United States Department of Agriculture

Forest Service

Briefing Paper

Date: July 27, 2018

Topic: Assessment of Forest Sector Carbon Stocks and Mitigation Potential for the State Forests of Pennsylvania

Background:

To avoid the most harmful effects of climate change, it has been recommended that significant reductions in greenhouse gas (GHG) emissions be achieved across all economic sectors. The potential of forests to play a vital role in mitigating climate change has long been recognized. As a land steward and the state's leading conservation agency, the Pennsylvania Department of Conservation and Natural Resources (DCNR) has identified climate change as a principal forest stressor in Pennsylvania and has outlined a strategic framework to address climate change through mitigation and adaptation. Assessing past forest carbon dynamics and establishing forest sector baseline carbon stocks and emissions trends will help to improve understanding the biophysical potential for forests and their products to play an enhanced role in the mitigation of climate change.

Forest sector mitigation strategies may be diverse, targeting land use change and conservation, forest management practices and harvest regimes, and/or the use of harvested wood products (HWP) which both store carbon and displace other emission-intensive materials and fossil fuels. In some cases, activities that reduce GHG emissions from the ecosystem may increase emissions in the product sector. Thus, to evaluate a range of forest sector mitigation options and to account for interactions across the components that comprise the forest sector, it is necessary to apply a systems approach that assesses net emissions from the forest ecosystem (including land use change), harvest wood products, and the displaced emissions from using wood products in place of emission-intensive materials and fossil fuels.

Methods:

We assessed forest sector carbon trends and mitigation potential for Pennsylvania by applying a systems-based approach within a carbon modeling framework which includes: 1) a growth and yield-based ecosystem model, 2) a lifecycle harvested wood products model, and 3) published displacement factors to evaluate substitution benefits. While the principal scope is the State Forest lands, we provide similar analyses across all ownerships to compare carbon trends among land tenures.

We compiled site specific input data on forest characteristics and harvesting from the DCNR forest inventory and the Forest Service's Forest Inventory and Analysis (FIA) database as well as remotely sensed disturbance and land-use change data. We modeled past and prospective forest carbon stocks and emissions from 1990-2050 assuming a baseline "business as usual" scenario throughout the projection period.

In consultation with DCNR collaborators, we developed 10 hypothetical forest sector mitigation scenarios (Table 1). We evaluated the mitigation potential of each scenario as the difference between the net GHG emissions of the mitigation scenario and of the baseline scenario from 2020 to 2050. Net GHG emissions are estimated as the sum of emissions from the forest ecosystem, the product sector, and the displaced emissions from substituting wood for bioenergy and other materials.

Table 1. Indicators for the 10 forest sector mitigation scenarios evaluated for Pennsylvania. The parameter changes are relative to the baseline scenario. All scenarios are implemented from 2020-2050.

Scenario	Description[b]
Short rotation	Increase harvests and reduce minimum harvest age. All additional harvested wood is used for bioenergy.
Extend Rotation, high	Extend the length of harvest rotation to 130 years, reduce harvests, and increase the proportion of long-lived wood products (LLP) including saw logs and panels by 5% at the cost of pulp and paper (PP).
Extend rotation, low	Extend the length of harvest rotation to 100 years, reduce harvests, and increase the proportion of LLP by 2.5% at the cost of PP.
Deforestation[a]	Steadily increase the annual area deforested as a result of development (e.g. natural gas, urbanization) to 4,700 ha by 2050.
Residues	Increase harvest residue collection so that 100% of residues are recovered. All additional harvest residues are used for bioenergy.
Productivity	Increase productivity of existing Oak/hickory stands through silvicultural activities.
Portfolio	Combine the Extend Rotation (low), residues, and productivity scenarios.
Longer-lived products (LLP)	Increase the proportion of harvested wood for LLP at the cost of PP.
Increase Bioenergy (BioE_PP)	Increase the proportion of harvested wood for bioenergy at the cost of pulp and paper.
Increase Bioenergy (BioE_LLP)	Increase the proportion of harvested wood for bioenergy at the cost of LLP.

[a] Scenario does not seek to achieve mitigation, but rather to evaluate the impacts of potential deforestation.
[b] Scenario descriptions and parameters for SFL. Some scenarios are applied differently across ownerships.

Key Findings:

The results presented here are estimates and projections that are contingent on the models, datasets, and assumptions applied, which contain uncertainty.

