PROJECT REPORT

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Influence of relative density and composition on growth and understory in the boreal mixed-woods

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Influence of relative density and composition on growth and understory in the boreal mixedwoods

SFMN Project

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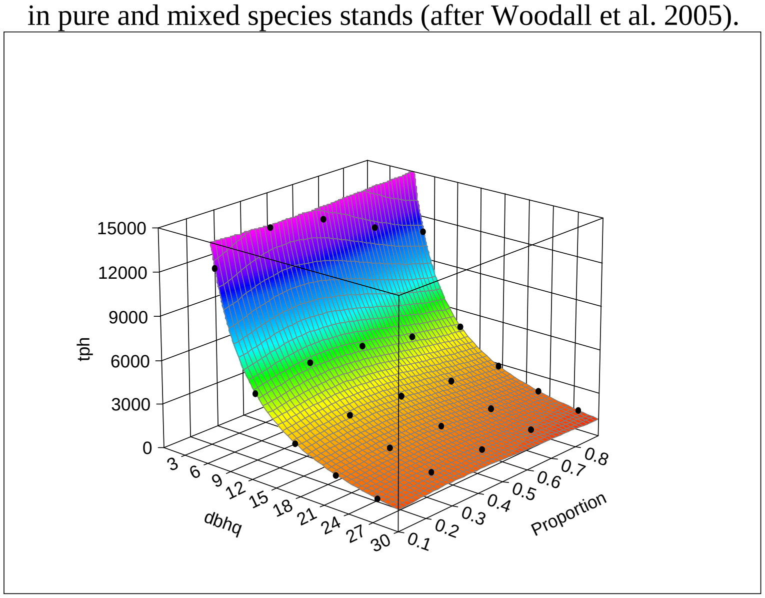
INTRODUCTION

Sustainable forest management requires the ability to estimate or predict the potential outcomes (in terms of forest structure, habitat and other ecological services, timber production, economics, and social implications) of forest management practices. The 2006/2007 call for proposals by the Sustainable Forest Management Network indicated a need for research which will improve knowledge about "whether young stands arising from forest management practices today will develop into the stands which we predict" (Research Project Priority 1. Stand dynamics and succession: using juvenile stand condition to predict future composition, structure and habitat value). This topic was also a major focus of discussion during the 2005/2006 SFMN proposal development workshop held in Edmonton Sept. 2, 2004 (SFMN 2004) which indicated a need for better knowledge of successional pathways in managed and unmanaged mixedwood forests to support sustainable forest management. This study was developed in collaboration with partner organizations to examine the use of some tools which show promise in quantitatively linking early stand conditions in managed and unmanaged stands to future characteristics and habitat values.

In mixed species stands, component species densities, size and position in the canopy, vigour and stand composition, are expected to be key factors influencing pathways and rate of development. Puettmann et al. (1992) suggest that stands may follow a range of paths along the 3 dimensional surface defined by the maximum density – dbh – and species proportion relationship. Previous studies suggest that there are upper limits to density-size relationships that exist in mixed as well as pure stands. Figure 1 illustrates the relationship between maximum density, average diameter and species proportion for Douglas-fir mixtures in the western U.S.

Figure 1. Upper boundary line for density (tph) in relation to quadratic mean diameter (dbhq) and species proportion (Douglas-fir) in pure and mixed species stands (after Woodall et al. 2005).



Documenting the dynamics of mixed species stands has proven to be challenging due to variability in species abundance, and effects of site, age, and other factors on component species growth rates. Since density by itself does not directly indicate space or resource utilization, other measures of crowding (ie. relative density, tree-area ratio, stand density index) are likely to be more useful than density in defining the optimal combinations or in representing the impacts of each stand component (species or size class) on the growth of other components. Studies in mixed conifer and uneven-aged stands suggest that Reineke's Stand Density Index (SDI) may be useful as a measure of abundance, site utilization, and competition between component strata in mixedwood stands. It is closely related to the -3/2 power law and is considered to be independent of the effects of stand age and ecological site characteristics (Long 1985). SDI is calculated as "the number of trees per hectare as if the quadratic mean diameter of the stand were 25 cm" based on the formula: $SDI=N \times (DBHq/25)^{1.6}$ (Long 1985). SDI is related to light capture (Vales and Bunnell 1988) and therefore it may be useful in characterizing effects of species abundance and degree of site occupancy on growth of component species and strata. Although originally developed for even-aged single species stands, SDI can also be applied in mixed-species and multi-storied stands (Long 1996).

