Management Effects on Sustainable Wood Production and Carbon Sequestration in Uneven-aged Northern Hardwood Forests

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- To sustain levels of carbon sequestration and volume production in uneven-aged northern hardwood stands through three cutting cycles, it is crucial to balance selection harvest intensity with cutting cycle length
- Maintaining an Arbogast residual stocking structure with a 10-year cutting cycle provides sustained timber yields while sequestering the greatest annual total carbon

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http://www.nsrcforest.org

Project Summary

With the important role that forests play in the carbon cycle, it is essential that forest managers explore potential opportunities for increasing terrestrial carbon storage through sustainable silviculture. To evaluate and compare how various uneven-aged selection system options influence carbon budgets, a growth and yield simulator was used to predict sequestered carbon and merchantable volume for uneven-aged sugar maple stands over three cutting cycles. Four management options were considered;

A. three selection system harvests with residual basal areas of
   1) 21.1 m^2ha^{-1}, with a 10-year cutting cycle,
   2) 17.2 m^2ha^{-1}, with a 15-year cutting cycle,
   3) 14.9 m^2ha^{-1}, with a 20-year cutting cycle,

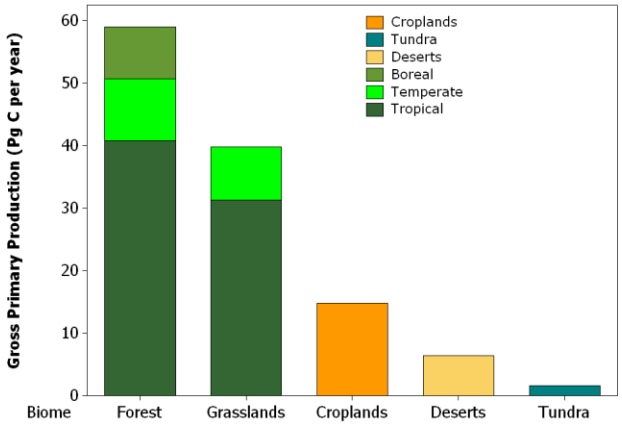
B. and diameter-limit cutting
   4) truncated at 30 cm, with a 20-year cutting cycle.

Project Summary

Our research revealed that the first three options provided consistent and commercial levels of timber production while maintaining a reserve carbon stock that was maintained through three cutting cycles. Management resulted in vigorous growth which increased carbon sequestration over the three successive cutting cycles. The fourth option failed to produce an operable cut after the first entry and resulted in the lowest levels of sequestered carbon. Implications of results for the Northern Forest region suggest that balanced selection system designs that balance harvest intensity with cutting cycle length preserve carbon production over time while maintaining sustained harvest volumes, supporting the idea of additionality of carbon through sustainable management.

Background and Justification

- The role of forests in the global carbon cycle has become the focus of much research in the last decade as result of global climate change and creation of carbon markets.



Source: Beer et al. 2010. Science v329

- Forest managers must anticipate the opportunity by exploring potentials for increasing terrestrial carbon storage through silviculture.
- Uneven-aged silviculture has added complexity since forest managers can apply varying combinations of harvest intensities, residual stand structures, and cutting cycle lengths.

