# PROJECT REPORT
## September 30, 2008
**FINAL PROJECT REPORT**

sustainable forest management network

réseau sur la gestion durable des forêts

# Regeneration of spruce and aspen under different levels of partial harvest in boreal mixed woods

**Victor Lieffers**
**John Spence**
**Derek Sidders**

A Network of Centres of Excellence
Un réseau de centres d'excellence

# Regeneration of spruce and aspen under different levels of partial harvest in boreal mixed woods

**SFMN Project: The First Re-measurement Of the Emend Experiment and Associated Work**

**By:**

**Victor Lieffers**
Department of Renewable Resources
University of Alberta, Edmonton, Alberta
victor.Lieffers@ualberta.ca

**John Spence**
Department of Renewable Resources
University of Alberta, Edmonton, Alberta
john.spence@ualberta.ca

**Derek Sidders**
Canadian Forestry Service
Northern Forestry Centre
dsidders@NRCan.gc.ca

**September 30, 2008**
**Edmonton, Alberta, Canada.**

# ABSTRACT

Survival and growth of planted white spruce and the root suckering of aspen and balsam poplar was assessed 8-9 years after logging in the partial-harvesting of the EMEND experiment located in northern Alberta. For the planted spruce there was little difference in survival across the different levels of canopy retention but survival was better when soil was mounded or mixed. The best growth of spruce was obtained under 50% cover of residual aspen coupled with soil treated with mounding or mixing. The poorest growth was obtained under 75% retention of a conifer canopy and when the organic layer was scalped off the soil. In terms of the aspen regeneration, stand with more aspen prior to logging produced the greatest density of suckers. Nine years after harvest we observed a nearly linear decline in sucker density and volume per hectare with increasing retention levels of mature aspen (or both poplars combined); sucker density declined by 50% when only 20% of the original basal area was left in the stand. Leaving residual spruce trees in the stand had considerably less negative influence than aspen on the number of suckers and their total volume per hectare.

**Keywords:** Spruce, aspen, regeneration, suckering, partial harvest, mechanical site preparation.

# ACKNOWLEDGEMENTS

We thank the NCE-Sustainable Forest Management, Diashowa-Marubeni Internation and CanFor for Funding. Thomas Gradowski, Simon Landhäusser, Jan Volney, Tim Keddy and were major contributors to this work. We thank Bonnie Aubrey, Martin Blank, Jason Edwards, Charlene Hahn, Jennifer Langhorst, Nancy Mayo, Jessica Snedden and the EMEND core crew for field assistance.

# TABLE OF CONTENTS

# RESEARCH QUESTIONS AND OBJECTIVES

In this study we examined the regeneration of trees in the EMEND (Ecosystem Management Emulating Natural Disturbance) between 8 and 9 growing seasons after logging. EMEND was established to evaluate effects of leaving residual trees in forests after logging – most of the work on this project so far has been aimed at assessing the effects of leaving residual structure on biodiversity. This study, however examined the success of tree regeneration in these sites in terms of different levels of variable retention harvesting in different forest types of the boreal forest. The EMEND experiment had the following treatments: six levels of residual canopy (0, 10, 20, 50 75% or 100% residuals) within each of four forest compositions (> 75% deciduous, 25 to 75% coniferous/deciduous, >75 coniferous, and deciduous-dominated with a spruce understory). No vegetation management was applied to this experiment. Portions of this experiment were used for two studies of tree regeneration that are summarized below.

### *Establishment and Growth of Planted Spruce*

Mounding, mixing, scalping or no treatment were applied to the 0%, 50% and 75% residual treatments in both the conifer dominated and deciduous dominated forests. Spruce were planted in the first year after logging and evaluated after 8 growing seasons to determine the survival, and growth of the spruce in the different combinations of cutting and site preparation.

### *Establishment and growth of Aspen*

Nine growing seasons after establishment of the experiment, the aspen and poplar regeneration were assessed in all of the different levels of canopy retention in the deciduous, mixed and conifer stands.

# KEY FINDINGS

### *Establishment and Growth of Planted Spruce*

Up to the end of year 8, there was no difference in survival for the spruce seedlings across the different levels of overstory retention, but survival was higher in the mixed and mounding treatments. Survival within these site preparations was 83% compared to 74% in the non-site prepared treatments.