Maximum values for SDI can be identified for pure or mixed stands (Long 1985). Schuler and Smith (1988) found that mixtures of pinyon pine and juniper had 30% higher maximum SDI, higher leaf area index (LAI), and higher rates of wood biomass increment than pure stands. Puettmann et al. (1992) found a non-linear effect of composition on the maximum size-density limit for mixtures of Douglas-fir and red alder which supported the hypothesis that maximum size-density limits of mixed stands should not exceed those of the monocultures (White 1985). However, in mixtures of perennial species which differ in resource requirements or other features (such as in mixtures of deciduous shade intolerant trembling aspen with evergreen shade tolerant white spruce) – certain levels of species mixture should be capable of supporting higher total densities at a given tree size (ie. higher maximum SDI) (Woodall et al. 2005). This is consistent with observations indicating greater productivity in mixed stands of white spruce and trembling aspen than in pure stands (Man and Lieffers 1999, MacPherson et al. 2001).
Relative density (RD) is the ratio of measured SDI in a stand to the potential maximum value (based on mean diameter) for that stand. RD indicates the proportion of full stocking or full site utilization. Increment in even-aged single species stands is expected to be near maximum at a RD of between 0.35 and 0.6 (Smith and Hann 1986; Drew and Flewelling 1979, Long 1985). However, composition and sizes of component species are likely to influence relationships between increment and RD in mixedwood stands.

Understory shrub and herb layer abundance (cover, leaf area index, or biomass) is generally inversely related to relative density, overstory cover, basal area and leaf area index in boreal mixedwood stands and is also be influenced by tree species (ie. understory shrub and herb cover is usually higher under aspen than under spruce stands) (Vales and Bunnell 1988, Moore and Deiter 1992; Lieffers and Stadt 1994; Comeau et al. 2004a; Hart and Chen 2006; Bartemucci et al. 2006). Changes in understory cover following tending or harvesting can be effectively related to changes in these structural characteristics. Since declines in relative density (and reduced dominance of ecosystems by trees) result in increased understory abundance - RD might be

useful in developing prescriptions for stand structure and composition that consider non-timber values (understory vegetation) of the ecosystem.
Leaf area index (LAI) is another potentially useful measure of growing space occupancy and is strongly related to stand volume increment (Waring 1983). In addition, growth of each component in a mixture (including understory vegetation) is expected to be proportional to the amount of light it intercepts (Cannell and Grace 1993). Maximum stand LAI values are controlled by site quality, and actual LAI values reflect the level of site occupancy by the stand (O'Hara et al. 2001). Dean and Baldwin (1996) report strong relationships between LAI and SDI in loblolly pine stands. O'Hara and Gersonde (2004) demonstrate the use of LAI as a measure of growing stock and space utilization in pure and mixed conifer stands. Gersonde and O'Hara (2005) found that growth efficiency (ratio of volume increment to LAI of individual trees) was greatest for individual trees in mid-canopy positions and present models relating individual tree volume increment to leaf area index and light availability. A knowledge of LAI and its distribution among stand components (species and size classes of trees and understory vegetation), and the relationships between RD, LAI, and productivity are potentially useful in understanding factors which influence productivity and dynamics of mixed-species stands and the habitat values which they provide.

While several studies illustrate potential for the application of crowding indexes such as Reineke's Stand Density Index (SDI) in the characterization and management of complex (ie. uneven-aged or mixed-species) stands, (e.g. Roach 1977, Marquis et al. 1992, Puettmann et al. 1992, Torres-Rojo and Velazquez-Martinez 2000) there are no published studies exploring their application in boreal aspen-spruce mixedwood stands. There are currently no published studies which have examined and compared maximum density-size relationships and effects of relative density and stand composition on growth rates (woody biomass or stem volume increment), LAI, and light capture in aspen-spruce mixtures. While SDI in single-species stands is thought to be uninfluenced by age, this has not been tested in mixed species stands (ie. it is possible that the location of the maximum density point may change with changes in component species DBHq).

PURPOSE

The purpose of this study is to examine and demonstrate the application of relative density (based on SDI) in the management of boreal spruce-aspen mixtures for both timber production and management of stand structure and understory vegetation. This includes examination of the use of composition and relative density for predicting future composition and sizes of component trees and examination of relationships between RD, stand growth and abundance of understory vegetation. Results from this research will contribute to development of tools to assist with sustainable management of boreal mixedwood stands and will also contribute to development of forest and stand forecasting models.

