The Carbon Benefits of Climate-Smart Forest Management (II)

Summary of Research for Eastern Forests

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For each article, I describe its focus and key findings. For some, I add a short discussion to help interpret the findings. Where possible, the discussion includes an estimate the economic value of forest-related carbon stores. This value generally represents the decrease in climate-related damages that would follow from a change in forest management that would increase the amount of carbon stored in forest ecosystems and wood products.

The estimates of economic value come from multiplying the article's estimate of the increase in carbon stores (usually shown as the metric tons of carbon dioxide-equivalent, or $MtCO_2e$) times an estimate of the social cost of carbon dioxide ($SCCO_2e$), i.e., the benefits to society from sequestering one $MtCO_2e$. I primarily employ estimates of the $SCCO_2e$ from the most recent, comprehensive analysis: Ricke, K, L. Drouet, K. Caldeira, and M. Tavoni. 2018. Country-level social cost of carbon.

This analysis provides two estimates of the $SCCO_2e$. One, $417, represents the *expected* benefits from sequestering one $MtCO_2e$. The other, $800/$MtCO_2e$ shows the potential benefits *if climate change proves to be more harmful than was expected* at the time the study was completed. The true $SCCO_2e$ likely falls closer to the latter, insofar as 11,000+ scientists just stated that "The climate crisis has arrived and is accelerating faster than most scientists expected…. It is more severe than anticipated, threatening natural ecosystems and the fate of humanity…." Moreover, all current estimates of $SCCO_2e$ fail to incorporate all the harms resulting from GHG emissions, including, for example, the full costs of ocean warming and acidification.

Note: these summaries represent my understanding of the major findings of each article. Before incorporating a specific article into your work, I recommend you read the original to ensure that your efforts represent it accurately and comprehensively.

Please, let me know if you:

- Find any errors or ambiguities in the summaries.
- Have any suggestions for making the summaries more useful.
- Know of studies you think I should summarize.
- Have any questions.

Estimates of Forest Carbon: Eastern U.S.

E-1. Carbon credits for non-industrial landowners of oak forest in Southern Appalachian Mountains, 2011[1]

Study's Focus	Estimate the impacts on landowner behavior if offered carbon-credit payments of $10/MtCO_2$ for increases in stored carbon from slowing harvest cycles, increasing post-harvest retention levels, minimizing timber harvest impacts to the soil and residual growing stock, and/or preserving forestland to protect against timber extraction.
Findings	Payments of $10/MtCO_2$ would not be sufficient to induce many landowners to participate in the carbon-credit program.
Discussion	

E-2. Carbon impacts of forest-management alternatives in Maine, 2018[2]

Study's Focus	Test the sensitivity of Maine's state-wide forest sector GHG emissions (above- and below-ground live and dead biomass, forest products in use and in landfills, substitution for building materials, bioenergy, landfill methane) to changes in forest management.
Findings	More extensive and intensive even-aged management should increase total emissions over 100- and 300-year periods. Increasing the area of no-harvest set asides should reduce emissions, especially for the 100-year period, although accounting for substitution effects creates ambiguity. The best carbon outcomes should occur through increases in the areas managed to produce uneven-age forests.
Discussion	These findings likely understate the net carbon benefits from forest-management alternatives that diminish timber production, insofar as they are inconsistent with research that indicates the carbon benefits of timber products (long-lived products, substitutes for carbon and steel, and bioenergy) are lower.[3]

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[1] Grinnell, J. 2011. Project evaluation of sustainable upland hardwood management in the U.S. South with the monetization of carbon.

[2] Gunn, J.S. and T. Buchholz. 2018. Forest sector greenhouse gas emissions sensitivity to changes in forest management in Maine (USA).

[3] *See*, for example, Law, B.E., and M.E . Harmon. 2011. Forest sector carbon management, measurement and verification, and discussion of policy related to mitigation and adaptation of forests to climate change; and Harmon, M.E. 2019. Have product substitution carbon benefits been overestimated? A sensitivity analysis of key assumptions.

