Evaluating and predicting the regional effects of silviculture and site factors on established regeneration in the northern conifer forest

Principal Investigator: Mohammad Bataineh
Affiliation/Institution: University of Arkansas
Email: Bataineh@uamont.edu
School of Forest Resources, 110 University Court, Monticello, Arkansas 71655
Co-Principal Investigators: Arun K. Bose1, Aaron Weiskittel[1],
Laura Kenefic[1], Ben Rice[3], and Robert Seymour[1]
Affiliations/Institutions: [1]University of Maine, [2]University of Arkansas, [3]LandVest
Emails: Aaron Weiskittel (aaron.weiskittel@maine.edu), Arun K. Bose (arun.kantibose@maine.edu), Laura Kenefic (lkenefic@fs.fed.us), Ben Rice (ben.rice@maine.edu), Robert Seymour (rseymour@maine.edu)
Collaborators and Affiliations: Michael Saunders, Associate Professor, Purdue University, msaunder@purdue.edu
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- Relative to harvesting treatments, biotic (e.g., overstory structure and composition) and abiotic factors (e.g., temperature, soil attributes) were more influential in explaining the pattern of natural regeneration at both stand- and landscape-scale.
- Low intensity partial harvesting will not be enough to change the regeneration composition (e.g., balsam fir to red spruce or American beech to sugar maple). Site preparation treatments including soil scarification, controlling browsing pressure, and controlling the regeneration of aggressive species (e.g., American beech) are necessary.

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http://www.nsrcforest.org

Project Summary

Natural regeneration remains the dominant method for the development of new stands in the Northern Forest. This trend is expected to continue in the future in light of the growing prominence of partial harvesting. Limited understanding of how partial harvesting practices, and biotic and abiotic factors influence regeneration composition (species) and abundance (number of regeneration) restricts our ability to evaluate management alternatives and project future wood supply. The objectives of this project were to: 1) quantify the relation between overstory, site, and understory characteristics; 2) identify key factors and constraints associated with regeneration of desired species; and 3) develop predictive models that can be incorporated into the Acadian Variant of FVS. The objectives were evaluated both at the stand- and the landscape-level using the long-term measurement plots of Penobscot Experimental Forest and the US Forest Service Forest Inventory and Analysis dataset, respectively. At the stand-level, the regeneration abundance was primarily associated with the local site factors including overstory composition and soil attributes. Harvesting treatments were less influential in explaining the pattern of natural regeneration abundance and composition relative to biotic (e.g., overstory structure and composition) at the stand-level. Our results showed, mean annual temperature and overstory tree-size diversity were the most important abiotic and biotic variable, respectively to explain the abundance and composition of natural regeneration at the landscape-level. Our results indicate, the moderate growing condition and moderate overstory tree-size diversity incorporate higher number of species as well as higher number of regeneration than productive/poor growing conditions or uniform/highly diverse overstory. Our models are ready to incorporate into the Acadian Variant of FVS. The overall results suggest low intensity partial harvesting will not be enough to change the regeneration composition (e.g., balsam fir to red spruce or American beech to sugar maple). Site preparation treatments including soil scarification, controlling browsing pressure, and controlling the regeneration of aggressive species (e.g., American beech) are necessary.

Background and Justification

- Forestry practices in the Northern Forest rely almost exclusively on natural regeneration for the development of new stands with less than 1% of harvested area planted each year[1].

- The growing prominence of partial harvesting in response to ecological, legislative, and social constraints has created near total reliance on natural regeneration for stand establishment.

- In addition, regional forest simulators that are vital to predicting future forest conditions and calculating sustainable harvest levels are severely limited in estimating and projecting regeneration.

- However, modelling natural regeneration is complex due to its association with a broad range of biotic and abiotic factors that limit the success of natural regeneration at every stage of forest stand development[2,3].

- Few studies for the Northern Forests have addressed the influence of overstory, site and disturbance factors on natural regeneration[4].

- Moreover, no comprehensive analysis of how these factors affect established regeneration at landscape scales has been conducted.