OBJECTIVES

The objectives of this study are to: 1) develop size-density relationships and relative density/crowding indexes for aspen-spruce mixtures and examine their application in linking early stand characteristics to future stand conditions; 2) evaluate relationships between growth of component species and size classes and RD or leaf area index (including examining relationships between relative density/crowding measures and leaf area index or light capture) and how these change for various component strata with age; 3) determine if a single relationship exists for stands in Ontario, Manitoba, Alberta and B.C. or if it is necessary to develop region specific relationships; 4) evaluate relationships between understory abundance (cover of shrub, herb and grass layers, understory LAI) and RD or overstory LAI; and 5) examine rates of change in RD in mixedwood stands and explore application of RD in management of mixedwood stands.

METHODS (APPROACH)

Data

The study is using data from permanent sample plots (PSP's) in stands of pure aspen, pure white spruce, and mixtures of these two species from circum-mesic (submesic-subhygric) sites in the Central Mixedwoods Ecological Subregion of Alberta and Saskatchewan, from Riding Mountain, Manitoba, and from Ontario. For the boreal forests of Ontario we are examining pure deciduous (aspen/birch), pure conifer (black spruce, white spruce, and balsam fir), and mixtures. Alberta PSP's are variable in size, but most of them are 0.10 ha in area (31.62 x 31.62 m), with all individual trees taller than 1.3 m in height or larger than 5 cm in diameter marked and repeatedly measured at 5 or 10 year intervals. Establishment and measurement of these PSP's followed rigorous standards (Forest Management Branch, 2005). Similarly, PSPs in Ontario are established in a wide range of stand condition including the stand types (pure spruce, pure aspen, and their mixtures) with varying ages. They are 400 m^2 circular plots with a similar measurements protocol to that used in Alberta.

We are using data from over 1200 plots in Alberta (pure aspen, white spruce and mixtures), from approximately 1500 plots established near Riding Mountain, Manitoba by the Dominion Forest Service (including 284 plots which were remeasured in 2002 and which provide between 54 and 56 years of growth measurement history) and at least 300 plots in Ontario.

Data preparation

To date, data from Alberta and from Riding Mountain have been compiled and processed to calculate total quadratic mean diameter (QMDtot), % basal area in aspen (PBAaw) and in deciduous species (PBAdec), spruce and other species, and various measures of density and relative density (by species, and diameter class) including: number of trees/ha (TPHtot), basal area/ha (BAha), volume/ha (VOLha) and Reineke's SDI. Periodic annual increment (PAI) in volume and basal area (plot and stand level) have been also compiled for these plots. Site index has also been calculated for Alberta PSP's, based on aspen or white spruce. Additional site quality information has been obtained for Alberta data, which includes: soil moisture and nutrient regimes, natural subregion, age, ecosite, etc.

Individual tree volumes were calculated using provincial equations for each natural subregion in Alberta. Individual volumes were then transformed to per plot and per hectare values.

Analysis

Multiple linear and non-linear regression analysis (maximum likelihood method) are being used to examine relationships between maximum density (TPHtot), QMDtot and composition (PBAdec), and between PAI and component species or total SDI and other independent variables (age, composition, etc.). Log data transformation, although used historically in these types of analysis, is not being used in this study to avoid potential biases associated with data transformation (Huang 2001). The use of non-linear models fit to untransformed data also provides an opportunity to address potential non-linearity observed in the relationship between log density and log QMD (Huang 2001). Analysis will also include the use of a modified model which provides for modeling variable slopes (Torres-Rojo and Velazquez-Martinez 1999). Size – density analysis are performed based on the use of 90th and 95th percentile values within each 5 cm diameter class.

Fifty-seven permanent sample plots (18 pure aspen, 25 mixed and 14 pure spruce) were selected to cover the range of ages, species composition and densities that exist in the Alberta PSP dataset. These 57 plots were measured in the summers of 2007 and 2008 to determine leaf area index and light absorption/transmittance of overstory and understory (using hemispherical photography and LAI-2000 plant canopy analyzers) and to collect data on cover of aspen, spruce, and understory shrub, herb, grass and moss layers. Vegetation cover was visually estimated for each layer within each of four 10 m x 10 m subplots in each PSP. LAI-2000 measurements were also taken above the tallest understory shrub at each of 5 points inside each PSP. Four points were set up 5 m away from the plot center, each in one of the 4 cardinal points (North, South, West and East) and the fifth point was the plot center.