Baseline forest ecosystem and harvested wood products (HWP) carbon stocks and emissions:

- From 1990 through 2017, average carbon stock density (carbon per unit area) was the highest on the Allegheny National Forest, followed by State Forests, while stock density was lowest on Private lands (Fig. 1).
- Soils make up the largest ecosystem carbon pool, storing approximately 40% of all carbon in the forest, followed by aboveground live trees (30%).
- Over the past few decades, forest ecosystem carbon stocks across land ownerships in PA have been increasing

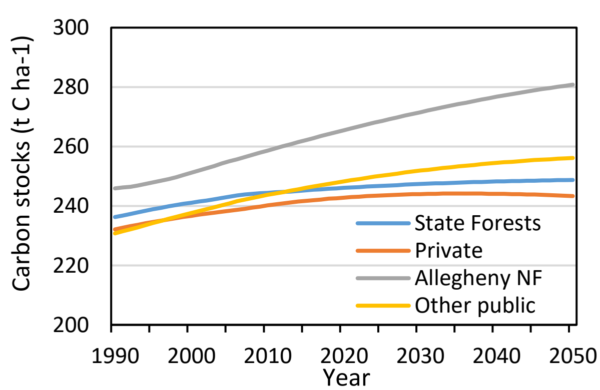

***Figure 1**. Estimated total forest carbon stock density from 1990 to 2050 across ownership classes in Pennsylvania. Values after 2011 are projected.*

resulting in forests being a net sink of CO_2. State Forest carbon stocks increased from an estimated 236 t C ha^{-1} in 1990 to 249 t C ha^{-1} in 2017 (Fig. 1).

- Although stocks have been increasing, as forests continue to age the strength of this sink (rate of sequestration) is projected to decline. State Forests have the oldest stand age distributions among ownerships (Fig. 2) due to their relatively low rates of harvesting and extended rotations. While older forests typically store more carbon, their productivity (growth rate) is lower and emissions are higher due to greater morality and respiration from decay of dead organic matter. Thus, emissions from State Forests have been slightly higher than other ownerships, averaging an estimated 1.94 t CO_2e per ha per year, compared to the state average of roughly 2.38 t CO_2e per ha per year.

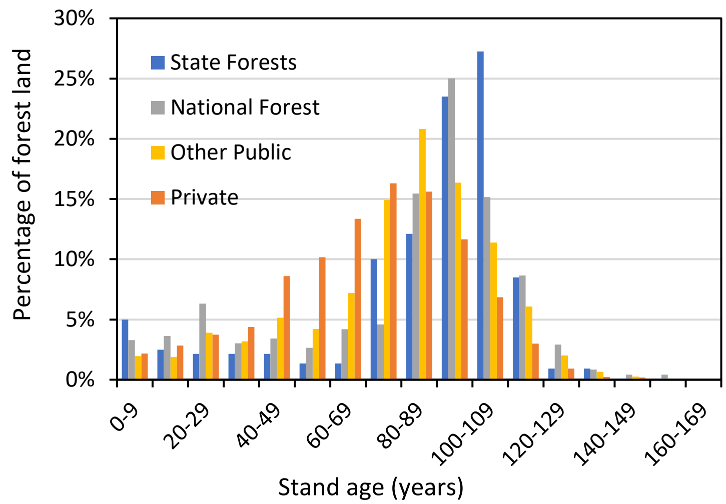

***Figure 2**. Percentage of forest in 2015 by age class and ownership class, Pennsylvania.*

- Forest carbon emissions on Private lands would have been roughly 20% lower in 2017 if deforestation had not occurred from 1990 through 2017.

- Private lands followed by State Forest lands have accumulated the most carbon in HWP per unit area since 1990. While most of the HWP carbon is stored in sawlogs, the majority of HWP emissions are from short-lived products including use of mill residues and pulpwood. Products with longer retention times store carbon for longer and thus have lower annual emissions. However, when mill residues are burned for fuel, they can offset fossil emissions.

- On State Forests, C storage in the forest ecosystem and HWP combined increased from an estimated 239 t C ha^{-1} in 1990 to approximately 251.9 t C ha^{-1} in 2017. HWP accounted for 30% of this increase, while the forest ecosystem, mostly increases aboveground live biomass, accounted for the other 70%.

- Despite projected forests aging, declines in productivity, and forest cover loss (private land), when combining carbon accumulation in the forest ecosystem with that in HWP, the PA forest sector is projected to continue to maintain a C sink through 2050.

Forest Sector Mitigation:

- Of the 10 hypothetical mitigation scenarios we evaluated (Table 1) from 2020 through 2050 on State Forests, extending harvest rotations to 130 years (*ExtendRot_high*), which results in a decrease in annual harvest removals, is project to have the greatest mitigation benefit, reducing cumulative emissions by an estimated 6% by 2050 (Fig. 3). More growing stock are left to absorb carbon, while HWP emissions decline as fewer commodities are produced. Because less wood is harvested, this results in less product and bioenergy substitution benefits. The other two scenarios that more conservatively extended rotations, *Portfolio* and *ExtendRot_low*, ranked second and third in mitigation potential.