Growth of seedlings was affected by canopy retention. In the conifer-dominated sites, the best growth was in the clearcut, while in the deciduous dominated sites, the best growth was when 50% of the overstory was retained (Fig. 1). Overall, growth of spruce was slightly better on the deciduous site type. The mounding produced the largest seedling on the conifer site type and the mixing treatment was best on the deciduous site type; the scalping treatment was no better than the control treatment.

### *Establishment and Growth of Aspen*

The Deciduous stands had greater stand density and stand volume than the coniferous stands (Fig. 3). The regeneration density declined with increasing level of retention of the overstory (Fig. 4). Overall, there was a decline in aspen regeneration in relation to both the basal area of residual trees, but regeneration density increased in relation to the number of deciduous trees in the stand prior to logging (Fig. 5). Leaving 20% of the original overstory as dispersed residuals will result in nearly 50% decline in stem density and stand volume of poplar regeneration. Interestingly, the density of suckers appeared to be inhibited more by the basal area of residual balsam poplar and aspen more than the basal area of the spruce (Table 1). This suggests that the hormonal control of suckering through root connections to residual trees is more important than the shading of the ground caused by the dense crowns of the residual spruce. We were also surprised to the see that growth of aspen was more negatively affected by basal area of aspen than by the spruce. This suggests that there is also a hormonal influence of the residual aspen trees on growth of the suckers.

**Figure 1.** The effect of canopy retention in conifer and deciduous-dominated forest stands on root collar diameter, stem height, stem volume and stand volume (means) of planted white spruce under two different composition types. Bars with different letters are significant different (α = 0.05, Tukey-Kramer test) (n=3).

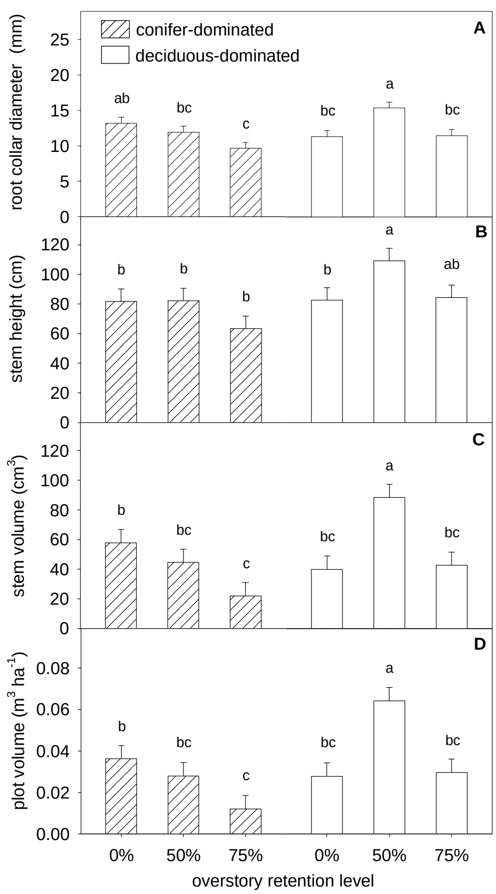


**Figure 2.** The effect of four site preparation treatments (control (ct); mix (mx), mound (md); and scalp (sc) on root collar diameter, stem height, stem volume and stand volume (means) of planted white spruce under coniferous and deciduous composition types. Bars with different letters are significant different (α = 0.05, Tukey-Kramer test) (n=3).