These measurements are being used to estimate total LAI, overstory LAI, understory LAI as well as light capture. Hemispherical photographs were also taken at 1.6 m height at each point to determine gap fraction, leaf area index, diffuse transmittance, beam transmittance, and total transmittance using SLIM software (Comeau et al. 2004b). Since hourly measurements of open-sky light (PPFD) during the growing season are required for these light calculations, we installed light sensors (Hobo PAR sensors) attached to dataloggers (Hobo microstation dataloggers) in the open at 5 selected locations in Northern Alberta. The locations of the light sensors were selected to represent the range of sites were the field data were collected (near Grande Prairie, Swan Hills, Athabasca and Cold Lake in Alberta).
In each of these 57 PSP's an L-shaped transect approach (BC- Ministry of Forests, 2005) was used to quantify coarse woody debris. The first 24 m transect was located on a randomly selected bearing from plot center, and a second 24 m long transect ran from the end of the first at 90°. The diameter of all the woody material above 7.5 cm in diameter was recorded along these two transects.

All data collection in Ontario was completed by August 2008. Ontario growth and yield databases have been obtained from the Ontario Ministry of Natural Resources. Field data collection on 30 stands of varying composition from pure jack pine (Pj), trembling aspen (Po), and mixture of Pj and Po with or without black spruce (Sb) in understory were completed by September 2008. Field data included detail tree measurements (DBH, height, species, and crown position), coarse woody debris (snags and downed logs), soil description, and understory vegetation survey. Understory light measurements were also done for all plots using sunfleck ceptometers (Model SF-80, Decagon Devices, Pullman, Wash.), but the results do not seem to be reliable. We will attempt to re-measure understory light in summer 2009, pending NSERC's support for two LI-Cor LAI-2000 units.

HQP

Valentin Reyes-Hernandez (PhD candidate) has been working on compilation and analysis of the Alberta datasets, and field work in Alberta. He will also complete the examination of regional effects on density-size relationships. He expects to complete his thesis before April of 2010.

For the work in Ontario - Zhiyou Yuan (PhD candidate), helped with data collection, along with Stephen Hart (research assistant), Triin Ilisson (PhD candidate), Xavier Cavard (PhD candidate), Brian Brassard (PhD candidate). But, Zhiyou has decided to focus on belowground process of the mixedwood ecosystems for his PhD program. Two MSc students (Yu Zhang and Samuel Bartels) were recruited in September 2008 to work on ecosystem productivity (Yu Zhang) and understory vegetation diversity (Samuel Bartels) components, respectively. Yu Zhang is currently conducting a literature review and will begin data analysis. Samuel Bartels is also conducting a literature review, is expected to measure understory light in summer 2009, and then begin data analysis in September 2009. Both students are expected to complete their respective MSc programs by April 2010.

RESULTS AND PROGRESS ON THE SEVERAL POINTS OF THE ORIGINAL PROPOSAL

1. Determination of maximum density-size relationships ("lines") for spruce, aspen and mixed stands based on a boundary line analysis of density-diameter relationships, with species composition used as a second independent variable

Basal area was used as the driving variable for selecting data points for the maximum density-size analysis. Ranges of quadratic mean diameter by plot (QMDtot) and aspen density (%BA aspen) were divided into specified number of intervals. QMDtot groups were 5 cm length, and aspen density groups were 10% basal area (0-10%, 11-20%, and so on). Data points having the maximum density within each combination of QMDtot and % basal area in aspen were selected for inclusion in the analysis. Two plot selections were performed: the first one was done by selecting the plots with the top 10% of densities in each cell (combination of QMD and composition class) and the other one by selecting the top 5% of the data points (based on density) within each cell. When there were fewer than 30 data points within a cell, three data points were selected. Non-linear (power and exponential) regression models were evaluated for estimating the maximum density – size relationship (Table 1).

Goodness-of-fit indicates that the same group of models performed reasonably well for both the top 10 and top 5 % of the maximum density points, with adjusted R^2 values ranging between 0.77 to 0.82 (Table 1). The non-linear power function ($z= a + bx+ cx^2 +dy^e$) shows the best fit for both data sets (model 6 with R^2=0.82 for top 5% and model 1 with R^2=0.79 for top 10%). All parameters in these two models are either highly significant (**) or significant (*) which indicates that percentage basal area in deciduous species (PBAdec) and total quadratic mean diameter (QMDtot) are important for explaining variation in maximum densities that stand can support.

As shown in figure 2, model 6 indicates that pure stands of aspen and spruce support higher maximum densities than mixed stands. The lowest maximum densities are supported in stands that are a 50:50 mixture of aspen and white spruce. This result is unexpected, since the theory of niche complementarity would suggest that a mixture would support higher total densities (as suggested by Schuler and Smith 1988). These results also differ from those presented by Puettmann et al. (1992), in that they indicate the mixtures will have lower densities than pure stands of either species. Further exploration of these data and of the underlying causes of this trend is required.

Figure 2. Maximum density (trees per hectare) in relation to quadratic mean diameter (QMDtot) and species composition (Proportion basal area in deciduous species) in pure and mixed aspen- white spruce stands in Alberta.