[1]Maine Forest Service, 2015. Silvicultural Activities Report 2014 (including Annual Report on Clearcutting and Precommercial Activities). Maine Department of Agriculture, Conservation and Forestry. Augusta, ME.
[2]Weiskittel, A.R., Hann, D.W., Kershaw, J.A., and Vanclay, J. 2011. Forest growth and yield modeling. Wiley-Blackwell.
[3]Kozlowski, T.T. 2002. Physiological ecology of natural regeneration of harvested and disturbed forest stands: implications for forest management. Forest Ecology and Management 158: 195–221.
[4]Brissette, J.C. 1996. Effects of intensity and frequency of harvesting on abundance, stocking and composition of natural regeneration in the Acadian forest of eastern North America. Silva Fennica 30: 301–314.

Methods

Study sites

- Stand-level analysis: Penobscot Experimental Forest (PEF), a 16.18-ha mixedwood forest in Bradley and Eddington, Maine[5].

- Landscape-level analysis: The US Forest Service Forest Inventory and Analysis (FIA) dataset was used to analyze all forest areas of Maine[6].

[5]Bataineh, M., Kenefic, L., Weiskittel, A., Wagner, R. & Brissette, J. 2013. Influence of partial harvesting and site factors on the abundance and composition of natural regeneration in the Acadian Forest of Maine, USA. Forest Ecology and Management 306: 96–106.
[6]Bose, A.K., Weiskittel, A., Wagner, R.G., Kuehne, C., 2016. Assessing the factors influencing natural regeneration patterns in the diverse, multi-cohort, and managed forests of Maine, USA. Journal of Vegetation Science 27, 1140-1150.

Methods

Response variables

- Stand-level analysis: Regeneration density by species[5].
- Landscape-level analysis: Regeneration density, species richness (number of species), intolerant hardwood regeneration density, tolerant softwood regeneration density[6].

Explanatory variables

- Stand-level analysis: Five different harvesting treatments, a range of biotic and abiotic factors[5].
- Landscape-level analysis: Harvesting intensity, time since harvest, and a range of biotic and abiotic factors[6].

[5]Bataineh, M., Kenefic, L., Weiskittel, A., Wagner, R. & Brissette, J. 2013. Influence of partial harvesting and site factors on the abundance and composition of natural regeneration in the Acadian Forest of Maine, USA. Forest Ecology and Management 306: 96–106.
[6]Bose, A.K., Weiskittel, A., Wagner, R.G., Kuehne, C., 2016. Assessing the factors influencing natural regeneration patterns in the diverse, multi-cohort, and managed forests of Maine, USA. Journal of Vegetation Science 27, 1140-1150.

Methods

Analysis

1. Stand-level analysis[5]:

- Seedling density among the five harvesting treatments was tested using one-way ANOVA.
- Cluster analysis and non-metric multi dimensional scaling were used to group plots based on similarities in regeneration composition and abundance.
- Redundancy analysis was used to relate regeneration patterns to single and pairwise-combined predictors (i.e., treatment, site, and spatial location) and determine the proportion of variance accounted for by each of these predictors.

2. Landscape-level analysis[6]:

- Ten models were formed based on biological hypotheses for each response variable.
- Effects of explanatory variables were assessed using linear-mixed effect models.
- Since a large number of sample plots were used in this analysis, 95% confidence intervals were quantified along with predicted mean.
- Adjusted R^2, percentage RMSE (root mean square error) and percentage MB (mean bias) for each model.

[5]Bataineh, M., Kenefic, L., Weiskittel, A., Wagner, R. & Brissette, J. 2013. Influence of partial harvesting and site factors on the abundance and composition of natural regeneration in the Acadian Forest of Maine, USA. Forest Ecology and Management 306: 96–106.