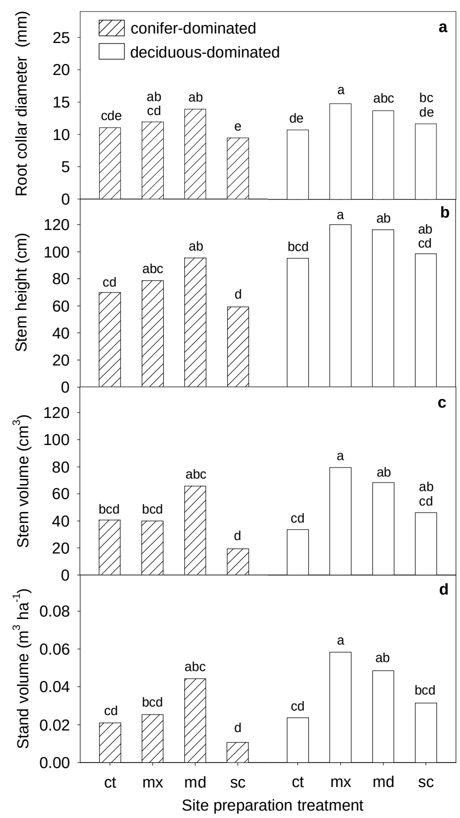

**Figure 3.** The effect overstory composition prior to logging (DEC – deciduous dominated, MIX – mixedwood, and CON – coniferous dominated) on stem volume, stem density and volume per hectare of poplar regeneration 9 growing seasons after cutting. Bars with the same letter were not significantly different (Tukey's test, □ = 0.05) - lower case letters related to aspen alone and upper case letters to aspen + balsam poplar combined.

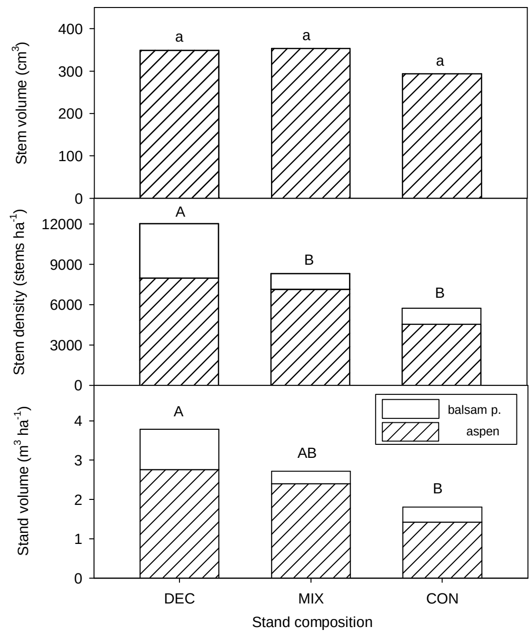


**Figure 4.** The effect overstory retention level on stem volume, stem density and volume / ha of aspen + balsam poplar regeneration 9 growing seasons after cutting. Bars with the same letter were not significantly different (Tukey's test, α = 0.05) - lower case letters related to aspen alone and upper case letters to aspen + balsam poplar combined.

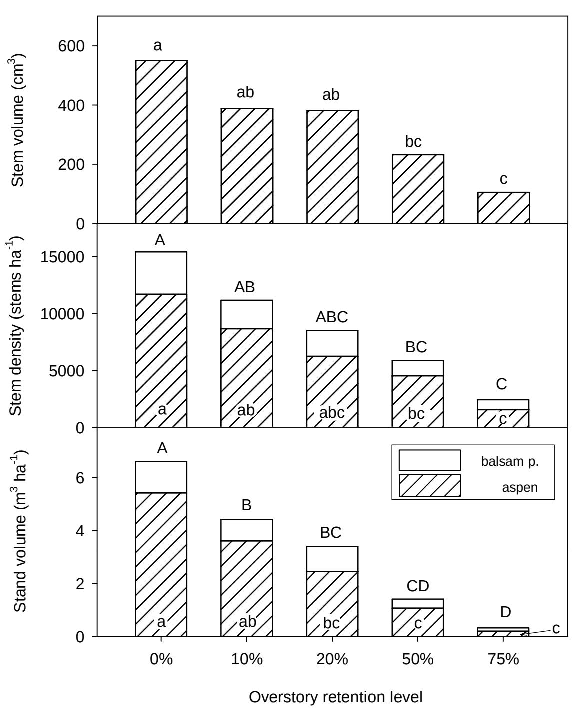

**Figure 5.** Sucker density of aspen + balsam poplar regeneration 9 years after cutting in relation to the pre-harvest and post-harvest residual basal area (BA) of poplars. Model: poplar sucker density = 6838.5 + 365.91 x (pre-harvest BA of poplars) – 1043.91 x (post-harvest BA of poplars) + 16.49 x (post-harvest BA of poplars)2, R2 = 0.70. Stands were harvested in the winter of 1998-99 and overstory basal area was measured in 2003.