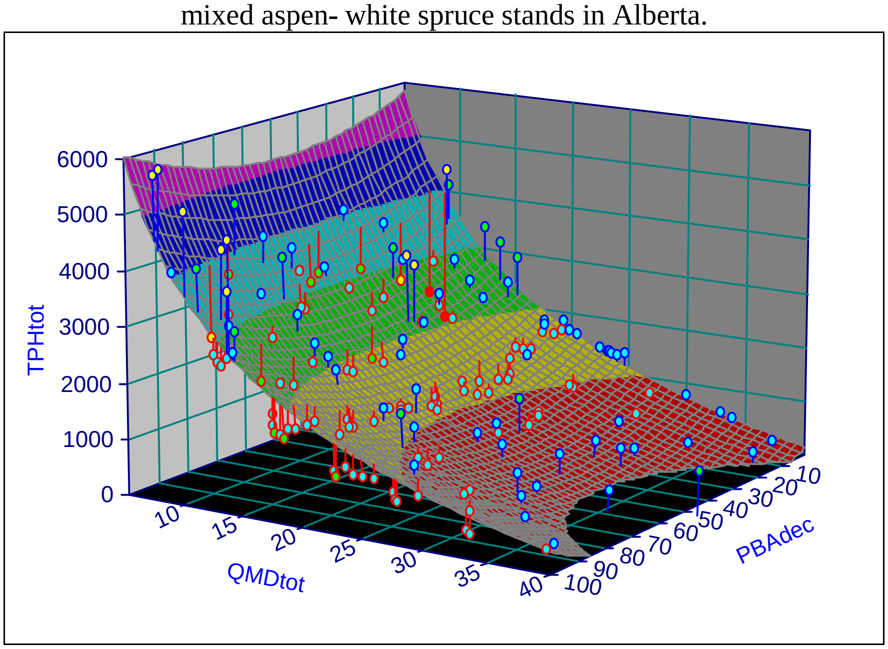


Table 1. Models fitted to the relationship of density (total TPH) with QMD and PBA in deciduous species. The first five are models using the top 10% of points, and the other 5 are models obtained using the top 5 % of points. Models are presented as they were ranked in Table curve output.

Percentil	Model #	Model	Parameters						Adj R^2	Fit Std error	F-val	P>F
			a	b	c	d	e	f				
90	1	$z= a + bx+ cx^2 +dy^e$	-7104.6	-25.12**	0.26**	19174.5**	-0.26*	----	0.79	502.8	285.2	0.000
90	2	$z =a+bx^c+dy^e+fx^c *y^e$	7375.3	-11495	0.023	-17317	-0.35**	33008	0.77	522.6	206.9	0.000
90	3	$z=ax^b+cy^d+ex^b*y^d$	-5291.6	0.096*	3002.3**	-0.26*	11542**	------	0.77	524.4	256.2	0.000
90	4	$z=a+by+cy^2+dx^e$	1559.7	-326.8**	4.87**	4316.1	-0.0001	____	0.74	560.6	214.9	0.000
90	5	$z=a+bx+cy^d$	-7965.5	2.46**	18947**	-0.24	___	____	0.74	562.9	283.0	0.000
95	6	**$z= a + bx+ cx^2 +dy^e$**	**-6171.9**	**-26.2****	**0.28****	**19695****	**-0.31***	____	**0.82**	**505.1**	**208.6**	**0.000**
95	7	$z =a+bx^c+dy^e+fx^c *y^e$	-2305.2	-872.3	0.36	9991.2**	-0.33*	2286	0.79	552.8	133.9	0.000
95	8	$z=ax^b+cy^d+ex^b*y^d$	-3492.2	0.11*	4089.9*	-0.35*	9823**	_____	0.79	551.7	167.9	0.000
95	9	$z=a+by+cy^2+dx^e$	1835.4	-346.4**	5.1**	4418.8	-0.001	_______	0.78	571.3	153.7	0.000
95	10	$z=a+bx+cy^d$	-6857.0	2.81*	19237**	-0.28	____	_____	0.77	571.9	204.0	0.000