Background and Justification

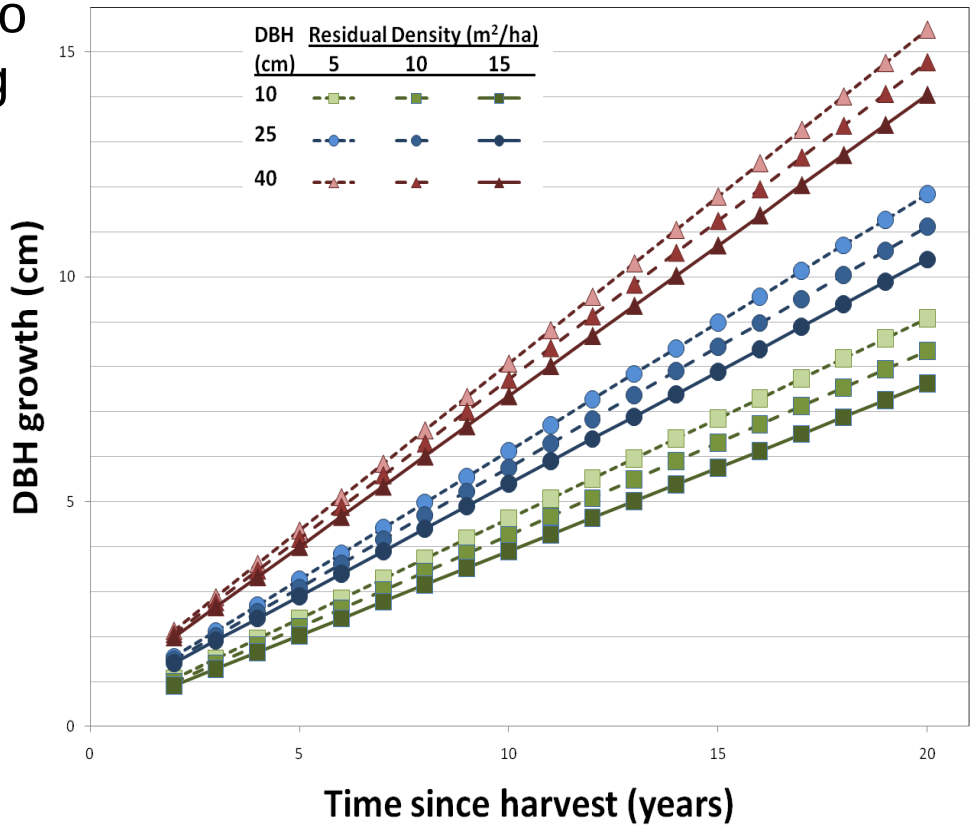
- Difficult to study all combinations of uneven-aged silviculture through direct on-the-ground comparisons.
- Through the use of stochastic forest simulation models developed from sound scientific data and knowledge, we can forecast individual tree and stand responses under varying management strategies to allow users to compare major differences among a range of alternative silvicultural options.

Methods

- We modified an existing version of Hansen's (1983) simulator to explore alternative structures and residual densities for selection system in uneven-aged northern hardwood stands dominated by sugar maple (*Acer saccarhum* Marsh.)
- New components added to the simulator:
  - New diameter growth model (Kiernan et al. 2008)
  - New mortality function (Kiernan et al. 2010)
  - Three new stochastic (Monte Carlo) components
    - Variation in individual tree growth within a diameter class
    - Variation in individual tree growth through three cutting cycles
    - Random
  - New generalized whole-tree biomass equations and conversion to carbon (C) content equivalents

Methods

- New diameter growth model (Kiernan et al. 2008)
  - Based on long-term remeasurement data from 946 residual sugar maple trees up to 25 years after a cutting
  - Fitted a linear mixed model to capture within and between tree differences in growth responses through time
  - Accelerated growth in the larger size trees



Methods

Simulations

- Four management options were simulated
  1. Selection cut with residual BA of 21.1 m^2ha^{-1} &10 yr cutting cycle
  2. Selection cut with residual BA of 17.2 m^2ha^{-1} &15 yr cutting cycle
  3. Selection cut with residual BA of 14.9 m^2ha^{-1} & 20 yr cutting cycle
  4. Diameter limit cut (30 cm) with 20 yr cutting cycle
- Each option was run for three (3) consecutive cutting cycles
  - Cut nothing less than 10 cm
  - Allowed for 13% loss in 0-5 cm size class due to logging damage
- Compared total merchantable volume, cut, total carbon, and carbon components at end of each cutting cycle