E-3. Carbon impacts of industrial forest-management practices in North Carolina, 2019[4]

Study's Focus	Synthesize and analyze the best available climate science on the impacts of industrial forest practices in North Carolina.
Findings	Industrial clearcutting, timber plantations, application of chemicals and fertilizers, and dense networks of logging roads reduce the carbon stored in vegetation and soils, and result in large greenhouse-gas emissions. Current carbon stocks are about 50% relative to nature's baseline. Managing industrial lands over the next 100 years so they carry more trees (afforestation and reforestation) and allowing existing trees to grow to maturity (proforestation) could result in the sequestration and storage of nearly 3 billion metric tons of CO_2. This is equivalent to 20 years of North Carolina's currently reported greenhouse gas emissions. Forests logged on short rotations to produce paper, pellets, and low-quality timber have created carbon-sequestration dead zones encompassing 2.6 million acres. Allowing trees to grow older before being logged would shrink these dead zones, produce more timber per acre, and, perhaps, double the rate of carbon sequestration in a given watershed.
Discussion	

E-4. Carbon impacts and costs of extending harvest rotations of industrial forests in southern states, 2008[5]

Study's Focus	Describe the potential quantity and costs of sequestered carbon from extending rotation ages in softwood forests of southern states (Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee).
Findings	A 5-year increase in harvest rotation increases average sequestration by about 22 tons of CO_2 per hectare, and the average marginal cost by \$57 per ton CO_2. Increasing the harvest rotation by 10 and 15 years would sequester 35 and 43 tons of CO_2 per hectare, with marginal costs of \$75 and \$84 per ton CO_2, respectively. Marginal costs increase by \$0.79 per ton CO_2 for every \$1/m^3 increase in timber prices, and by \$3.51 per ton CO_2 for every additional 1 m^3/ha/year in annual wood production (site index). Extending the harvest rotation for slash pine stands results in marginal costs \$27 per ton CO_2 higher than the costs for loblolly pine stands.
Discussion	The most recent estimate, by Ricke, et al (2018), shows that the $SCCO_2e$ is \$417 per Mt CO_2e for expected changes in climate, rising to \$800 if climate change proves more harmful than expected. These values indicate that society's climate-related benefits from extending the harvest rotation by 5, 10, or 15 years would exceed landowners' costs.

[4] Talberth, J. 2019. Climate impacts of industrial forest practices in North Carolina; Part I.
[5] Sohngen, B., and S. Brown. 2008. Extending timber rotations: Carbon and cost implications.

E-5. Carbon impacts from extending the harvest-rotation age for forests, 2009[6]

Study's Focus	For 26 different forest types in eastern regions of the U.S., estimate the amount of additional forest carbon (live tree, standing and down deadwood, understory, forest floor, and wood products) that would be sequestered by extending the harvest-rotation age by 5 years or 100 years.
Findings	All eastern forest ecosystems showed an increase in the amount of carbon (metric tons of CO_2e) sequestered with longer rotations, estimated with three commonly used estimation methods. These results come from using the Verified Carbon Standard (VCS), which yields the lowest estimates:

Additional Sequestration (VCS Protocol) with a 5-Year Extension of Rotation Age ($MtCO_2e$/ha/yr)

Northeast States		**South Central States**	
Aspen-Birch	0.12	Elm-Ash-CottonWood	0.11
Maple-Beech-Birch	0.17	Loblolly-Shortleaf Pine	0.17
Oak-Hickory	0.22	Oak-Gum-Cypress	0.11
Oak-Pine	0.15	Oak-Hickory	0.11
Spruce-Fir	0.12	Oak-Pine	0.13
White-Red-Jack Pine	0.14	**Southeast States**	
Northern Lake States		Loblolly-Shortleaf Pine	0.13
Aspen-Birch	0.11	Longleaf-Slash Pine	0.12
Elm-Ash-CottonWood	0.08	Oak-Gum-Cypress	0.13
Maple-Beech-Birch	0.13	Oak-Hickory	0.14
Oak-Hickory	0.13	Oak-Pine	0.13
Spruce-Balsam Fir	0.13	**Northern Plans States**	
White-Red-Jack Pine	0.19	Elm-Ash-CottonWood	0.10
		Maple-Beech-Birch	0.08
		Oak-Hickory	0.09
		Oak-Pine	0.12

Discussion

Results for three eastern forest ecosystems compare the additional sequestered carbon and forgone timber from a 100-year extension of the rotation age. The data, combined with the social cost (Ricke, et al 2018) that would result from carbon dioxide emissions over the next few years ($417/Mt CO_2e), suggest the timber prices that would be needed to exceed the value of the carbon gains:

	per m^3	per thousand board feet*
Southeast Loblolly-Shortleaf Pine	$900	$2,100
Northeast Maple-Beech-Birch	$1,600	$3,700
Northern Lake States Aspen-Birch	$2,700	$6,400

The timber prices would have to be roughly twice as great to exceed the social cost of carbon emissions if climate change proves to cause damages higher than general expectations. Combined, this information strongly suggests that failing to extend the harvest-rotation age for eastern plantation forests U.S. would impose carbon-related harms that would exceed the value of the forgone timber production.