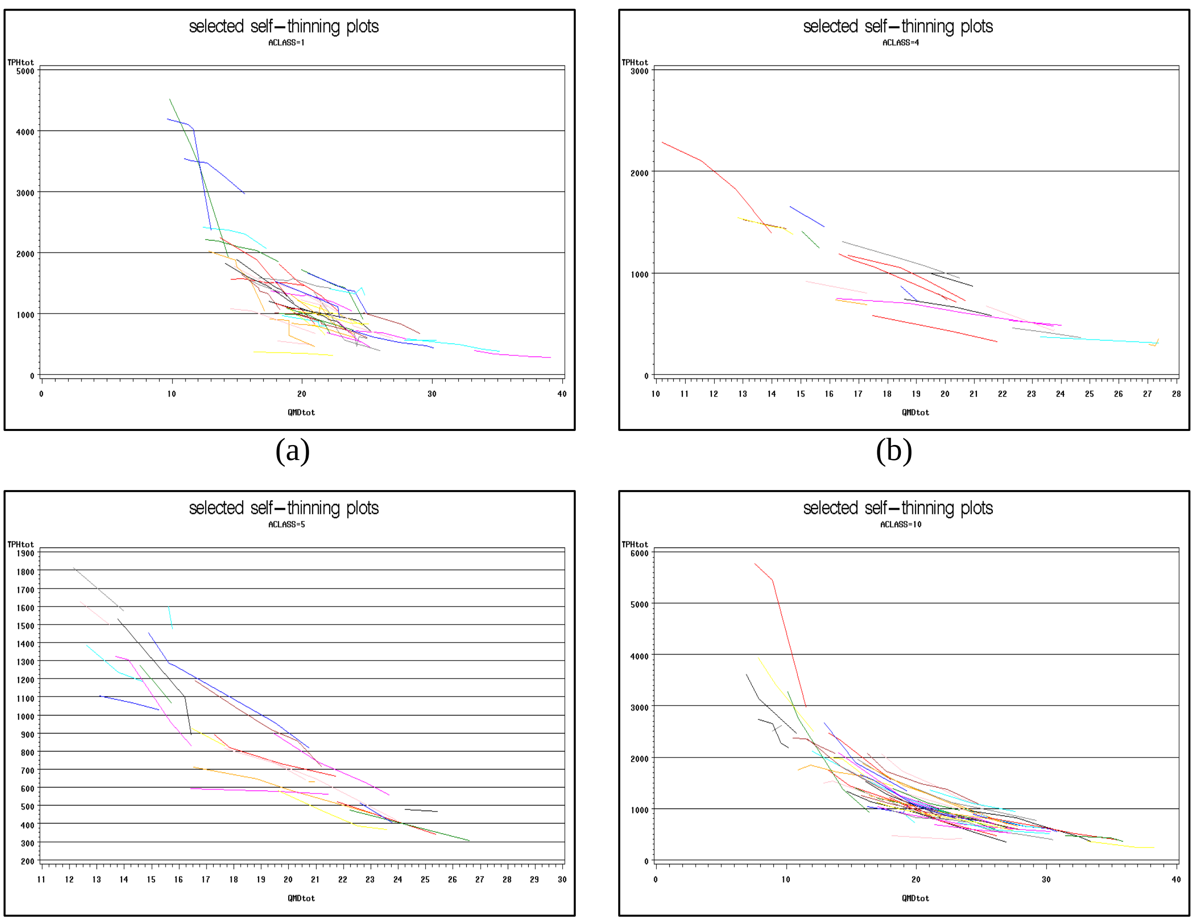
* Numbers in parenthesis indicate P>|t| for the parameter value; x=PBAdec; y=QMDtot; z=TPHtot; a, b, c, d, e and f are parameters of the model.

Plot selection to fit equations in the density-size relationship analysis

A visual inspection of plots densities throughout time was carried out in the full data set. Plots with more than 3 measurements and with evidence of mortality (Figure 3) presumably caused by self-thinning were selected for further analysis (size – density relationship) and model testing. Plot selection included some additional rules: they must be unmanaged plots with no evidence of mortality due to diseases, insect infestation, wind-throw or any other major disturbance. A non-linear regression analysis was performed with the data set obtained.

Comparing the trajectories for some of the selected self-thinning plots with different proportions of basal area in deciduous species - expressed as percentage basal area- shows that both the intercept and slope of the line defining the maximum stand density – size relationship varies with species composition. Results indicate a steeper slope as the percentage of deciduous species decreases.

