Linking forest structure to viable development pathways of diversely managed northern conifers: a pilot study exploring the potential of FIA data for modeling regional carbon dynamics

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- Information on forest structure that may be gleaned from FIA plots, while useful for broadly characterizing the forest resource, may be of limited value for making stand level assessments in complex-structured multiaged northern conifers.
- The reliability associated with forecasts of future conditions from stand dynamics models are constrained by structural and compositional complexity, and limited to timeframes considerably shorter than those of interest for certain purposes.

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Project Summary

Increased societal pressures have lead to a dramatic reduction in even-aged management in the Northeast, even among ownerships focused primarily on timber production. While amenable to a wide range of management approaches the conifer dominated forests of northern New England are particularly well suited to multi-aged management, yet there is a lack of accumulated experience with this general approach. This study sought to: (1) assess the viability of the current FIA (Forest Inventory and Analysis) sampling scheme for characterizing important differences in forest structure at the stand level; (2) assess the reliability of existing stand dynamics models at forecasting the development of complex structured stands; and, (3) quantify the carbon consequences associated with a range of multi-aged management scenarios in the Acadian Forest Region. To address these issues we: (1) superimposed FIA style inventory plots on an existing long-term sampling grid at the PEF (Penobscot Experimental Forest); (2) used remeasurement data from the PEF to assess the ability of a DMD (density management diagram) and an empirical growth and yield model (FVS; Forest Vegetation Simulator) to reliably predict the development of stands managed using multi-aged approaches; and, (3) applied an existing carbon accounting framework, including the life-cycle of wood products associated with harvests. We found that individual FIA-style plots were generally unable to capture the degree of structural complexity present in the managed multi-aged stands at the PEF. Neither modeling frameworks, the DMD nor FVS, were very satisfactory in terms of providing reliable predictions of stand dynamics, and particularly in the context of long-term forecasts (i.e. 50-100 yr). However, by calibrating FVS and making adjustments to the regeneration module, more reasonable outputs were obtained, at least over modest lengths of time (i.e. 10-20 yr). Consistent with findings from other studies, forest management appears incapable of sequestering additional carbon relative to a no-management scenario, at least barring catastrophic losses.

Background and Justification (1)

•Partial-cutting, wherein some proportion of the standing timber is left to grow following a commercial timber harvest, has become common practice on timberlands in Maine (Fig 1). As a result forest structure is becoming increasingly complex over time as more multi-aged stands are created.