*Assumes 1 m^3 = 424 board feet.

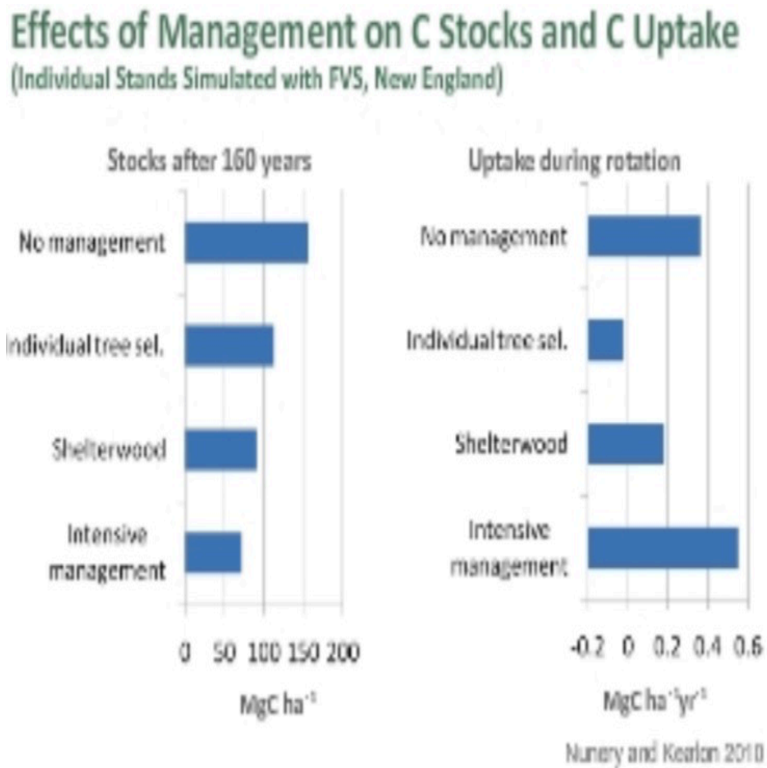
[6] Foley, T., D.deB. Richter, and C. Galik. 2009. Extending forest rotation age for carbon sequestration: a cross-protocol comparison of carbon offsets of North American forests.

E-6. Carbon accumulation in longleaf pine forests, 2017[7]

Study's Focus	Quantify the variation in ecosystem carbon density in stands of longleaf pine of different age, forest structure, management, and site quality.
Findings	Longleaf pine forests, mostly second growth and plantation, occupy about 3% of their historical range, limiting the scope of the analysis. On average, the live tree portions of these forests hold 36 Mg C/ha. Ecosystem carbon increased with age primarily through aboveground growth, rather than through change in soil carbon. Live-tree carbon is predicted to reach 57 Mg C/ha, about 71% of the maximum indicated by modeling. Highly productive sites can hold greater amounts of carbon, especially in lateral coarse roots, which seem to play a larger role than with many other forest types. Other southern pine species accumulate carbon more quickly over a short period, but older, longleaf pine can play an important role in regional forest diversity.
Discussion	

[7] Samuelson, L.J., T.A. Stokes, J.R. Butnor, K.H. Johnsen, et al. 2017. Ecosystem carbon density and allocation across a chronosequence of longleaf pine forests.

E-7. Management options for carbon sequestration in eastern forests, 2011[8]

Study's Focus	Increase understanding of different forest-management options and their carbon-sequestration potential.
Findings	This figure shows that leaving a forest unmanaged for 160 years would store more carbon than intensively managing an equivalent forest (top and bottom bars of left graph) even though, during the period, the intensively managed forest would remove more carbon from the atmosphere (right graph). The difference occurs because the unmanaged forest holds onto its initial stock of carbon at the beginning of the period, but the intensively managed forest loses its initial stock when the forest is first logged, with much of the carbon returning to the atmosphere. 
Discussion	

[8] Birdsey, R. 2011. Forest management options for carbon sequestration: considerations in the eastern U.S.