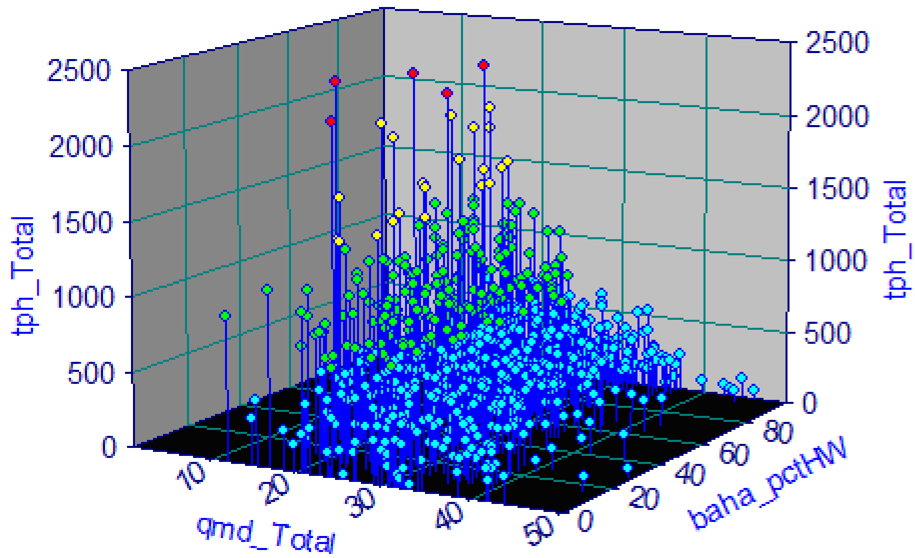
Figure 3. Thinning trajectories of individual selected plots (self-thinning), (a) Aspen density class=1 (PBAdec<10%); (b) Aspen density class=4 (PBAdec=between 30-40%); (c) Aspen density class=5 (PBAdec=between 40-50%); (d) Aspen density class=10 (PBAdec>=90%).



(a) (b)

(c) (d)

Figure 4. Scatter plot showing patterns of density (tph_Total), qmd (qmd_Total), and percent basal area in broadleaves (baha_pctHw) for the three measurements of all 280 plots from Riding Mountain, MB



Data from Riding Mountain, Manitoba collected in 1947 (age 110-120), 1967 (age 130-140) and 2002 (age 165-175) (Figure 4) indicate that self-thinning may be continuing (or that growth back to the maximum density-size line) may be occurring in at least some of these stands. Maximume density-size relationships and density-size trends for these 280 plots will be compared to trends found in the other datasets (where many of the sampled stands are much younger).

2. Examination of relationships between total PAI (all species combined) with RD/SDI and species composition

Once total volume per hectare was calculated (all species combined), mean volume and mean volume increment (periodic annual increment - PAI) was calculated for the full data set (for all species combined). Linear and non-linear regression analysis was performed to analyze relationships between PAI and qmd, stand composition and density. Results (table 2) indicate that quadratic mean diameter and density are positively related to periodic annual increment. Composition (percentage basal area in deciduous species), stand density index and nutrient regime are also important variables in explaining periodic annual increment in volume. The best model of those shown in table 2 uses nutrient regime to explain variation in PAIv.

Table 2. Models fitted to the relationships between periodic annual increment with density, diameter, composition and site quality index (nutrient regime).

Model	Parameter			F value	P>F
	a	b	c		
$PAI_v=a*TPH_{tot}^b*QMD_{tot}^c$	0.00617 (0.007)	0.246 (0.1089)	0.9028 (0.2163)	193.06	<0.0001
$PAI_v=a+b*\ln(SDI_{tot})$	-0.3738 (0.245)	0.1314 (0.038)	---------	11.46	0.0007
$PAI_v=a*SDI_{tot}^b+QMD_{tot}^c$	0.0164 (0.013)	0.2689 (0.107)	0.5593 (0.1464)	193.88	<0.0001
$PAI_v=a*PBA_{dec}^b$	0.386 (0.062)	0.0453 (0.041)	----	262.04	<0.0001
$PAI_v=a+PBA_{dec}^b$	-0.6143	0.0188		1.28	0.2580
$PAI_v=a*PBA_{dec}^b*NUREG^c$	0.2580 (0.08)	0.0492 (0.041)	0.3326 (0.2273)	175.34	<0.0001
$PAI_v=a*NUREG^b$	0.310 (0.081)	0.3264 (0.21)	--------	277.17	<0.001

PAI_v= periodic annual increment in volume; TPH_{tot}= total number of trees per hectare (all species combined); QMD_{tot}=total quadratic mean diameter (all species combined); SDI_{tot}= Stand density index (all species); PBA_{dec}=percentage basal area in deciduous species; NUREG= nutrient regime; a, b, c=parameters.

3. *Analysis of relationships between PAI of each 5 cm dbh class and RD for aspen and spruce diameter classes larger than, smaller than, and in the same diameter class (to evaluate effects of one-sided and two-sided competition, considering both intra and inter specific competition)*

Analysis of growth of individual diameter classes is underway and will be completed before June of 2009.

