Forest Service
U.S. DEPARTMENT OF AGRICULTURE

Northern Research Station

Rooted in Research

ISSUE 34 | JUNE 2024

Understanding Old-Growth Forest Carbon Storage Potential in the Central Hardwoods Region

Stretching from Missouri through Arkansas to Georgia and New York and covering 609,000 square kilometers, the Central Hardwoods region is the world's largest continuous deciduous forested area. Today, most of the forests in the Central Hardwoods region are second-growth forests, meaning that they have been harvested once in the past two centuries. Very few of the forests are old-growth forests, which are defined as uneven-aged forest with trees more than 150 years old and minimal harvesting or manipulation over the last 40 to 100 years.

Jacob Fraser, a research ecologist with the U.S. Department of Agriculture, Forest Service, Northern Research Station, and colleagues wanted to understand how these old-growth forests store carbon in order to better guide climate-adaptive management strategies. Fraser and his co-authors published their findings, Carbon dynamics in old-growth forests of the Central Hardwoods Region, USA, in 2023.

"Old-growth forests store a lot of carbon because of the multiple-age structures that are occurring on them," Fraser says. "They're also still accumulating carbon—although not at as fast a rate as younger forests—and are serving an important purpose by locking up carbon at a net positive rate. In other words, they're still sequestering and storing more carbon than they're releasing through processes like decomposition and respiration."

KEY MANAGEMENT CONSIDERATIONS

- Over 20 years, aboveground carbon increased by 7 percent in old-growth forests in the Central Hardwoods region and increased in 9 of 10 sampling sites.
- Forest structure and productivity can influence baseline carbon storage potential.
- Disturbance can positively or negatively influence carbon storage.
- Old-growth forest structure and carbon storage dynamics over time can guide active forest management efforts that aim to promote old-growth characteristics.

Extending 1990s Data to Today

For their study, Fraser and colleagues investigated carbon storage in old-growth forests by returning to 10 old-growth sampling sites in Indiana, Illinois, and Missouri. Established in the 1990s by other researchers, the east-to-west sampling gradient was spread out over 770 kilometers, with more productive forests on the eastern end (in areas characterized by silty, nutrient-rich soils) and less productive forests on the western end (in areas with steeper slopes and coarser soils).

Fraser and colleagues continued the work of earlier researchers. They documented structural changes in forests by recording tree species, measuring tree height and diameter, and recording the status of the trees by their crown class and live crown ratio. These new measurements and soil carbon samples extended the original dataset to 20 years and enabled Fraser and colleagues to study how changes in carbon storage capacity relate to forest structure and productivity. They also examined how disturbances like ice storms and windstorms affected carbon dynamics.

Big Spring is a 140 ha site located in Missouri that was inventoried in 1992 and again in 2012. USDA Forest Service photo by Jacob Fraser

Complexities in Carbon Storage

Over the 20-year study period, total aboveground carbon storage increased by 7 percent in the old-growth forest study areas. Other observed increases in carbon pools included downed dead wood carbon (5 percent), standing dead wood (7 percent), live roots (4 percent), and dead roots (68 percent). Nine of the 10 sampling sites experienced an increase in aboveground carbon. Carbon storage generally followed the east-to-west gradient: More productive sites had higher total carbon storage.

Despite the overall increase, researchers noted that stochastic disturbances, such as ice storms or windstorms, could either positively or negatively influence carbon storage. For example, the single site that did not experience an overall increase in aboveground carbon, Laughery Bluff, had experienced a blowdown event two weeks before the first measurements in the 1990s were made. Over the next 20 years, total aboveground carbon decreased in this forest even though overstory carbon increased. Loss of carbon through decomposing woody debris may be the reason that aboveground carbon did not increase overall.

"When you have a large windstorm or ice storm that removes a significant portion of the mature overstory trees," says Fraser, "carbon is moved directly into downed, woody debris that starts to decompose. It's important to recognize that those dynamics are happening in these types of forests."

Some disturbances, however, can increase aboveground carbon storage. For example, the Dark Hollow ice storm that occurred in 1994 had residual effects two decades later in terms of carbon storage, specifically a 20 percent increase in aboveground carbon that corresponded with an increase in overstory carbon.

Reflecting on major forest disturbances, Fraser says, "In the immediate aftermath, these types of events may seem almost catastrophic, but over a long period of time in an old-growth system, events like these layer upon one another to create the type of structure that we recognize as old growth, which ultimately increases overall carbon storage."

In addition to site productivity and disturbance as predictors of carbon storage, Fraser and his colleagues found that successional diversity, or the distribution of successional stages in stands, can also predict forest productivity and carbon storage better than species richness.

Guidance from Old-Growth

Although old-growth forests are rare in the Central Hardwoods region today, there are many aging, late-successional forests that could become old-growth someday. These forests have immense potential to store carbon if they are managed to promote old-growth characteristics. This research identifies key factors that influence carbon storage and provides more insight into old-growth forest structure, which could improve silvicultural guidance for managers seeking to promote old-growth forest characteristics in their stands using active forest management. Fraser and his colleagues hope to use LiDAR to for future measurements which will further increase the understanding of old-growth forest structure and carbon storage and inform climate-adaptive management.

Jacob Fraser, research ecologist, coring a white oak tree in Kaskaskia Experimental Forest. Coring trees allows scientists to discern tree age and growth patterns over time. USDA Forest Service photo by Lauren Pile Knapp

PROJECT LEADS

Jacob Fraser is a research ecologist with the Ecological Sustainability of Forests and Grasslands in the Central Hardwoods research work unit at the Northern Research Station.

Lauren Pile Knapp is a research ecologist with the Ecological Sustainability of Forests and Grasslands in the Central Hardwoods research work unit at the Northern Research Station.

FURTHER READING

Fraser, Jacob S.; Pile Knapp, Lauren S.; Graham, Brad; Jenkins, Michael A.; Kabrick, John; Saunders, Michael; Spetich, Martin; Shifley, Steve. 2023. Carbon dynamics in old-growth forests of the Central Hardwoods Region, USA. Forest Ecology and Management. 537: 120958. https://doi.org/10.1016/j.foreco.2023.120958.