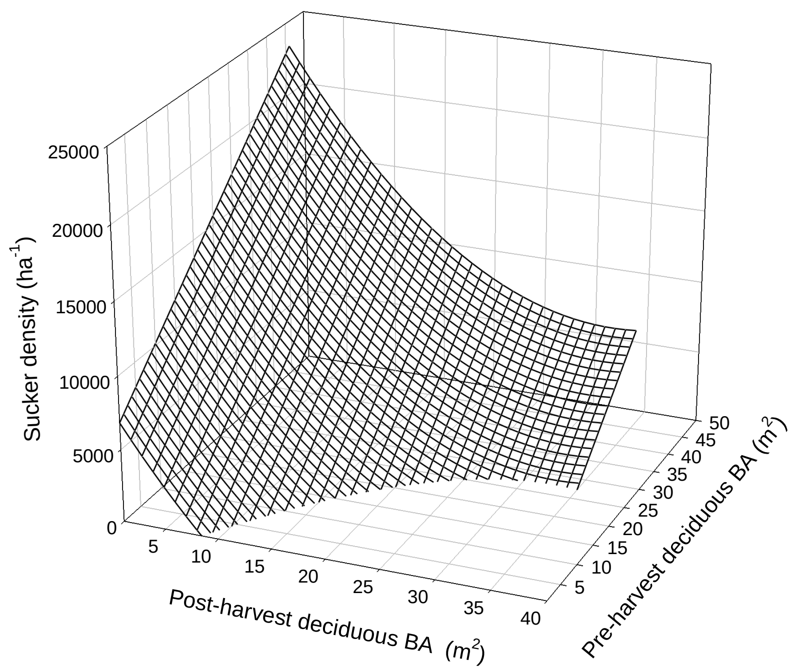

**Table 1.** Regression slopes estimates and p-values describing the effects of pre- and post-harvest basal area of overstory trees on individual stem volume, stem density and volume per area of aspen and poplar regeneration (aspen + balsam poplar).

| | slope estimate | 95% CL for slope | | $H_o$: b=0 p-value |
|---|---|---|---|---|
| ASPEN - stem volume | **$R^2$=0.32** | | | |
| intercept | 461.00 | 378.80 | 543.20 | < 0.0001 |
| post-harvest BA of aspen | -20.01 | -33.82 | -6.21 | 0.0055 |
| post-harvest BA of coniferous species | -8.40 | -14.47 | -2.33 | 0.0078 |
| | | | | |
| BOTH SPECIES - stem volume | **$R^2$=0.43** | | | |
| intercept | 473.48 | 404.93 | 542.03 | < 0.0001 |
| post-harvest BA of deciduous species | -13.81 | -20.65 | -6.98 | 0.0002 |
| post-harvest BA of coniferous species | -8.17 | -12.83 | -3.50 | 0.0010 |
| | | | | |
| ASPEN - sucker density | **$R^2$=0.70** | | | |
| intercept | 3405.09 | 1948.21 | 4861.97 | < 0.0001 |
| pre-harvest BA of aspen | 458.77 | 360.42 | 557.12 | < 0.0001 |
| post-harvest BA of aspen | -637.54 | -861.18 | -413.89 | < 0.0001 |
| | | | | |
| BOTH SPECIES - sucker density | **$R^2$=0.70** | | | |
| intercept | 6838.50 | 4697.99 | 8979.01 | < 0.0001 |
| pre-harvest BA of deciduous species | 365.91 | 276.66 | 455.16 | < 0.0001 |
| post-harvest BA of deciduous species | -1043.91 | -1409.37 | -678.45 | < 0.0001 |
| (post-harvest BA of deciduous species)$^2$ | 16.49 | 4.06 | 28.91 | 0.0106 |
| | | | | |
| ASPEN - volume per area | **$R^2$=0.62** | | | |
| intercept | 2.002 | 0.543 | 3.460 | 0.0084 |
| pre-harvest BA of deciduous species | 0.287 | 0.083 | 0.492 | 0.0071 |
| (pre-harvest BA of deciduous species)$^2$ | -0.004 | -0.009 | 0.001 | 0.0644 |
| post-harvest BA of deciduous species | -0.604 | -0.819 | -0.388 | < 0.0001 |
| (post-harvest BA of deciduous species)$^2$ | 0.013 | 0.005 | 0.021 | 0.0010 |
| | | | | |
| BOTH SPECIES - volume per area | **$R^2$=0.66** | | | |
| intercept | 1.972 | 0.431 | 3.512 | 0.0134 |
| pre-harvest BA of deciduous species | 0.416 | 0.200 | 0.632 | 0.0004 |
| (pre-harvest BA of deciduous species)$^2$ | -0.006 | -0.011 | -0.002 | 0.0091 |
| post-harvest BA of deciduous species | -0.739 | -0.966 | -0.511 | < 0.0001 |
| (post-harvest BA of deciduous species)$^2$ | 0.016 | 0.008 | 0.023 | 0.0002 |