4. *Analysis of relationships between survival of each 5 cm dbh class and RD for aspen and spruce diameter classes larger than, smaller than, and in the same diameter class*

This analysis remains to be completed.

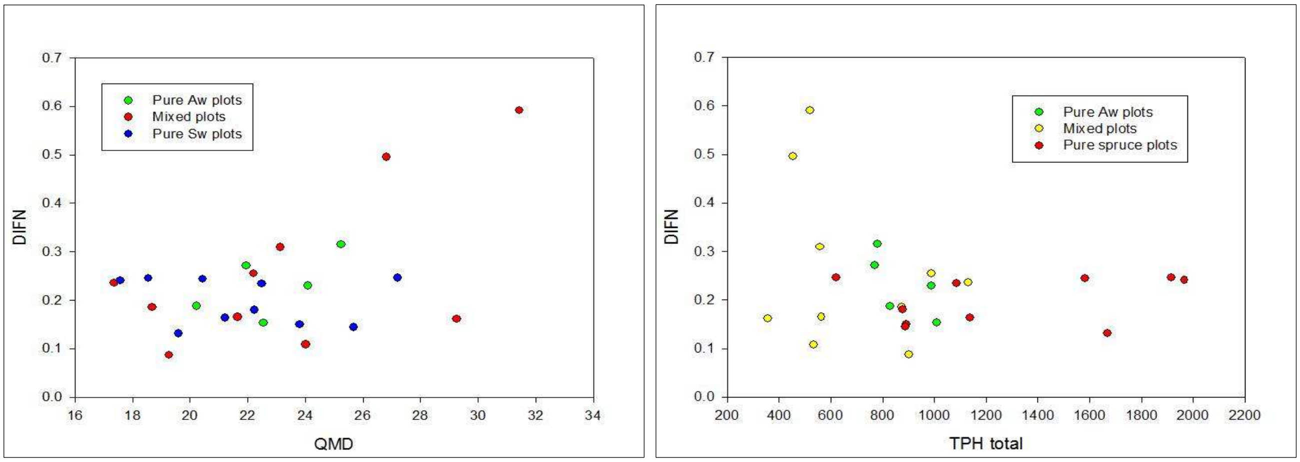
5. *Analysis of relationships between RD and LAI, including examination of relationships between PAI and LAI and the influence of stand composition on these relationships*

These data still require processing and analysis.

6. *Analysis of relationships between RD and light capture, including examination of relationships between PAI and light capture and its distribution among stand components and the influence of stand composition*

Preliminary results (from part of the dataset) show that quadratic mean diameter and stand density are correlated with light capture (DIFN) in these stands (Figure 5). Analysis of these data will be completed in 2009.

Figure 5. Relationship between understory light (DIFN) and (a) total density (TPHtot) and (b) total quadratic mean diameter (QMDtot) for some plots sampled in 2007 and 2008.



(a) (b)

7. Analysis of relationships between understory vegetation (shrub and herb) cover/LAI and variables such as RD, composition, and tree LAI

Understory vegetation cover data were collected in 57 permanent sample plots in Northern Alberta. Analysis of these data will be completed during 2009.

8. Analysis and illustration of development of stands through the density, size, composition matrix and determine if these patterns can be predicted based on species composition and contribution to relative density (including examination of whether long-term trends can be predicted from regeneration data). This component will include comparison of results from remeasurement data with predictions provided by the Mixedwood Growth Model (MGM)

This work will be completed during 2009, and has been awaiting completion of work on MGM and release of MGM2009 (which will occur in April of 2009)

9. *Determination of whether similar patterns and relationships exist for boreal aspen-spruce mixedwood stands in Ontario, Manitoba, Alberta, and B.C. (regression models will be compared using dummy variable/additional sums of squares procedures)*

Compilation and analysis of the Ontario, Saskatchewan and Manitoba data have been partially completed. Difficulties in compiling data with different structures have slowed progress on this component of the project. However, we expect to complete this work in 2009.

CONCLUSIONS

Results reported here indicate that species composition may play a significant role in the maximum density – size relationships in boreal mixedwoods. Although more analysis is needed, our results show a significant effect of species composition on this relationship. The non-linear power function ($z= a + bx+ cx^2 +dy^e$) was the model with the best goodness of fit for our data set, showing that size-density relations in this type of forest can be expressed as a power function as it is most often expressed.
Reasonable progress has been made on this project to date. All the proposed fieldwork to be was completed. A total of 57 PSP's were sampled between 2007 and 2008 (we had proposed sampling 50). More than 855 hemispherical photos were taken during the two field seasons and remain to be processed and analysed. Data from Saskatchewan, Manitoba and Ontario PSP's will be incorporated in the final analysis.

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