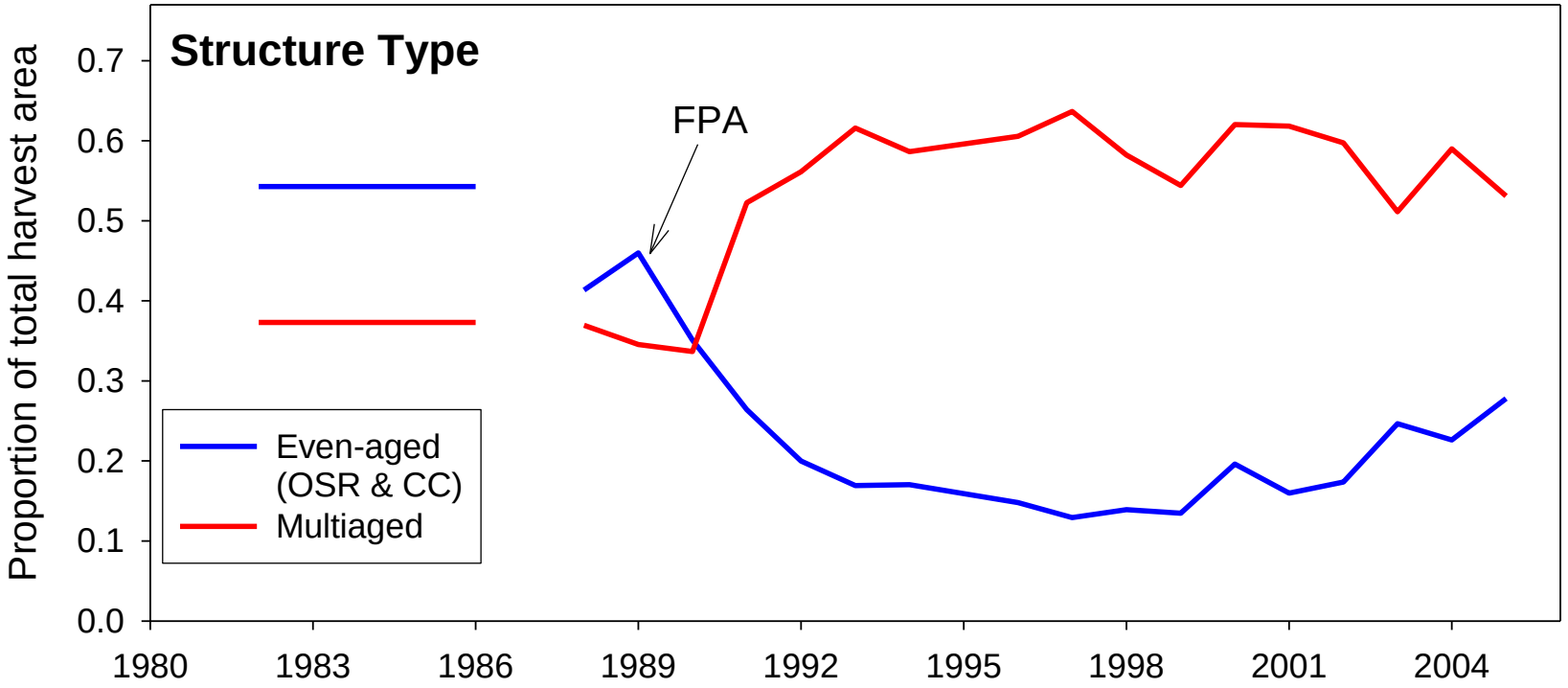

Figure 1. Proportion of harvest generated forest structure types (even- vs. multi-aged) over time relative to the institution of the Forest Practices Act (FPA) in Maine.

Background and Justification (2)

- Existing approaches to forecasting stand dynamics are closely tied to observations and relationships derived from even-aged, and thus less structurally complex, stands.
- While developers have presented these approaches and theories as fairly robust to novel conditions, adequate testing of these claims has been lacking.
- The ability to address questions associated with the contemporary multi-aged management paradigm requires reliable models of stand dynamics be identified.

Methods (1)

- Data from a long-term (50-yr) Forest Service compartment study at the PEF in Bradley, ME (Fig 2) were used to test sampling schemes and validate models in this study.
- Permanent 5th ac plots have been remeasured at 5-yr intervals over the past 50 yr.
- A range of partial-cutting treatments are represented:
  - Selection system on 5, 10 and 20-yr cutting cycles.
  - Fixed and flexible diameter-limit cuttings.
  - Commerical clearcutting and an untreated control.
- Detailed records of harvest removals and tree conditions have been maintained over time.

