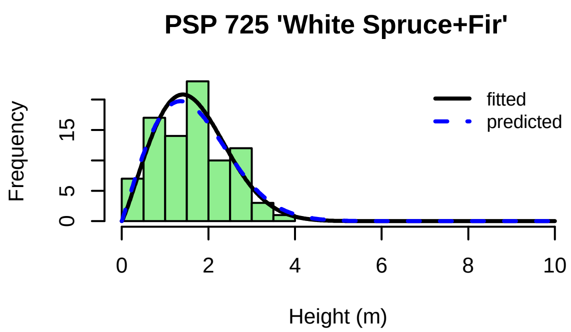
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Frequency
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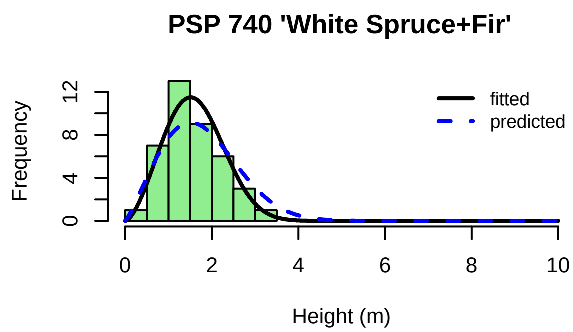
fitted
predicted
0 2 4 6 8 10
Height (m)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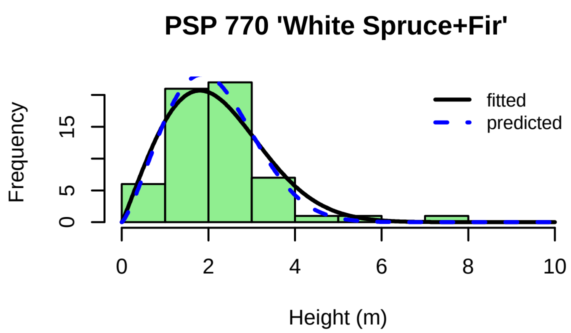
fitted
predicted
0 2 4 6 8 10
Height (m)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fitted
predicted
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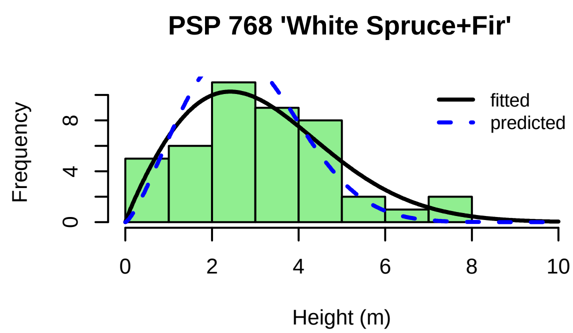
Height (m)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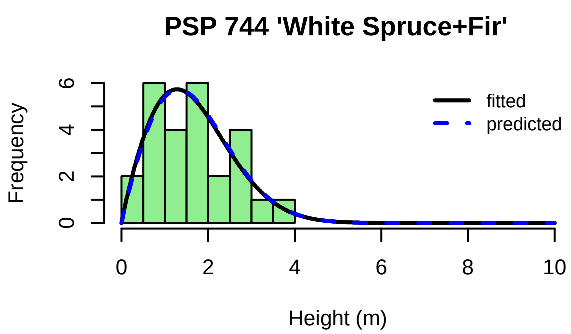
Frequency
0 4 8
fitted
predicted
0 2 4 6 8 10
Height (m)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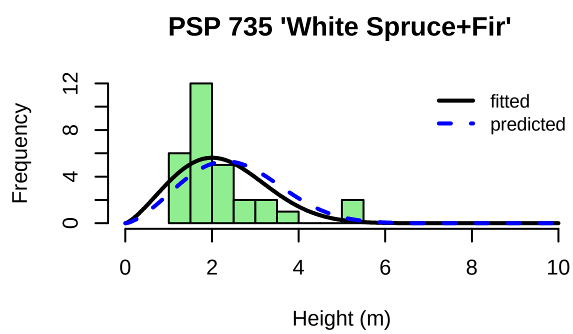
Frequency
0 2 4 6
fitted
predicted
0 2 4 6 8 10
Height (m)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Frequency
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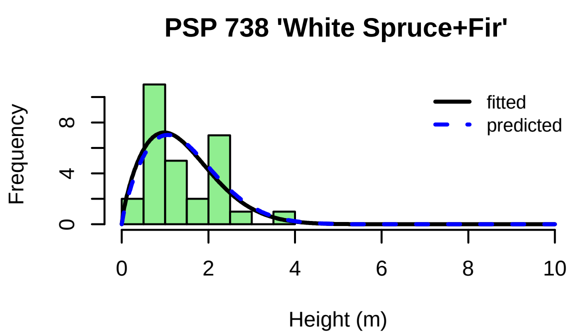
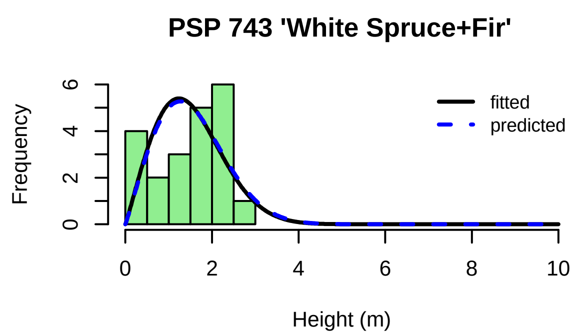
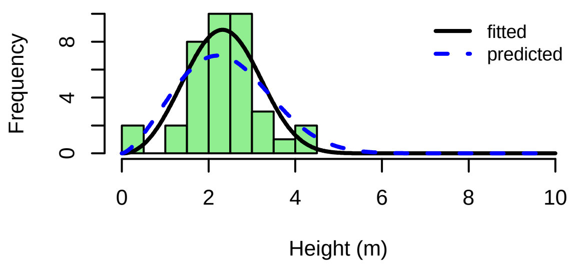
fitted
predicted
0 2 4 6 8 10
Height (m)


PSP 738 'White Spruce+Fir'
Frequency
0 4 8
fitted
predicted
0 2 4 6 8 10
Height (m)


PSP 743 'White Spruce+Fir'
Frequency
0 2 4 6
fitted
predicted
0 2 4 6 8 10
Height (m)

PSP 726 'White Spruce+Fir'



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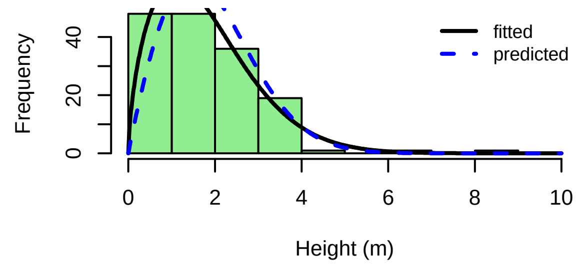

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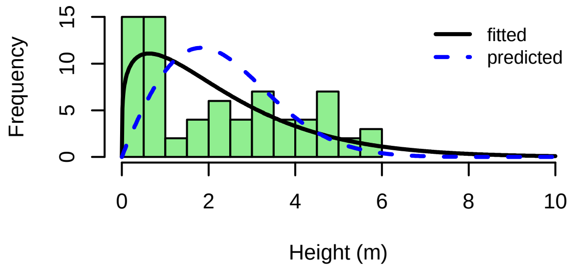
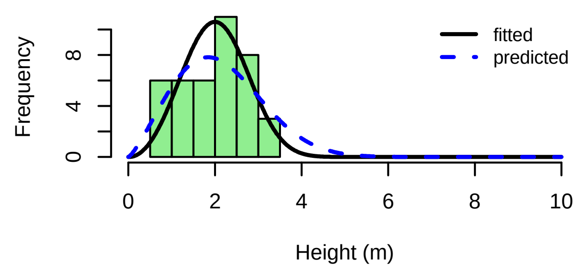


PSP 749 'White Spruce+Fir'



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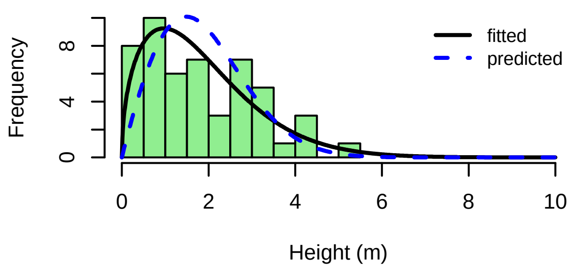

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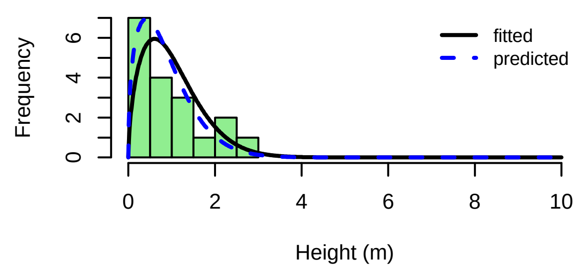
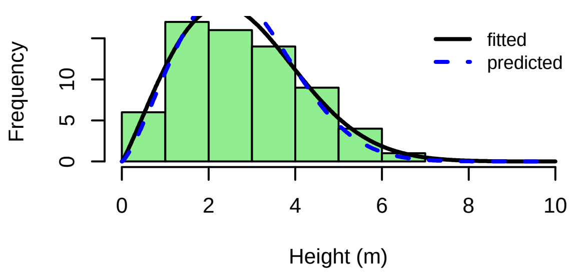
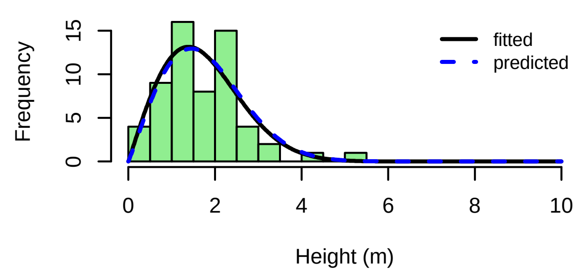
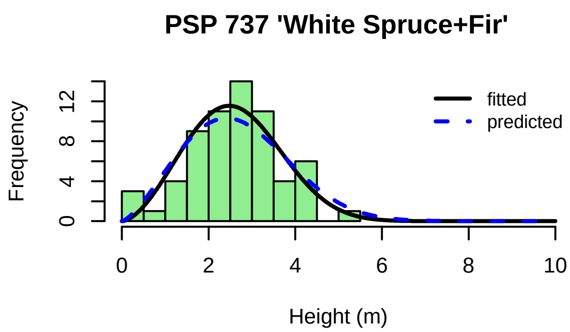


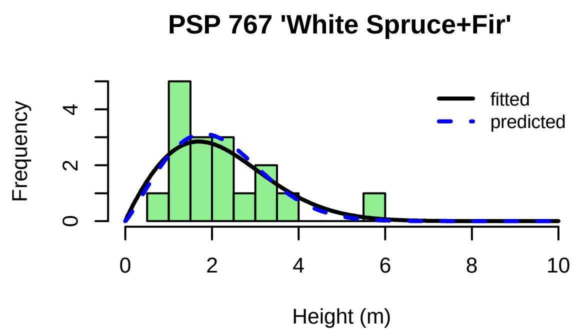
PSP 736 'White Spruce+Fir'

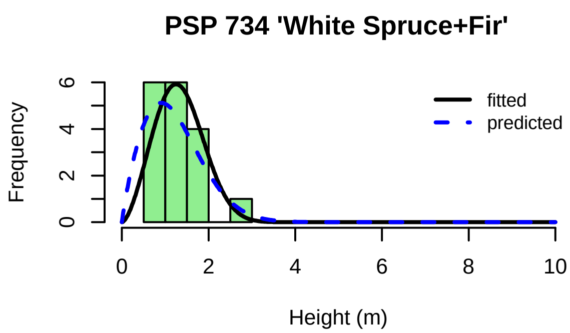


PSP 750 'White Spruce+Fir'




PSP 737 'White Spruce+Fir'
fitted
predicted
Frequency
Height (m)


PSP 767 'White Spruce+Fir'
fitted
predicted
Frequency
Height (m)


PSP 734 'White Spruce+Fir'
fitted
predicted
Frequency
Height (m)

Appendix VIII – Gap Area Loss Calculations

MEMO

To: Gitte Grover, Alberta-Pacific Forest Industries Inc.

From: Dan Jensen[1]

Cc: Katrina Froese

Date: May 5, 2014

Re: Calculation of Gap Area Loss for the Alberta-Pacific FMA Area

Overview

The Mixedwood Growth Model (MGM) simulates individual tree growth based on stand productivity and the competitive relationships between trees. A gap area loss increases competitive effect between trees to account for the fact that the model assumes trees are evenly distributed across stands, but in fact gaps exist and trees are actually growing more densely in the remaining areas.

This memo documents the methods used to determine gap area loss factors for MGM using AVI and LiDAR point cloud data for 8 primary cover types from a sample of100 townships within the Alberta-Pacific Forest Management Agreement (FMA) area.

Data sets:

Five data sets were acquired to determine canopy cover across the AlPac FMA.

LiDAR data was acquired from AlPac in February of 2014. These layers are part of the Provincial LiDAR database. These layers consist of:

- Unfiltered LiDAR point cloud data. The dates in which this data was acquired ranged from July 2006 to June 2011. Leaf on/Leaf off status was inconsistent. The average point cloud density was approximately 1.6 hits per square meter across the landscape.
- The bare earth digital elevation model created from the point cloud. These files were acquired in ASCII format at a resolution of 1.00 square meters.

GIS layers for the area were acquired from ForCorp in Feb 2014. These layers consisted of the following:

- Alberta Vegetation Inventory data for the 100 townships analysed.
- Land use dispositions for these townships that show the surface activities across the FMA.
- Seismic Lines: A layer with all of the seismic exploration conducted across the FMA. This was represented as line features.

[1] M.Sc. Candidate, Department of Renewable Resources, University of Alberta.

Township Selection:

To estimate the percentage of gap area for each cover type a random sample of townships across the entire AlPac forest management area was conducted. To do this, the FMA was broken up into three sections: north consisting of FMUs S11, S14, S22, A14 and A15; southeast consisting of L1, L3, L8 and L11; and southwest consisting of L2, S7 and S18. Near equal proportions of townships were selected from each of the three sections.

Landbase Exclusions

With the large amount of land development within the FMA since the last AVI update, areas under new dispositions were excluded from the analysis, as were seismic lines. This landbase update was conducted in three steps:

- The land use layer acquired from ForCorp which consisted of all dispositions within the FMA was erased from AVI within ArcMap 10.1.
- The amount of area affected by seismic lines was estimated. Specifically, the seismic line layer provided by ForCorp, consisted of linear features without widths, such that widths were added to each feature to estimate area. This was done with ArcMap 10.1 by buffering each line feature (2.5 meters on either side of the line) to create polygons. A 5 meter width was selected as it correlated reasonably well with widths that could be sensed by the LiDAR point cloud.
- The new seismic polygons layer was then combined with the modified AVI layer using an Identity procedure. This allowed for the seismic lines to be considered within each polygon, and for the AVI polygon areas to be updated.

Stand Selection within each township:

Gap area was estimated for eight unique cover types in the FMA. These cover types include aspen dominant (Aw), aspen dominant with a spruce understory (AwSwU), Aspen/Spruce mixtures where aspen was a leading species (AwSx), White spruce dominant (Sw), Spruce/Aspen mixtures where spruce is the leading species (SxAw), black spruce dominant (Sb), jack pine dominant (Pj), and jack pine mixtures (MxPj). To select these cover types the AVI category “YLD_2015” was used.

With only a portion of polygons within these stand categories being merchantable and having a likelihood of being harvested, criteria were set for each cover type to select stands that could potentially be harvested. These criteria are:

AVI Category	Aw	Aw/Sw	AwSx	SxAw	Sw	Sb	Pj	MxPj
Landbase	Forested	Forested	Forested	Forested	Forested	Forested	Forested	Forested
TPR	G,M,F	G,M,F	G,M,F	G,M,F	G,M,F	G	G,M	G,M
Density	B,C,D	B,C,D	A,B,C,D	A,B,C,D	A,B,C,D	A,B,C,D	A,B,C,D	A,B,C,D
Height	>18 m	>18 m	>18 m	>18 m	>18 m	>18 m	>18 m	>18 m
Age	60<x<100	60<x<100	60<x<100	80<x<140	80<x<140	80<x<140	80<x<140	80<x<140
Sp1 and Sp2	No Lt	No Lt	No Lt	No Lt	No Lt	No Lt	No Lt	No Lt
Mod1	Null	Null	Null	Null	Null	Null	Null	Null
Description	Null	Null	Null	Null	Null	Null	Null	Null

Within the Inventory, Sp1 and Sp2 related to the leading and second leading species within the polygon and Mod1 refers to any modifications that may have occurred within the polygon including harvesting. The description category was added to the AVI attributes table during the Identity procedure. This category identifies any areas that were classified as seismic lines. These areas were also excluded from the area used in this procedure. In addition, for polygons to be included in this analysis, the polygons had to be at least 2.0 hectares after seismic and land use exclusions were considered.

LiDAR Processing

The raw LiDAR was processed using the FUSION/LDV software package developed by Bob McGaughey of the USDA-FS (Version 3.41, Pacific Northwest Research Station, 28 January 2014). To process tracts of data larger than a single township, production level methods were required using the LTK Processor. This involved taking the supplied LiDAR tiles and breaking them into smaller buffered tiles. Once the processing was completed the buffers around each tile were clipped to create a single seamless landscape.

With the bare earth surface digital elevation model (DEM) already supplied, a canopy height model (CHM) was created from the point cloud. This process involved the use of the CanopyModel, ClipDTM, MergeDTM and DTM2ASCII tools in the FUSION software package. These tools do the following:

The CanopyModel tool takes the raw point cloud and normalizes the points to the bare earth surface. Using the DEM as a reference, the canopy points are extracted to create a surface raster of the canopy. Any points classed as outliers (points above 35 meters) are removed from data set, and the maximum value within each pixel is used to reduce the bias towards height underestimation. For Aspen leading strata (Aw, AwSx, Aw/Sw) the raster resolution was 2 m^2. For conifer leading strata (Sw, SxAw, Sb, Pj, PjMix) the raster resolution is 3 m^2. The buffers from the resulting tiles were then clipped using the ClipDTM process. The tiles were then merged using MergeDTM and converted into an ASCII format using DTM2ASCII so that they can be imported into ArcGIS.

GIS Analysis and Canopy Cover Estimation

Using the raster model, we were able to estimate the canopy cover within the selected polygon boundaries. The basic steps involved the selection of AVI polygons for a target stratum from the AVI tiles and clipping these polygons from the CHM raster. The clipped CHMs are then reclassified into canopy and gap pixels based on the merchantability criteria presented above. From there, the raster was converted to a vector polygon using simplified polygons and an identity function. This associated the canopy and gap polygons with the AVI polygon layer created earlier (seismic and land use layers removed).

This process was carried out in ArcMap 10.1 following these steps: The target AVI polygons were selected from the AVI layer, which had been updated for both land use and seismic exploration, based on the selection criteria listed above using the “Select by Attributes” tool. Following the selection, the raster created from the LiDAR point cloud was clipped to these selected polygons using the Clip tool within the Data Management tool box. To clip the raster to the boundaries of the selected polygons the “use input features for clipping geometry” function was selected.

With these polygons selected the resulting raster was then reclassified using the “Reclassify” tool to differentiate each pixel as either part of the canopy or part of the gap fraction. Reclassification was based on merchantability criteria, which was based on a height estimate for trees that could produce at least one merchantable log. For this analysis, 13 meters was used as the merchantability criteria, as a result, all pixels with height values below 13 meters were reclassified as gaps, and those above 13 meters were reclassified as canopy.

Following the reclassification of the pixels, the raster was converted into a vector using the “Raster to Polygon” tool. This step allows for a simplification from pixel counts into polygons of like pixels, and allows for simpler calculations of polygon areas. Following this step, the newly created vector was combined with the AVI data using the “Identity” tool which associate these newly created polygons with the AVI polygon numbers and the resulting attributes tables were exported.

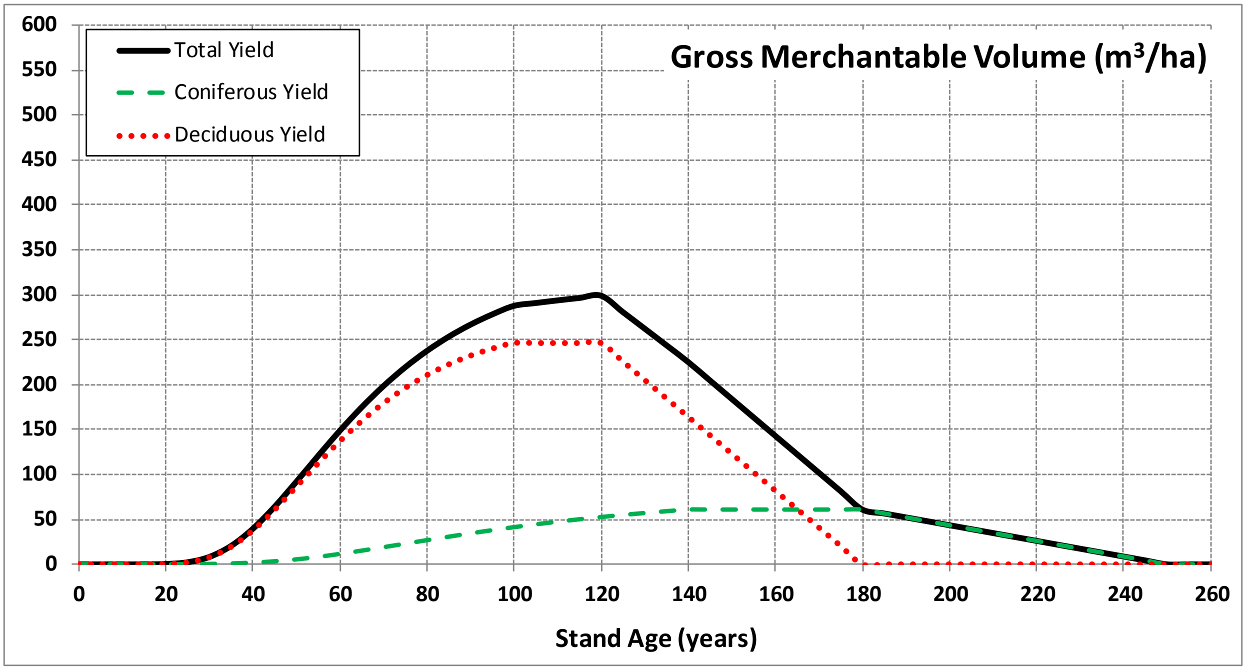
The attributes tables were imported into Microsoft Excel so that the polygon areas data could be summarized   Gap areas too small to hold merchantable trees, those smaller than 30 m^2, were removed from the gap area sums and counted as part of the canopy area. The 30m^2 area was chosen based on a supporting study that identified the approximate occupancy area a single tree, in stands similar to those sample here, require under full to near full stocking. Summary tables provided the total canopy area and gap fraction area which were then used to calculate the weighted percentages for each fraction across the sample of townships. These final values are presented in the table below.

Cover Type	Polygons Analysed (n)	Canopy Area (ha)	Gap Area (ha)	Weighted Canopy Area (%)	Weighted Gap Area (%)
Aw	1697	12444.80	3162.60	79.74	20.26
AwSx	282	1115.69	375.13	74.84	25.16
AwSwU	738	6154.00	1581.10	79.56	20.41
SwAw	1062	4602.19	1906.35	70.71	29.29
Sw	1762	6933.48	3036.77	69.54	30.46
Sb	9	17.31	11.50	60.09	39.91
Pj	588	1332.11	2689.26	66.87	33.13
PjMix	293	1316.44	393.17	77.00	23.00

These procedures were based on methods used in MSc research conducted by Dan Jensen (2014, not yet published). Further justifications can be explored within this thesis.

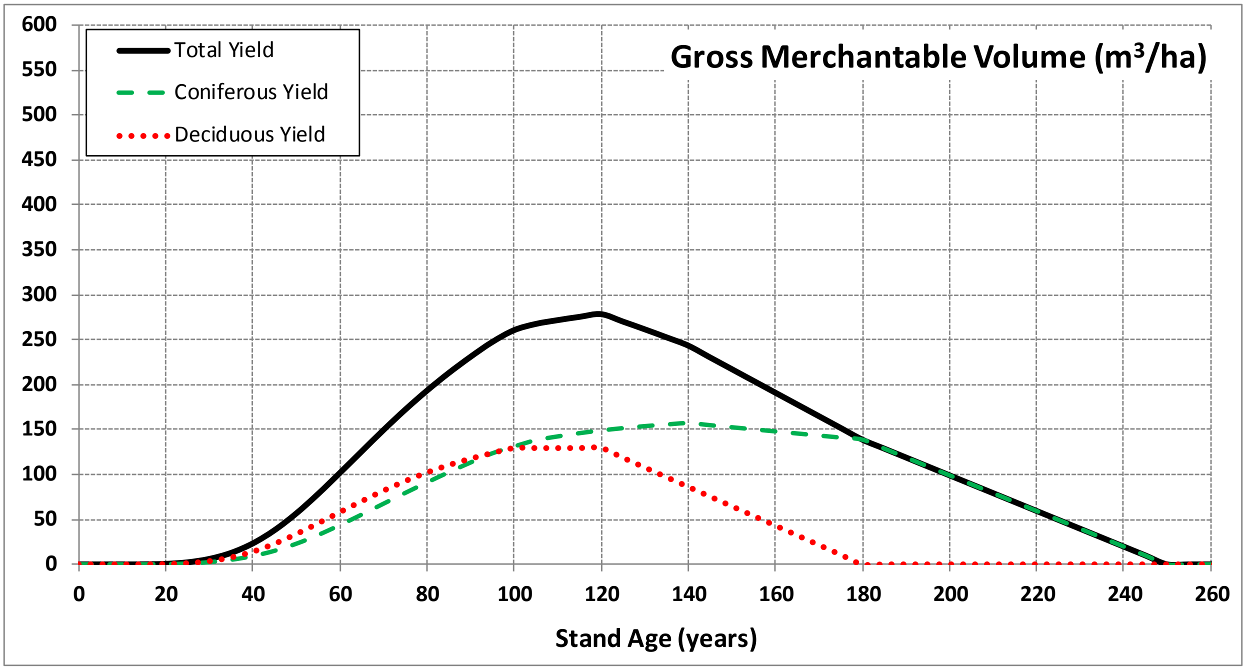
Appendix IX – Area-Weighted Yield Curves

Broad Cover Group:	D	TYPE	Deciduous	Area (ha):	874,324



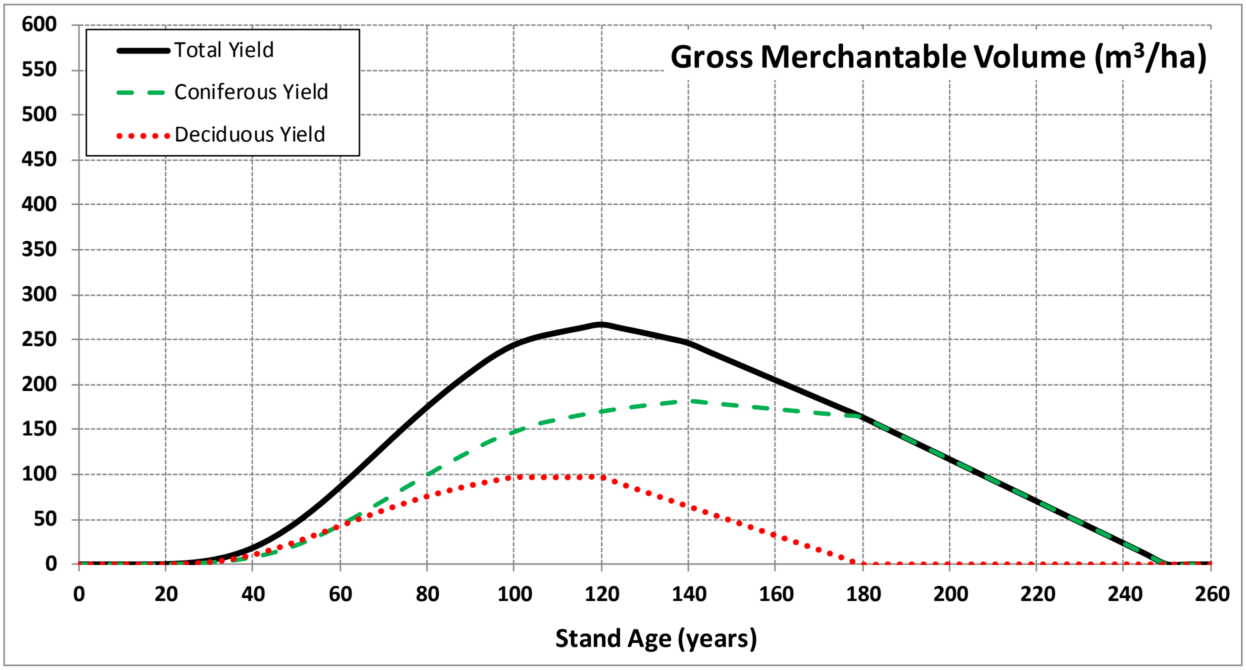
Stand Age	Merchantable Volume (m³/ha)			Mean Annual Increment (m³/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.3	0.0	0.4	0.02	0.00	0.02
30	7.7	0.5	8.2	0.26	0.02	0.27
40	37.5	1.9	39.4	0.94	0.05	0.99
50	86.2	5.5	91.8	1.72	0.11	1.84
60	137.0	11.6	148.6	2.28	0.19	2.48
70	179.2	19.1	198.3	2.56	0.27	2.83
80	210.6	26.9	237.5	2.63	0.34	2.97
90	232.3	34.5	266.7	2.58	0.38	2.96
100	246.3	41.4	287.7	2.46	0.41	2.88
110	246.3	47.5	293.7	2.24	0.43	2.67
120	246.3	52.7	299.0	2.05	0.44	2.49
130	205.2	57.1	262.4	1.58	0.44	2.02
140	164.2	61.0	225.2	1.17	0.44	1.61
150	123.1	61.0	184.1	0.82	0.41	1.23
160	82.1	61.0	143.1	0.51	0.38	0.89
170	41.0	61.0	102.0	0.24	0.36	0.60
180	0.0	61.0	61.0	0.00	0.34	0.34
190	0.0	52.3	52.3	0.00	0.28	0.28
200	0.0	43.6	43.6	0.00	0.22	0.22
210	0.0	34.8	34.8	0.00	0.17	0.17
220	0.0	26.1	26.1	0.00	0.12	0.12
230	0.0	17.4	17.4	0.00	0.08	0.08
240	0.0	8.7	8.7	0.00	0.04	0.04
250	0.0	0.0	0.0	0.00	0.00	0.00

Broad Cover Group:	DC	TYPE	Coniferous	Area (ha):	108,477



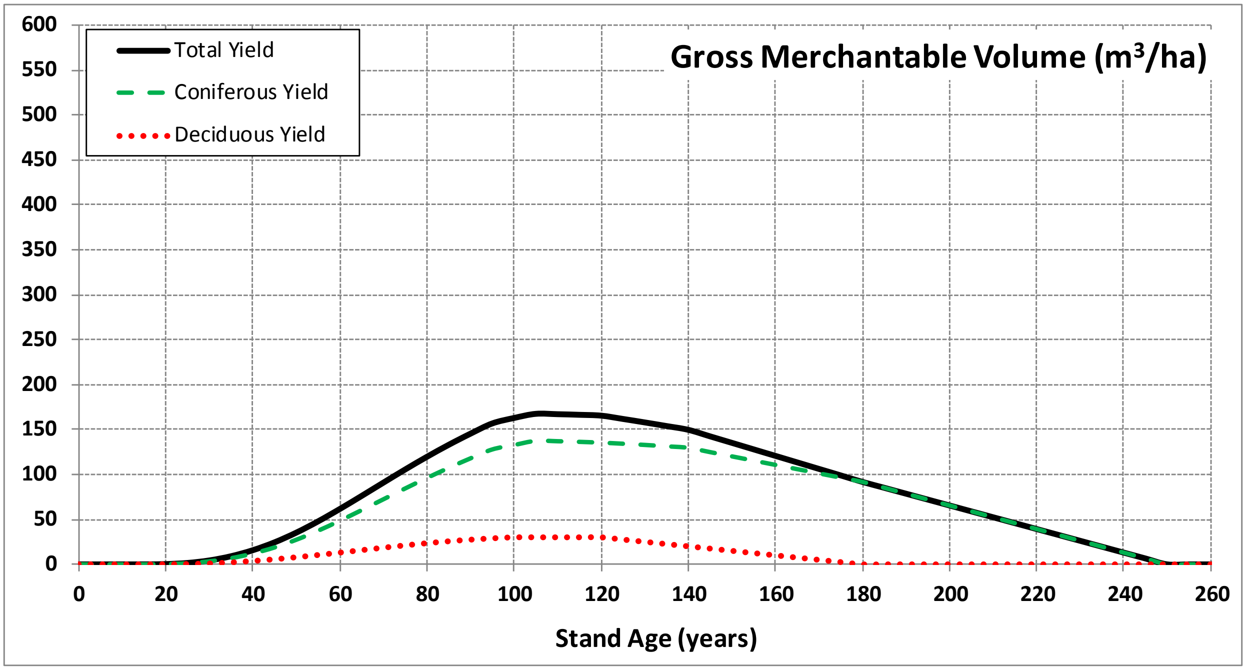
Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.3	0.2	0.5	0.01	0.01	0.03
30	3.5	2.5	6.0	0.12	0.08	0.20
40	14.1	9.2	23.2	0.35	0.23	0.58
50	33.7	22.9	56.6	0.67	0.46	1.13
60	58.0	43.6	101.7	0.97	0.73	1.69
70	81.9	67.4	149.3	1.17	0.96	2.13
80	102.1	91.1	193.3	1.28	1.14	2.42
90	117.6	113.3	230.9	1.31	1.26	2.57
100	129.4	131.1	260.6	1.29	1.31	2.61
110	129.4	142.3	271.7	1.18	1.29	2.47
120	129.4	149.0	278.4	1.08	1.24	2.32
130	107.8	153.8	261.6	0.83	1.18	2.01
140	86.3	157.2	243.4	0.62	1.12	1.74
150	64.7	152.6	217.3	0.43	1.02	1.45
160	43.1	148.0	191.1	0.27	0.92	1.19
170	21.6	143.4	164.9	0.13	0.84	0.97
180	0.0	138.8	138.8	0.00	0.77	0.77
190	0.0	118.9	118.9	0.00	0.63	0.63
200	0.0	99.1	99.1	0.00	0.50	0.50
210	0.0	79.3	79.3	0.00	0.38	0.38
220	0.0	59.5	59.5	0.00	0.27	0.27
230	0.0	39.6	39.6	0.00	0.17	0.17
240	0.0	19.8	19.8	0.00	0.08	0.08
250	0.0	0.0	0.0	0.00	0.00	0.00

Broad Cover Group:	CD	TYPE	Coniferous	Area (ha):	87,140



Stand Age	Merchantable Volume (m³/ha)			Mean Annual Increment (m³/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.1	0.2	0.3	0.01	0.01	0.02
30	2.3	2.0	4.4	0.08	0.07	0.15
40	10.5	7.8	18.3	0.26	0.20	0.46
50	25.2	21.2	46.4	0.50	0.42	0.93
60	42.6	43.4	86.0	0.71	0.72	1.43
70	60.1	70.8	130.9	0.86	1.01	1.87
80	75.5	99.3	174.8	0.94	1.24	2.19
90	87.8	125.9	213.7	0.98	1.40	2.37
100	96.8	147.2	244.1	0.97	1.47	2.44
110	96.8	161.1	257.9	0.88	1.46	2.34
120	96.8	170.0	266.9	0.81	1.42	2.22
130	80.7	176.7	257.4	0.62	1.36	1.98
140	64.6	181.7	246.3	0.46	1.30	1.76
150	48.4	177.2	225.7	0.32	1.18	1.50
160	32.3	172.8	205.1	0.20	1.08	1.28
170	16.1	168.3	184.4	0.09	0.99	1.08
180	0.0	163.8	163.8	0.00	0.91	0.91
190	0.0	140.4	140.4	0.00	0.74	0.74
200	0.0	117.0	117.0	0.00	0.59	0.59
210	0.0	93.6	93.6	0.00	0.45	0.45
220	0.0	70.2	70.2	0.00	0.32	0.32
230	0.0	46.8	46.8	0.00	0.20	0.20
240	0.0	23.4	23.4	0.00	0.10	0.10
250	0.0	0.0	0.0	0.00	0.00	0.00

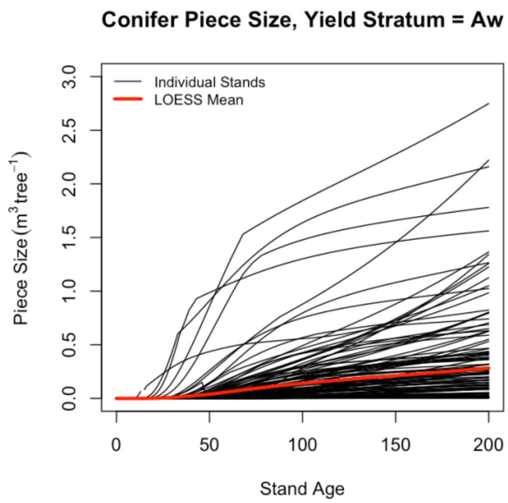
Broad Cover Group:	C	TYPE	Coniferous	Area (ha):	543,940



Stand Age	Merchantable Volume (m^3/ha)			Mean Annual Increment (m^3/ha/year)		
	Deciduous	Coniferous	Total	Deciduous	Coniferous	Total
10	0.0	0.0	0.0	0.00	0.00	0.00
20	0.1	0.2	0.3	0.00	0.01	0.02
30	1.0	3.4	4.3	0.03	0.11	0.14
40	3.7	12.0	15.7	0.09	0.30	0.39
50	7.9	27.4	35.3	0.16	0.55	0.71
60	13.1	48.5	61.6	0.22	0.81	1.03
70	18.5	72.4	90.9	0.26	1.03	1.30
80	23.5	96.1	119.7	0.29	1.20	1.50
90	27.5	117.9	145.4	0.31	1.31	1.62
100	30.1	132.8	162.9	0.30	1.33	1.63
110	30.1	137.0	167.1	0.27	1.25	1.52
120	30.1	135.4	165.5	0.25	1.13	1.38
130	25.1	132.9	158.0	0.19	1.02	1.22
140	20.1	129.7	149.7	0.14	0.93	1.07
150	15.0	120.2	135.3	0.10	0.80	0.90
160	10.0	110.7	120.8	0.06	0.69	0.75
170	5.0	101.3	106.3	0.03	0.60	0.63
180	0.0	91.8	91.8	0.00	0.51	0.51
190	0.0	78.7	78.7	0.00	0.41	0.41
200	0.0	65.6	65.6	0.00	0.33	0.33
210	0.0	52.4	52.4	0.00	0.25	0.25
220	0.0	39.3	39.3	0.00	0.18	0.18
230	0.0	26.2	26.2	0.00	0.11	0.11
240	0.0	13.1	13.1	0.00	0.05	0.05
250	0.0	0.0	0.0	0.00	0.00	0.00

Appendix X – Piece Size Curves

Stand	Merchantable Piece Size (m³/tree)																	
	Aw		AwU		AwSx		SxAw		Sw		SbFM		SbG		PjMx		Pj	
Age	Dec	Con	Dec	Con	Dec	Con	Dec	Con	Dec	Con	Dec	Con	Dec	Con	Dec	Con	Dec	Con
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.02
30	0.02	0.01	0.01	0.00	0.02	0.02	0.02	0.01	0.02	0.01	0.00	0.00	0.00	0.02	0.00	0.02	0.00	0.05
40	0.05	0.02	0.04	0.01	0.04	0.05	0.04	0.02	0.05	0.03	0.00	0.01	0.00	0.04	0.01	0.04	0.01	0.08
50	0.10	0.04	0.09	0.03	0.06	0.09	0.06	0.04	0.07	0.06	0.01	0.01	0.00	0.06	0.03	0.07	0.02	0.11
60	0.15	0.06	0.14	0.06	0.10	0.13	0.09	0.07	0.09	0.11	0.01	0.01	0.01	0.07	0.05	0.11	0.02	0.14
70	0.22	0.08	0.20	0.09	0.13	0.16	0.13	0.11	0.12	0.16	0.01	0.02	0.01	0.08	0.08	0.14	0.03	0.17
80	0.29	0.10	0.26	0.12	0.18	0.19	0.17	0.16	0.16	0.21	0.01	0.02	0.02	0.09	0.11	0.16	0.04	0.20
90	0.38	0.12	0.33	0.15	0.22	0.22	0.21	0.20	0.19	0.25	0.01	0.03	0.03	0.10	0.15	0.19	0.05	0.24
100	0.46	0.14	0.40	0.18	0.26	0.26	0.25	0.24	0.23	0.30	0.01	0.04	0.03	0.12	0.19	0.22	0.05	0.28
110	0.55	0.16	0.48	0.21	0.31	0.30	0.30	0.28	0.26	0.34	0.01	0.04	0.04	0.14	0.23	0.25	0.06	0.32
120	0.65	0.17	0.56	0.24	0.35	0.33	0.34	0.32	0.29	0.38	0.01	0.05	0.04	0.15	0.26	0.28	0.06	0.36
130	0.74	0.18	0.63	0.26	0.40	0.37	0.38	0.36	0.31	0.42	0.01	0.06	0.04	0.17	0.30	0.32	0.07	0.41
140	0.83	0.20	0.71	0.29	0.43	0.41	0.42	0.40	0.33	0.47	0.00	0.06	0.04	0.19	0.33	0.36	0.07	0.47
150	0.93	0.21	0.78	0.31	0.47	0.45	0.46	0.45	0.34	0.51	0.00	0.07	0.03	0.21	0.35	0.40	0.07	0.52
160	1.02	0.23	0.85	0.34	0.49	0.49	0.49	0.50	0.34	0.56	0.00	0.09	0.03	0.23	0.37	0.45	0.07	0.59
170	1.10	0.24	0.92	0.37	0.52	0.54	0.51	0.55	0.34	0.61	0.00	0.10	0.02	0.25	0.39	0.50	0.06	0.66
180	1.18	0.25	0.98	0.40	0.53	0.58	0.52	0.60	0.35	0.67	0.00	0.11	0.02	0.28	0.40	0.56	0.06	0.74
190	1.26	0.27	1.02	0.43	0.56	0.63	0.53	0.66	0.35	0.73	0.00	0.13	0.02	0.31	0.41	0.62	0.06	0.82
200	1.32	0.28	1.07	0.46	0.59	0.69	0.52	0.72	0.35	0.79	0.00	0.14	0.01	0.34	0.41	0.68	0.05	0.91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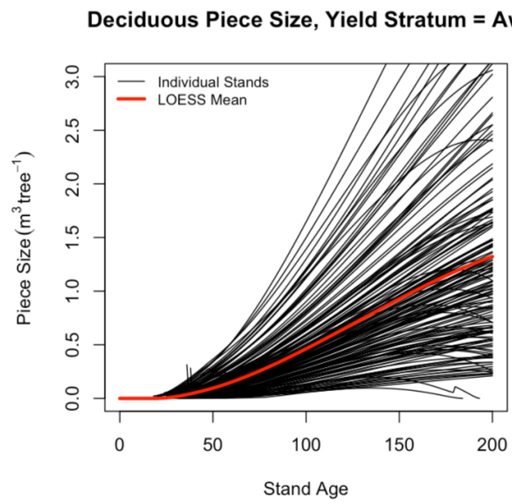
Individual Stands
LOESS Mean
Piece Size (m^3 tree^{-1})
Stand Age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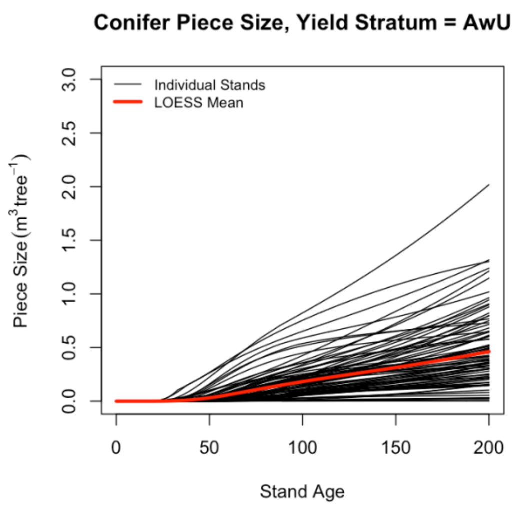
Individual Stands
LOESS Mean
Piece Size (m^3 tree^{-1})
Stand Age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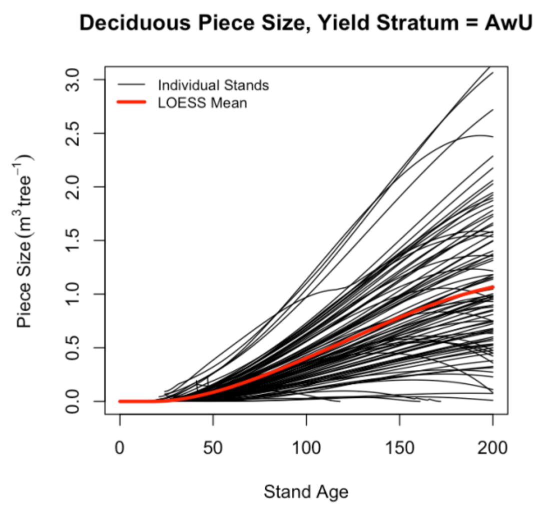
Individual Stands
LOESS Mean
Piece Size (m^3 tree^{-1})
Stand Age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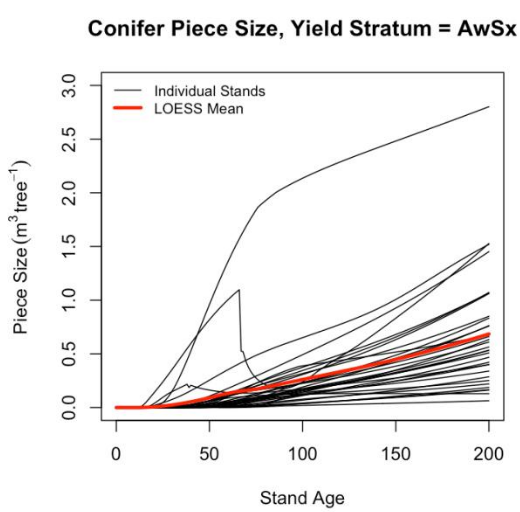
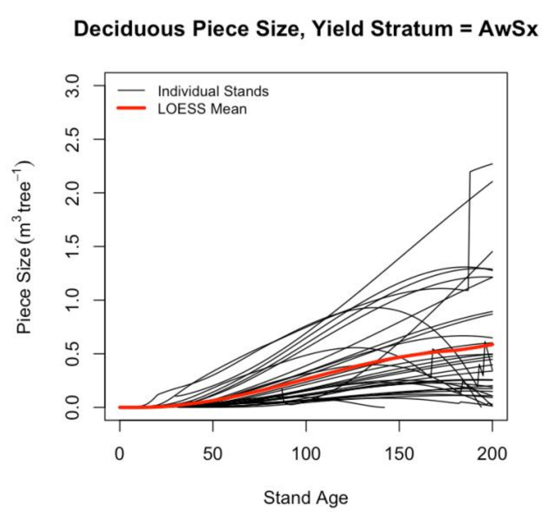
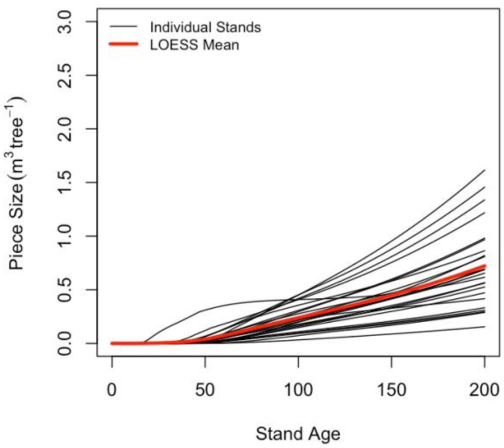
Individual Stands
LOESS Mean
Piece Size (m^3 tree^{-1})
Stand Age


Conifer Piece Size, Yield Stratum = AwSx
Individual Stands
LOESS Mean
Piece Size (m^3 tree^{-1})
Stand Age


Deciduous Piece Size, Yield Stratum = AwSx
Individual Stands
LOESS Mean
Piece Size (m^3 tree^{-1})
Stand Age

Conifer Piece Size, Yield Stratum = SxAw



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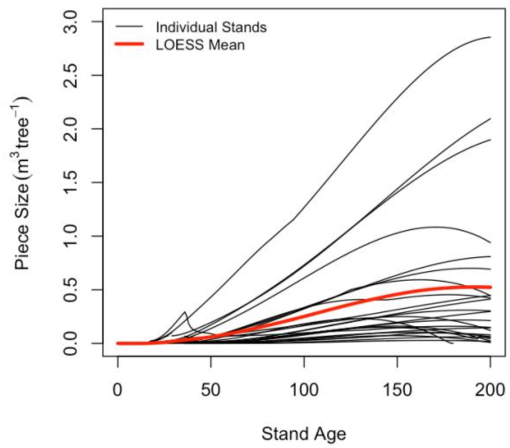

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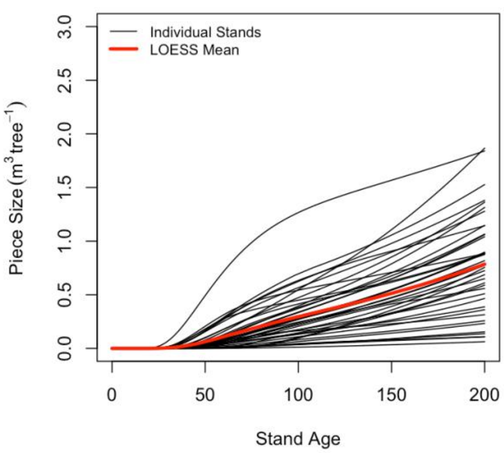

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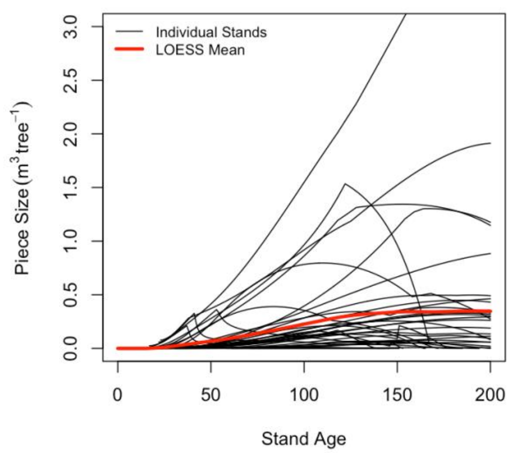
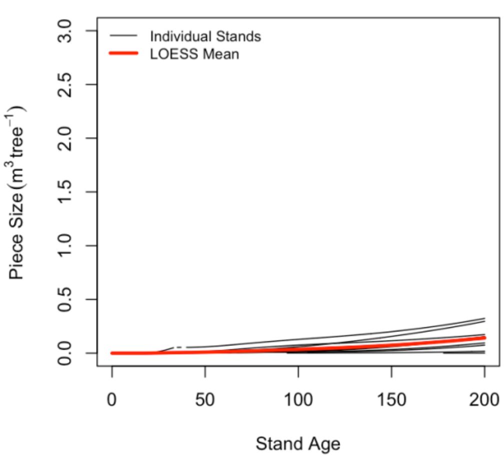
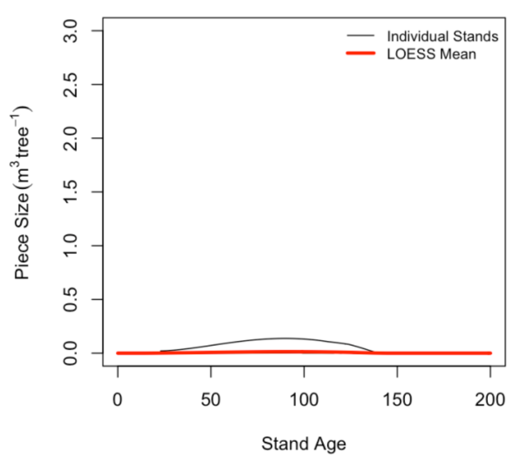
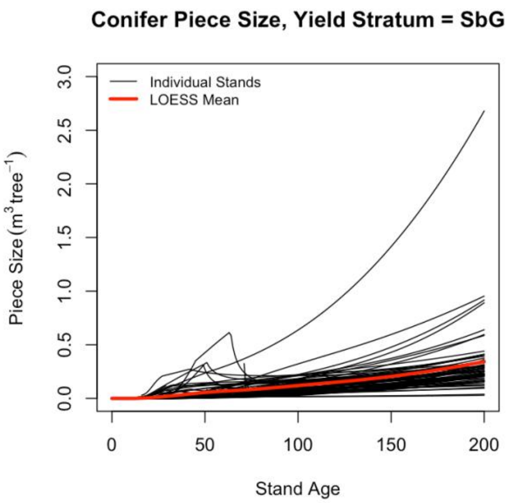


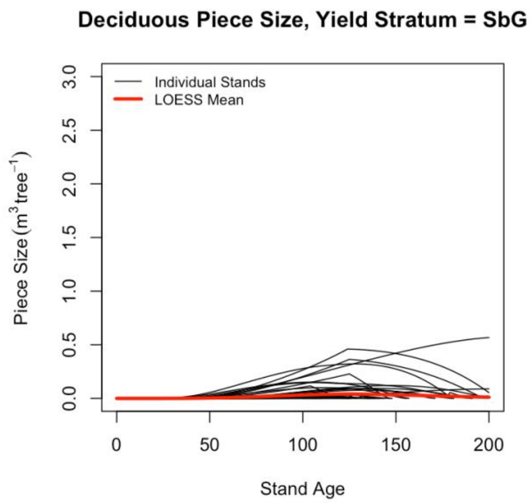
Conifer Piece Size, Yield Stratum = SbFM



Deciduous Piece Size, Yield Stratum = SbFM




Conifer Piece Size, Yield Stratum = SbG
Individual Stands
LOESS Mean
Piece Size (m³ tree⁻¹)
Stand Age
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
50
100
150
200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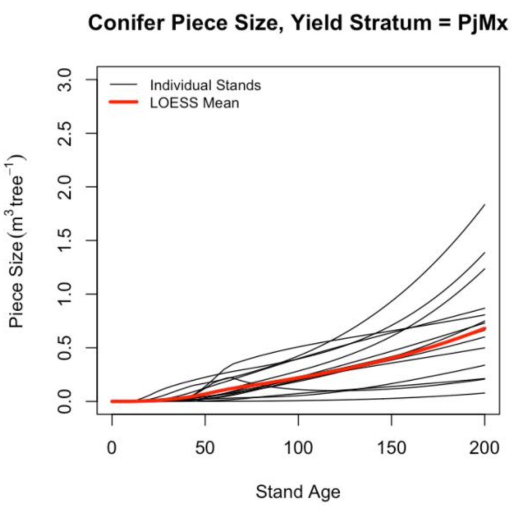
Individual Stands
LOESS Mean
Piece Size (m³ tree⁻¹)
Stand Age
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
50
100
150
200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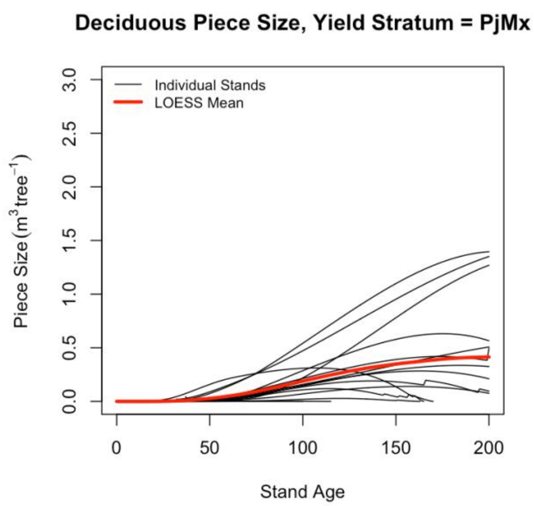
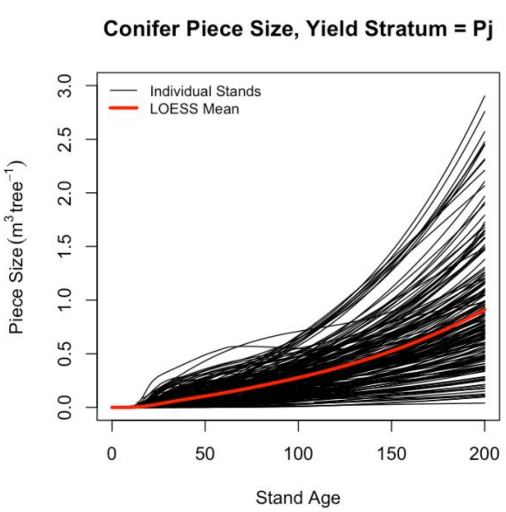
Individual Stands
LOESS Mean
Piece Size (m³ tree⁻¹)
Stand Age
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
50
100
150
200


Deciduous Piece Size, Yield Stratum = PjMx
Individual Stands
LOESS Mean
Piece Size (m³ tree⁻¹)
Stand Age
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
50
100
150
200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Individual Stands
LOESS Mean
Piece Size (m³ tree⁻¹)
Stand Age
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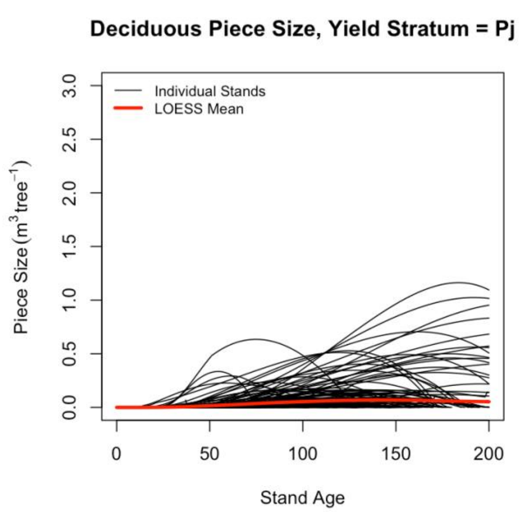
0.5
1.0
1.5
2.0
2.5
3.0
0
50
100
150
200


Deciduous Piece Size, Yield Stratum = Pj
Individual Stands
LOESS Mean
Piece Size (m³ tree⁻¹)
Stand Age
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
50
100
150
200

For additional information contact:

Dave Cheyne, Management Forester
Alberta-Pacific Forest Industries Inc.
P.O. Box 8000
Boyle, AB T0A 0M0

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