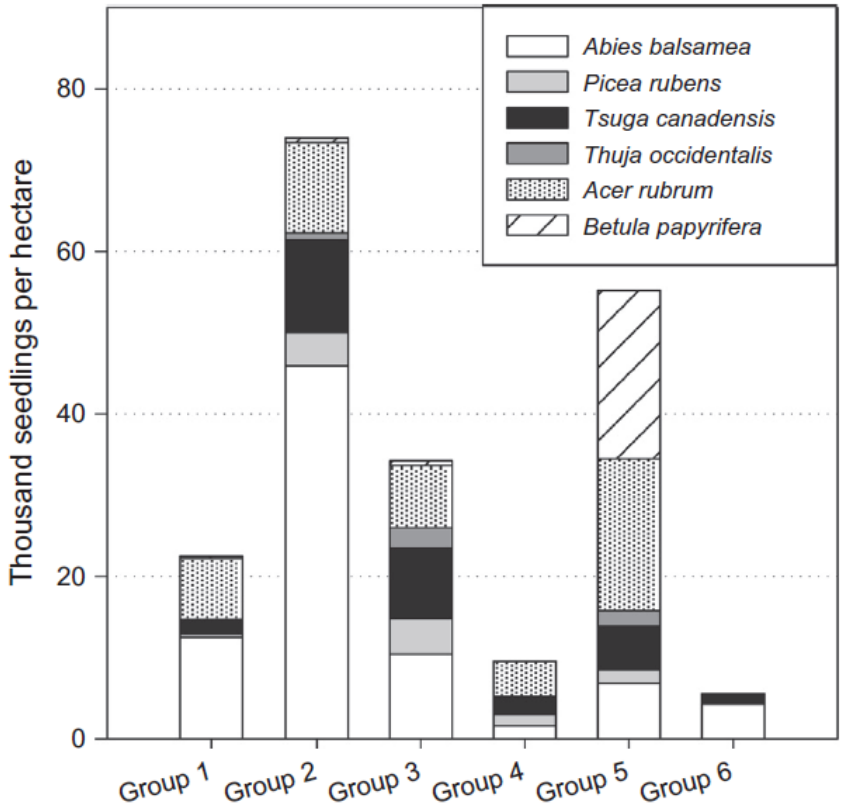
[6]Bose, A.K., Weiskittel, A., Wagner, R.G., Kuehne, C., 2016. Assessing the factors influencing natural regeneration patterns in the diverse, multi-cohort, and managed forests of Maine, USA. Journal of Vegetation Science 27, 1140-1150.

Results/Project outcomes

Stand-level analysis[5]

-Cluster analysis formed six groups

-Three groups (2, 3, and 5) were compositionally distinct, whereas the other three were mixed



[5]Bataineh, M., Kenefic, L., Weiskittel, A., Wagner, R. & Brissette, J. 2013. Influence of partial harvesting and site factors on the abundance and composition of natural regeneration in the Acadian Forest of Maine, USA. Forest Ecology and Management 306: 96–106.

Results/Project outcomes

Stand-level analysis[5]