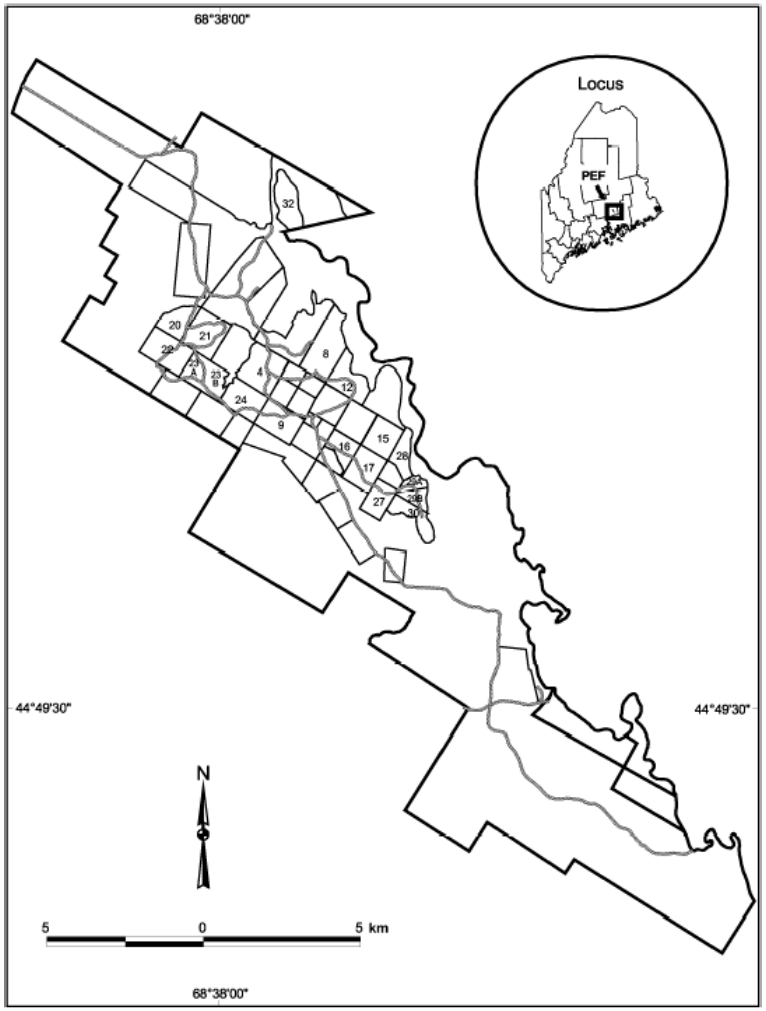

Figure 2. Location map of the 4,000 ac PEF showing the numbered compartments.

Methods (2)

- FIA-style plots (Fig 3) were superimposed on the existing sampling grid at the PEF to test the suitability of this sampling scheme for characterizing complex stand structure.
- Regression analysis was used to test correspondence between known (PEF plots) and sampled (FIA-style plots) forest structure attributes.
- Growth and yield data from the permanent plots at the PEF were used to test and calibrate stand dynamics models.
- Regeneration response measured on smaller nested plots was used to parameterize the natural regeneration module in FVS.
- Long-term carbon consequences of the various partial cutting treatments were quantified with the carbon accounting module in FVS.

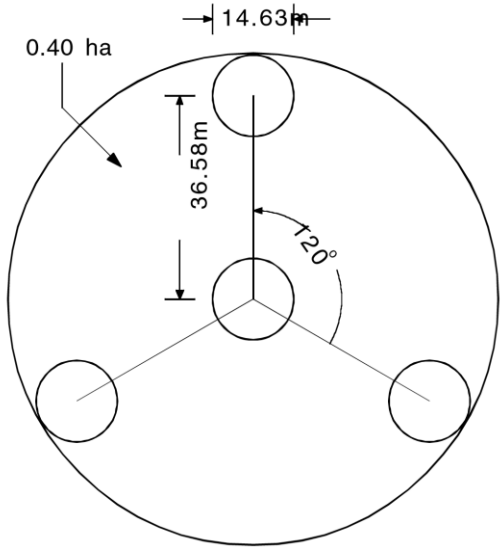

Figure 3. Overview of the plot layout used by FIA. The large circle (~1 ac) represents the plots 'footprint'. Trees are measured on the four 24th ac satellite plots indicated by the small circles. FIA plots are distributed systematically across the landscape at an average density of one per 6,000 ac.

Results/Project outcomes (1)

- The ability of individual FIA-style inventory plots to characterize stand structure represented by the multi-aged treatment compartments at the PEF appears suspect (Fig 4).
- While estimates of total basal area (BA) were largely unbiased, considerable unexplained variability was encountered.
- Further, we detected a tendency for the largest trees (SC4) to be under represented in the FIA style sample relative to the PEF inventory. Large trees form an important component of stand structure and therefore require accurate characterization.