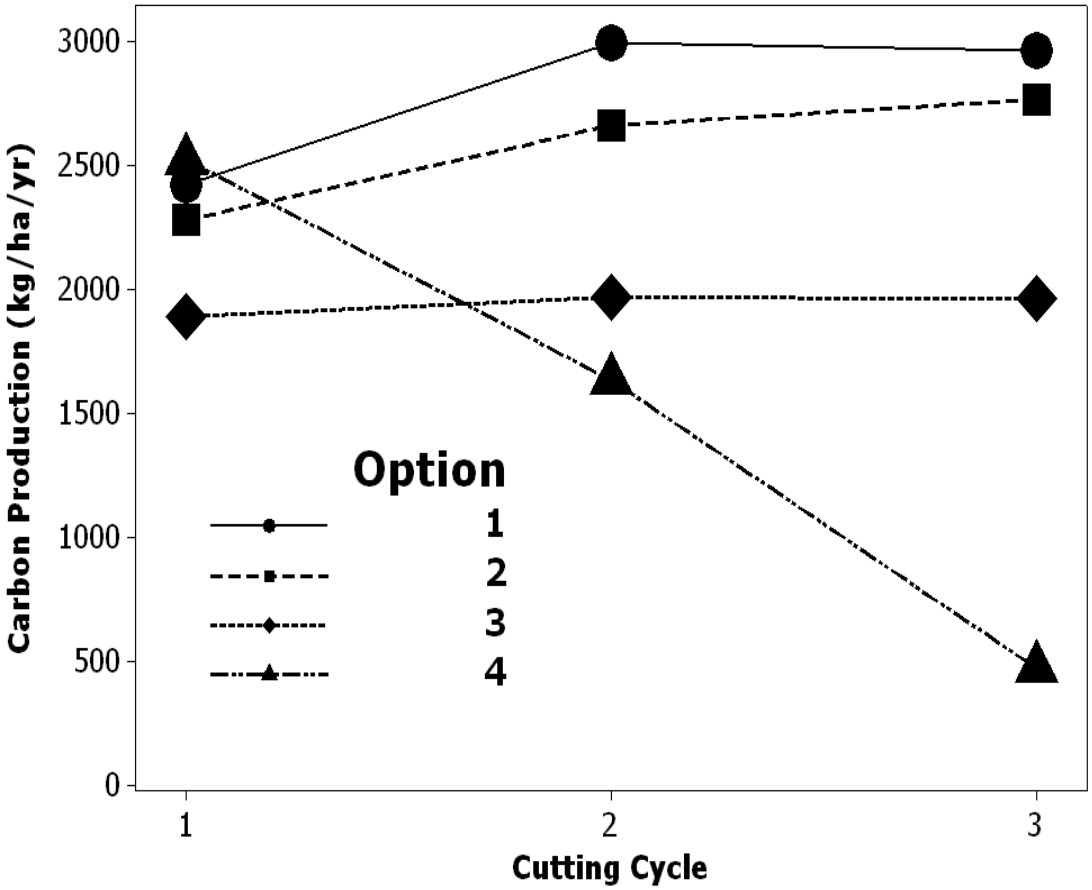
Results/Project outcomes

- Sustained sawtimber harvest volume averaged over three cutting cycles with balanced selection system
- On annualized basis, lighter, more frequent cutting (option 1) provides highest sawtimber harvest volume

Option	Avg. harvested sawtimber volume per cutting cycle		Annual avg. sawtimber volume ($m^3ha^{-1}yr^{-1}$)
	(m^3ha^{-1})	(bf ac^{-1})	
1	33.4	3106	3.34
2	45.8	4260	3.05
3	59.1	5493	2.95
4	31.7	2951	1.59