Variance explained,

-16% by the biotic factors

-4% by the harvesting treatments

-2% by the abiotic factors

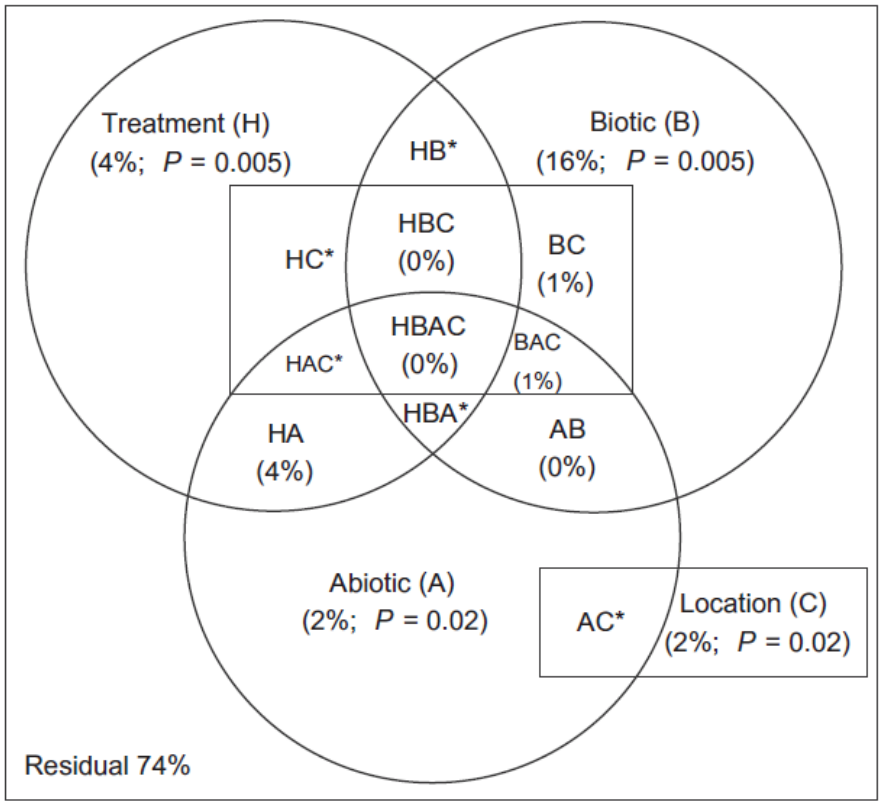


Fig. 3. Venn diagram of regeneration composition and abundance variance partitioning among treatment (H), biotic (B), abiotic (A), and location (C) predictor matrices. Treatment, biotic, abiotic, and location matrices contained three, six, five, and two factors, respectively. Starred values are <zero.

[5]Bataineh, M., Kenefic, L., Weiskittel, A., Wagner, R. & Brissette, J. 2013. Influence of partial harvesting and site factors on the abundance and composition of natural regeneration in the Acadian Forest of Maine, USA. Forest Ecology and Management 306: 96–106.

Results/Project outcomes

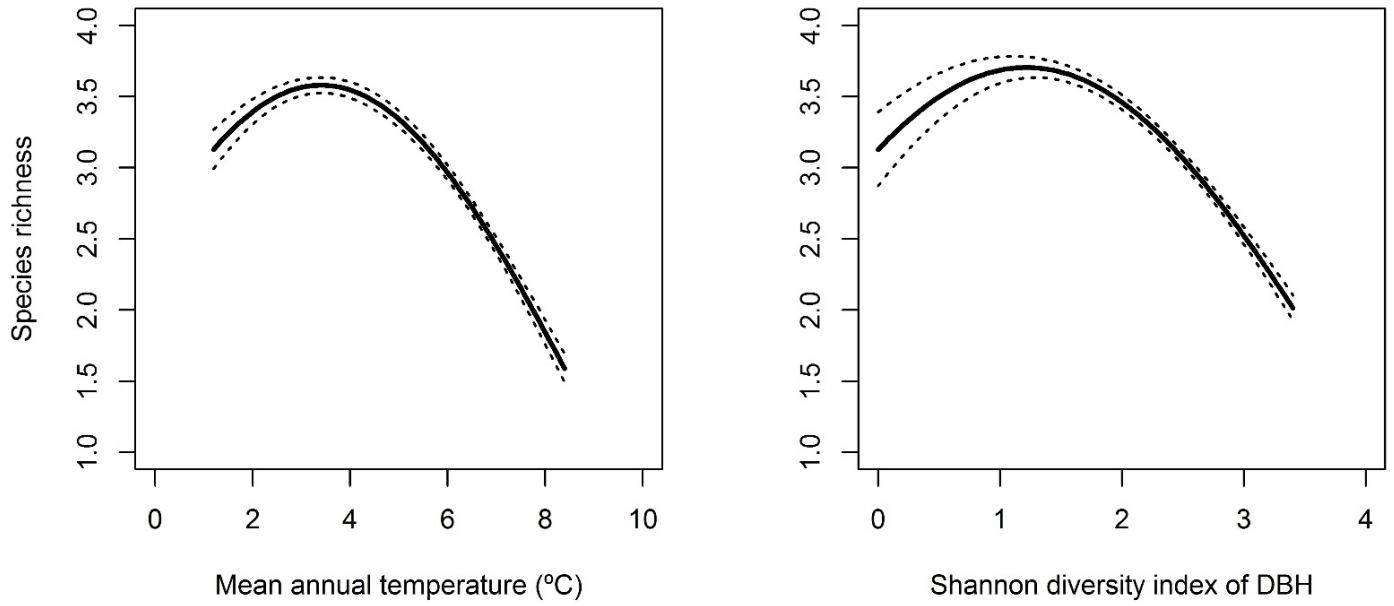
Stand-level analysis[5]