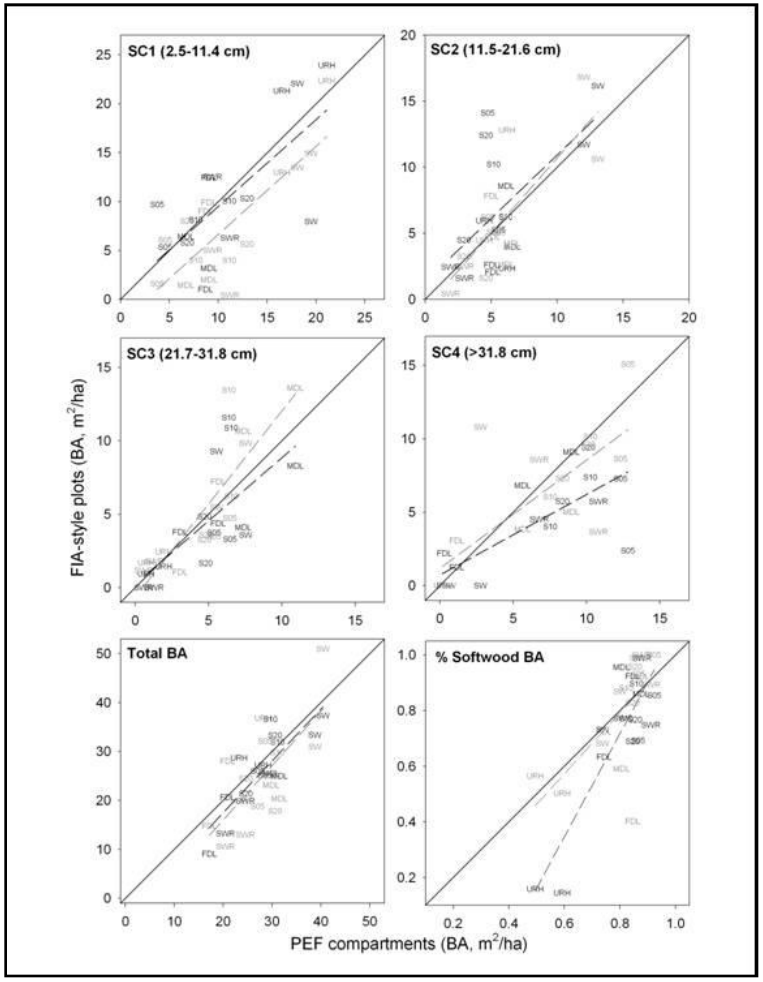

Figure 4. Comparison of predicted (FIA) and observed (PEF) basal area within various size classes by treatment.

Results/Project outcomes (2)

- Correspondence between growth and density management diagram based stocking was weak for the multi-aged treatments.
- However, stocking was a reasonable predictor of growth on the single-cohort plots, at least early in the stand development process, i.e. prior to the peak of periodic annual increment.
- Adjusting estimates of stand density index (SDI) with the summation method suggested for non-normal diameter distributions did not improve model performance.
- SDI appears to be of limited use for predicting growth response in multi-aged stands, at least based on long-term remeasurement data collected at the PEF.

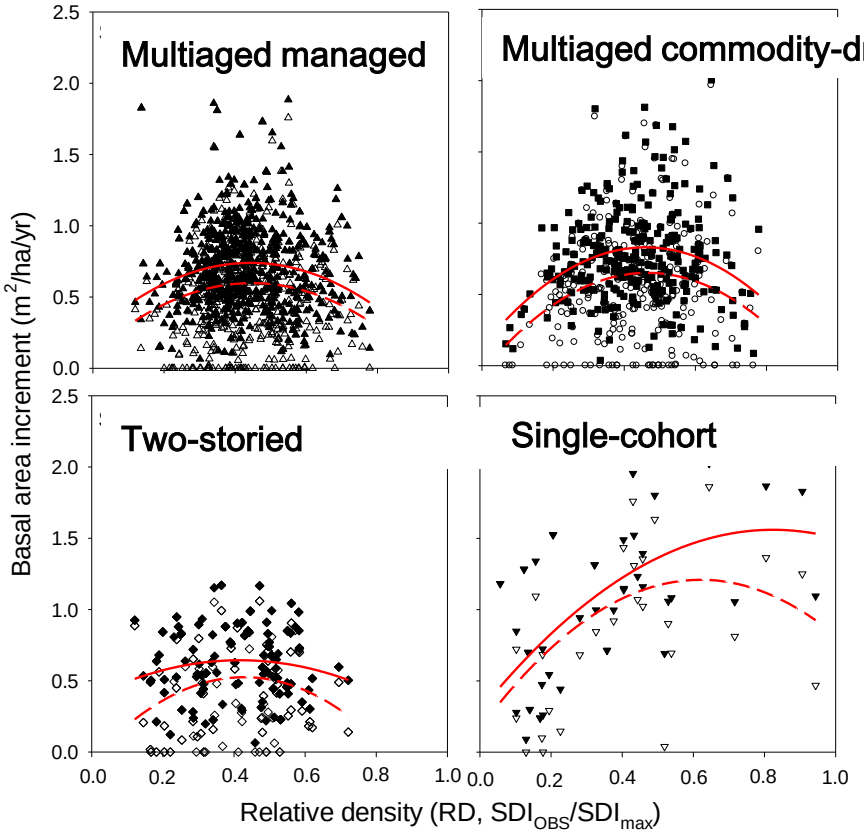

Figure 5. The relationship between stocking (SDI based RD) and growth (BAI) for various stand structure types.

Results/Project outcomes (3)

- Regeneration is a frequent occurrence in multi-aged stands, i.e. stands managed with partial cutting practices.
- The Northeastern Variant of FVS does not presently support an automated regeneration module, requiring users specify a response to treatment.
- We used data from the PEF to inform the use of this feature within both the production and beta versions of the model.
- A significant bias was detected between the predicted rate of ingrowth and regeneration density for the production model (Fig 6).
- Capping the density of regeneration input to the model at two stems per 0.001 ac plot resulted in unbiased predictions from the beta version of the model.
- We recommend focusing on the largest, and presumably most likely to survive, regeneration when conducting an inventory for this prupose.

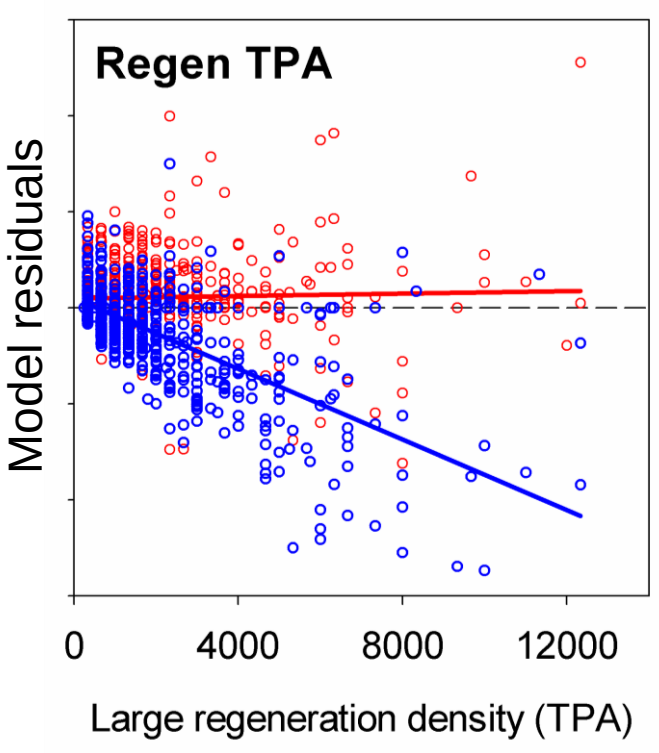

Figure 6. Relationship between regeneration density (TPA) and model residuals for ingrowth basal area according the old (blue) and new (red) Northeastern Variants of FVS.

Results/Project outcomes (4)

- The managed multi-aged stands at the PEF are complex both in terms of composition and structure. Calibration of FVS using diameter growth rates obtained from permanently numbered trees improved model performance, and particularly for the production version (Fig 7).
- In general, we found that the model tended to overestimate stand level growth relative to that observed on the multi-aged plots at the PEF. This was at least in part due to the model underestimating mortality.
- Accurate portrayal of mortality dynamics is arguably the most challenging aspect to capture in this type of model. FVS provides users the ability to adjust predicted mortality rates in order to bring them into line with observations.
- Finally, forecasts made over relatively short intervals, e.g. 5-10 yr, were fairly consistent with observations. By contrast, there was generally poor agreement between observed and predicted values for 20 yr intervals.

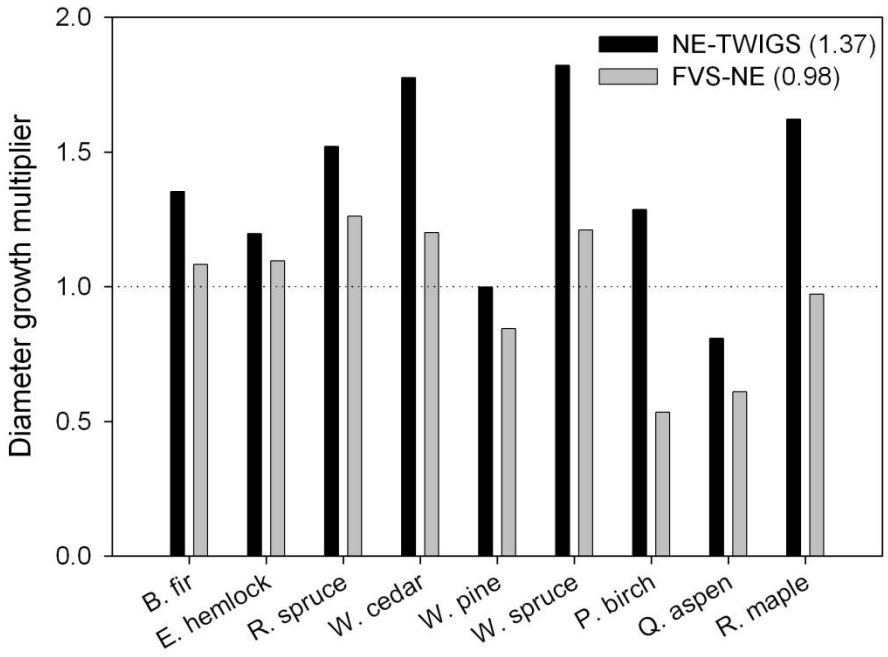

Figure 7. Multi-species calibration of the large-tree diameter growth model in FVS. Extensive remeasurement data from the PEF was used to adjust predictions (relative to 1.0) for the old (black bars) and new (grey bars) Northeastern Variant.

Results/Project outcomes (5)

- The carbon consequences associated with four different forest management scenarios was compared using FVS. The fate of forest products resulting from harvests was taken into account.
- Even though cumulative yields were higher with management (middle panel), the no-management control sequestered the most total carbon over the 100-yr simulation period.
- The multi-aged treatment sequestered somewhat more carbon than either of the even-aged scenarios (shelterwood on 60 and 100 yr rotation), primarily due to the higher proportion of long lived sawlog material harvested.

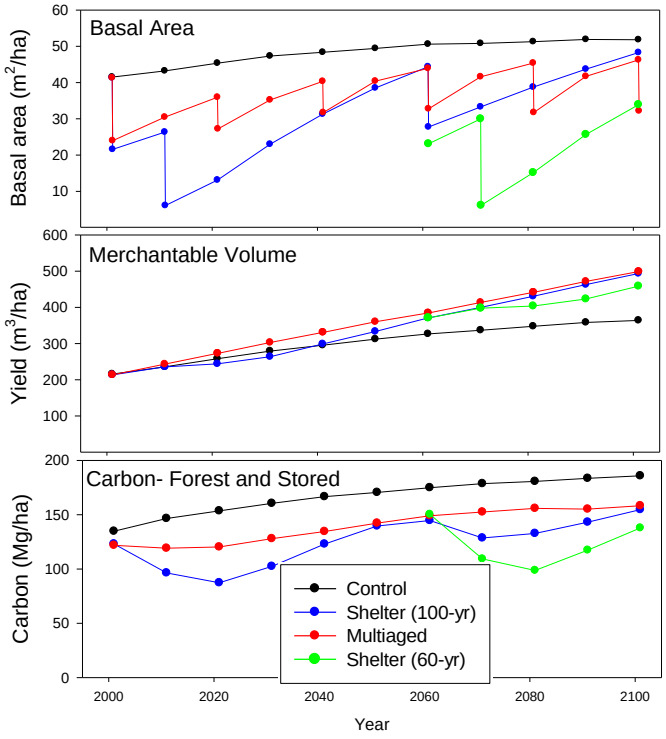

Figure 8. Comparison of the carbon consequences associated with contrasting management scenarios (bottom panel). More traditional measures are presented above, i.e. basal area growth, and cumulative yield.

Implications and applications in the Northern Forest region

- Reliance on coarse-scale inventory data, e.g. FIA plots, to characterize stand structure attributes appears to be problematic, at least for multi-aged stands in the Acadian Forest Region of northern New England. We suggest more intensive samples will be needed if fairly accurate descriptions of forest structure are deemed necessary.
- Stand structural complexity presents challenges for existing modeling frameworks. Theory based largely on even-aged constructs and underlying data are two major hurdles in this regard. Even so, the ability to calibrate FVS to local conditions in combination with realistic expectations about temporal resolution can make it a useful tool for comparing different management scenarios in this region.
- Managing forests for carbon sequestration is a contemporary objective in the Northeast. Large landowners looking for alternative revenue streams increasingly view this emerging market as a potential opportunity. Results of our simulation analyses suggest that while forest management appears incapable of sequestering additional carbon compared to a no management scenario, offset prices would need to increase substantially before it would make economic sense not to also manage for wood products.

