Predicting Carbon Storage of Great Lakes Forests in the Year 2050: Scientific Challenges and Management Decisions

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February 27, 2014
Roadmap for Today’s Webinar

✧ Why carbon storage by forests is important, how it happens, & why we are concerned about its future
✧ Modeling and measuring future forest carbon storage
✧ Linking canopy complexity to forest carbon storage
✧ Managing forests to increase complexity and sustain carbon storage into the future
Why Is Carbon Storage By Forests Important?

CO₂ produced by Sources like fossil fuel emissions or environmental disturbance is stored in CO₂ Sinks like forests and agricultural land and harvested products.

Forests are thought to be the largest terrestrial sink for atmospheric CO₂.

King et al. 2012
How Does Carbon Storage By Forests Work?

Three key points:
1. Carbon storage, or **Net Ecosystem Production**, is the difference between CO\textsubscript{2} taken up by photosynthesis and CO\textsubscript{2} lost by respiration.
2. Carbon storage can be **positive**, when the ecosystem is gaining carbon, or **negative** when it’s losing carbon.
3. Most carbon is stored long term in wood or soil.
Will Eastern North America Continue to be an Important Carbon Sink in the Future?

- Dark blue, lots of carbon storage
- Green, very little carbon storage
- Dark red, lots of carbon loss

Hayes et al. 2012
There are two Reasons for Concern

1: Eastern Forests are Getting Older

In the Great Lakes, forests were clearcut between 1860 and 1930 and have been regrowing since. Current harvesting does not prevent aging of these timberlands.
2: Conventional Ecological Theory Predicts a Steady Decline in Carbon Storage as Forests Age

Maximum C storage
Maximum wood production
Wood yield & C storage approach zero
Forest succession

\[ P_G = \text{Gross Production (photosynthesis)}, \ R = \text{Respiration} \]
\[ B = \text{Biomass}, \ P_N = \text{Net Production (Carbon Storage)} \]

Many Forest Growth Models Include This Theory and Predict Age-Related Declines in Forest Carbon Storage

Structure of the TRIPLEX-management model

Predictions of carbon sequestration in the southeastern U.S. using the FORE-SCE model.

Wang et al. 2012.

Zhao et al. 2013
However, **Measurements of Carbon Storage in Temperate Deciduous Forests Cast Doubt on the Generality of Declining Carbon Storage with Forest Age**

Measurements of Net Ecosystem Production (NEP), or carbon storage, from 40 temperate deciduous forests of different ages.

Gough et al. in prep.
In a 90 year-old Northern Michigan Forest, Carbon Storage Has Been Increasing Over Time

Our 14 year record shows *increasing* ecosystem carbon storage (NEP) but *decreasing* Leaf Area Index driven by aspen and birch mortality.
The UMBS Forest Carbon Cycle Research Program

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- Chris Gough, Virginia Commonwealth Univ.
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This research is supported by the Office of Science, U.S. Department of Energy, through the Midwestern Regional Center of the National Institute for Global Environmental Change, and the National Institute for Climate Change Research.
Meteorological Studies of Forest Carbon Storage
Ecological Studies of Forest Carbon Storage

Permanent Study Plots at UMBS
Older plots that are more structurally complex have higher wood production.

We measure canopy complexity (rugosity, $r$) with a portable canopy lidar system.

$$r = \sigma(\sigma[VAI]_z)_x$$

Vegetation density in plots of: Low (A), Intermediate (B), and High (C) rugosity but of similar total leaf area index (LAI).

Hardiman et al. (2011)
Relationship Between Canopy Complexity, Stand Age, and Wood Production

- Rugosity reaches a maximum value at 70-80 yrs.
- Wood production ($NPP_w$) is exponentially related to rugosity.
- Rugosity is related to both LAI and site index, and strongly correlated with wood production.
Our emerging conceptual model: Leaf *arrangement* is more important to C storage than leaf *quantity* as eastern forests age.
Continuing Efforts to Better Quantify Canopy Structural Complexity

Sensor hoist to 16m

Sensor hoist to 22m

Examining structural changes over time.

Full 3D characterization of canopy structure.
Older plots that are more biodiverse are more resilient to production declines with age.

Higher biodiversity = greater ecological resilience

Gough et al. (2010)
New forest management tools are needed that promote structural, compositional, and functional complexity.

Management Decisions

Unmanaged

Heavily managed

Management intensity

Clear cut/intensive plantations

Uneven age stand mgmt

Thinning w/natural regeneration

Early successional forests after disturbance

Old-growth forests

Simple (low)  Complex (high)

Structural & compositional complexity (climate change mitigation potential)

After Puettermann et al. (2009)
Hypothesis: By applying forest management one can **more quickly** obtain more natural diversity of species, age classes, and structural attributes.

Gaps of different size were cut into even-aged maple in 2010.

People Are Currently Working To Develop Those Management Tools!
Concluding Thoughts:

- As Great Lakes forests age, and early successional species die, they become more structurally and biologically complex.
- Increasing complexity sustains carbon storage, promotes resilience, and enhances biodiversity.
- Innovative forestry management may accelerate forest complexity.
- With increasing complexity, carbon storage in Great Lakes forests should not decline substantially by 2050.