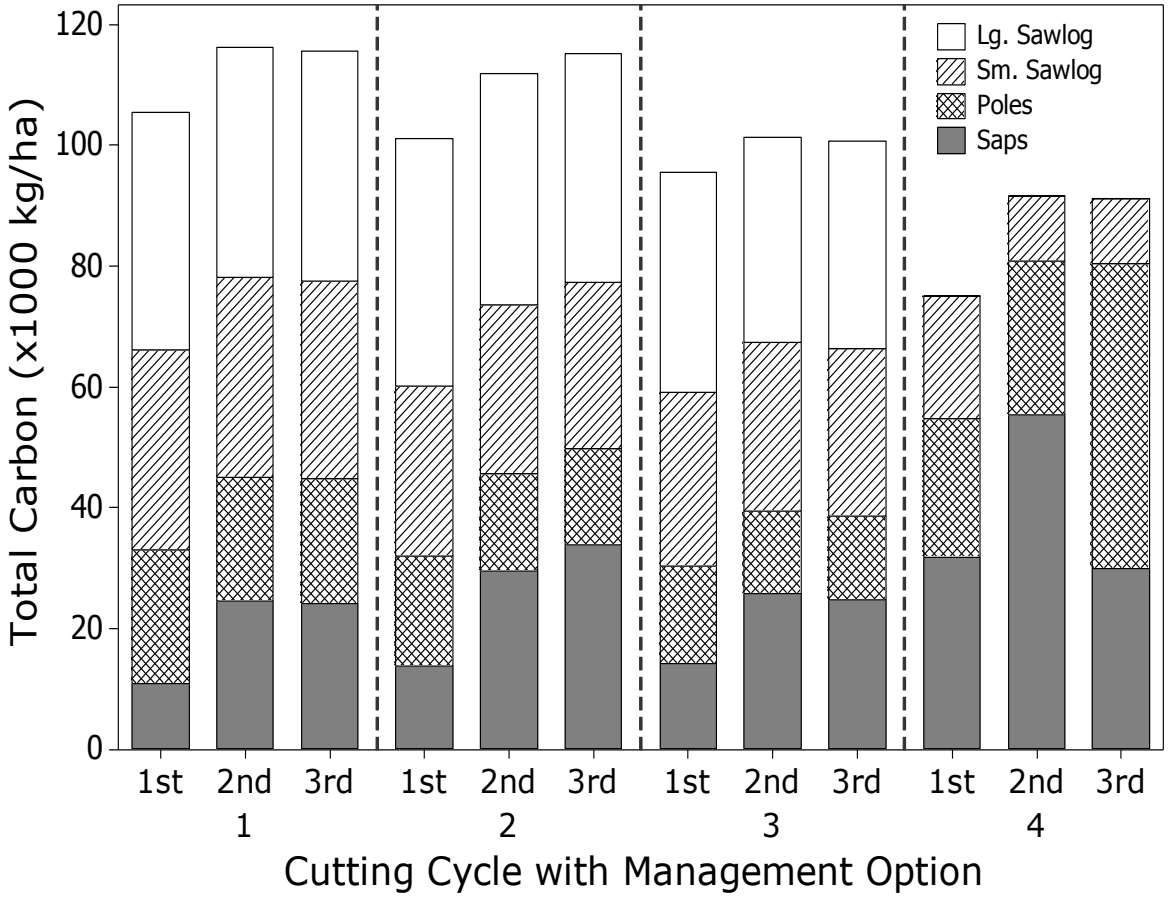
Results/Project outcomes

- Greater sustained carbon production was achieved with lighter, more frequent cutting (option 1)
- Decreasing carbon production without large diameter trees (option 4)



