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

Summary of Research from a National Perspective

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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: National Perspective

N-1. Overview of U.S. forest carbon, 2018[1]

Study's Focus	Present the most recent estimates of carbon stocks and stock changes across the continuum of land with trees in North America.
Findings	Managed forests in the U.S. (except interior Alaska, Hawai'i, and territories) absorbed about 267 Tg of atmospheric C per year from 2000 to 2015 and lost about 113 Tg C through harvest removals, for a net stock increase of 154 Tg C per year. The 2014 net uptake estimate from forestland remaining forestland was 742 Tg CO_2e per year, which offset about 11% of gross U.S. GHG emissions that year. Historical land clearing yields a legacy of carbon uptake in the Northeast; regrowth from contemporary harvesting dominates carbon uptake in the Southeast; and disturbances and environmental stresses (e.g., droughts, insects, and pathogens) raise carbon releases in the West. The amount of carbon in harvested wood products grew by 25–36 Tg C per year from 1990 to 2005. These products are not themselves a carbon sink, but a transfer in use of carbon previously stored in trees. Currently, annual afforestation slightly exceeds deforestation, but forest area is projected to level and then decline gradually after 2030. Assuming no policy intervention, annual carbon uptake will decrease to 320 Tg CO_2e per year in 2050 as a result of forest aging, forest disturbance, and land-use change. Severe warming of forest soils can accelerate loss of soil carbon emitted as CO_2.
Discussion	

N-2. Carbon impacts from business-as-usual management of U.S. forests, 2017[2]

Study's Focus	Calculate annual economic benefits for the nation from business-as-usual management of forests in the conterminous U.S., through 2050.
Findings	U.S. forests, on average, are expected to grow older and sequester more carbon (live tree above ground and below ground, deadwood, litter, and soil) in future years. This removal of CO_2 from the atmosphere will generate benefits by reducing the extent and intensity of the expected negative effects of climate change. A 2015 estimate of the social cost of carbon dioxide ($SCCO_2e$) indicates the stream of annual benefits is expected to be equivalent to a single, present value of about $700 per acre.[3] If climate change proves to be more harmful than expected in 2015, the benefits from this forest-based carbon sequestration could be about $2,000 per acre.
Discussion	Applying the most recent estimate of the $SCCO_2e$, by Ricke, et al (2018), raises the expected benefit about tenfold, to about $7,000 per acre. This research also raises the estimate for the benefit, if climate change proves to be more severe than expected, to about $14,000. This information suggests that, on average, converting U.S. land from another use to forest would generate carbon-related benefits of at least $7,000 per acre, with a significant likelihood that the benefit would exceed $14,000 per acre.

[1] Domke, G., C. A. Williams, R. Birdsey, J. Coulston, et al. 2018. Chapter 9: Forests. In *Second State of the Carbon Cycle Report (SOCCR2): A Sustained Assessment Report* [Cavallaro, N., G. Shrestha, R. Birdsey, M. A. Mayes, et al. (eds.)]. U.S. Global Change Research Program.
[2] Bluffstone, R., J. Coulston, R.G. Haight, J. Kline, S. Polasky, D.N. Wear, and K. Zook. 2017. Chapter 3: Estimated Values of Carbon Sequestration Resulting from Forest Management Scenarios. The Council on Food, Agricultural and Resource Economics (C-FARE) Report No. 0114-301c.
[3] U.S. Interagency Working Group on Social Cost of Carbon. 2013 (revised 2015). