Long-term studies to support mixedwood management in western Canada

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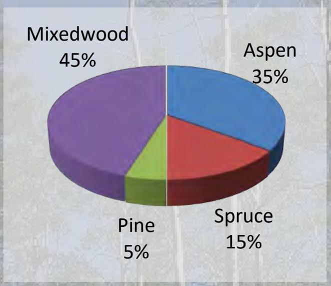
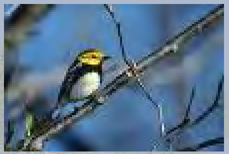
Mixedwoods

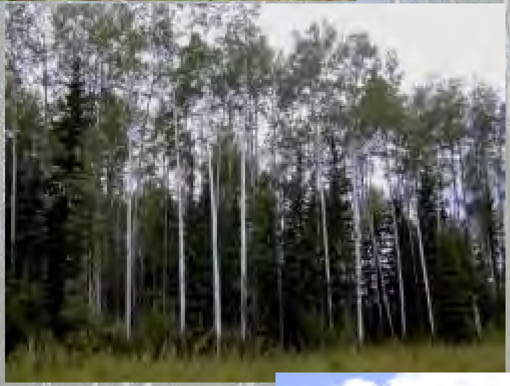
- Mixtures of aspen and white spruce are an important component of the natural landscape in the Boreal Plains (it is the dominant type on upland sites in the Boreal Mixedwoods of Alberta).
- Important source of wood fibre.
- Important to biodiversity (supported by stand and landscape level mix).
- Productivity and yields potentially higher in mixtures.
- Aspen reduces leader weevil and frost injury on young white spruce and suppresses growth of competing grasses.
- Mixedwoods are potentially more resilient than pure stands and mixtures carry less risk.





Successional Considerations

- Codominant mixtures of spruce and aspen occur in a mid-successional window
  - <60 – Aspen dominated with spruce in understory or spruce regenerating
  - Age 60-140+ classic mixedwoods
  - >140 – increasing conifer dominance or reversion to "young" aspen
- We can use time to create desired mixedwood structures (ie. work with succession)
  - But – if we are trying to do this in a short time frame (ie. 90 years) – then we may need to speed up development towards later successional stages (the spruce component is the issue).



Silviculture and Management in Boreal Mixedwoods

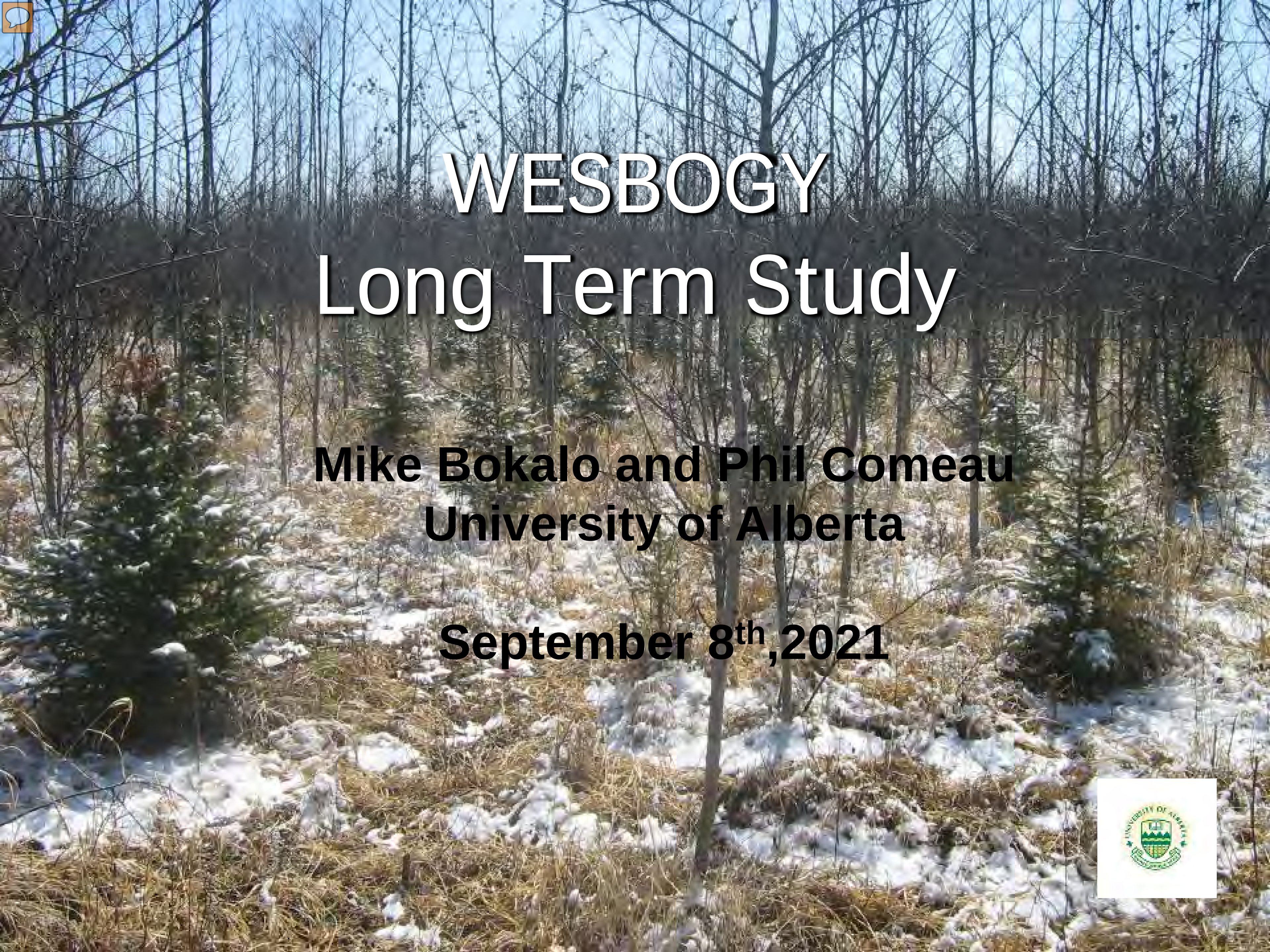
- Mixedwood regeneration and early tending
  - Mechanical site prep
  - Plant spruce, aspen natural regeneration
  - Herbicides – broadcast, patch, spot/radial
  - Brushing – spot
  - PCT
- Commercial Thinning with Understory Protection
- Partial cutting
  - Shelterwoods –uniform and group
  - Selection – uniform and group

Mixedwood Studies

- Focus of today’s presentation is on long-term studies focused on quantifying effects of stand composition and silviculture on stand dynamics, tree and stand growth, and yield.
- Purpose is to review major studies as part of a needs analysis for mixedwood management research being conducted by the Forest Growth Organization of Western Canada (FGrOW).
- Focus on projects that have been active during the past 10-15 years and with treatment areas sufficiently large (>0.10 ha) to support medium and long-term studies, most include PSP’s ≥0.04 ha.
- Studies supported by the Forest Growth Organization of Western Canada (FGrOW)
  - Western Boreal Growth and Yield Project (WESBOGY) Team (https://wesbogy.ualberta.ca/)
  - Mixedwoods Project Team (see Bergheim, Grover and Meredith. 2016. Mixedwood Management Association Historic Report: 2000-2015. March 2016)
- <u>Plus</u> studies established by CFS, GOA, U of A and others. Some going back decades, but to our knowledge these have not been maintained or remeasured.
- We apologize if we have missed any, and welcome input for additions to this list.

Value of long-term studies

- Tree growth is slow and dynamics happen over a long period in the boreal so need to collect data over a long period to document growth and yield outcomes (ideally to rotation, minimum 20+ years).
- Interactions and resulting dynamics may change over time, and effects of changes in temperature and drought may change over time. Long-term studies with regular measurements provide valuable information on how these changes influence stands in both the short and long-term. Continuing to monitor and measure these could be very valuable in adapting to climate change.
- Long-term data are useful in calibration and validation of growth models.
- Cost of establishment (ie. large measurement plots and large treatment plots) and remeasurements are important issues.



WESBOGY Long Term Study

Mike Bokalo and Phil Comeau
University of Alberta

September 8th,2021

WESBOGY Long Term Study
Aspen/Spruce Stand Development

- Advance our understanding of the dynamics of mixedwood stands following tending.
- Initiated in 1990, involved planting white spruce seedlings in recently clearcut areas where aspen regeneration had already been
- After a 5 year establishment phase, both the spruce and aspen were thinned to desired treatment densities
- The study uses a randomized block design with each agency setting up and maintaining one block of two installations;
- One installation on a superior site and one on a median site.
- Each installation consists of two replications of 15 plots representing the different combinations of spruce and aspen treatment densities.
- Today, the study includes a total of 615 plots in Alberta, British Columbia, Manitoba, Saskatchewan and the Northwest Territories.

WESBOGY Long Term Study Locations

Layout for each agency

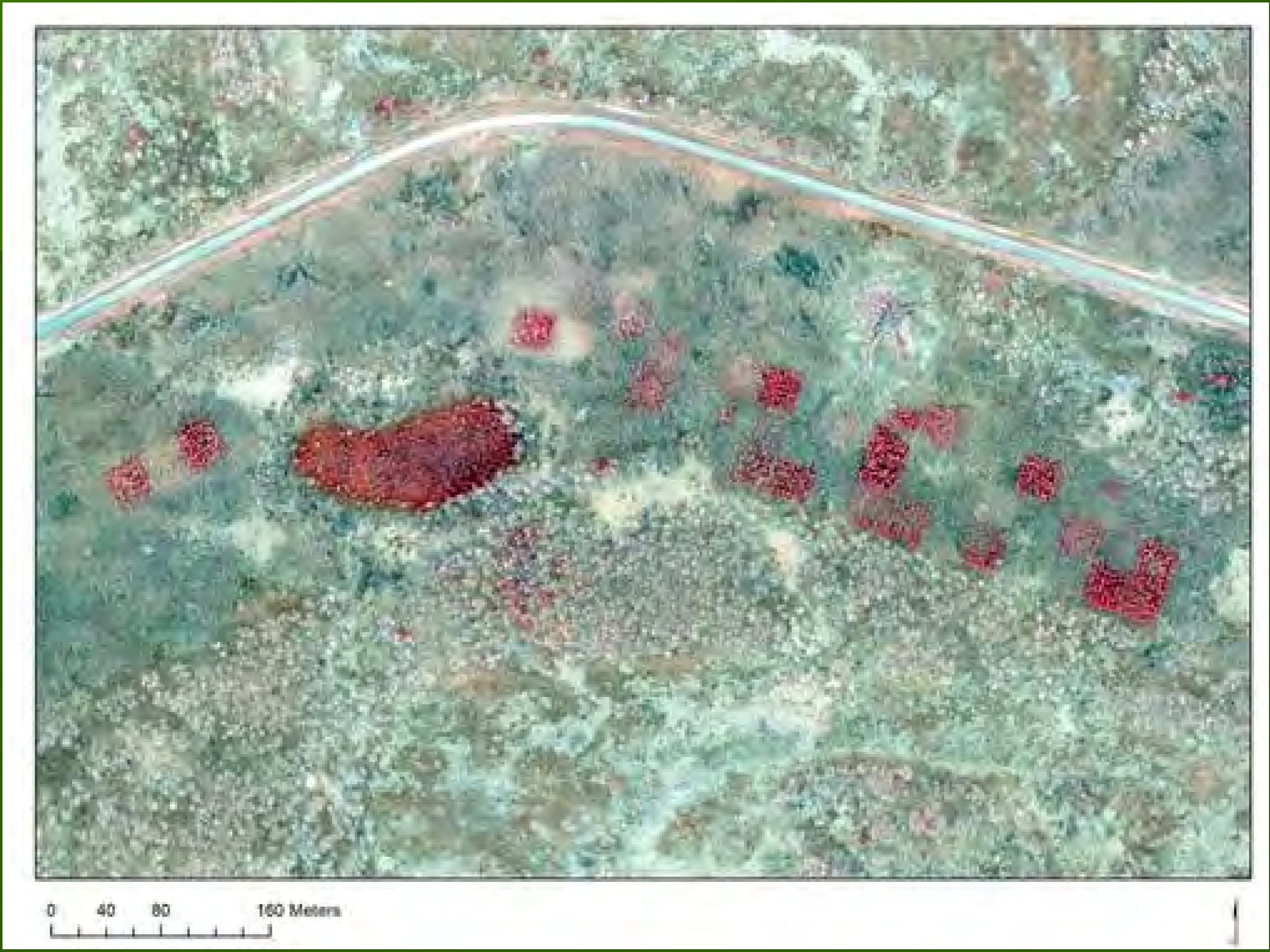
Randomized complete block design. 11 locations, 2 site classes (medium, superior), 2 replicate blocks per site class, 15 treatments in each block randomly assigned to plots.

Experimental Design for a block of plots

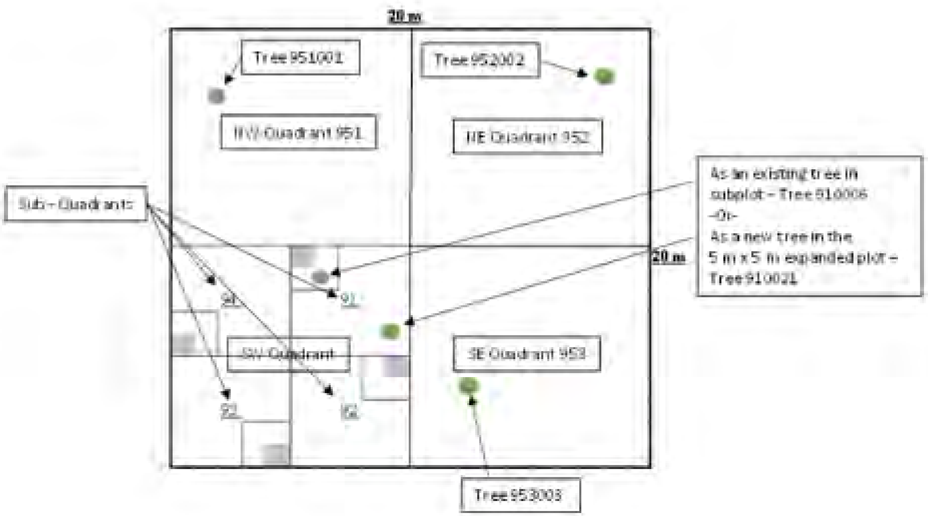
Replication	High Site Installation	Median Site Installation
1	15 plots	15 plots
2	15 plots	15 plots

Plot Numbers associated with Spruce and Aspen treatment densities

Sw\Aw	0	200	500	1500	4000	Natural
1000	1	2	3	4	5	6
500	7	8	9	10	11	12
0	x	x	x	13	14	15


0 40 80 160 Meters

LTS – Measurement Plot Layout



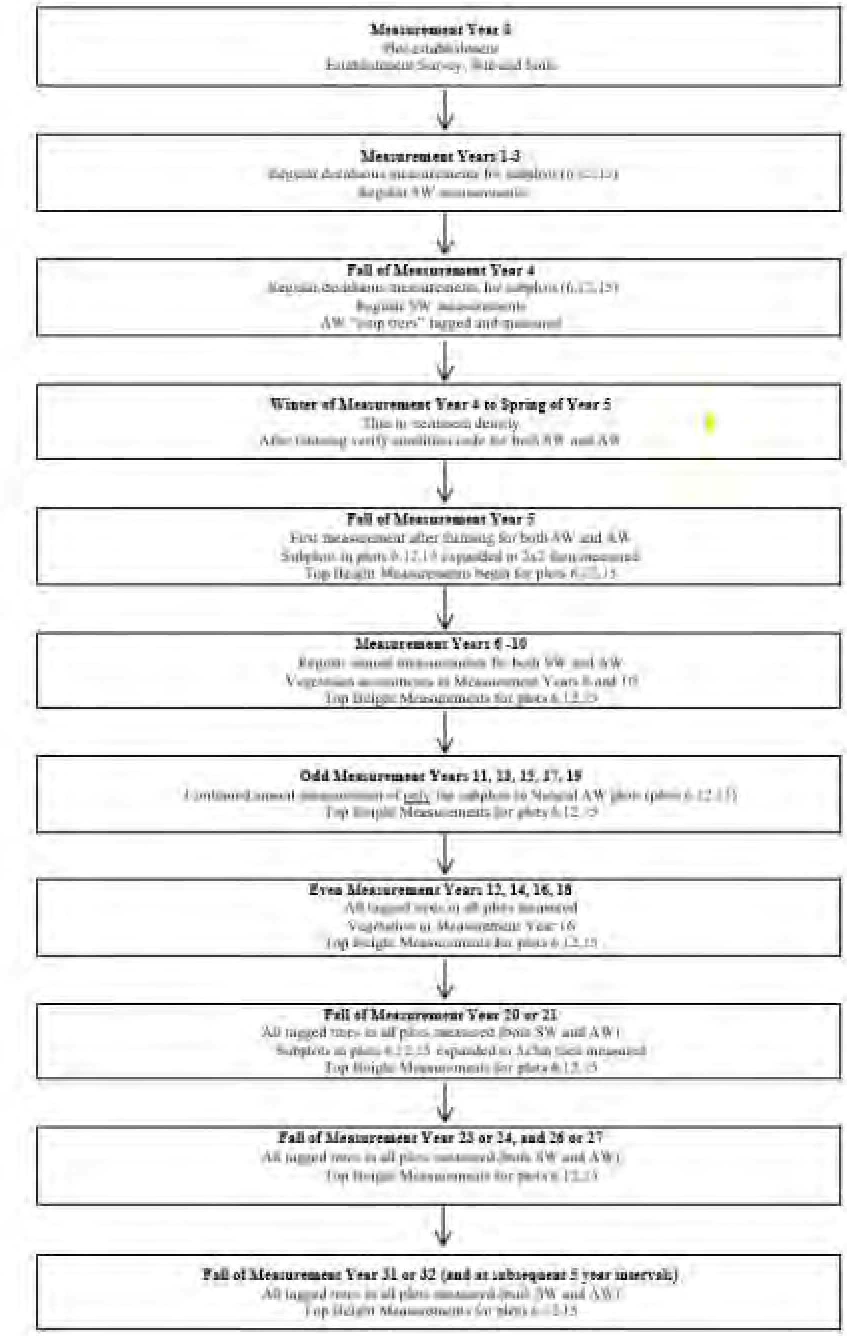
LTS Manual

Long Term Study (LTS) of growth and development of mixed stands of spruce and aspen

Experimental Design,
Data Collection and Database Maintenance Manual

March 26, 2021
Version 4.2

Prepared by:
Mike Bokalo, Susan Humphries and Phil Comeau



Timing of measurements relative to assessed measurement year.

LTS Database

- Access database by Agency
- Maintained at the U of A
- Members collect and submit measurement data
- Error checking
- Members access their data through online portal
  - Shared data/manuals/reports/publications
- Currently: ~763,000 tree records

WESBOGY Website

https://wesbogy.ualberta.ca/

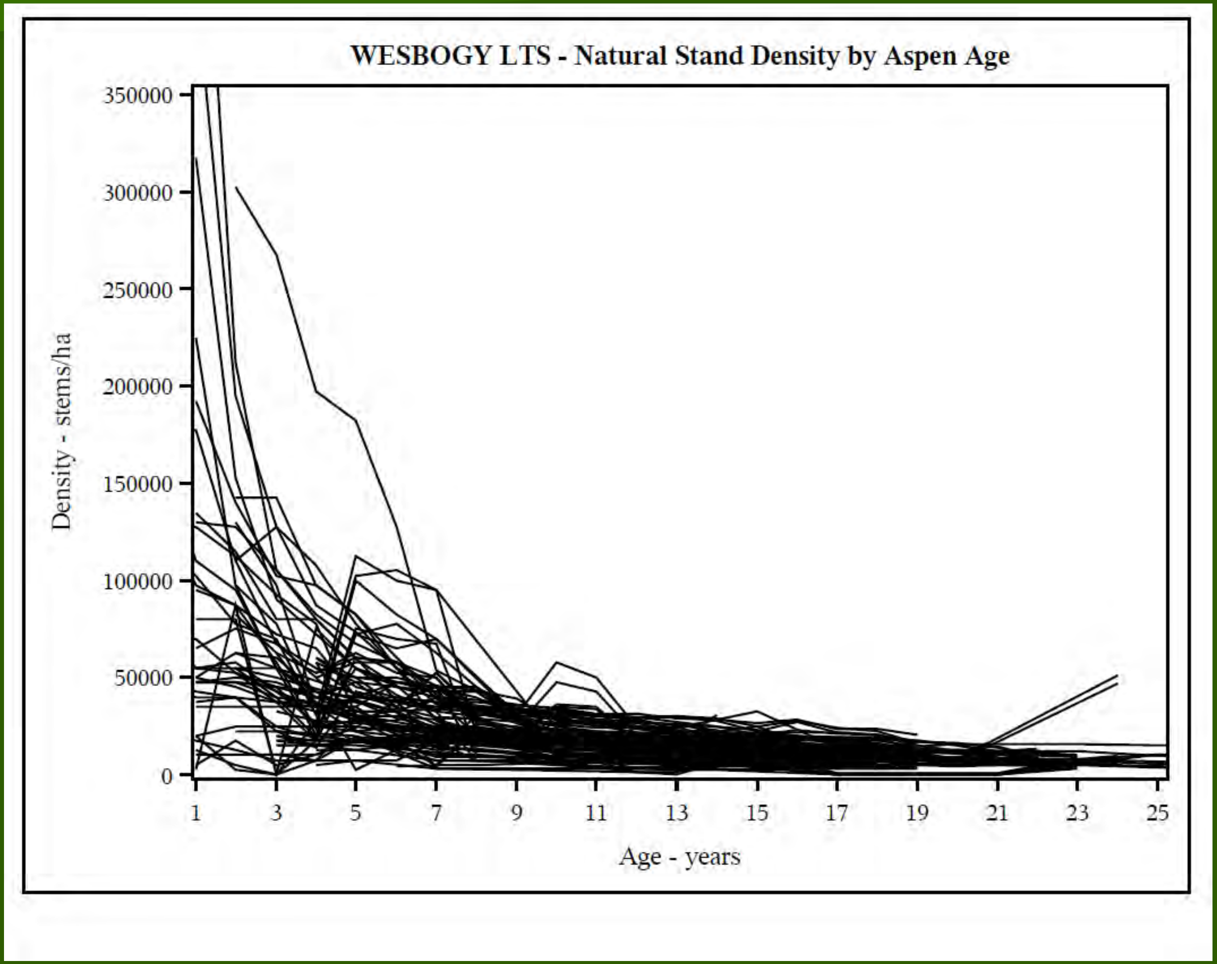
Current Measurement Status

Agency	Establishment Year	Next Measurement	Remeasurement Interval
ALP_MED	2001	21	2
ALP_SUP	1993	31	5
CFR_MED	2001	20	2
CFR_SUP	2000	23	3
Mer	1992	32	5
LPCDC	2000	23	3
LPCDC_SUP2	2003	21	2
LPCSR	1998	23	3
NWT	1993	X	X
SBR	1992	31	5
SPA	1990	31	5
AAF	1992	30	5
WFR	1992	32	5
WFR_SUP2	1994	30	5
WGP	1991	32	5

LTS - Research Questions

- Natural aspen mortality on untreated plots 6/12/15?
- Aspen treatment effect on aspen growth and yield?
- Aspen treatment effect on spruce growth and yield?
- What is the relationship between aspen density and spruce growth and yield?

Self-thinning of unthinned aspen [plots 6 and 12] (most are 5000 - 10000 sph at age 20)



ANOVA Dataset - LTS

- Aspen treatment effect on aspen growth and yield of oldest Agencies
- Aspen age 19/24 years
- 8 oldest agencies
  - SK, BR, NWT, WGP, AAF, WFR, MER, ALP

Mixed Model ANOVA – LTS Analysis

$$Y_{ijklm} = \mu + A_i + I_j + R_k(A*I)_{ij} + Aw_l + Sw_m + A_i*I_j + Aw_l*Sw_m + Aw_l*I_j + Sw_m*I_j + Aw_l*Sw_m*I_j + \varepsilon_{ijklm}$$

Y_{ijklm} = the response

μ = the overall mean

A_i = the random effect of i^th^ *agency*

I_j = the fixed effect of the j^th^ *installation*

$R_k(A*I)_{ij}$ = the random effect of the k^th^ replication nested within *agency* and *installation*

Aw_l = the fixed effect of the l^th^ *aspen treatment*

Sw_m = the fixed effect of the m^th^ *spruce treatment*

A_i*I_j = the random effect of the interaction between the i^th^ *agency* and j^th^ *installation*

Aw_l*Sw_m = the fixed effect of the interaction between the l^th^ *aspen treatment* and m^th^ *spruce treatment*

Aw_l*I_j = the fixed effect of the interaction between the l^th^ *aspen treatment* and j^th^ *installation*

Sw_m*I_j = the fixed effect of the interaction between the m^th^ *spruce treatment* and j^th^ *installation*

$Aw_l*Sw_m*I_j$ = the fixed effect of the interaction between the l^th^ *aspen treatment the* m^th^ *spruce treatment* and j^th^ *installa*

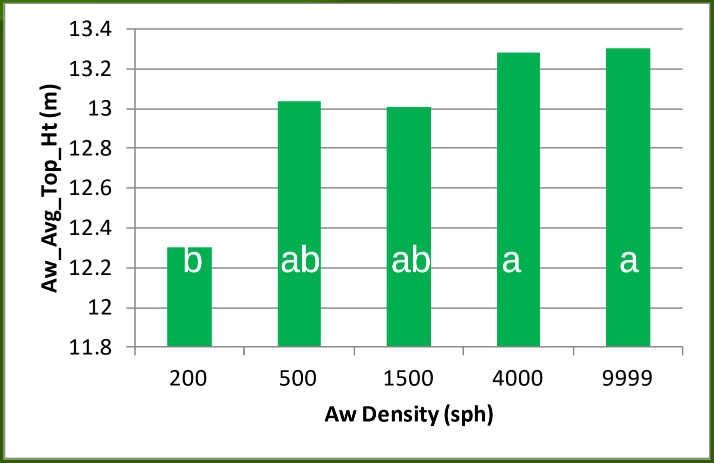
ε_{ijklm} = the residual

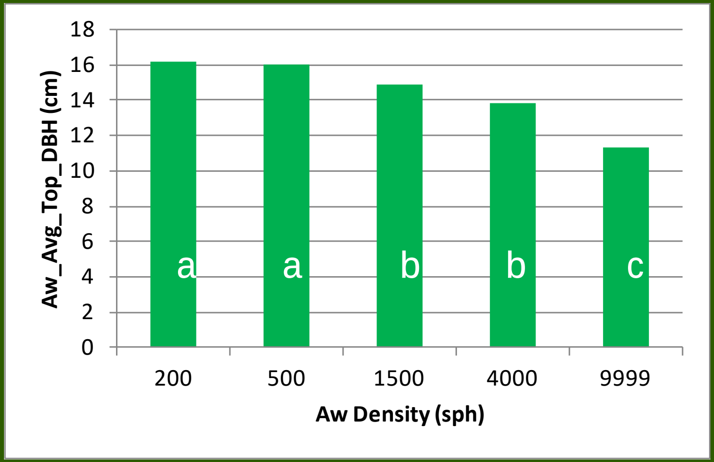
ANOVA - Thinning Effect on Aspen

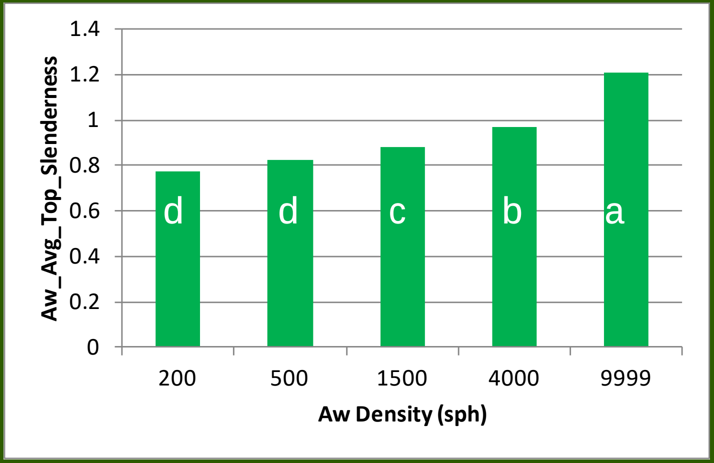
Source	df	HT P-value	DBH P-value	Slenderness P-value	CW P-value	HTLC P-value	BA P-value	VOL P-value
Agency (A)	7	-	-	-	-	-	-	-
Installation(I)	1	0.6755	0.4607	0.7033	0.5533	0.7571	0.9482	0.7535
Aspen Treatment Density (Aw)	4	**0.0102**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**
Spruce Planting Density (Sw)	1	0.6175	0.7623	0.7781	0.8839	0.9162	0.4169	0.4412
*A * I*	*5*	-	-	-	-	-	-	-
Replicate(A*I)	13	-	-	-	-	-	-	-
*Aw * Sw*	4	0.9016	0.6368	0.4349	0.4263	0.6618	0.9267	0.9305
*I*Aw*	4	0.3058	0.5354	**0.0358**	0.9729	0.4166	0.9647	0.9428
*I*Sw*	1	0.7564	0.6623	0.1837	0.9714	0.1575	0.478	0.9202
*I*Aw*Sw*	4	0.6793	0.826	0.1651	0.501	0.557	0.0957	0.2761
Residual Error	222	-	-	-	-	-	-	-
Total	266	-	-	-	-	-	-	-

Treatment Density	HT	DBH	Slenderness	CW	HTLC	BA	VOL
200	12.28b	16.14a	0.77d	2.16a	3.17d	3.49e	10.39e
500	13.03ab	16.04a	0.82d	2.23a	3.76c	6.46d	19.71d
1500	13ab	14.86b	0.88c	1.85b	4.24c	11.8c	37.03c
4000	13.3a	13.89b	0.96b	1.7b	5.25b	18.59b	60.1b
Natural	13.3a	11.31c	1.2a	1.39c	6.04a	23.03a	70.99a

WESBOGY LTS results – Aspen
letters indicate differences detected using Tukeys α=0.05 (8 agencies age 19/24)

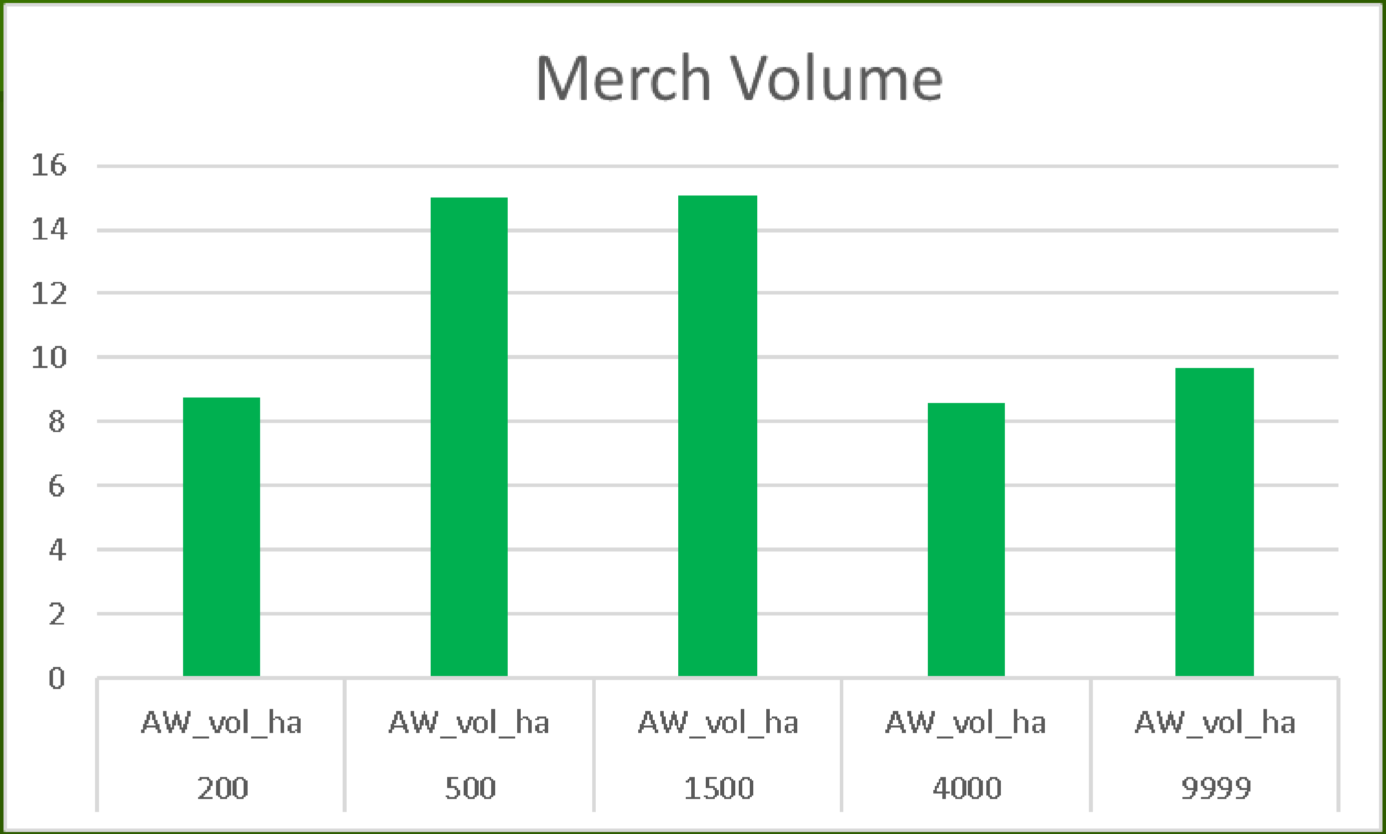






- Top height trees (largest diameter 100 trees/ha; 4 largest trees per 400 m^2 plot)
- N=268 plots
- Spruce density non-significant ($P>0.8$); Aw Density significant ($p<0.01$)

WESBOGY LTS - Aspen Merch Volume



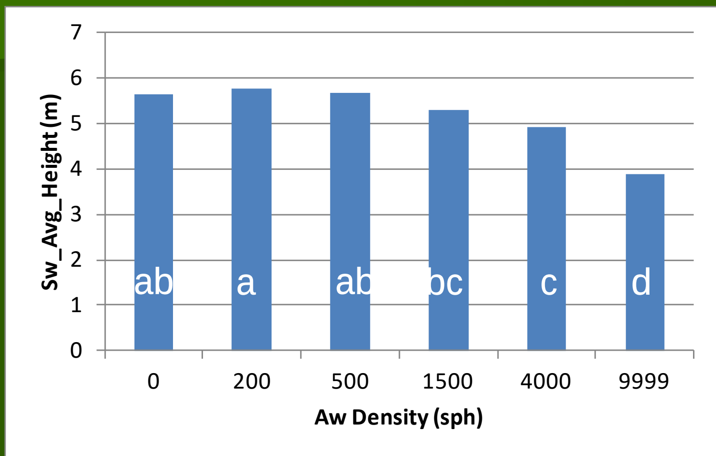
Aspen Thinning Effect on Spruce

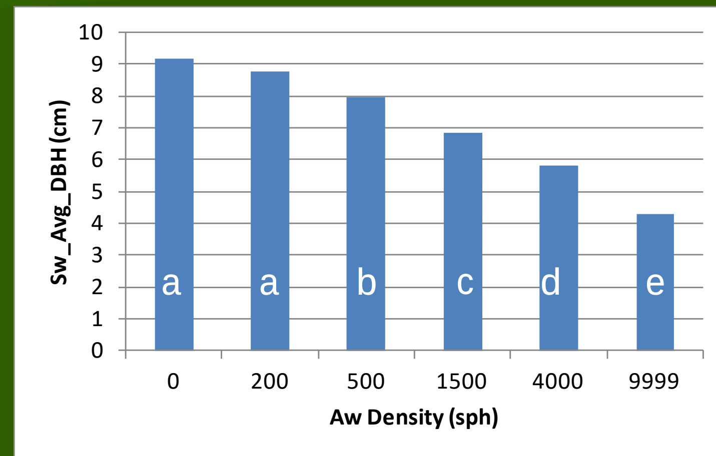
Source	df	HT P-value	DBH P-value	Slenderness P-value	CW P-value	HTLC P-value
Agency *(A)*	7	-	-	-	-	-
Installation*(I)*	1	0.805	0.5326	0.6089	0.6548	0.2907
Aspen Treatmer	5	**<.0001**	**<.0001**	**<.0001**	**<.0001**	0.3556
Spruce Planting	1	0.7433	**0.0163**	**0.0467**	**0.0073**	0.2204
*A * I*	*5*	-	-	-	-	-
Replicate*(A*I)*	13	-	-	-	-	-
*Aw * Sw*	5	0.5435	0.2855	0.3033	0.1297	0.1688
*I*Aw*	5	0.3602	0.5209	0.6164	0.5099	0.2545
*I*Sw*	1	0.9725	0.623	0.9797	0.9363	0.2561
*I*Aw*Sw*	5	0.6969	0.6971	0.755	0.7613	0.4251
Residual Error	274	-	-	-	-	-
Total	322	-	-	-	-	-

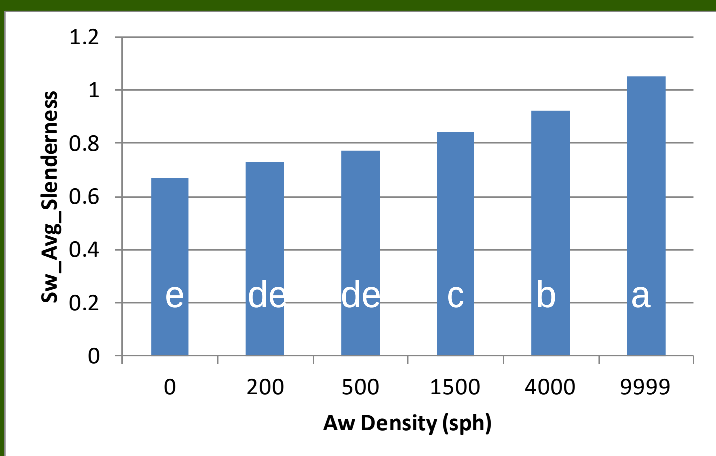
Treatment Densit	HT	DBH	Slenderness	CW	HTLC
0	5.79a	9.22a	0.67e	1.28a	0.55b
200	5.67ab	8.8a	0.73de	1.3a	0.57b
500	5.66ab	8.01b	0.76d	1.23ab	0.59ab
1500	5.31bc	6.86c	0.84c	1.16bc	0.61ab
4000	4.93c	5.84d	0.92b	1.07c	0.64a
Natural	3.89d	4.29e	1.04a	0.87d	0.67a

WESBOGY LTS results – White Spruce

letters indicate differences detected using Tukeys α=0.05
(8 agencies age 19/24)







- N=323 plots; 20-40 spruce per plot
- Spruce density non-significant for Ht (P>0.7); Aw Density significant (p<0.001)

SW - treatments at age 20

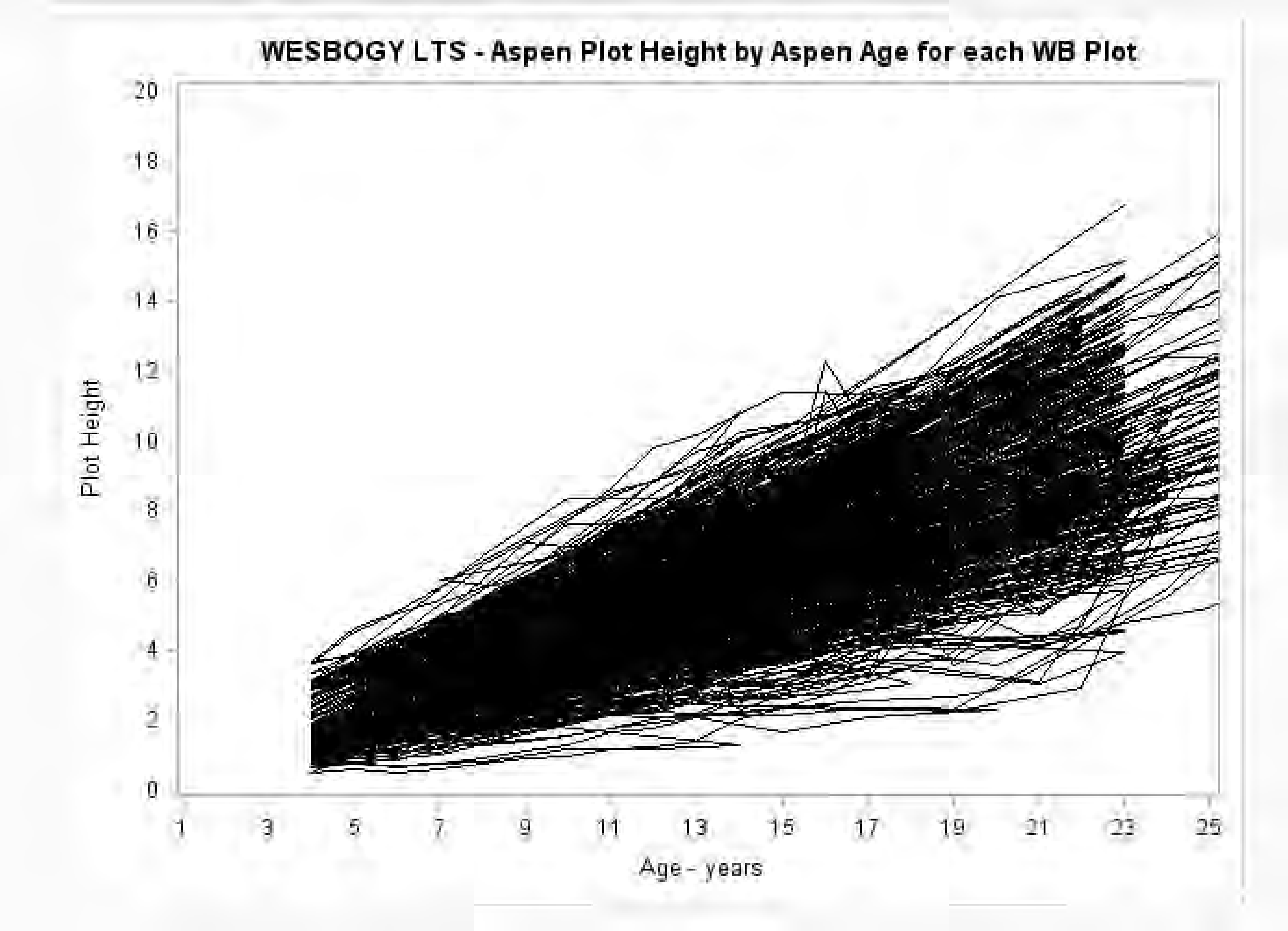
701 Sw=1000 sph
Aw=0 sph

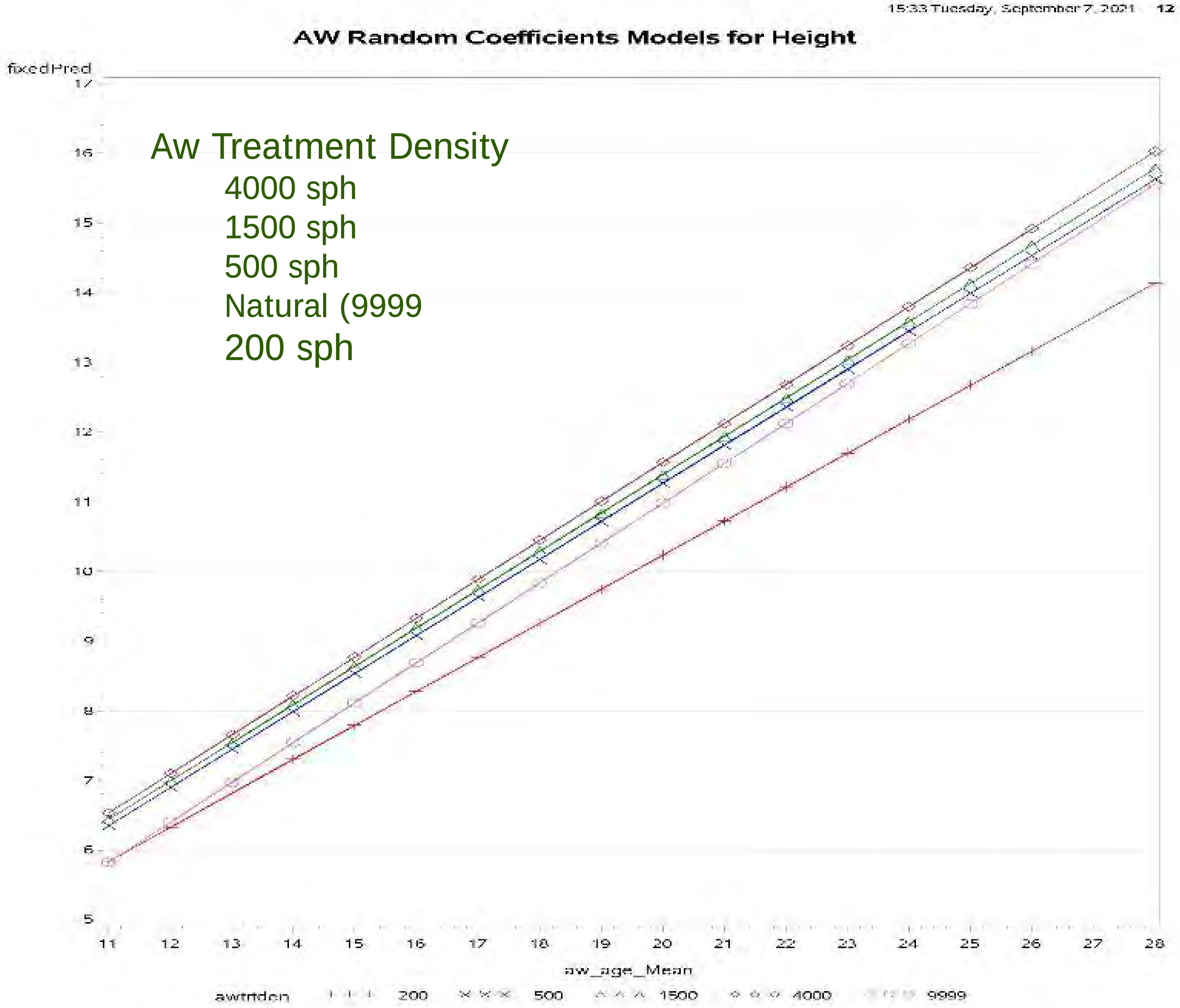
704
Sw=1000
Aw=1500

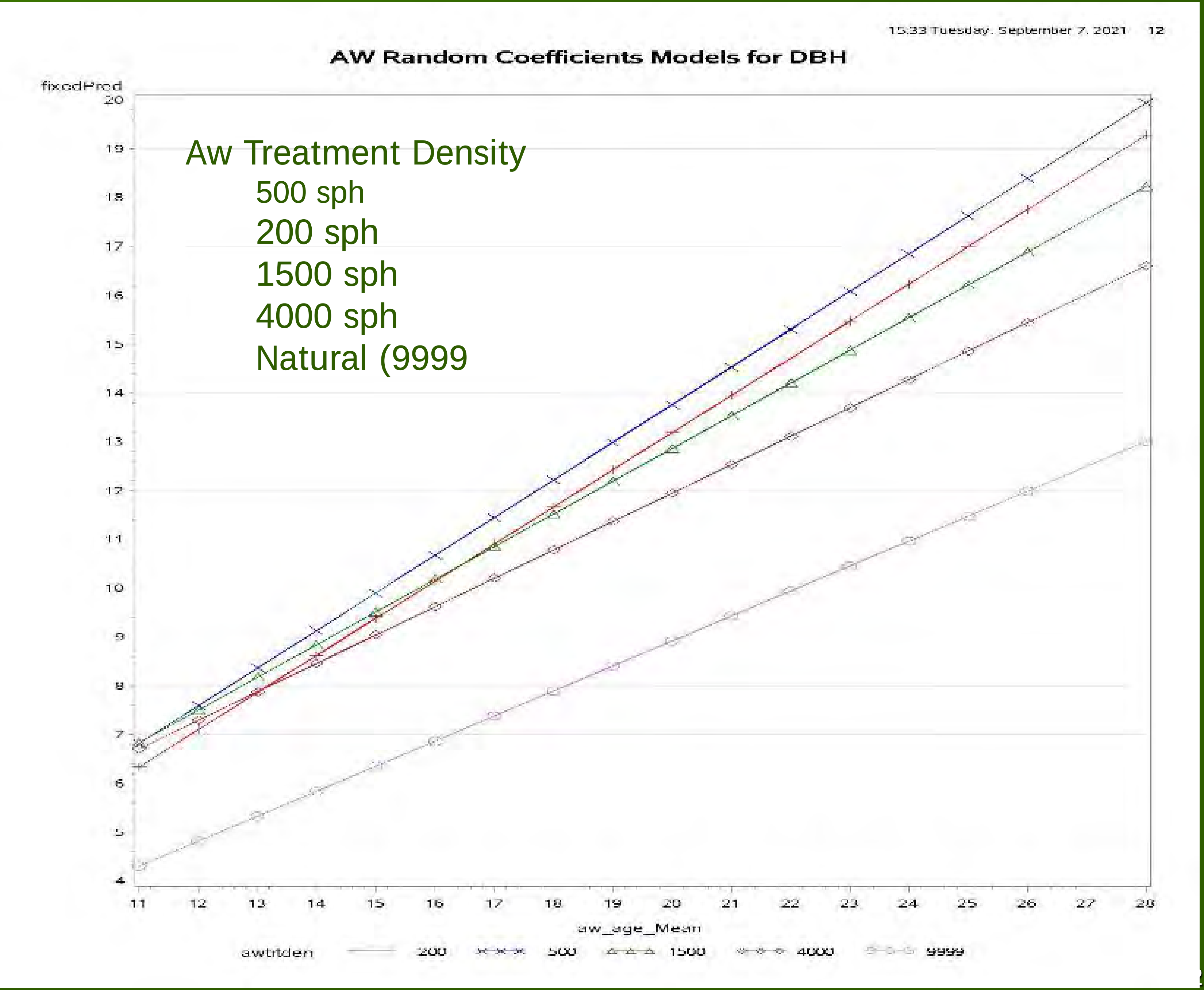
711
Sw=500
Aw=natural

Repeated Measurement Analysis (random coefficients modelling)

- Mixed modelling approach
  - Aw – average height and average diameter
  - Sw – average height and average diameter
- All plots over all ages
- Fixed effect = Aw treatment density
- Random effects = Intercept, Aw Age/Sw Age
- All parameters are significant (P<.001)


WESBOGY LTS - Aspen Plot Height by Aspen Age for each WB Plot
Plot Height
0
2
4
6
8
10
12
14
16
18
20
Age - years
1
3
5
7
9
11
13
15
17
19
21
23
25


15:33 Tuesday, September 7, 2021 12
AW Random Coefficients Models for Height
fixedPred
Aw Treatment Density
4000 sph
1500 sph
500 sph
Natural (9999
200 sph
aw_age_Mean
awtrtden 200 500 1500 4000 9999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Aw Treatment Density
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200 sph
1500 sph
4000 sph
Natural (9999
aw_age_Mean
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200
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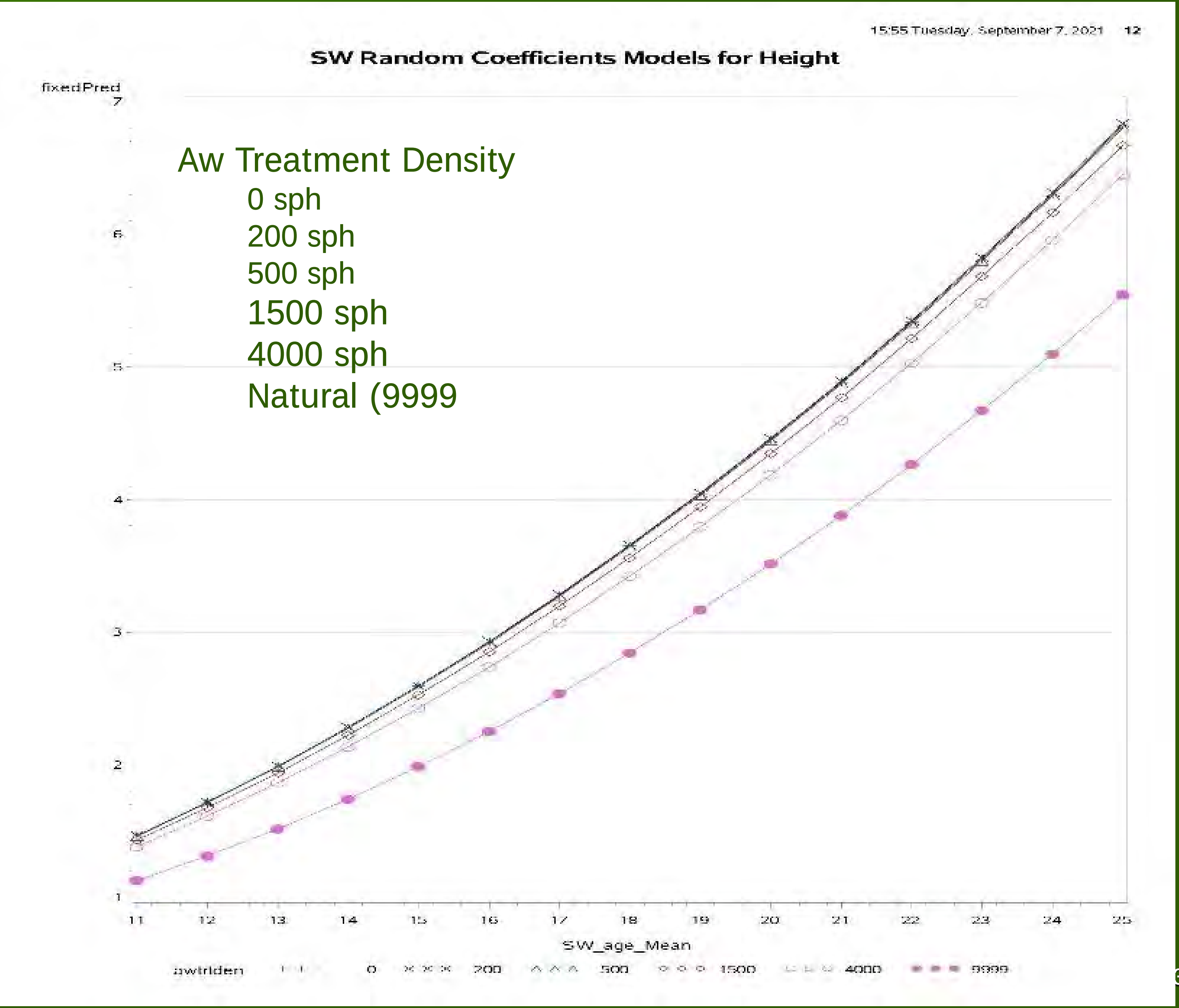
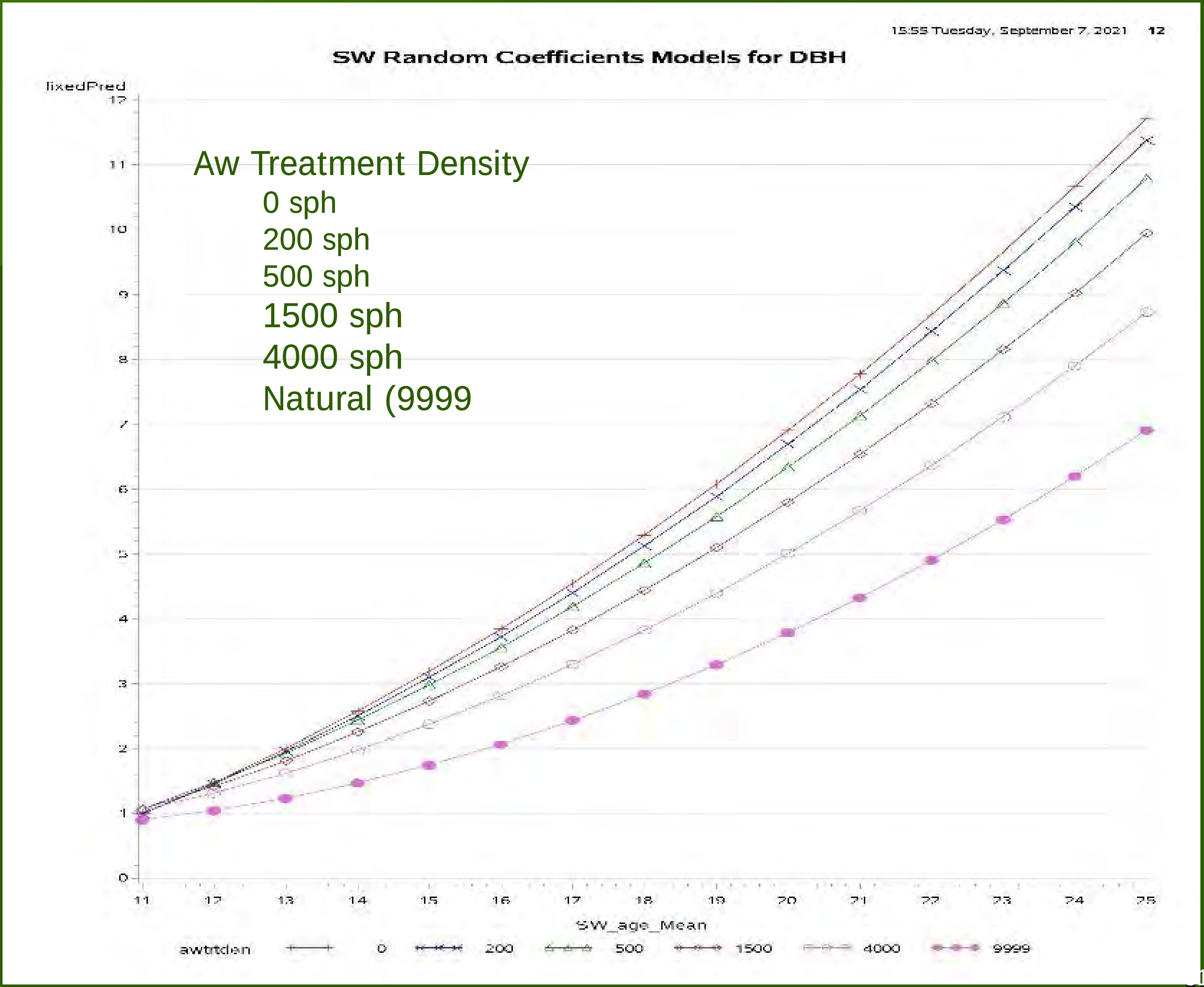
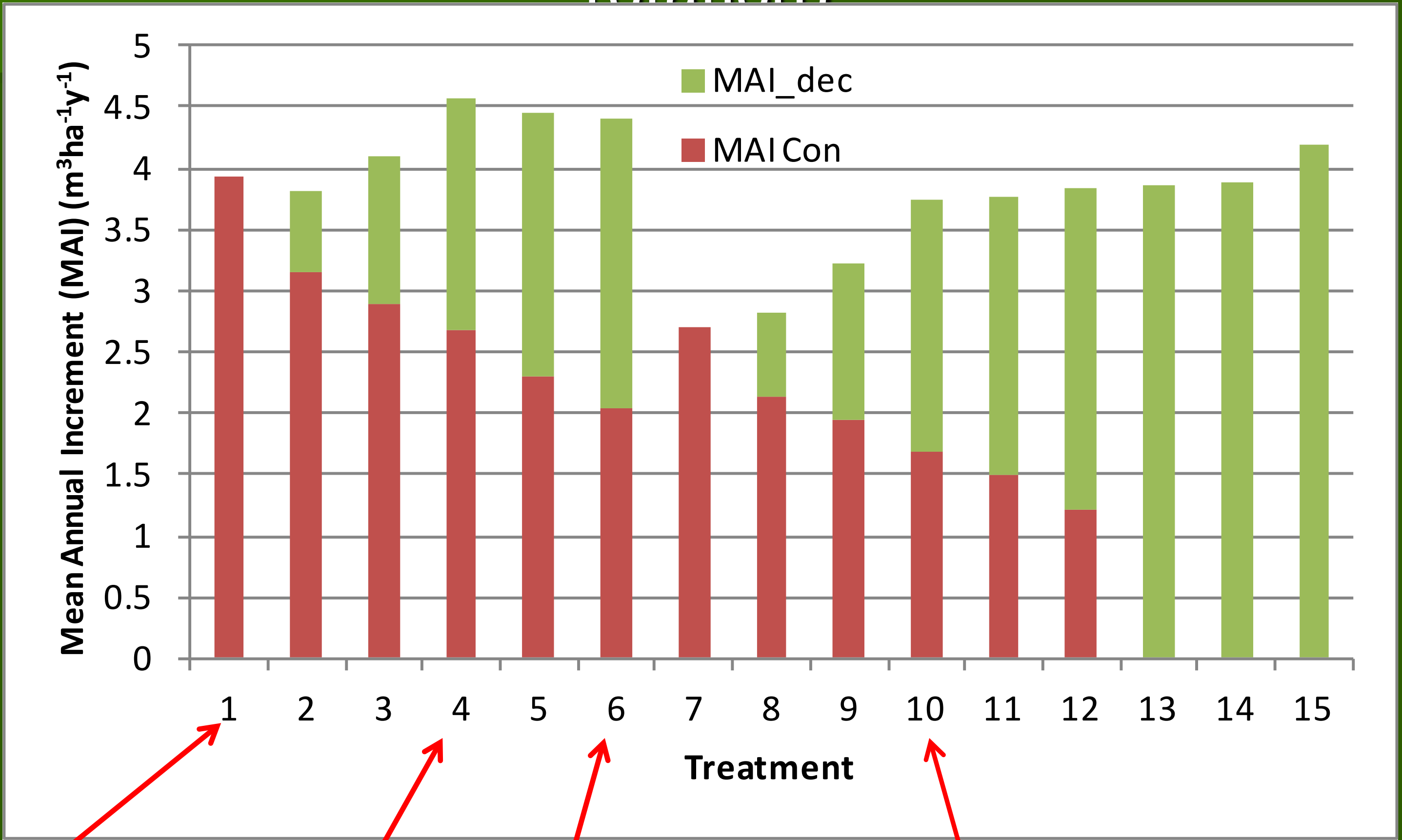

15:55 Tuesday, September 7, 2021 12
SW Random Coefficients Models for Height
fixedPred
Aw Treatment Density
0 sph
200 sph
500 sph
1500 sph
4000 sph
Natural (9999
SW_age_Mean
awtrtden 0 200 500 1500 4000 9999


15:55 Tuesday, September 7, 2021 12
SW Random Coefficients Models for DBH
fixedPred
Aw Treatment Density
0 sph
200 sph
500 sph
1500 sph
4000 sph
Natural (9999
SW_age_Mean
awtrtden 0 200 500 1500 4000 9999

Mixedwood Growth Model (MGM) simulations MAI for a 90 year rotation (299 LTS plots projected from measurement age to rotation)



T	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Aw	0	200	500	1500	4000	un	0	200	500	1500	4000	un	1500	4000	un
Sw	1000						500						0		

WESBOGY LTS - Conclusions

- 20 years after spacing:
  - aspen diameter and crown size decrease with increasing aspen density while slenderness increases.
  - Aspen density is having significant effects on white spruce height, root collar diameter, hdr.
  - Spruce size and growth decline as aspen density increases.
  - Spruce Crown diameter decreases with increasing aspen density.

- Long-term study data are being used in development and validation of the Mixedwood Growth Model (MGM)

- LTS will provide valuable quantitative information on the effects of aspen density and pre-commercial thinning of aspen on stand dynamics and yield.

- We will also continue collecting supplementary data on these sites to improve our understanding of factors influencing mixedwood stand dynamics.

Publications from the WESBOGY LTS

Refereed Journals

- Bokalo, M., P.G. Comeau and S.J. Titus. 2007. Early development of tended mixtures of aspen and spruce in western Canadian boreal forests. For. Ecol. Manage. 242: 175-184
- Comeau, P.G. 2021. Effects of thinning on dynamics and drought resistances of aspen-white spruce mixtures: Results from two study sites in Saskatchewan. Front. For. Glob. Change. 3: article 621752. DOI: 10.3389/ffgc.2020.621752
- Comeau, P.G. 2021. Effects of aspen and spruce density on size and number of lower branches 20 years after thinning of two boreal mixedwood stands. Forests 12, 211. DOI: 10.3390/f12020211
- Filipescu, C. and P. Comeau. 2007. Aspen competition affects light and white spruce growth across several boreal sites in western Canada. Can. J. For. Res. 37: 1701-1713
- Filipescu, C. and P. Comeau. 2011. Influence of *Populus tremuloides* density on air and soil temperature. Scand.J. For. Res., 26:5, 421-428
- Kweon, D., and P.G. Comeau. 2019. Factors influencing overyielding in young boreal mixedwood stands in western Canada. For. Ecol. Manage. 432: 546-557. doi: 10.1016/j.foreco.2018.09.053
- Oltean, G., P.G. Comeau and B. White. 2016. Linking depth-to-water topographic index to soil moisture on boreal forest sites in Alberta. For. Sci. 62: 154-165. doi: 10.5849/forsci.15-054
- Voicu, M. and P. Comeau. 2006. Microclimatic and spruce growth gradients adjacent to young aspen stands. For. Ecol. Manage. 221: 13-26

Publications from the WESBOGY LTS

Other publications

- Bokalo, M., K., Johnson and P. Comeau. 2016. Enhancing growth and yield data collection methods using airborne image technology. Report submitted to Government of Alberta. December 23, 2016.
- Comeau, P., M. Bokalo and S. Titus. 2004. Early dynamics of tended mixedwood stands. EFM Research Note 06/2004.
- Voicu, M. and P. Comeau. 2007. Gradients in microclimate and spruce growth adjacent to young aspen stands. EFM Research Note 01/2007.

Graduate student theses

- Filipescu, C.N. 2009. Dynamics of competition in boreal mixedwood stands. Ph.D. thesis. Univ. of Alberta. (supervisor: Phil Comeau)
- Griffiths, S. 2008. Characterization of leaf area index and understory vegetation development following precommercial thinning of boreal mixedwood forests. M.Sc. thesis. Univ. of Alberta. (cosupervisors: Phil Comeau and Ellen Macdonald)
- Kweon, D. 2018. Aspen density dynamics in boreal mixedwood stands and the implications in western Canada. Ph.D. thesis. Univ. of Alberta. (supervisor: Phil Comeau)
- Oltean, G.S. 2015. Estimation of site index and soil properties using the topographic depth-to-water index. M.Sc thesis. Univ. of Alberta. (supervisor: Phil Comeau)
- Voicu, M. 2004. Gradients in microclimate and spruce growth adjacent to young aspen stands. M.Sc. thesis. Univ. of Alberta (supervisor: Phil Comeau)

Comeau, P.G. 2021. Effects of aspen and spruce density on size and number of lower branches 20 years after thinning of two boreal mixedwood stands. Forests 12, 211. DOI: 10.3390/f12020211

Table 5. Effects of treatments on the number and size of branches in the branch whorl closest to 1 m height. Analysis of treatment effects was based on a factorial design with three levels for aspen density and two levels for spruce density. For both aspen treatment density (AwTDen) and spruce treatment density (SwTDen), means followed by different letters differed significantly ($\alpha = 0.05$) based on Tukey's HSD test.

	Average Branch Diameter in the Whorl Closest to 1 m Height		Number of Live Branches in the Whorl Closest to 1 m Height	
	p	Means (cm)	*p*	Means (cm)
AwTDen	*<0.0001*		ns	
SwTDen	ns		*0.0025*	
AwTDen*SwTDen	ns		ns	
AwTDen = 0		2.2a		2.1
AwTDen = 500		1.5b		2.4
AwTDen = 1500		1.6b		2.9
AwTDen = 4000		1.3bc		3.1
AwTDen = unthinned		1.0c		2.7
SwTDen = 500		1.5		3.2a
SwTDen = 1000		1.4		2.1b

Big River, SK LTS – wood quality

Comeau, P.G. 2021. Effects of aspen and spruce density on size and number of lower branches 20 years after thinning of two boreal mixedwood stands. Forests 12, 211. DOI: 10.3390/f12020211

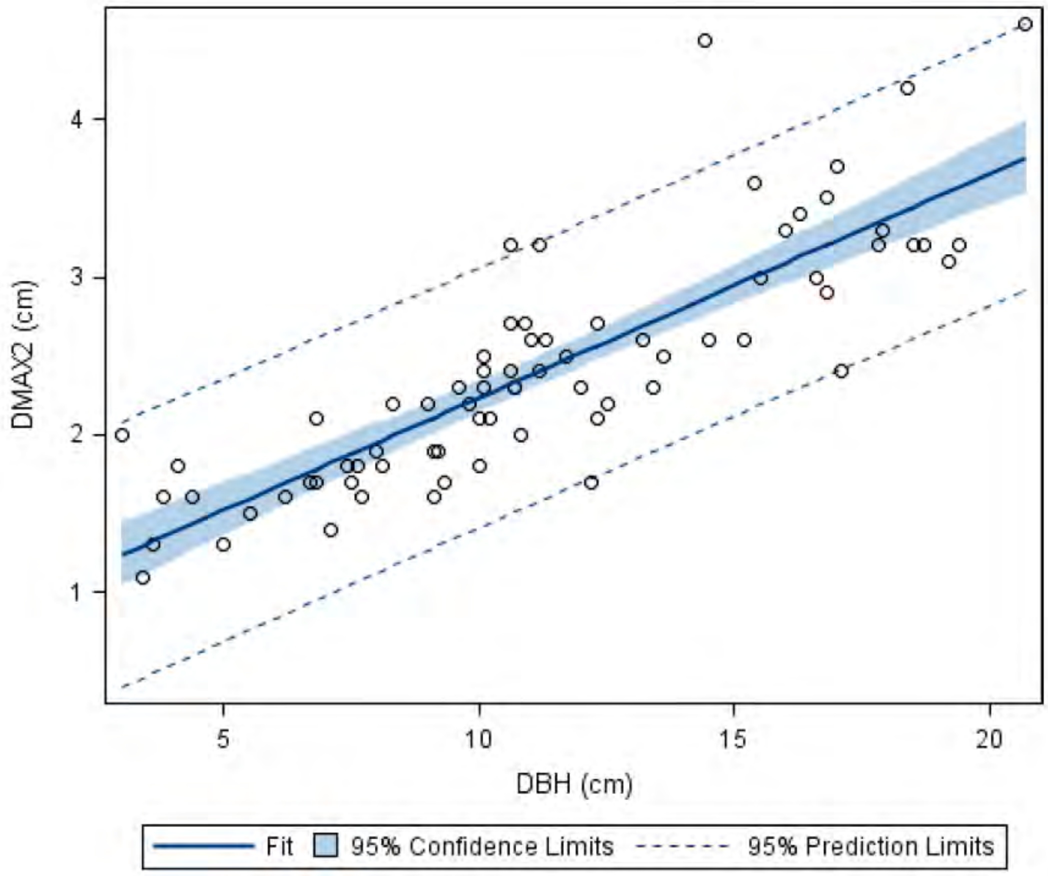


Figure 2. Relationship between maximum branch diameter on the lower 2 m stem section (DMAX2) and tree DBH. Parameter estimates for the linear model are provided in Table 8.

Big River - Initial tree size, aspen basal area and CMI have significant effects on basal area increment of individual **spruce**

Comeau, P.G. 2021. Effects of thinning on dynamics and drought resistances of aspen-white spruce mixtures: Results from two study sites in Saskatchewan. Front. For. Glob. Change. 3: article 621752. DOI: 10.3389/ffgc.2020.621752

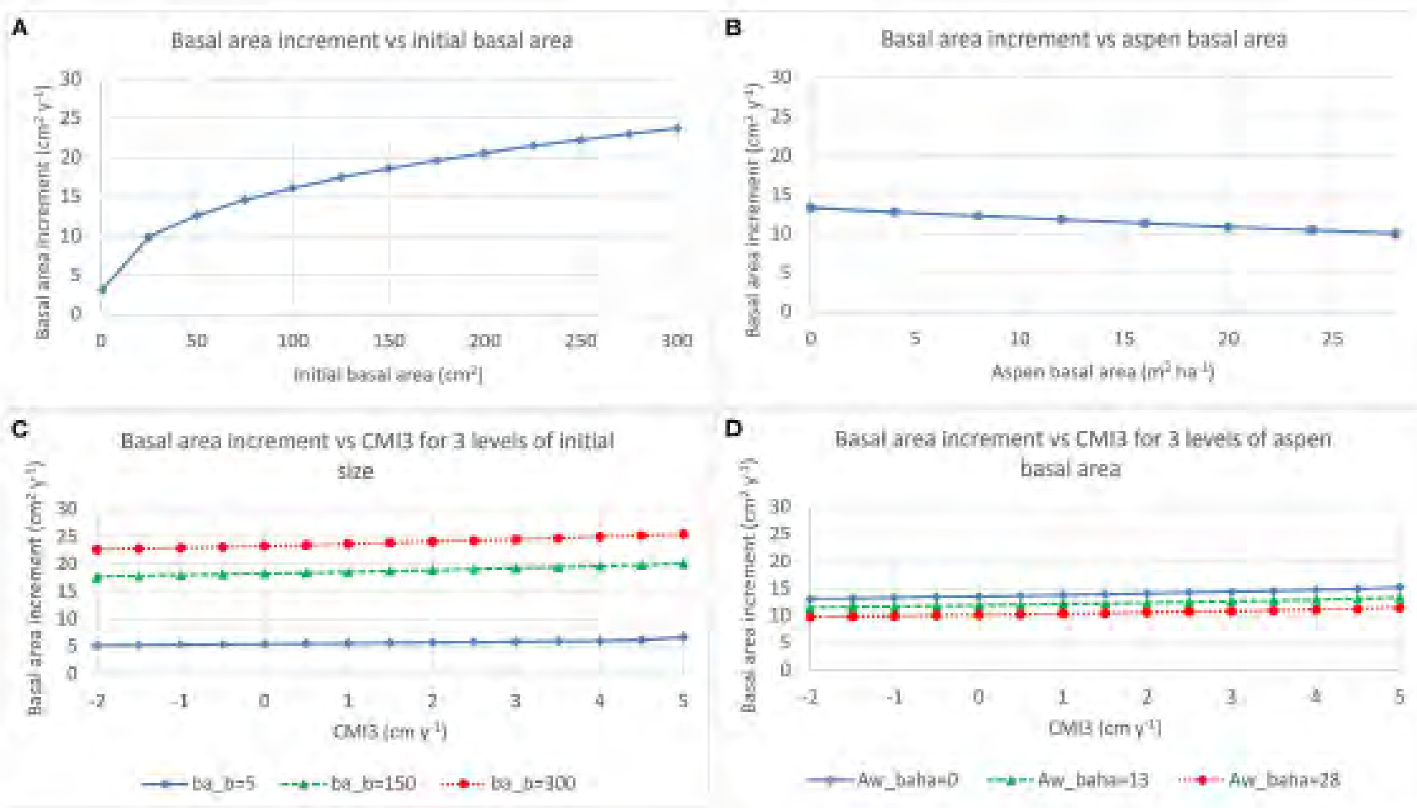


FIGURE 5 | Trends described by the model for annual basal area increment of spruce described in **Table 4**. Effects of initial basal area and aspen basal area on basal area increment are shown in **(A,B)**, respectively. **(C)** Shows effects of interactions between CMI3 and initial basal area (ba_b) and **(D)** shows interaction between CMI3 and aspen basal area (Aw_baha) (for each panel, average values were used for all other variables in the model).

Big River - Initial tree size, aspen basal area and CMI have significant effects on basal area increment of individual **aspen**

Comeau, P.G. 2021. Effects of thinning on dynamics and drought resistances of aspen-white spruce mixtures: Results from two study sites in Saskatchewan. Front. For. Glob. Change. 3: article 621752. DOI: 10.3389/ffgc.2020.621752

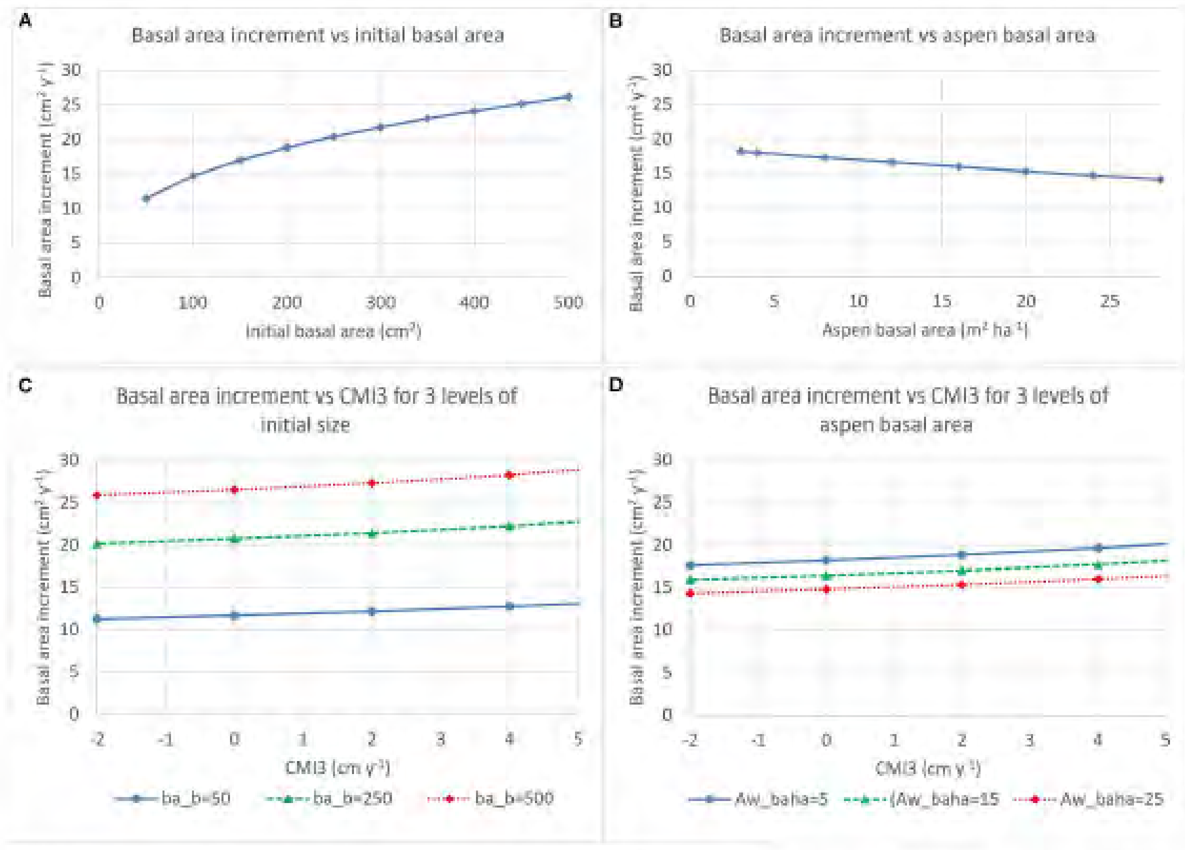


FIGURE 4 | Trends described by the model for annual basal area increment of aspen described in **Table 4**. Effects of initial basal area and aspen basal area on basal area increment are shown in **(A,B)**, respectively. **(C)** Shows effects of interactions between CMI3 and initial basal area (ba_b) and **(D)** shows interaction between CMI3 and aspen basal area (Aw_baha) (for each panel, average values were used for all other variables in the model).

SmartForests Canada

- SmartForests Canada is a Canada-wide project led by Dan Kneeshaw at UQAM, work in western Canada being led by Phil Comeau and Ellen Macdonald. Equipment purchase and installation funded by Canada Foundation for Innovation.
- Purpose: to improve our understanding of how climate and stand characteristics influence microclimate, tree growth and survival and the potential role of mixedwood management options in climate change adaptation.
- 10 selected WESBOGY LTS installations
  - 1 weather station was installed in a nearby opening
  - Microclimate stations installed in 4 treatments (#1 [1000 spruce per hectare/0 aspen per hectare], #4 [1000 spruce per hectare/1500 aspen per hectare] , #6 [1000 spruce per hectare/natural aspen density], and #15 [0 spruce per hectare/natural aspen density]) . Monitoring air and soil temperature, soil moisture, relative humidity, and understory light. Weather stations are monitoring air temperature, relative humidity, precipitation and light (diffuse and direct PAR).

Associated Research Questions

- Better understand climate and microclimate conditions in central mixedwoods and lower foothills
- Determine linkage between climate and soil moisture conditions across a range of sites (note most sites being examined are mesic)
- Examining tree and stand responses to a range of levels of stresses.
- Examining effects of stand composition, density on microclimate.
- Test ClimateNA and other interpolation models.
- How do climate and stand composition influence tree growth and survival in boreal mixedwood settings, how do year to year variation in temperature, drought stress and other factors influence growth under different stand conditions?
- How do levels of retention (EMEND PFM) influence tree and stand responses to climate?
- How do aspen and spruce densities influence tree and stand responses (WESBOGY, Banding, Judy Creek)
- What is the potential role of mixedwood management options in adaptation to climate change?

SmartForests Canada – 10 WESBOGY LTS Installations

Study	Agency	Installation	Year Established	Latitude	Longitude	Year Instrumentation Installed
WESBOGY LTS	AAF	Median	1992	55.3169	-114.0698	2019
	ALPAC	Median	2001	55.2164	-111.9130	2020
	CANFOR	Median	2001	54.7597	-117.3997	2020
	LPCDC	Median	2000	53.7582	-120.051	2021
	LPCSR	Median	1998	56.4851	-101.251	2021
	Mercer	Superior (Peace River)	1992	56.3854	-118.589	2019
	Mercer	Median (Hines Creek)	1992	56.4144	-117.729	2019
	SK	Median	1990	53.7594	-105.551	2021
	WFR	Median	1992	53.7601	-116.678	2020
	WGP	Median	1991	54.9177	-118.898	2020

The Dynamic Aspen Density Experiment (DADE)

- Initiated in 2008 by the Mixedwood Management Association of Alberta (which became the Mixedwoods Project Team of the Forest Growth Organization of Western Canada (FGrOW) in 2015).
- Project lead: Gitte Grover and Willi Fast
- Purpose: To examine the response of white spruce and aspen to late precommercial thinning.
- Objectives:
    1) examine effects of aspen density on stand development;
    2) examine effects of aspen density on survival and growth of white spruce; and,
    3) evaluate the impacts of optimizing white spruce survival and growth on hardwood production (how much aspen is sacrificed to gain spruce volume increases?).

Bjelanovic, I., Comeau, P., Meredith, S., Roth, B. 2021. Precommercial thinning increases spruce yields in boreal mixedwoods in Alberta, Canada. Forests 12(4) 412. https://doi.org/10.3390/f12040412

Study design

DADE



- Seven installations established in **17-year old stands**
- Seven installations established in **22-year old stands**

- Spruce: planted after clear-cut harvest (~1000 stems/ha pre-treatment)
- Aspen: > 6-10K stems/ha pre-treatment
- There was no delay between harvesting and planting
- No further silvicultural treatments until experiment establishment

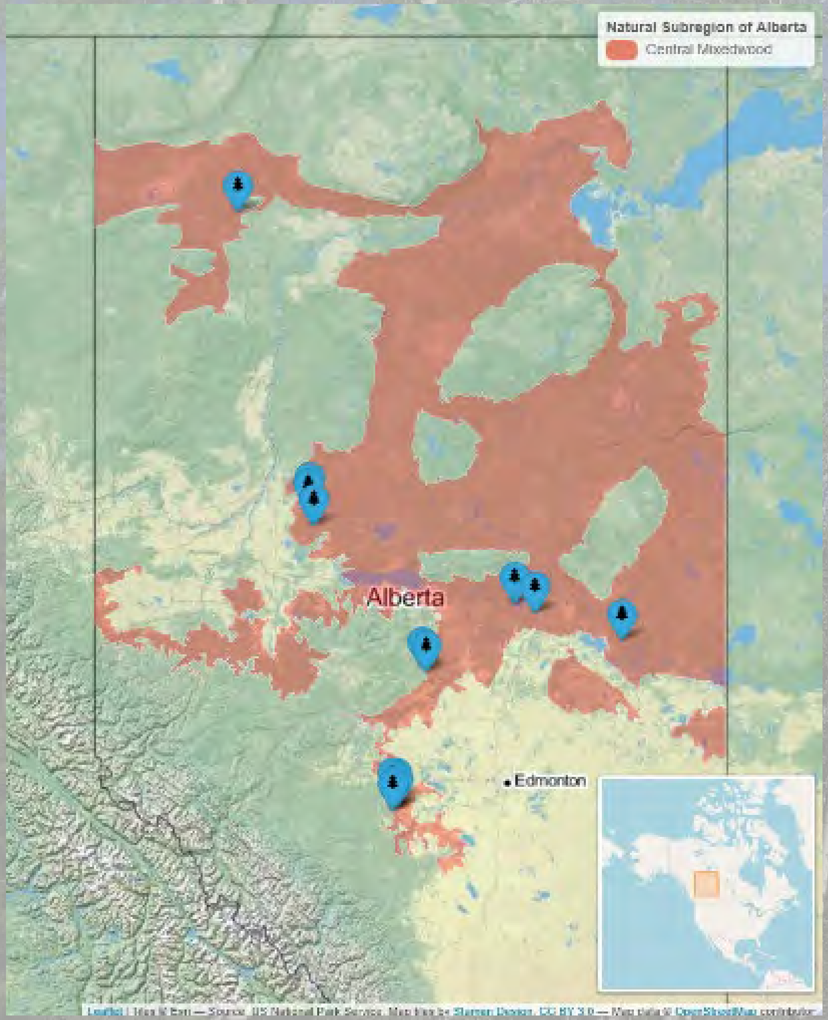
Treatments:

- 1 rep of each of 5 aspen density treatments in each installation:
  - 0 stems/ha
  - 1000 stems/ha
  - 2500 stems/ha
  - 5000 stems/ha
  - unthinned (control)
- Sw thinning applied, if necessary, to achieve desired spacing and reduce Spruce-Spruce competition and “clumpiness” (i.e. ‘double-planted” trees)

Study design:

- Five treatment plots were established in each stand (installation)
- Randomized block design with treatments randomly assigned to plots in each installation; installation=“block”

Study area



- Central Mixedwood Natural Subregion
- Ecosite (mapped; DEP) for all installations:
  - Ecosite d (low-bush cranberry)
  - Mesic SMR
  - Medium SNR

- Range in elevation: 420-880 m

- Climate (1985-2018 averages)
  - CMI: 0.8 - 6.3
  - MAT: -0.7 - 3.3°C
  - MAP: 433 - 538 mm
  - NFFD: 146 - 158 days
- SI: AW=19.6-24.7 m@age50 SW=17.1-24.0 m@age50

Measurements

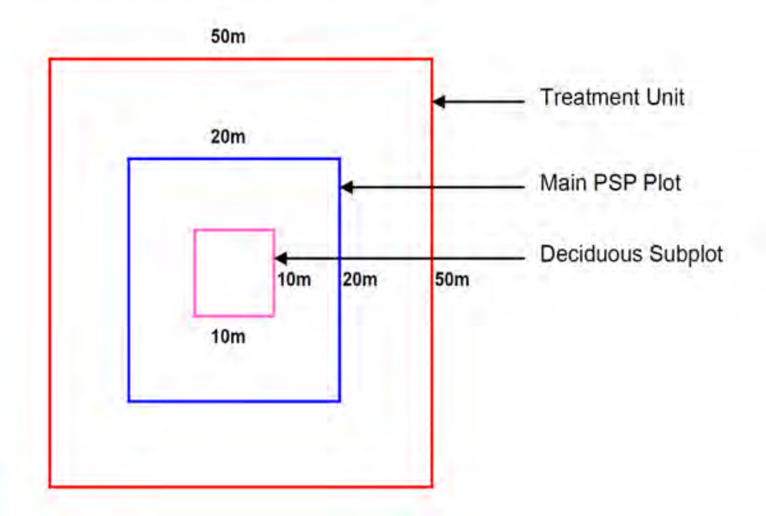
DADE

Company FMA	Installation Number	Location	Establish	3-Year Remeasure.	8-Year Remeasure.
Al-Pac	CM 17-1	Touchwood Lake Road	2007	2010	2015
Al-Pac	CM 17-2	Al-Pac "C" Road	2007	2010	2015
Weyco	CM 17-3	Sinkhole Lake, Drayton Valley	2009	2013	2017
Weyco	CM 17-4	Sinkhole Lake, Drayton Valley	2009	2013	2017
Weyco	CM 17-5	Sinkhole Lake, Drayton Valley	2009	2013	2017
Weyco	CM 17-6	Sinkhole Lake, Drayton Valley	2009	2013	2017
Weyco	CM 17-7	Sinkhole Lake, Drayton Valley	2009	2013	2017
Al-Pac	CM 22-1	Al-Pac 1000 Road	2007	2010	- (destroyed by herbicide treatment)
Al-Pac	CM 22-2	Al-Pac 1000 Road	2007	2010	2015
Al-Pac	CM 22-3	Al-Pac 1000 Road	2008	- (destroyed by herbicide treatment)	-
Al-Pac	CM 22-4	Al-Pac 1000 Road	2008	- (destroyed by herbicide treatment)	-
DMI	CM 22-5	South Harmon Valley MOF	2008	2011	2016
DMI	CM 22-6	Kimewan Lake MOF	2008	2011	2016
DMI	CM 22-7	South Harmon Valley MOF	2008	2011	2016
MWFP	CM 22-8	Fort Assiniboine	2013	2016	2021
MWFP	CM 22-9	Fort Assiniboine	2013	2016	2021
Tolko	CM 22-10	High Level	2015	2018	? 2023

13 installations remain. 22-10 burned. Age 13 measurements completed in 2020 for 17-1, 17-2 and 22-2. 17-2 had Martini Plow MSP and should probably be dropped. Weyco installations are clustered in a few blocks in one area.

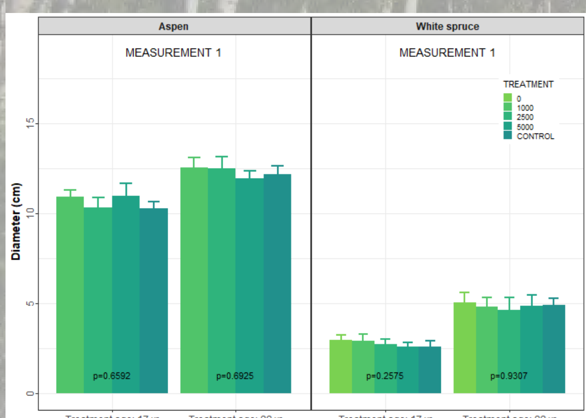
Measurements

Post-treatment measurements



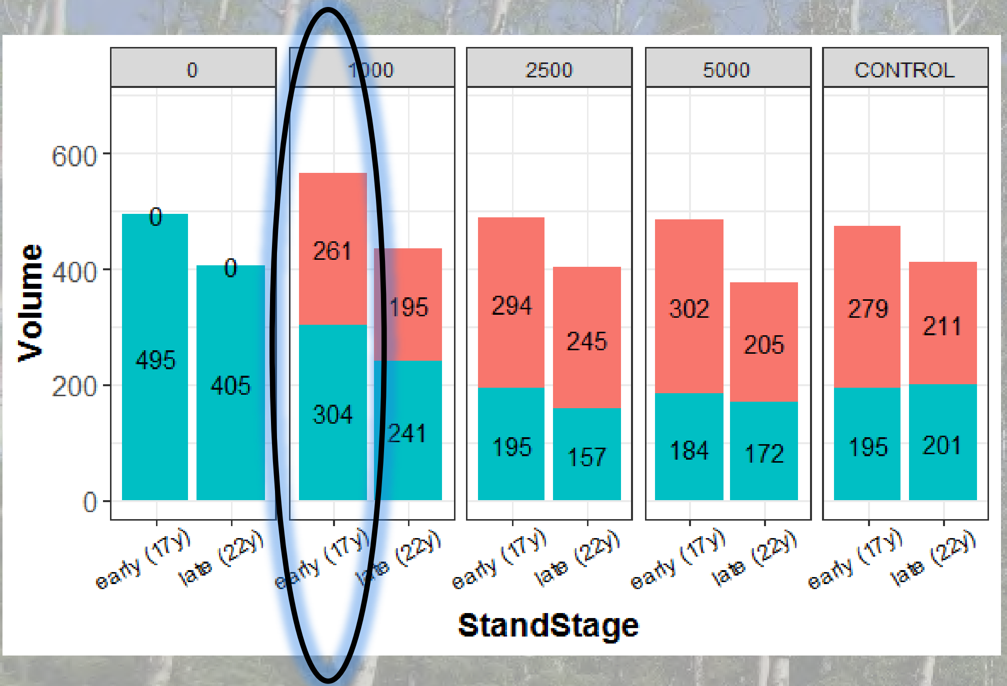
Post-treatment measurements
- key findings -

- Aspen densities had no significant effect on survival of planted spruce
- Eight years after thinning diameter of dominant aspen was increased by thinning while there was no effect of thinning on aspen height growth
- Spruce height and diameter growth increased with thinning intensity and with time after treatment. There was a slight adjustment in spruce height growth during the first 3 years after pct reflecting a shift in growth allocation to diameter over height for the 0 aspen density.



Yield projections (MGM18)

15/10 utilization standard



"1000": Culmination (Stand MAI) age is 78.6y

MGM:

- Conifer volume at culmination within treatment "1000" for installations thinned at age 17 and was significantly larger than all other mixture treatments.
- Yield projections show that heavy precommercial aspen thinning (~1000 aspen crop trees/ha) can result in an increase in merchantable conifer volume with a small reduction of aspen volume at the time of harvest
- Light to moderate thinning, reducing density of aspen trees to 2500 stems/ha or higher, is unlikely to result in gains in either deciduous or conifer merchantable harvest volume over those of unthinned stands

Judy Creek Mixedwood Experiment

- Designed by Doug Pitt, Milo Mihajlovich, Phil Comeau and Dan MacIsaac.
- Established in 2002.
- Objective: To evaluate potential benefits of spot herbicide treatments (glyphosate and triclopyr), in combination with pct, in comparison to selected broadcast treatments.
- 17 treatments.
- 40 treatment plots: 35 m x 35 m (broadcast) and 45 m x 45 m (radial).
- Measurement plots: 25 m x 25 m, with four 5 m x 5 m subplots established in each for measurement of deciduous in unthinned plots.
- Measured: y 0, 1, 2, 3, 4, 5, 10, 15. Future: 20, 25, ….

Pitt, D.G., Comeau, P.G., Parker, W.C., Hoepting, M.K. MacIsaac, D. McPherson, S. Mihajlovich,M. 2015. Early vegetation control for the regeneration of a single-cohort, intimate mixture of white spruce and aspen on upland boreal sites – 10th year update. For. Chron. 81: 238-252.

Comeau, Hoepting, Pitt and Mihajlovich. In prep. Year 15 results

17 Treatments

Treatment	Sw planting density (sph)	Vegetation Control	Thinning (sph) (in 2012)
BC	1600	Broadcast, glyphosate, maintained for 10 years.	
BW	1600	Broadcast, triclopyr, 2002	
BH	1600	Broadcast control of understory herbacious	
RW-U	400	Spot (2 m radius) woody control, with triclopyr in 2002	unthinned
RW-2000	400	Spot (2 m radius) woody control, with triclopyr in 2002	2000
RW-1200	400	Spot (2 m radius) woody control, with triclopyr in 2002	1200
RW-800	400	Spot (2 m radius) woody control, with triclopyr in 2002	400
RC_2-U	400	Spot (2 m radius) complete control, with glyposate in 2002 and 2003	unthinned
RC_4-U	400	Spot (2 m radius) complete control, with glyposate in 2002, 2003, 2004, and 2005	unthinned
RC_2-2000	400	Spot (2 m radius) complete control, with glyposate in 2002 and 2003	2000
RC_4-2000	400	Spot (2 m radius) complete control, with glyposate in 2002, 2003, 2004, and 2005	2000
RC_2-1200	400	Spot (2 m radius) complete control, with glyposate in 2002 and 2003	1200
RC_4-1200	400	Spot (2 m radius) complete control, with glyposate in 2002, 2003, 2004, and 2005	1200
RC_2-800	400	Spot (2 m radius) complete control, with glyposate in 2002 and 2003	800
RC_4-800	400	Spot (2 m radius) complete control, with glyposate in 2002, 2003, 2004, and 2005	800
BN	1600	none	unthinned
BA	0	none	unthinned

- **Woody Control** (BW and RW) used a back-pack basal bark application (streamline method) with **triclopyr** butoxyethyl ester (Release®) and mineral oil mixed 25:75 by volume. The RW treatments targeted all deciduous trees and shrubs within a 2-m radius around each spruce planting location and the BW treatment targeted all deciduous trees and shrubs within the 35 m x 35 m treatment plot.
- **Complete Control** (BC and RC). BC plots received complete, whole-plot vegetation control (BC), using **glyphosate** applied at a rate of 9 L ha-1 (3204 g ae glyphosate/ha) in 100 L ha-1a of solution applied with a 2-m spray boom equipped with 11002 Turbo TeeJet nozzles. BC plots received touchup treatments to control shrubs, herbs and grasses during the ensuing 9 years using a 10% solution of glyphosate. On the 3 plots receiving whole-plot herbaceous-only vegetation control (BH), a backpack equipped, roller-wipe applicator was used in 2002 to treat all vegetation within the plot boundary, except aspen. Spot (RC) treatments used a backpack-equipped, hand-held rotating boom to apply 9 L ha-1 (3204 g ae glyphosate/ha) in 100 L ha-1a of solution within the 2 m radius spots, centered on the planted tree.

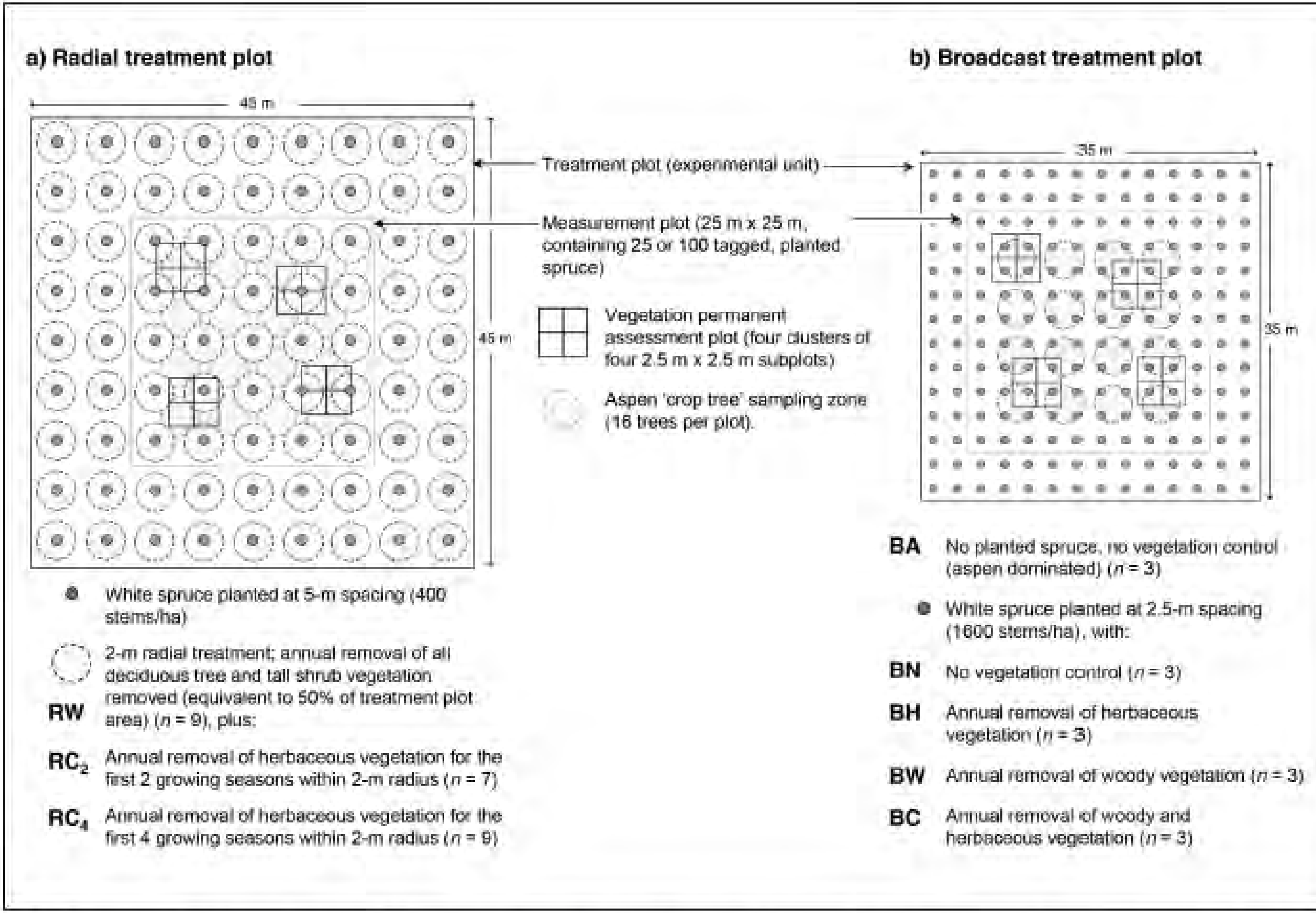


Fig. 1. Plot layout, sampling locations and treatment definitions for a) radial and b) broadcast treatments. Reference to "tall shrub" vegetation includes woody species capable of reaching 2 m in height; "herbaceous" vegetation includes grasses, forbs, ferns, and low shrub species.

BH (age 11)

BW (age 11)

RC2-U (age 11)

RC4-1200 (age 11)

Judy Creek – Conclusions so far

- Radial treatments effectively improved survival and growth of white spruce, however spruce growth was best with broadcast removal of both woody and herbaceous vegetation (BC). Spruce survival was better in radial treatments than in broadcast complete or woody control and much lower (40%) in the untreated control.
- Radial treatments, while reducing aspen density and basal area at the plot level, did not affect aspen growth to age 14.
- Thinning at age 10 reduced aspen density and basal area, and lead to a significant increase in dbh of the top 400 trees/ha at 5 years post thinning, but did not significantly affect height.

Judy Creek – treatment effects on deciduous at age 15

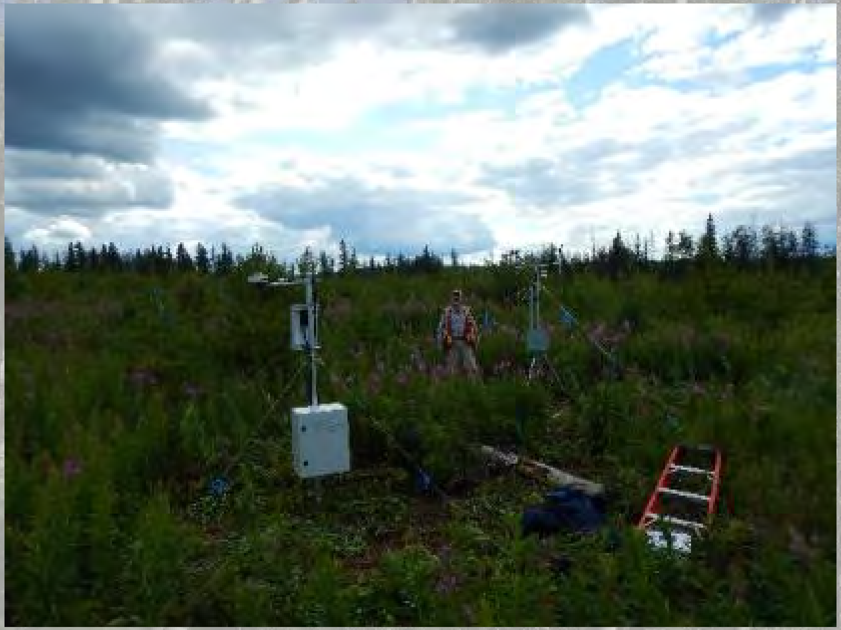
Treatment	n	Deciduous trees per hectare (#/ha)			Deciduous basal area per hectare (m^2/ha)			Aw height (cm)			Aw DBH (mm)			Aw Top DBH (top400) (mm)		
		Mean	sd		Mean	sd		Mean	sd		Mean	sd		Mean	sd	
BC	3	0	0	e	0.00	0.00	b	.			.			.		
BW	3	0	0	e	0.00	0.00	b	.			.			.		
RC-T	10	840	268	de	4.36	1.09	b	827.8	132.3	a	79.4	17.8	a	92.9	14.1	a
RW-T	5	781	324	de	4.00	1.50	b	827.0	149.1	a	79.3	15.4	a	89.9	11.5	a
RC-U	4	14000	2034	bc	21.68	3.86	a	640.0	367.4	a	37.7	20.2	b	63.3	28.8	a
RW-U	4	9117	9606	cd	25.50	6.65	a	536.9	209.5	a	33.6	18.3	b	80.1	9.4	a
BH	3	19500	1300	ab	26.43	2.25	a	584.6	224.4	a	37.1	18.8	b	86.8	8.0	a
BN	3	24533	3134	a	28.62	1.74	a	586.4	186.9	a	34.6	16.1	b	61.6	15.6	a
BA	3	20467	2450	ab	28.87	1.56	a	626.2	186.0	a	37.7	16.6	b	68.8	29.2	a
p		**<0.0001**			**<0.0001**			**0.0218**			**<0.0001**			**0.0023**		

Judy Creek – treatment effects on spruce at age 15

Treatment	n	Survival (%)			Height (cm)			DBH (mm)		
		Mean	sd		Mean	sd		Mean	sd	
BC	3	77.0	13.2	ab	495.5	101.3	a	82.1	24.2	a
BW	3	77.3	13.6	ab	375.6	127.5	ab	49.9	25.8	b
RC-T	10	84.4	15.9	a	379.2	140.4	ab	51.7	26.8	b
RW-T	5	90.4	5.4	a	373.4	130.8	ab	48.0	23.2	bc
RC-U	4	73.6	16.4	ab	387.8	175.3	ab	43.9	25.8	bc
RW-U	4	82.7	6.1	a	243.9	160.6	bc	22.2	20.9	cd
BH	3	65.3	6.4	ab	119.9	100.8	cd	5.1	10.4	d
BN	3	40.3	13.9	b	42.2	47.1	d	0.7	4.2	d
p		**<0.0011**			**<0.0001**			**<0.0001**		

Smartforests at Judy Creek

- One weather station plus microclimate stations installed in 18 plots.



“Banding” Study

[Phil Comeau]

- Purpose: to evaluate and demonstrate potential use of patch/banding treatments and mechanical site preparation for regenerating mixedwood stands. Measured at establishment, year 1, 3, 6 and 10. Future measurements planned at 5 year intervals.
- 5 locations with 1 rep of each treatment. Established 2006 - 2008
- Treatment plots: 60 m x 80 m or larger
- PSP’s: 30 m x 30 m, trees tagged for remeasurement. In unthinned, unherbicided or unbrushed plots, aspen were measured in four 3.99 m radius plots established in each measurement plot.
- Measured at establishment (after planting), year 1, 3, 6 and 10. Future measurements planned at 5 year intervals.
- Establishment (2016)and 3 years of measurement funded by MWMA with subsequent funding from the 5 partner companies (Alpac, Alberta Plywood, DMI, Vanderwell, Weyerhaeuser).


Banding Study Installations
Legend
Banding
Lake Athabasca
Birch Mountains
Sulphur Lake Banding
Snake Mtn Banding
Driftpile Banding
Fawcett Banding
Conklin Banding
Canada
Alberta
Edmonton
Manitoba
Lake Winnipeg
Saskatchewan
Google Earth
Columbia Mountains
Calgary
N

Treatment assignment to Banding Experiment plots.

				Site, year planted and plot assigned to each treatment				
Treatment Number	**Site Prep**	**Herbicide**	**Thinning**	ALPAC Lac La Biche	Weyerhaeuser Snake Mountain	Vanderwell - Fawcett Lake (SL17-L5 block 1701)	DMI – Sulphur Lake (DTPP140046, Block 6)	West Fraser Driftpile
				2006	2006	2008	2008	2008
1	Mound entire plot (2.5 m spacing of mounds for planting)	none	Thin aspen to 1500 sph	1	X	8	4	4
2	Mound entire plot (2.5 m spacing of mounds for planting)	none	Radial brushing (2.0 m radius around every 2nd spruce in every 2nd row (5m spacing between brushed spruce)	2	X	X	8	5
3	Merricrusher – alternating 15 m wide bands	none	none	9	3	X	X	X
4	Mound entire plot (2.5 m spacing of mounds for planting)	glyphosate application to 15 m wide strips (leaving 15 m untreated between each strip) (y 2-4)	none	3	2	3	3	10
5	Mound entire plot (2.5 m spacing of mounds for planting)	none	none	4	7	X	10	7
6	none	none	Thin aspen to 1500 sph at age 4	X	X	10	5	3
7	none	none	Radial brushing (2.0 m radius around every 2nd spruce in every 2nd row (5m spacing between brushed spruce)	6	X	5	7	9
8	none	glyphosate application to 15 m wide strips (leaving 15 m untreated between each strip) (y2-4)	none	8	8	2	1	1
9	none	none	none	5	5	7	9	2
10	Arsenal herbicide planting spots	none	none	X	X	4	2	6
11	Arsenal alternating 15 m wide bands	none	none	X	X	6	6	8

Sulphur Lake – mounded (July 2009) (year 3)

Sulpur Lake – Arsenal spot (July 2009) (year 3)

Sulphur Lk - Arsenal Band (Aug. 2009) (year 3)

LLB – Glyphosate band – 2012 (1 year post applications)

LLB-Merricrusher Band 2012 (year 9)

LLB – spot radial brushing (2012, 1 year after treatment)

Trials at Mistahae (est 2000 and measured in 2006), at Judy Creek, and near LLB show spot radial brushing about as effective as spot radial herbicide treatments.

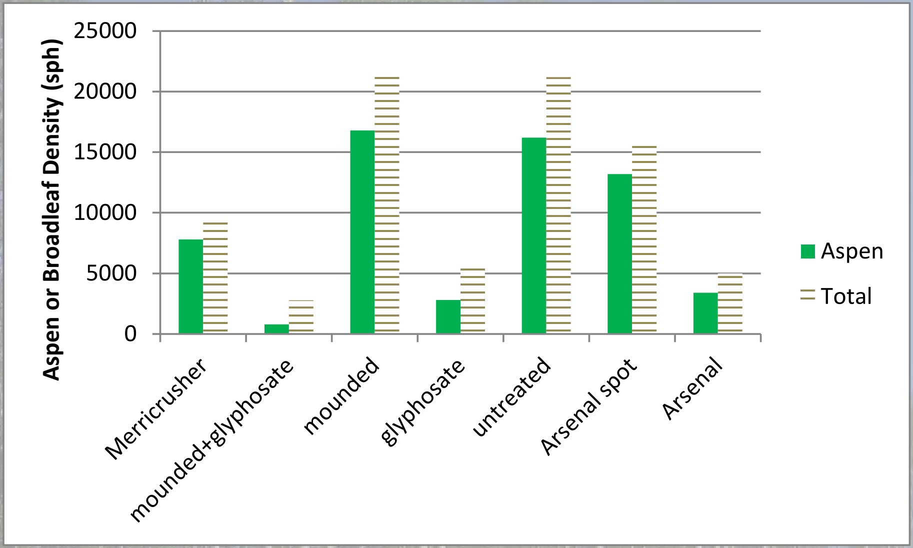
LLB – untreated –(Sept. 2009) (year 6)

Treatment effects on average spruce height, rcd and hdr at age 6

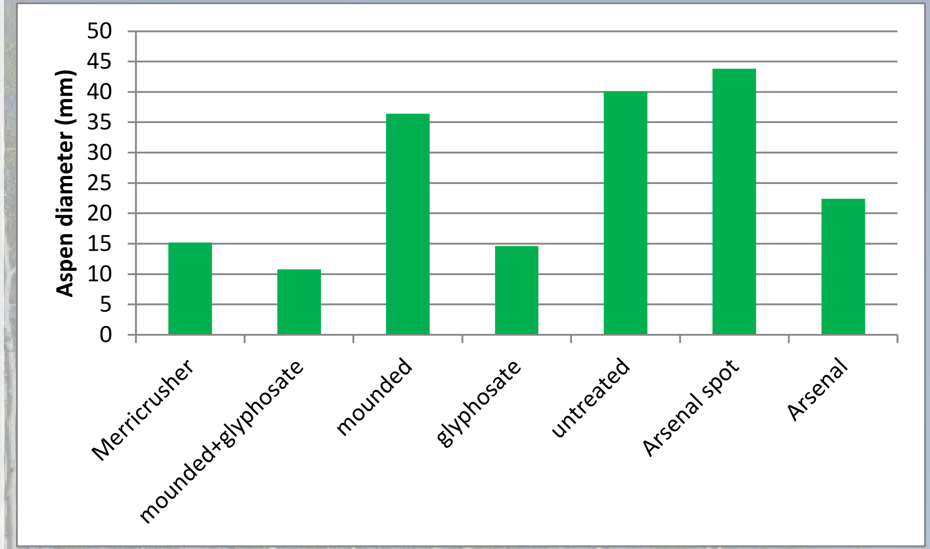
Treatment	**Treatment description**	**Height (cm)**	**RCD (mm)**	**HDR**
1	mounded, aspen thinned	77.4ab	12.38abc	6.42abcd
3t	Merricrusher	63.2b	12.57abc	5.31cde
4t	mounded+glyphosate	94.3a	17.82a	5.25de
5 (mounded control)	mounded	76.6ab	11.98bc	6.47abc
8t	glyphosate	64.1b	12.61abc	5.06e
9 (untreated control)	untreated	63.9b	9.44c	6.84ab
10	Arsenal spot	75.5ab	10.51bc	7.23a
11t	Arsenal	90.7ab	15.37ab	5.95bcde
Significance (p)		**0.0059**	**0.0001**	**<0.0001**

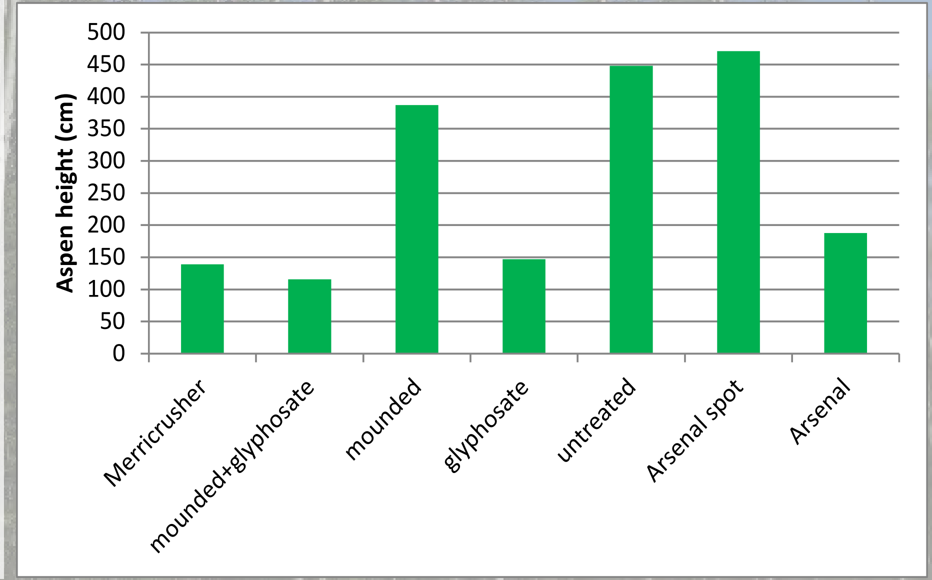
-Spruce height and rcd highest in mounded plus glyphosate;
-Mounded, mounded+glyphosate, and arsenal show significantly increased RCD over untreated, other treatments are intermediate

- Age 6: Deciduous density highest in untreated and mounded, and reduced by other treatments.
- Deciduous density lowest in mounding+glyphosate (4t) and Arsenal (11t) treatments with these treatments being significantly lower than the mounded control (5) and untreated control (9). Other treatments had intermediate densities and did not differ significantly.



- **Aspen diameter**: significantly smaller in Merricrusher (3t), mounding+glyphosate (4t), and glyphosate (8t) treatments than in mounding (5), untreated control (9) and Arsenal spot (10) treatments
- Arsenal spot treatments resulted in the largest diameter aspen and this treatment has significantly larger diameters than Merricrusher (3t), mounding+glyphosate (4t), and glyphosate (8t) and Arsenal (11t) treatments.
- **Aspen height**: Merricrusher (3t), mounding+glyphosate (4t), and glyphosate (8t) treatments resulted in significant reductions in aspen height over values in untreated control (9) or arsenal spot (11t) . Merricrusher (3t), mounding+glyphosate (4t), and glyphosate (8t) treatments significantly smaller than Mounding (5) by itself.





SmartForests in Banding installations

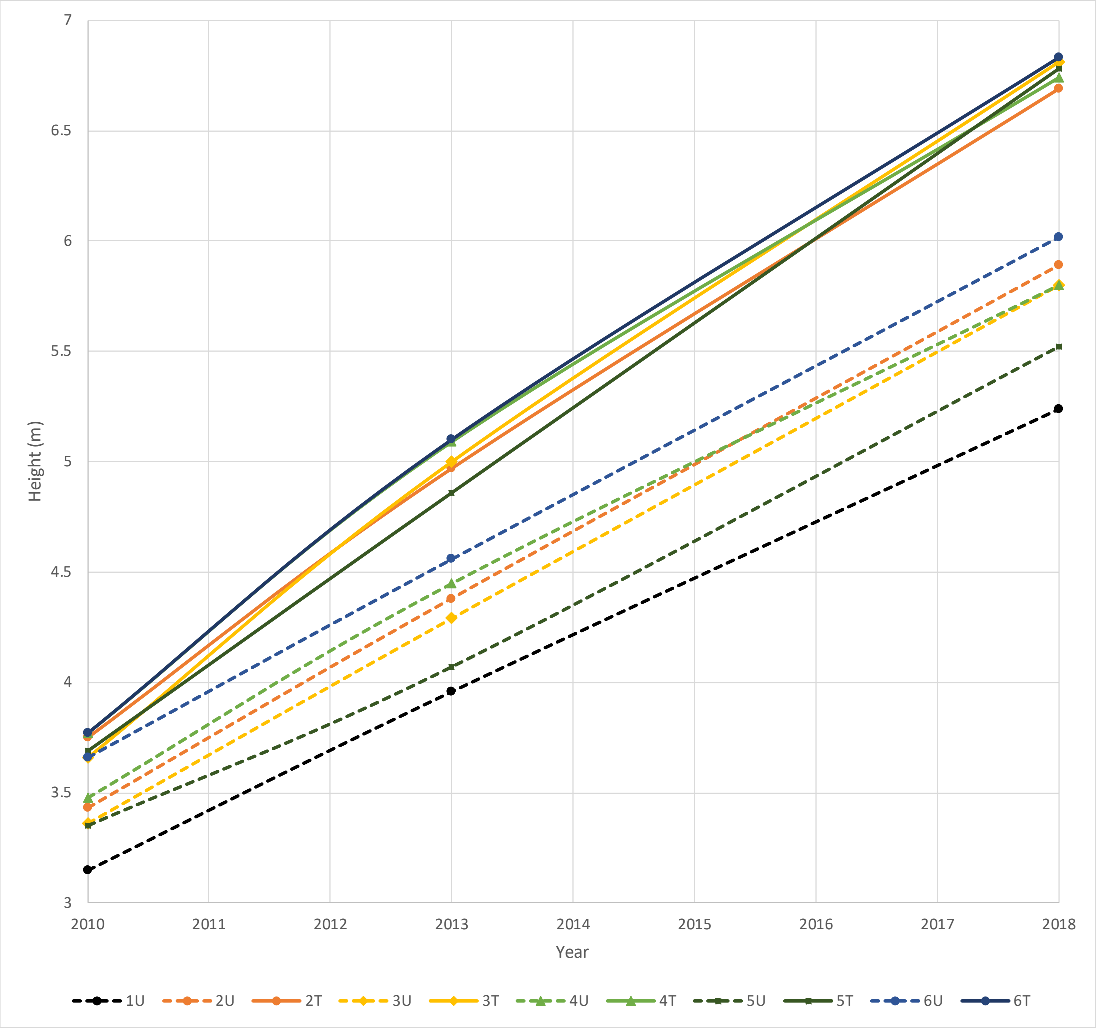
- Peace River, Fawcett Lake and Conklin Installations
- Microclimate stations installed in 4 treatments
  - 1) Control (Sw planted but no further treatments),
  - 2) unmounded + 15 m wide bands of vision herbicide (Sw planted and very little aspen in the treated band) (note that this plot is not useable at Conklin due to flooding in early years and death of planted spruce so a plot with merricruser banding treatment was used for this site),
  - 3) mounded + 15 m wide bands of vision herbicide (Sw planted and very little aspen in the treated band), and
  - 4) Aspen thinned to 1500 sph.
- Weather station installed in an opening near each installation.

Pulse spray – Comeau and Mihajlovich

Figure 4. Aerial view of blocks 23 and 30 (July 2009).

- Objective: To examine effects of size of pulse spray patches used to treat 40% of ground using VISION herbicide (accuflow nozzles, electronic switch on boom)
- 12 m wide spray swath, with different “lengths” (6, 9, 12 & 18 m) with 4 m buffer between spray swaths+ 12 m x 18 m with 8 m between swaths+ untreated
- 12 year old plantations 80 km northeast of High Level.
- 24 treatment plots; PSP’s (32 x 32 m) established near center of each treatment “block”. 4 reps for each of 6 treatments. 1.78 m radius decid. subplots in untreated areas
- Established and treated in 2007.
- Measured: 2008 (age 13), 2010 (age=15), 2013 (age=18), and 2018 (age=23). Future: 2023?
- Funding provided by Tolko High Level

Height trends for white spruce in untreated (U) and treated (T) areas for each treatment.



Swath length: 1=0 (untreated); 2=6m; 3=9m; 4=12m, 5=18m, 6=18m.

Key Findings

- Effectively treated areas represented between 30% and 36% of the total area. Between 38% and 51% of the spruce within the measurement plots were in treated portions of the plots.
- Size of treated patches did not significantly alter spruce size. In 2018 (11 years after treatment) spruce in treated areas showed significant increases in size (1.17x height, 1.36 x dbh, 1.3x height growth, 1.37x dbh increment, and 1.98x volume index) compared to untreated spruce. Spruce in the untreated matrix of treated plots were significantly larger than spruce in the completely untreated plots.
- Aspen density (summer of 2009) in the untreated matrix was approximately 49,000 stems/ha, with average height and dbh of aspen of 4.9 m and 2.85 cm, respectively. In 2018 aspen density was 10,312 stems/ha with average height and dbh of aspen of 7.71 m and 4.95 cm, respectively.

Strip Cut Understory protection (Mixedwoods Project Team)

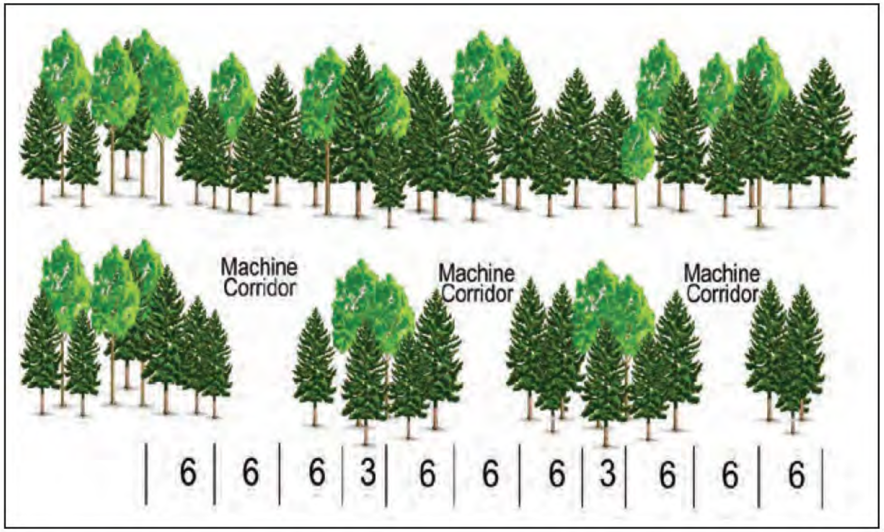
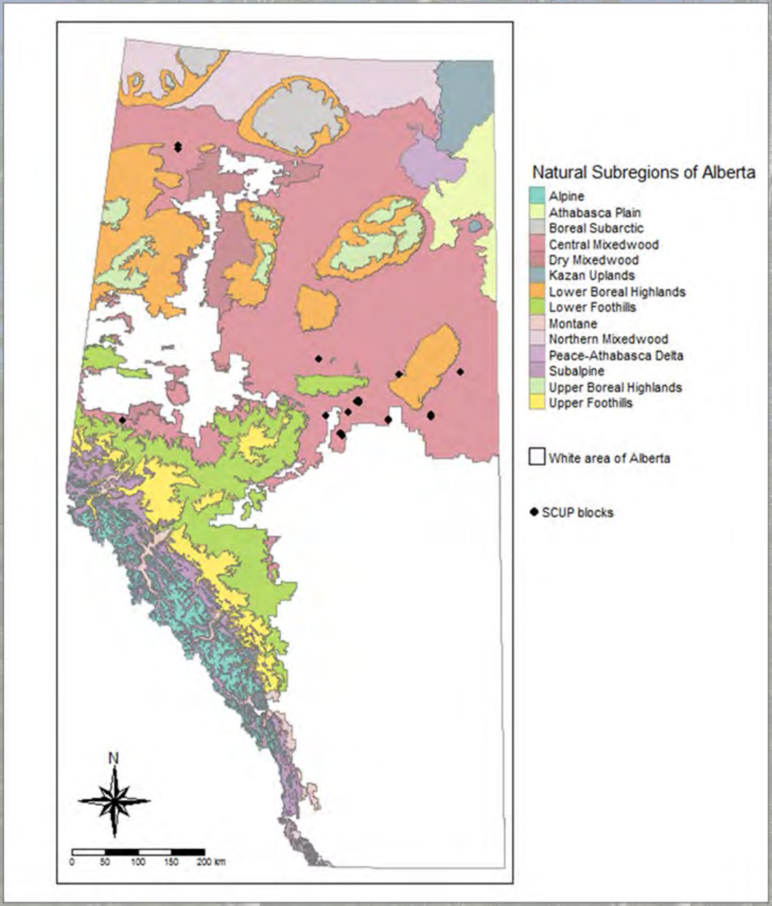


Fig. 2. Single-pass strip cut understory protection harvest pattern.

From: Grover, B.E., Bokalo, M., Greenway, K.J. 2014. White spruce understory protection: from planning to growth and yield. For. Chron. 90: 35-43

MWMA SCUP (Strip Cut Understory Protection) Trial design



- Developed by Mixedwood Management Association, under the leadership of Gitte Grover and Willi Fast
- Objectives: to collect data on understory white spruce growth after overstory removal through strip cut harvesting, and on aspen regeneration and growth in machine corridors and removal areas.
- Established in 18 blocks between 2005 and 2007

- Central Mixedwood Natural Subregion
- Ecosite:
  - Ecosite: **d** (83 plots) and **e** (9 plots)
  - Mesic SMR: mesic to subhygric*
  - Medium SNR: medium to rich*
- Range in elevation: 351-770 m
- Climate (2004-2018 averages)
  - CMI: -2.2 - 3.5
  - MAT: -0.3 - 2.5 ∘C
  - MAP: 431 - 507 mm
  - NFFD: 149 - 158 days
- Topography
  - Slope: 0-20% (85 plots within 10% slope)
  - Slope position: all (8 plots at upper slope or crest)

SCUP Trial design

Vanderwell SCUP block

SCUP blocks

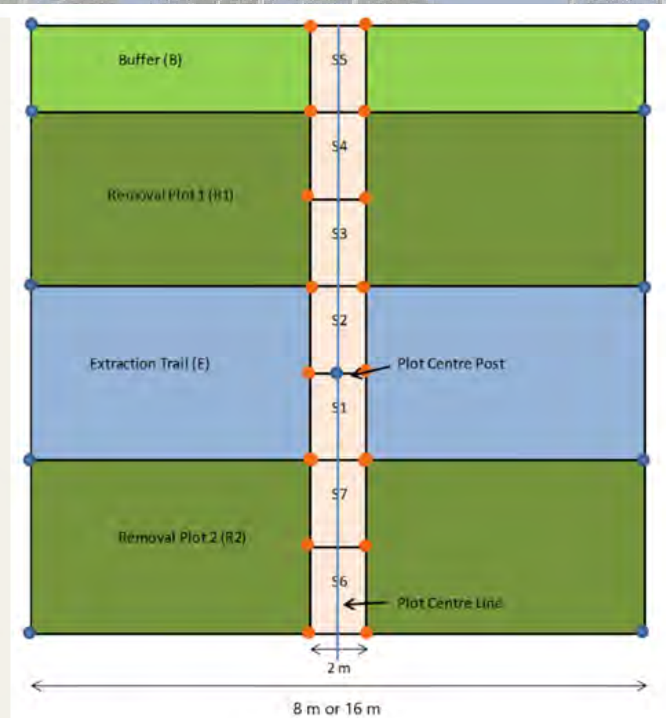
- Total of 92 cluster PSP plots established; 2 or 6 per block
- 5-year measurement schedule
- Measurement protocol changed effective 2013
- Assessment of top height trees for aspen and spruce was added to the protocol

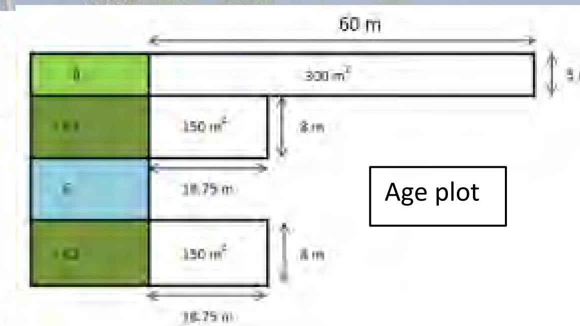
<u>Project objectives</u>

- analysis of spruce response to release
- analysis of mortality of residual spruce and aspen
- analysis of ingress in extraction and removal areas

General layout of a SCUP plot cluster

- Plot length is 8 or 16 m, and is the same for each subplot (wind buffer (B), retention area (R1/R2), and extraction trail (E) treatments) (8 m length used when buffers >10 m wide, and 16 m length used when buffers <u><10 m wide)</u>
- Sapling subplots (S1-S7) are 2 m long
- Subplot widths, including nested sapling subplots, vary with width of each SCUP treatment
- Total plot cluster sizes range between 150 m^2 and 463 m^2
- Age plots to determine ages and SI–two types:
  - adjacent to the buffer 300 m^2 subplot for aspen sampling (100 m2 prior to 2013)
  - two age plots of 150 m^2 in size were located adjacent to removal subplots for sampling of spruce post-release height growth





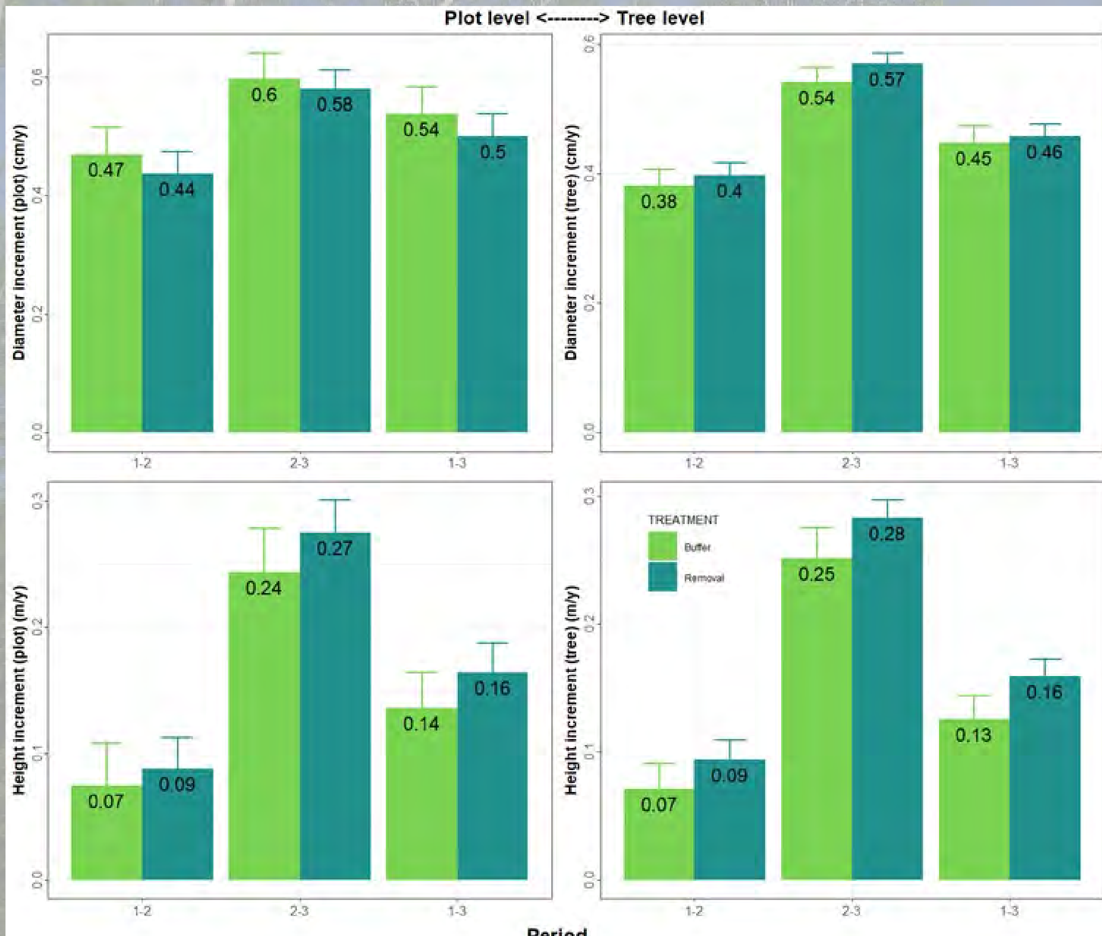
Measurements for the 18 SCUP Installations

Company FMA	Block Number	Number of Plots	Established	5-year Remeasure	Site Index Assessed	10-year Remeasure
Vanderwell	7012	6	2005	2010	2012	2015
Al-Pac	27131	6	2005	2010	2012	2015
Al-Pac	19191	6	2005	2010	2012	2015
Al-Pac	29691	6	2005	2010	2012	2015
Al-Pac	16751	6	2005	2010	2012	2015
Al-Pac	11911	6	2007	2012	2012	2016
Al-Pac	22361	6	2007	2012	2012	2016
Al-Pac	36551	6	2007	2012	2012	2016
Al-Pac	36271	6	2007	2014	2014	2019
Al-Pac	36381	6	2007	2014	2014	2019
Al-Pac	34591	6	2007	2013	2013	2018
Al-Pac	27631	6	2007	2013	2013	2018
Al-Pac	15571	6	2007	2013	2013	2018
Ainsworth	572	2	2007	2014	2014	2019
Tolko HL	330	2	2007	2014	2014	2019
Tolko HL	2212	2	2007	2014	2014	2019
Al-Pac	17781	6	2007	2013	2013	2018
Al-Pac	20631	2	2007	2013	2013	2018

- The measurement protocol evolved over time
- Growth, mortality and ingress of spruce and aspen trees:
  - Measurements for each tagged tree in the retention and buffer subplots above the common tagging limit (≥7.1 cm in DBH) for both, deciduous and conifers
  - species, total height, DBH, height to live crown, lean (%), crown class, and tree condition recorded
- Saplings (by species):
  - Saplings defined as deciduous or coniferous trees ≥ 1.3 m height and < 7.1 cm DBH
  - Species, total height, DBH, lean (%), crown class, and, tree condition
- Data from 10-year remeasurement suitable for MGM initiation for yield estimation for all installations
- Remeasured every 5 years to age 20, and every 10 years after age 20.
- In age plots, height is remeasured for measured/cored trees.

Key findings (Bjelanovic et al. in prep)

- No differences in spruce growth were evident between removal and buffer areas (ie. spruce growth improved in both).
- Spruce height increment during the second 5-year period (age 5-10) increased approximately 3 times of that observed in the first period after the SCUP harvest.
- Diameter increment of spruce increased immediately after overstory removal, and increased a further 25% in the 5 y second period.
- Aspen saplings were more abundant in removal (14,637 sph) than in extraction (7,654 sph) at age 10, although there was substantial variation in aspen densities between blocks. Aspen sapling density in buffer areas averaged 6,686 stems/ha.
- At age 10 spruce sapling density averaged 1,140 sph in removal areas, 696 sph in buffer areas and 55 in extraction areas.
- Seventy years after understory protection harvest MGM estimates yields of 105 m^3/ha for deciduous and 168 m^3/ha for conifer.
- Recommendations: Addition of preharvest measurements should be considered for future installations.
- Remeasurements are planned for 5 year intervals.

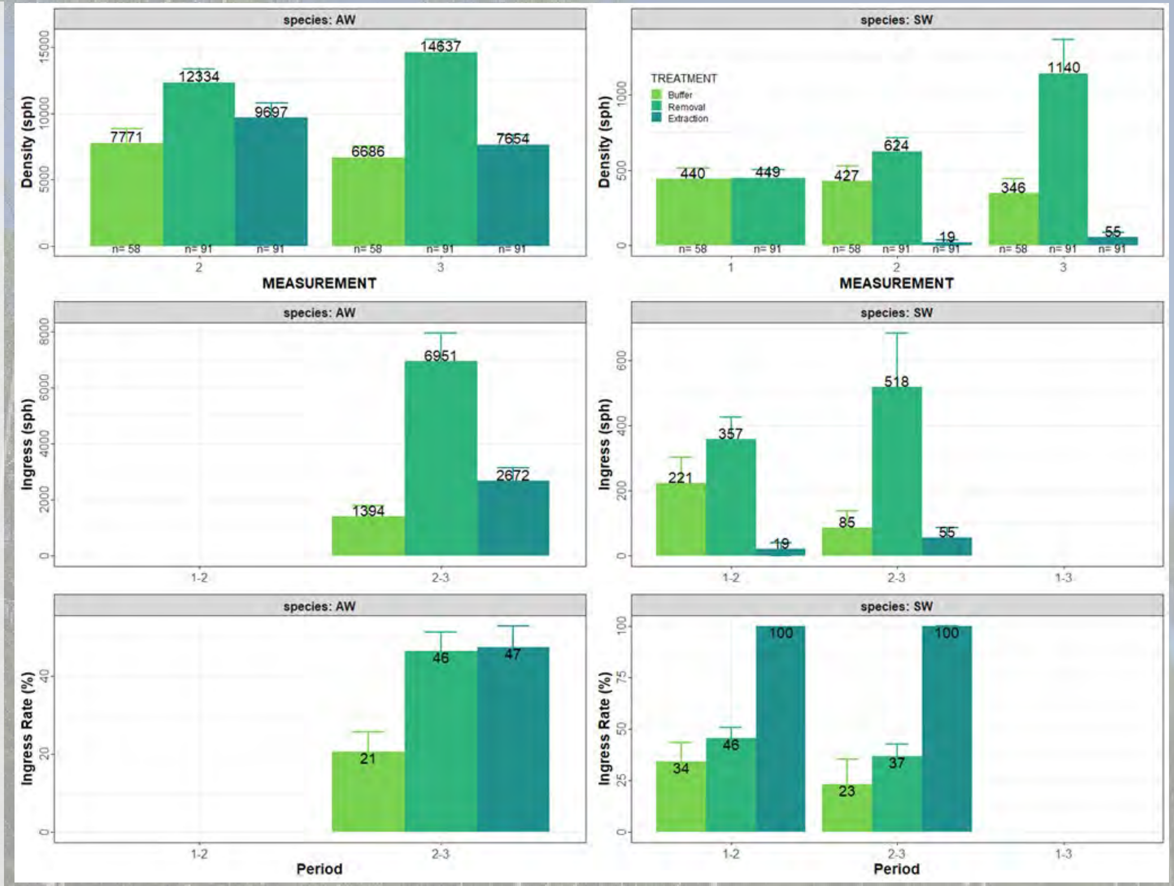


Spruce growth response

- There was an immediate increase in spruce **diameter increment**.
- **Height growth response** was delayed to the second measurement period (2-3).

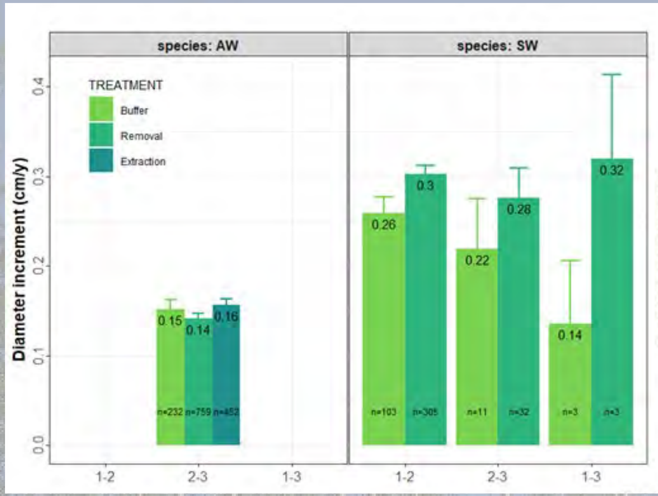
Density and ingress of saplings
(> 1.3 m height and < 7.1 cm DBH)

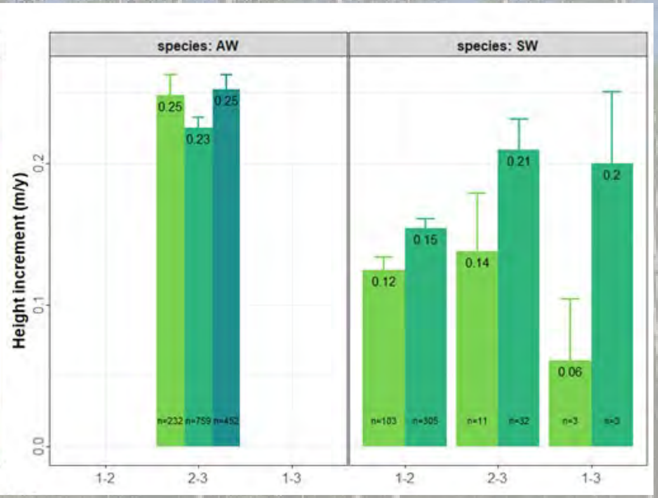
- Aspen saplings more abundant in removal (14,637 sph) than in extraction (7,654 sph) at age 10, although there was substantial variation in aspen densities between blocks.
- Aspen sapling density in buffer areas averaged 6,686 stems/ha.



Growth responses of aspen and spruce saplings

- Lower tagging limit is 1.3 m height and upper tagging limit is 7.1 cm DBH for both species.
- No re-measured spruce found in the extraction trails.
- Aspen - diameter increment of aspen saplings during the second growth period ranged between 0.14 and 0.16 cm/y, and height increment ranged between 0.23 and 0.25 m/y.
- Spruce - during the first period annual spruce sapling diameter increment averaged 0.26 and 0.30 cm/year, for buffer and removal, respectively, with second period values of 0.22 and 0.28 cm/year. Mean annual height increment of the spruce saplings was 0.12-0.15 m/year during the first period, and 0.14-0.21 m/year during the second period.





SmartForests in SCUP Installations

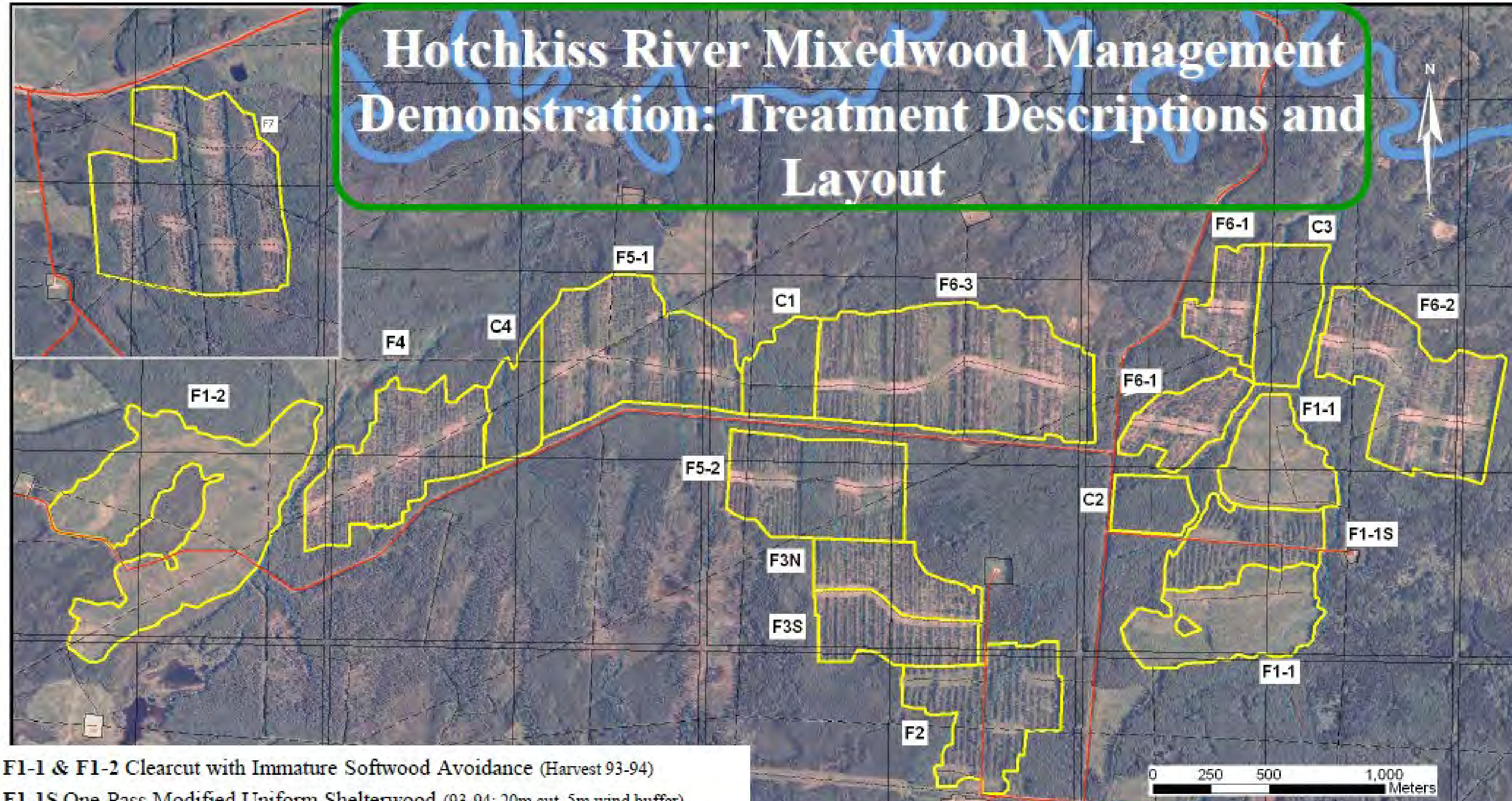
- In each of 4 plot clusters in the Vanderwell Fawcett Lake UP Block 7012 –microclimate stations installed adjacent to 2 removal area and 1 extraction trail subplots.

Hotchkiss River Mixedwood Management Demonstration

(Canadian Forest Service)

- Objective: To evaluate effects of harvesting patterns on windthrow risk to understory spruce.
- Established in 1992 by CFS.
- located 50 km NW of Manning, Alberta.
- Stand had 90 year old aspen and a 60 year old understory of white spruce when established.
- Treatments: one- and two-pass modified uniform shelterwoods, two- and three-pass strip shelterwoods, two-pass alternate strip shelterwoods and four-pass progressive strip shelterwoods.
- 19 treatment blocks, each harvesting treatment applied to one block, except for the clearcut which was applied to 3 blocks + 4 control plots.
- Measurements: 5 m wide belt transects across width of each treatment block, trees >1.3 m height tagged and measured preharvest. Measurements taken preharvest, postharvest, 5, 10, 15 and 10 years.
- MacIsaac, D.A., Krygier, R. 2009. Forestry 82: 323-342. doi:10.1093/forestry/cpp013 [Year 10].
- Report in preparation based on 20 year measurements.

Hotchkiss River Mixedwood Management Demonstration: Treatment Descriptions and Layout



F1-1 & F1-2 Clearcut with Immature Softwood Avoidance (Harvest 93-94)

F1-1S One-Pass Modified Uniform Shelterwood (93-94: 20m cut, 5m wind buffer)

F2 One-Pass Modified Uniform Shelterwood (93-94: 20m cut, 10m wind buffer)

F3N Two-Pass Modified Uniform Shelterwood (93-94 20m cut alternating with 98-99 20m cut)

F3S Two-Pass Modified Uniform Shelterwood (93-94 20m cut alternating with 98-99 15m cut, 5 m wind buffer)

F4 Two-Pass Shelterwood (50m strips, 93-94: 50% removal beside 100% removal alternating with 98-99:50% removal beside 100% removal)

F5-1 Three-Pass Shelterwood (50m strips, 93-94: 50% removal beside 100% removal, 98-99 remove balance of 50% in first pass plus 50% removal in new strip, 03-04 remove balance of 50% in second pass plus 100% removal in new strip)

F5-2 Three-Pass Shelterwood (same pattern as F5-1 except with 100m wide strips)

F6-1 Two-Pass Alternate 50m Strip (93-94 100% removal alternating with 98-99 100% removal)

F6-2 Two-Pass Alternate 100m Strip (93-94 100% removal alternating with 98-99 10 m wind buffer with 40m 100% removal- 10 m wind buffer with 40m 100% removal)

F6-3 Two-Pass Alternate 150m Strip (93-94 100% removal alternating with 98-99 10 m wind buffer with 40m 100% removal/ 10 m wind buffer with 40m 100% removal/ 10 m wind buffer with 40m 100% removal)

F7 Four-Pass Progressive 50m Strip (93-94 100% removal adjacent to 98-99 100% removal adjacent to 03-04 100% removal)

C1-C4 Un-cut Controls

For F4, F5-1, F5-2 and F7, harvesting of subsequent passes progressed east to west into the direction of the prevailing wind.

Hotchkiss – Key findings

- Windthrow reduction best with single entry harvest with 35 m wide removal strip and 5 m wide buffer and machine corridors on 20 m centres
- Windthrow increases when removal area width exceeds 2.5 x the height of the canopy (75 m at Hotchkiss)
- Sw advance regeneration >7 m tall require wind buffers

CFS Adaptive Mixedwoods

(Derek Sidders, Canadian Forest Service)

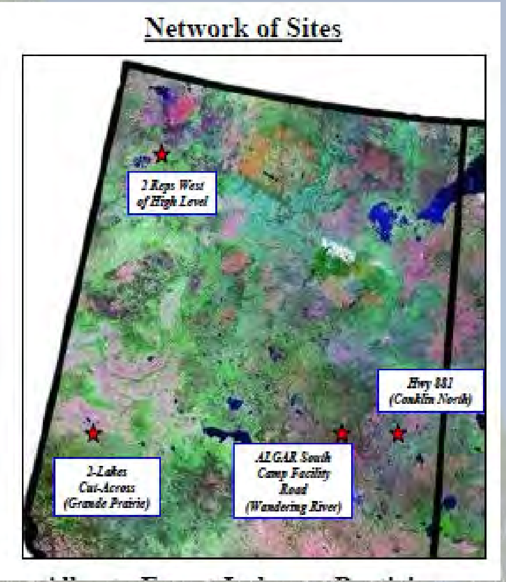
– Objective: To test options for managing mature aspen stands with understory spruce and establish a network of sites and psp's.

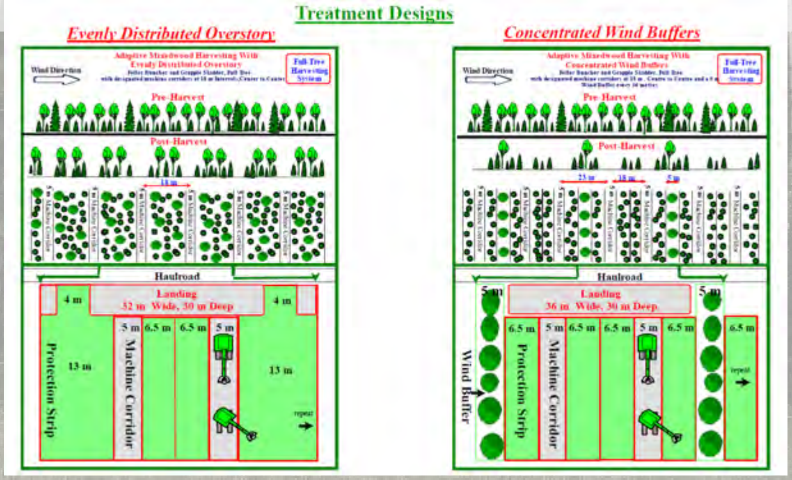
– Locations: 4, total of 6 reps

– 3 Treatments: Concentrated wind buffers with 40 m spacing, evenly distributed retention of 10-15% of aspen basal area, control. Completed winter 2005/2006.

– Measurements: 5 m wide belt transects across width of each treatment block, trees >1.3 m height tagged and measured preharvest. Measurements taken preharvest, postharvest. Year 7 measurements collected at Grande Prairie (2012).

  – **Key findings: evenly distributed and retained overstorey is the most successful for aspen volume recovery, Sw release response and blowdown protection. (Derek Sidders, pers. comm., Sept 7, 2021)**





Growth responses of white spruce to release from trembling aspen (CFS-MS-153)

CFS - Yang, R. C. (1989). Growth response of white spruce to release from trembling aspen. Edmonton, AB, For. Can., North. For. Cent. Information Report NOR-X-302.

Osika et al. 2013. Can. J. For. Res. 43:139-148

- Established 1951-1954
- 8 sites ranging in age from 25 to 60 - Candle Lake (x2), Big River (x2) Montreal Lake, Bertwell and Reserve in Saskatchewan and Riding Mountain, Manitoba
- At each site four 38 m x 38 m treatment plots with 0.04 ha (20 m x 20 m) psp's. Two plots had all aspen removed and two left as controls.
- Most recent remeasurements for 5 sites in 2002? by Dan MacIsaac
- Yang 1989 also mentions MS8 est in 1936 in the Duck Mountains, MB

Underplanting trials

- CFS - “Duffy” underplanting and others
- Alpac (Grover) underplanting trials
- Stewart, J., Landhausser, S.M., Stadtm K.J., Lieffers, V.J. et al. 2000. Regeneration of white spruce under aspen canopies: seeding, planting and site preparation. W. J. Appl For. 15:177-182

EMEND
(Ecosystem Management Emulating Natural Disturbance)
(U of A and CFS)

- Initiated in 1998/99 under the leadership of John Spence and Jan Volney.
- 100 experimental compartments of ~ 10 ha each representing a range of boreal mixedwood forest types from ‘pure’ broadleaf to broadleaf-conifer mixtures to ‘pure’ conifer.
- 8 Treatments: 5 levels of retention (2, 10, 20, 50, 75) plus unharvested control in a fully replicated factorial experiment, plus slash burn in 10% retention and prescribed burn in unharvested.
- Six PSP’s (each 2 m x 40 m (for trees with DBH≥5cm), include two 2 m x 10 m regen/shrub subplots for trees >1.3 m height but <5cm DBH) established in each “treatment block” with three replicates for each forest type by harvesting treatment combination.
- PSP’s established in 1998 preharvest, and remeasured in 1999, 2001, 2004/05, 2009/10 and 2014/15 (year 15).
- Several (54) psp’s have been instrumented under SmartForests to track effects of retention and stand structure on microclimate.

EMEND
(Ecosystem Management Emulating Natural Disturbance)
(U of A and CFS)

MSP and Retention Study

– Lieffers, V.J., Sidders, D., Keddy, T., Solarik, K.A, Blenis, P. 2019. A partial deciduous canopy coupled with site preparation produces excellent growth of planted white spruce. Can. J. For. Res. 49: 270-280. doi: 10.1139/chfr-2018-0310
– 25 m x 25 m treatment plots.
– Treatments: 2 Stand types (DDOM, CDOM) x 3 retention levels (0, 50, 70) x 4 site prep (mound, mix, scalp, control).
– Spruce planted July 1999
– Individual trees tagged.
– Best spruce growth in the DDOM, 50% retention with mound or mix sp

BC studies

- **BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development**
  - Group shelterwood in aspen-white spruce stands. (Kabzems. 2001. Prince George Forest Region Note #PG-24) – Est. 1996 and 1998. Tested 40 m and 113 m diameter openings. Measurements collected along transects (individual trees or small plots)
  - Siphon Creek and Bear Mtn (Kabzems, Bokalo, Comeau and MacIsaac. 2016. Forests 7,5). Est. in 1989 to test effects of aspen density (0, 1000, 2000, 5000, and 1000 sph) on spruce and aspen growth and on yield. (four 0.04 ha subplots measured in each treatment plot). *Close parallel to WESBOGY LTS*.
  - Sierra Rd. Underplanting (Kabzems, Comeau, Filipescu, Rogers and Nemec. 2016. Can. J. For. Res. 46:1217-1223). Objective: To test effects thinning and fertilization on growth of retained aspen and undeplanted spruce. Est. 1991 in a 39 year old aspen stand. PSP= 0.04 ha. Remeasured periodically, last reported measurement in 2014.

BC studies (continued)

- **BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development**
  - Fort Nelson Growing Space Study (Kabzems, Harper and Fielder. 2011. West. J. Appl. For. 26: 82-90) – Established in 2001 in a regenerating stand to test the effectiveness of 5 treatments involving spot or broadcast control of aspen in growing intimate aspen spruce mixedwoods. Each treatment replicated 3x. Treatment plots 50 m x 50 m, psp=0.025 ha (9 m radius), regen plots =0.005ha (3.99 m radius).

Table 1. A summary of treatments applied at the Fort Nelson site. White spruce was planted throughout all treatments in July 1998 at 1,200 stems/ha.

Treatment	Timing	Method
Manual complete aspen removal	August 2001	Brush saws.
Chemical complete aspen removal	August 2001	Foliar treatment with Vision herbicide (glyphosate) applied by backpack sprayer (2% solution) at 1.6 kg [ai] ha.
	September 2004	Manual removal of aspen stems where initial chemical treatment was incomplete.
	August 2005	Spot foliar treatment of aspen regeneration with Vision herbicide (glyphosate) applied by backpack sprayer (2% solution) at 1.6 kg [ai] ha.
Manual spot—1.25-m radius aspen removal	August 2001	Brush saws with treatment centered on spruce tree. Approximately 52% of plot area was brushed.
Chemical spot—1.25-m radius aspen removal	October 2001 (after leaf drop)	Basal treatment with Release herbicide (triclopyr ester) mixed with mineral oil at 20% concentration applied to each stem by backpack sprayer fitted with narrow-angle, flat-fan nozzle. Treatment plot centered on spruce tree. Approximately 59% of plot area was treated.
Aspen spacing	July 2005	Aspen uniformly spaced with brush saws to an average of 1233 stems per hectare post treatment (3 × 3 m).
Untreated control		No treatment.

Herbicide trials with a spruce focus:

Impacts of single and repeated glyphosate herbicide applications on plant community diversity in an Alberta spruce plantation

Phil Comeau[1], Erin Fraser[2] and Susan Humphries[1]

[1] Department of Renewable Resources, University of Alberta, Edmonton, Canada

[2] Alberta Agriculture and Forestry, Edmonton, Canada

Comeau, P.G., Fraser, E.C. 2018. Plant community diversity and tree growth following single and repeated glyphosate herbicide applications to a white spruce plantation. Forests 9, 107 doi: 10.3390/f9030107

Funding for establishment provided by Alberta Forest Products Association.

Funding for age 10 remeasurement funded by Alberta Environment and Sustainable Resource Development (now Agriculture and Forestry)

Treatment application funded by Vanderwell Contractors and supervised by Richard Chemago

Objectives

Experiment established in 2004 to examine:

1. effects of one and two glyphosate treatments, and effects of timing of a single glyphosate treatment on plant community diversity
2. treatment effects on aspen density and size
3. growth of planted white spruce.

Location: Southwest of Calling Lake, Alberta (55.46° N 113.25° W)

- L2-L81 near Calling Lake; 4 blocks harvested in winter 2003/2004
- Central Mixedwoods Ecological Subregion; SMR: mesic-subhygric; SNR: medium-rich; D3 ecosite phase (lowbush cranberry Sw)
- No MSP (in plots); Sw 1+0 PSB 412 planted July 2004 (1600 sph)

4 Treatments

- a) untreated (control);
- b) aerial application of glyphosate (Vision) at 2.1 kg ai/ha in the first growing season after harvesting (2004);
- c) aerial application of glyphosate herbicide at 2.1 kg ai/ha in the third growing season after harvesting (2006); and
- d) aerial application of glyphosate herbicide at 2.1 kg ai/ha in the second AND fourth growing seasons after harvesting (two treatments; 2005 and 2007).

VISION® (glyphosate) herbicide applied at a rate of 6 l/ha of product, diluted in 44 l of water for a total spray volume of 50 l/ha.

Herbicide treatment was completed by Western Aerial Applicators using a Lama helicopter with spray booms fitted with Accuflow nozzles.

Design

- Randomized Incomplete Complete Block Design
- Treatment plots 100 x 200 m or larger
- 5 “blocks”
- 4 plots per block

Measurement plots

- 1 measurement plot established in representative area near center of each treatment plot
- Measurement plots follow NIVMA TRENDS design –
    - 30 m x 30 m plot
    - Vegetation assessment completed in **quadrant #1** (15 m x 15 m)
    - Four 3.99 m radius Small Tree Description plots
    - All Sw measured

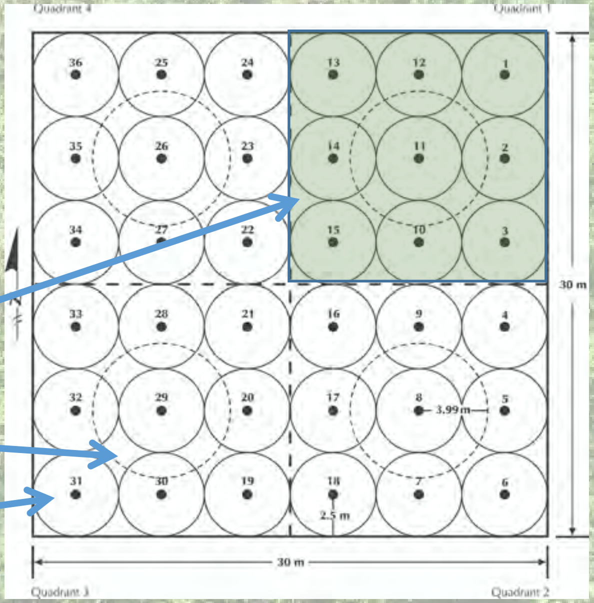


Figure 2. Layout of a measurement plot using the *TRENDS*© silvicultural protocol illustrating quadrants, 3.99 m radius subplots, grid points and numbering convention.

2014

Untreated

Treated
2006

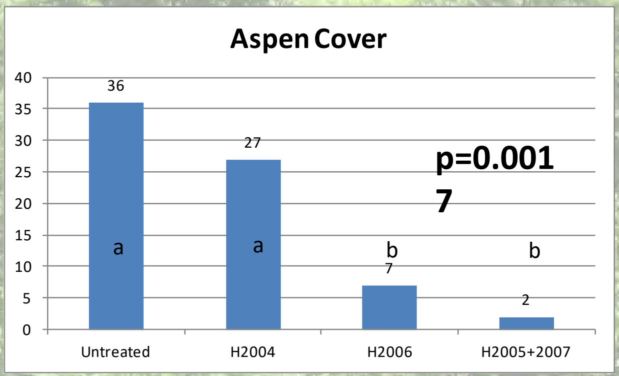
Treated
2005+2007

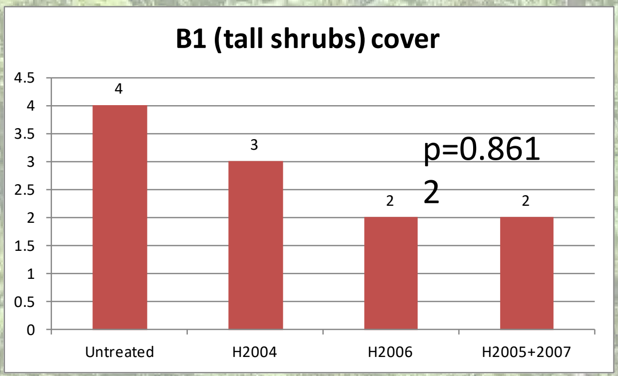
Key findings

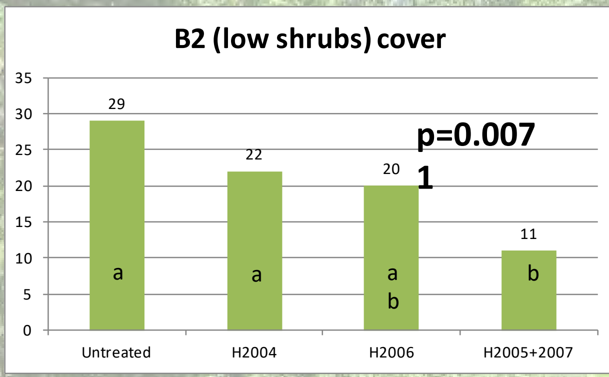
- Herbicide treatments had major impacts on aspen cover, height and density. In addition, low shrub cover was reduced by treatments.
- Effects of herbicide treatments increased with age of the block at time of treatment as reported by others.
- Richness, evenness and Shannon index did not differ between treated and untreated.
- A single treatment in the year of planting (2004) resulted in higher values for most diversity measures than 2006 or 2005+2007 treatments – and a significant increase in Shannon H over untreated
- Spruce diameter – slow response and high variability. Benefits of treating twice are very evident, with diameter in this treatment being nearly double that of the untreated in 2014.
- Reductions in aspen density by these treatments are likely to have long-term impacts on spruce growth and will likely accelerate development of a spruce stand type with later successional species.

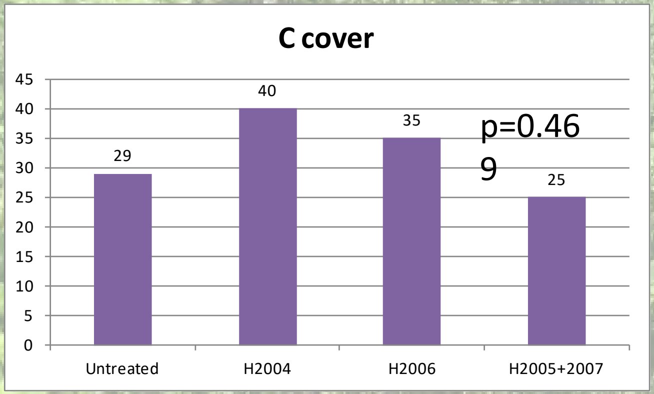
Treatment effects on vegetation cover in 2014

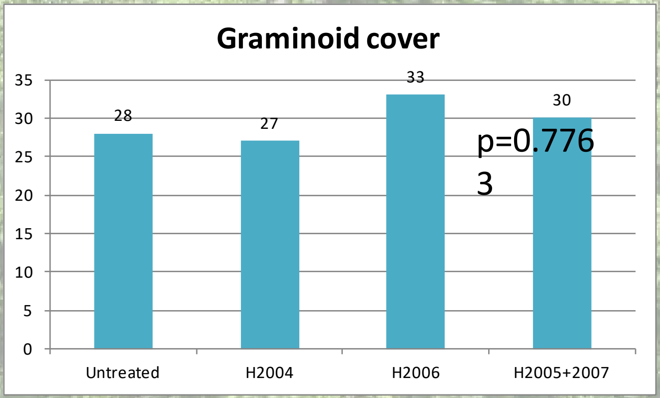
(letters indicate differences detected using Tukey's test, α=0.10)



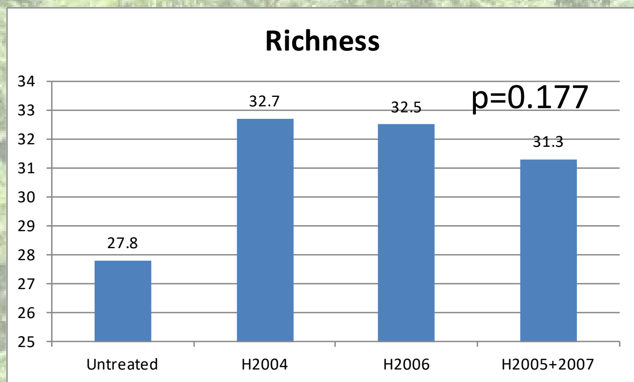


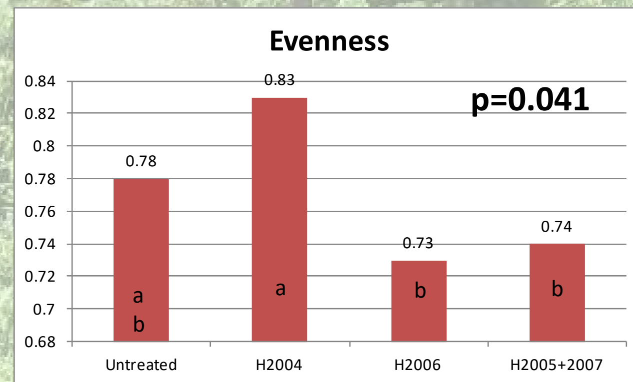


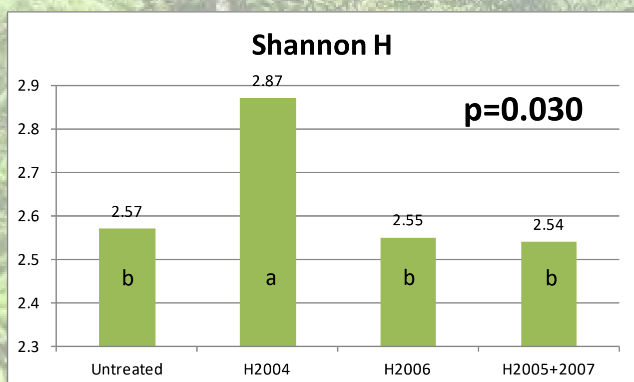


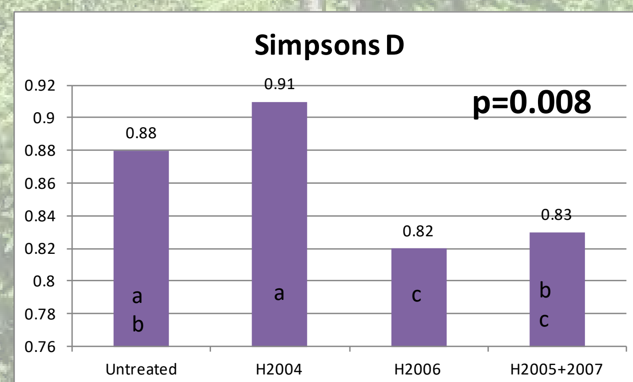


Diversity index values at age 10 (2014 data)





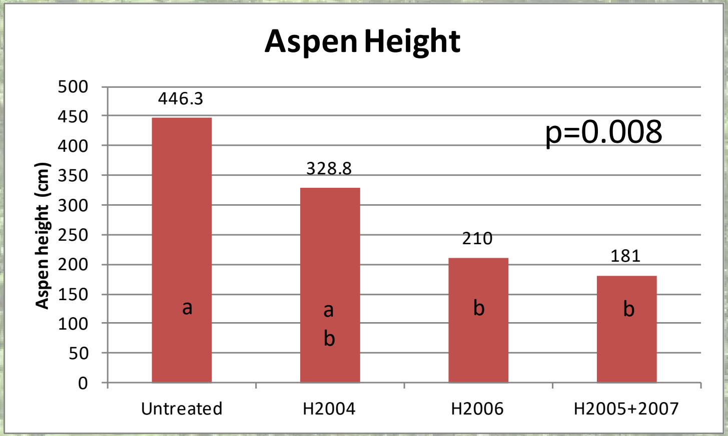


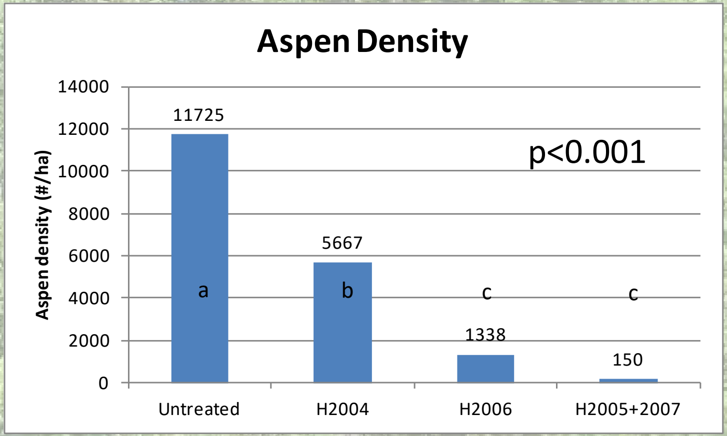


Aspen height and density in 2014

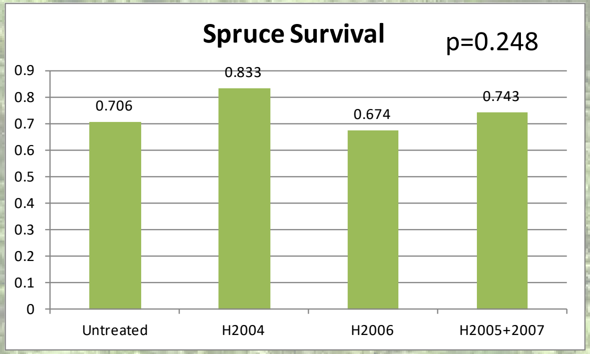
-2006 and 2005+2007 treatments significantly reduced aspen height in 2014

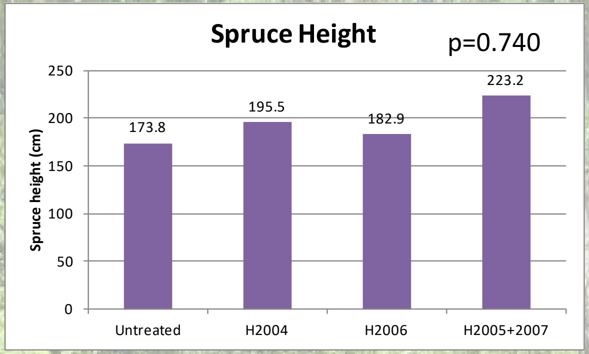
-Treatments reduced aspen density in 2014

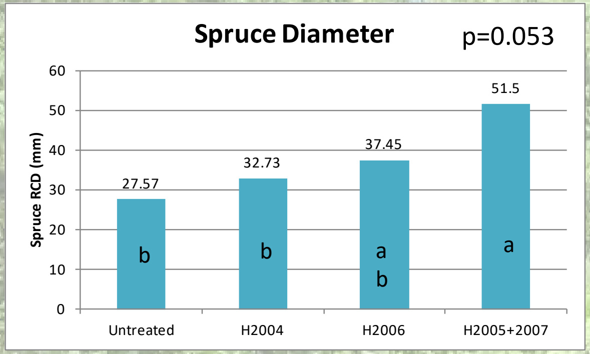




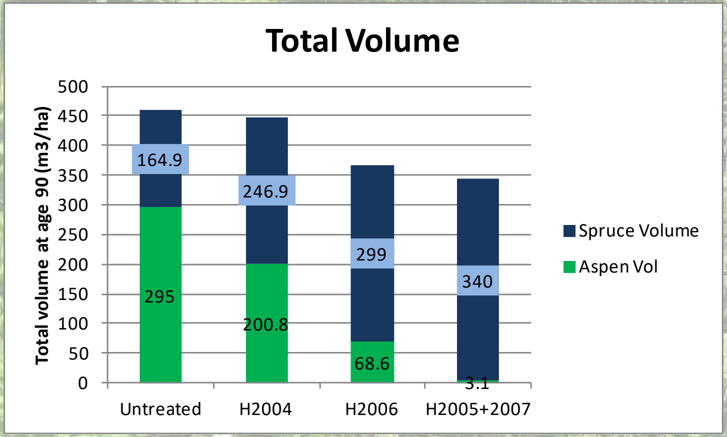
Treatment effects on spruce

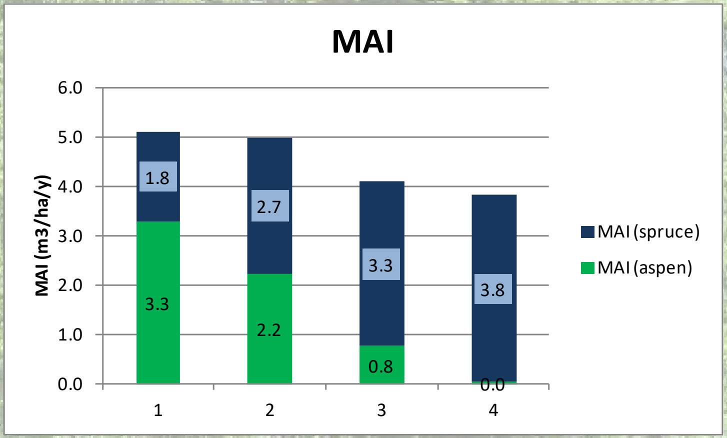






MGM (Mixedwood Growth Model) Yield Forecasts – age 90





MGM website: http://www.rr.ualberta.ca/Research/MixedwoodGrowthModel.aspx

Herbicide trials with a spruce focus:
Juvenile stand responses and potential release efforts on Alberta’s spruce-aspen mixedwood sites

- Pitt, D.G, Mihajolovich, M., Proudfoot, L.M. 2004 Juvenile stand responses and potential release efforts on Alberta’s spruce-aspen mixedwood sites. For. Chron: 80: 583-597
- Remeasured 12 Herbicide Monitoring Installations – pairs of untreated and aerially herbicided plots (>2.5 ha in size)
- Established five 10 m^2 subplots in each plot.
- Some of these and some other herbicide monitoring installations remeasured in 2019/2020 by Mihajlovich et al. (report and paper in preparation)

Conclusions

- These mixedwood studies are a gold-mine of quality data on stand dynamics.
- Because they are well documented and their history is known most provide a valuable basis for continued monitoring to examine effects of climate, site, stand and tree characteristics and their interactions on tree mortality and tree and stand growth.
- The study installations provide opportunities for developing and testing applications of remote sensing to data collection as has already been done using WESBOGY LTS, Judy Creek, and SCUP plots, as well as separate data collection work (e.g. S17) by Mike Bokalo and Kirk Johnson .
- Other studies, e.g. competitive interactions, monitoring annual growth, crown and branch characteristics and wood quality have been conducted in selected installations – and there are opportunities for many other similar add-ons in the future.
- There is also a need for new studies to evaluate and compare alternative ways to manage mixedwoods.

Thank-you for your attention.
Questions?