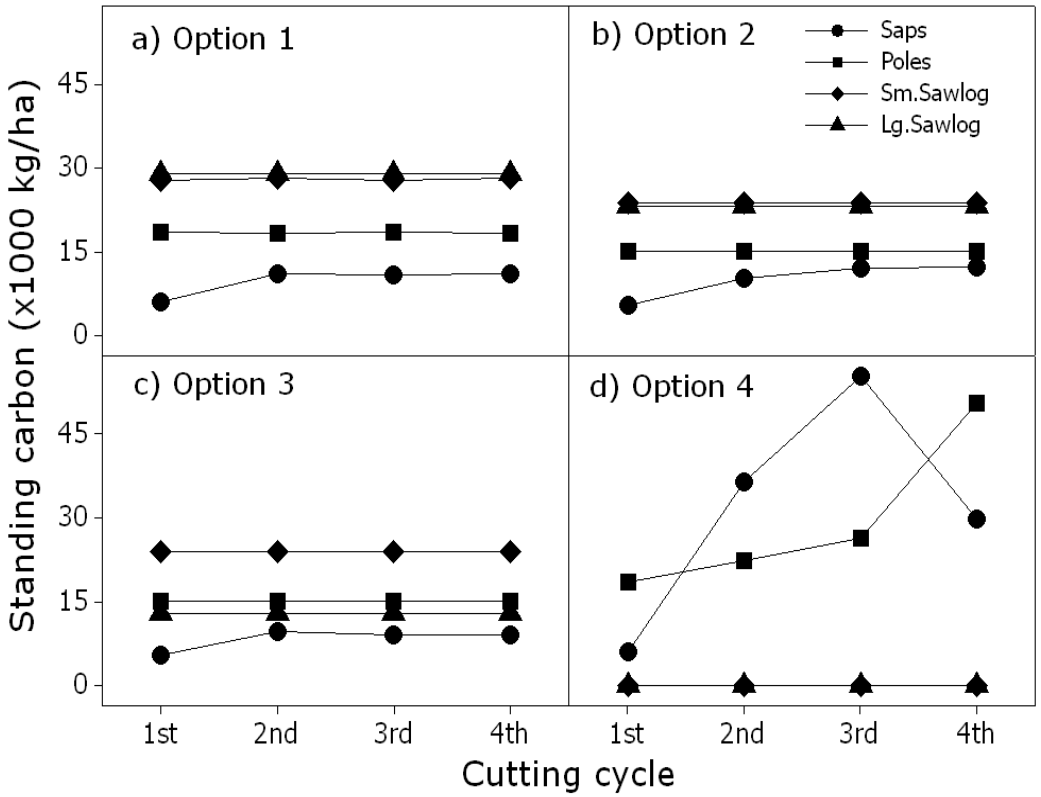
Results/Project outcomes

- Increased total carbon sequestered obtained with lighter, more frequent cutting (options 1 & 2)
- Larger amounts of carbon in the larger trees



Results/Project outcomes

- Stable stand structure (distribution of trees by size class) through time with selection system (options 1-3)
- Unstable stand structure with diameter limit cutting (option 4)



Implications and applications in the Northern Forest region

- Support for sustainable forest management as a tool for controlling terrestrial carbon is growing, and alternative management solutions must be developed for forest landowners to meet the coming future changes.
- Selection system management supports the claim that sustainable management practices keep the forest growing, continually sequestering carbon, instead of the cessation of additional sequestration in unmanaged stands nearing or at biological maturity when “sequestered carbon equals emitted carbon through decay.”

Implications and applications in the Northern Forest region

- Key to successful implementation of selection silviculture is to balance intensity of harvest with length of cutting cycle.
- Three (3) balanced designs presented in this research showed increased carbon production over time while maintaining sustained harvest volumes, supporting the idea of additionality of carbon through sustainable management.

Future directions

- This research looked at one type of forest (uneven-aged, sugar maple dominated northern hardwood stands), and found that selection system has the flexibility to mesh carbon and timber successfully in the objectives.
- The three balanced selection system options resulted in consistent, acceptable levels of timber production while increasing carbon production over additional cutting cycles.
- Additional work is necessary to investigate whether selection system can work as well in other forest types – e.g., even-aged northern hardwoods, eastern white pine managed with shelterwood system.

List of products

Peer-reviewed publication

Kiernan, D., Bevilacqua, E. and Nyland, R. 2011. Managing for carbon and timber using selection system: a simulation approach. Canadian Journal of Forest Research (In review).

Conference presentations

Kiernan, D., E. Bevilacqua, and R. Nyland. Simulated Carbon Projections for Uneven-aged Northern Hardwood Stands. Eastern CANUSA Forest Science Conference, Faculty of forestry of Université de Moncton, Edmundston, New Brunswick. October 14-16, 2010

Bevilacqua, E., D. Kiernan, and R. Nyland. Simulating Carbon Sequestration within Uneven-aged Northern Hardwood Stands. Stockbridge, MA. 14th Annual Northeastern Mensurationalist Organization (NEMO) Meeting. November 1-2, 2010.