•Regeneration groups were structured along a gradient of decreasing understory cover:

- Mixed and hardwood-white-cedar groups occupied sites with low amounts of herb and shrub cover,
- Balsam fir group occupied sites toward the opposite end of Mixed and hardwood-white-cedar groups.
- The spruce-hemlock group occupied an intermediate position along the herb and shrub cover gradient.

[5]Bataineh, M., Kenefic, L., Weiskittel, A., Wagner, R. & Brissette, J. 2013. Influence of partial harvesting and site factors on the abundance and composition of natural regeneration in the Acadian Forest of Maine, USA. Forest Ecology and Management 306: 96–106.

Results/Project outcomes

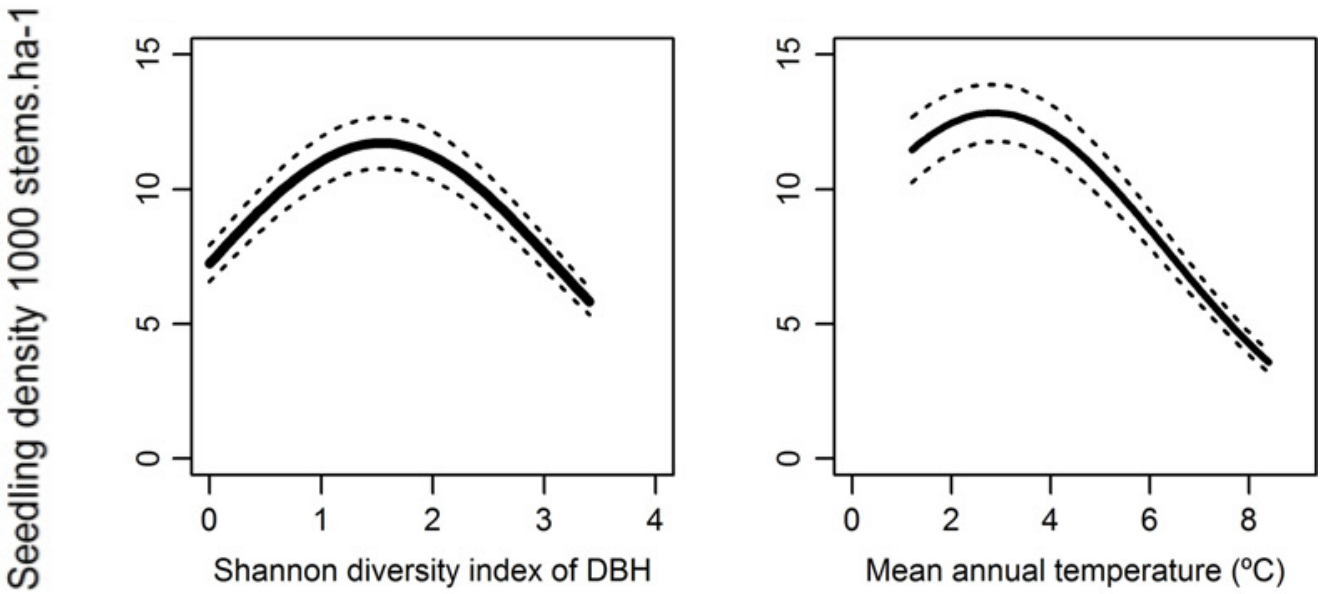


Landscape-level analysis[6]

- Species richness (SR) in regeneration had curvilinear relationships with mean annual temperature and overstory tree-size diversity.
- Soil fertility and stand density index had negative effects on SR, whereas time since harvest and overstory species diversity had positive effects on SR.