- Shortening harvest rotations and using additional harvested wood for bioenergy resulted in a net increase in GHG emissions by roughly 3.2%, which were not fully offset by substitution benefits. However, it may take several decades and multiple rotations for the forest system to accrue the carbon removed from the ecosystem and emitted via the combustion of bioenergy.

- Increasing the proportion of commodities used for long-lived wood products is also projected to have a mitigation benefit (roughly 2.7% reduction in emissions) because it reduces HWP emissions and displaces emissions from alternative fossil fuel intensive materials (steel, concrete) (Fig. 3).

- Of the bioenergy scenarios evaluated, increasing residues for bioenergy (*Residues*) as well as shifting woody material from pulpwood production to bioenergy (*BioE-PP*) had mitigation benefits, reducing emissions by an estimated 1.4% and 1.7%, respectively. Increasing roundwood harvests for bioenergy (*ShortRotation*) and shifting materials from long-lived products to bioenergy (*BioE_LLP*) is projected increase net emissions.

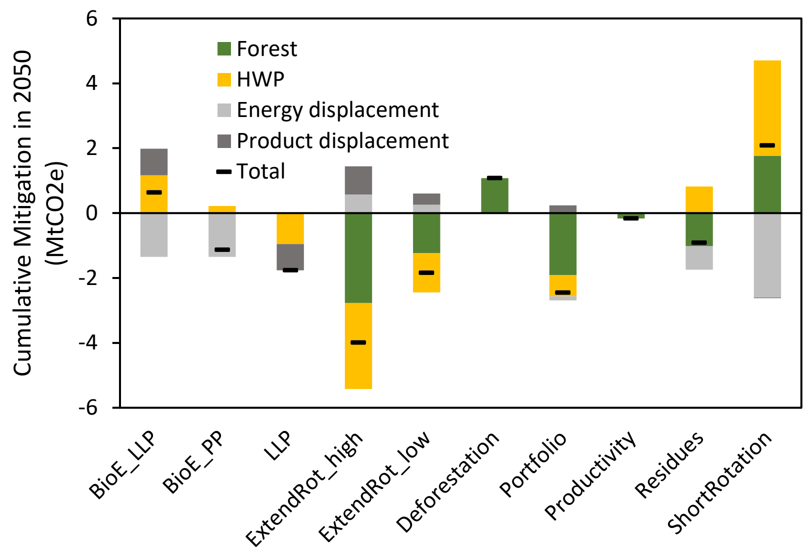

Figure 3. *Modeled cumulative mitigation by forest sector component in 2050 for State Forest lands in Pennsylvania. A negative value indicates a mitigation benefit.*

- A hypothetical conversion of 4,700 ha of State Forests to natural gas or other non-forest development by 2050 is projected to result in an estimated 1 million tonne increase in CO_2 emissions (1.6% increase in emissions) by 2050 (Fig. 3).

Conclusions:

Although forest ecosystem carbon stocks across ownerships in PA have been increasing over the recent past indicating a net carbon sink, the strength of this sink is expected to decline over the next few decades as forests continue to age causing lower productivity. According the 2012 update to Resource Planning Act (RPA) Assessment and other recent studies, this trend is projected for much of the forestland in the Northeastern U.S. Results indicate that management actions that extend harvest rotations have the greatest mitigation benefits over this 30-year analysis period. Shifting commodity ratios from products with shorter life spans like paper products to those with longer life spans such as sawlogs is also projected to be an effective strategy. Results suggest that management decisions over extended periods of time can change CO_2 emission trajectories, but that the magnitude of those impacts is low (<10% emission reduction) depending on the action. Limitations in this analysis, assumptions made in the models, the need for companion economic analyses and feasibility assessments, and the lack of rigorous socioeconomic research regarding how to successfully implement climate adaptation and mitigation efforts should be cause for caution in the direct application of the results from this analysis. While carbon mitigation is likely to increase in importance in future years, it is but one of many of considerations forest managers will be called upon to weigh.

Contacts:

Alexa Dugan, Natural Resource Specialist, USFS, Northern Research Station, adugan@fs.fed.us, 215-534-0243
Al Steele, Physical Scientist, USFS, Northeastern Area, asteele@fs.fed.us, 304-285-1588
David Hollinger, Project Leader, USFS, Northern Research Station, dhollinger@fs.fed.us, 603-868-7673