Future directions (1)

- FVS is a useful tool for comparing management alternatives in the Northeast. However, because the Northeastern Variant (FVS-NE) applies to 13 states, extending from northern New England to the Mid-Atlantic, predictions for a given location may be suspect. In light of increasing interest in forecasting future conditions we believe it would be advantageous to parameterize and repackage FVS-NE at a more local scale, as has been done for the western US. One possible approach would be to do so by forest type within the broader Northeastern region, e.g. spruce-fir, oak-pine, northern hardwoods, etc.

Future directions (2)

- Unlike with even-aged cutting methods, partial cutting leads to the frequent creation of new age classes (regeneration), and thus the need to account for its presence within realistic models of stand dynamics. Again, certain Western variants of the FVS program have ‘full’ regeneration models and are therefore capable of capturing this dynamic. Extending this capacity to FVS-NE would provide a degree of realism that is not a feature of the current model yet is necessary in order to portray contemporary management of Northeastern forests.

List of products

- **Publications**
  - Ray, D.G., M.R. Saunders, R.S. Seymour. (in review). Some recommendations for users of the Northeastern Variant of the Forest Vegetation Simulator (FVS-NE). Research note intended for Northern Journal of Applied Forestry
  - Ray, D.G., R.S. Seymour. (currently being revised). Stocking control in variably structured multiaged stands: Is SDI an appropriate tool? Canadian Journal of Forest Research.
  - Ray, D.G., Seymour, R.S., Scott, N.S. and W.S. Keeton. (in press). Mitigating Climate Change with Managed Forests: Balancing Expectations, Opportunity, and Risk. Commentary in Journal of Forestry.
  - Ray, D.G., C. Keyser, R. Seymour, J. Brissette. 2008. Predicting the recruitment of established regeneration into the sapling size class following partial cutting in the Acadian Forest Region: Using long-term observations to assess the performance of FVS-NE. Proceedings of the 3rd Forest Vegetation Simulator Conference. Feb. 2007. USDA For. Serv. For. Manage. Ctr., Fort Collins, CO.

- **Posters**
  - The effect of plantation density, site quality and commercial thinning on an afforestation based CO2 offset project: The case of RGGI in the northeastern US. CHEMRAWN XVII and ICCDU-IX Conference on Greenhouse Gases - Mitigation and Utilization, Ontario, Canada. July 2007.
  - Simulating the long-term carbon consequences of common timber harvesting practices in Maine. New England Society of American Foresters Winter Meeting. Fairlee, VT. March 2007.
  - Early development of gap origin northern conifers: Do modest sized canopy openings provide for timely recruitment opportunities? New England Society of American Foresters Winter Meeting. Portland, ME. March 2005.
  - Crown dimensions of four northern hardwood species in developing even-aged stands: the influence of shade tolerance on growing space occupancy. Eastern CANUSA Forest Science Conference. University of New Brunswick, Fredericton, New Brunswick. October, 2004.

- **Presentations**
  - Managing for forest carbon: a Northeastern perspective. Joint Annual Meetings of the Longleaf Alliance and The Forest Guild. Sandestin, FL. October 2008.
  - The effect of plantation density, site quality and commercial thinning on an afforestation based CO2 offset project: The case of RGGI in the northeastern US. The 6th North American Forest Ecology Workshop. Vancouver, British Columbia. June, 2007.
  - Multi-aged silviculture in the Acadian Forest of northeastern North America – the case for area-based structures. The 6th North American Forest Ecology Workshop. Vancouver, British Columbia. June, 2007.
  - A test of FVS-NE for simulating the long-term growth dynamics of partially-cut stands in the Acadian forest region. Eastern CANUSA Forest Science Conference. Quebec City, Quebec, CA. 19-21 October, 2006.
  - Stocking control in variably structured multiaged stands: Is SDI an appropriate tool? International Union of Forest Research Organizations (IRFRO). Uneven-aged Silviculture Research Group Conference. Rouyn-Noranda, Quebec. May 2006.