[6]Bose, A.K., Weiskittel, A., Wagner, R.G., Kuehne, C., 2016. Assessing the factors influencing natural regeneration patterns in the diverse, multi-cohort, and managed forests of Maine, USA. Journal of Vegetation Science 27, 1140-1150.

Results/Project outcomes



Landscape-level analysis[6]

- Similar to SR, regeneration density (RD) had curvilinear relationships with both mean annual temperature and tree size diversity.
- Soil fertility had a negative effect on RD, whereas time since harvest (first entry) had a positive effect on RD.

[6]Bose, A.K., Weiskittel, A., Wagner, R.G., Kuehne, C., 2016. Assessing the factors influencing natural regeneration patterns in the diverse, multi-cohort, and managed forests of Maine, USA. Journal of Vegetation Science 27, 1140-1150.

Results/Project outcomes

Landscape-level analysis[6]

•Regeneration density of intolerant hardwood species increased with time since harvest, but decreased with species and size diversity of overstory trees and stand average shade tolerance.

•In contrast to intolerant hardwood species, regeneration density of tolerant softwood species increased with increasing stand average shade tolerance, but decreased with time since harvest.

•Overstory tolerant softwood basal area and maximum stand density index had positive effects on regeneration density of tolerant softwood species.

[6]Bose, A.K., Weiskittel, A., Wagner, R.G., Kuehne, C., 2016. Assessing the factors influencing natural regeneration patterns in the diverse, multi-cohort, and managed forests of Maine, USA. Journal of Vegetation Science 27, 1140-1150.

Implications and applications in the Northern Forest region

- Our results of both the stand- and the landscape-level analysis showed that relative to harvesting treatments, biotic (e.g., overstory structure and composition) and abiotic factors (e.g., temperature, soil attributes) were more influential in explaining the pattern of natural regeneration at both stand- and landscape-scale.

- Low intensity partial harvesting will not be enough to change the regeneration composition (e.g., balsam fir to red spruce or American beech to sugar maple). Site preparation treatments including soil scarification, controlling browsing pressure, and controlling the regeneration of aggressive species (e.g., American beech) is necessary.

Future directions

- A more mechanistic modelling approach that incorporates spatial and temporal interactions with the most influential factors reported in this study will further future regeneration research in this region.

- For example, along with harvesting treatments, manipulative experiments that incorporate various growing conditions (i.e., establishment substrates, and lights) for natural regeneration need to be developed to strengthen the mechanistic understandings for all commercial species.

List of products

Peer-reviewed publications

1.Bataineh, M., Kenefic, L., Weiskittel, A., Wagner, R. & Brissette, J. 2013. Influence of partial harvesting and site factors on the abundance and composition of natural regeneration in the Acadian Forest of Maine, USA. Forest Ecology and Management 306: 96–106.

2.Bose, A.K., Weiskittel, A., Wagner, R.G., Kuehne, C., 2016. Assessing the factors influencing natural regeneration patterns in the diverse, multi-cohort, and managed forests of Maine, USA. Journal of Vegetation Science 27, 1140-1150.

3.Bose, A.K., Weiskittel, A., Wagner, R.G., (in review). Climate driven landscape-level changes in key hardwood species occurrence and abundance over the last three decades in forests of Northeastern USA. *Journal of Applied Ecology*.

Conferences

1.Bose, A. K., Weiskittel, A. and Wagner, R.G. 2016. Climate driven landscape-level changes in key hardwood species occurrence and abundance over the last three decades in forests of Northeastern USA. ECANUSA, University of Vermont, Vermont, USA.

2.Bose, A. K., Weiskittel, A., Wagner, R.G. and Kuehne, C. 2015. Predicting regional patterns in natural regeneration. Northeastern Mensurationists Organization Annual Meeting, Vermont, USA.