# KEY DELIVERABLES

***Presentations***
Training of Tomasz Gradowski, Post-Doctoral Fellow.

Presentations at NCE-SFM Partners Meeting in Vancouver 2008.

Presentations at the EMEND annual meetings in both 2007 and 2008.

***Publications***
Gradowski, T., Sidders, D., Keddy, T., Lieffers, V.J. and Landhäusser S.M. 2008. Effects of overstory retention and site preparation on growth of planted white spruce seedlings in deciduous and coniferous dominated boreal plains mixedwoods Forest Ecol. Manage. 255: 3744-3749.

Gradowski, T. Lieffers, V.J., Landhäusser, S.M., Sidders, D., Volney J. and Spence, J.R. 2009. Regeneration of aspen nine years after variable retention harvest in boreal mixedwood forest. Submitted for publication.

NCE-SFM Research Note – Tree Regeneration at EMEND by Victor Lieffers and Derek Sidders.

# BENEFITS TO PROJECT PARTNERS AND OTHERS

The largest benefits of this project to forest industry and government partners relates to the large scale and the long-term nature of the results. This test of different cutting patterns on growth of trees is from one of the largest experiments of its kind any where in the world. For the spruce experiment, there were 18 cutting areas planted with spruce and each of these had 4 different means of treating the soil – each with 100 planted trees. The results from this experiment, after 8 growing seasons, provides reliable data on the benefits to spruce of different silvicultural treatments. It showed that if no vegetation control is applied, 50% canopy of aspen provided the best growing conditions for spruce. It also showed that mounding or mixing were superior ways of treating the soil. Similarly, statements can be made for the assessment of the hardwood regeneration. Here the results were based upon the mean response within 45 different blocks with different levels of hardwood and conifer left as residual trees. The long time of 9 years before assessment provides added assurance that the results of this study provide a reliable response to treatment. Managers can now use this information to predict the growth of spruce and aspen in partial harvest systems in the boreal forest.

## MANAGEMENT IMPLICATIONS

- Despite the lack of tending treatments, there was little mortality of planted spruce in these EMEND site in the 7 years after planting.

- Mounding or mixing treatments were far superior treatments for establishing spruce compared to scalping or no site preparation. On conifer sites, removing all of the overstory is better than leaving 50 or 75% of the canopy. In contrast, for the sites dominated by deciduous overstory (which has a more porous canopy than the conifers), 50% retention was the best level of residual canopy – likely due to protection from frost or other microclimatic effects.

- In variable retention systems, regeneration of aspen and balsam poplar will be suppressed by leaving residual trees of these species. Leaving 20% residuals will suppress density of regenerating stems by nearly 50%. Leaving 75% retention will result in negligible redevelopment of the aspen and balsam poplar. The work provides regression models for prediction of density or growth of aspen or aspen+poplar after logging in boreal forests.

- Leaving aspen as residual trees has a larger negative impact on regeneration of aspen than leaving conifers. This knowledge can be used to prevent or promote aspen suckering in variable retention systems.

## SUGGESTIONS FOR FUTURE RESEARCH

- Both studies would have benefited from better understanding of the specific soil conditions of each of the plots. This would have provided more complete understanding of the mechanisms that controlled spruce growth and secondly the density and growth of aspen suckering.

- Further insight into the extent of interconnectivity of root systems of aspen and the hormonal control over suckering and growth would provide better understanding of suckering in partial-cut stands.

- More work should be done on the spatial arrange of residual aspen on the development of suckers.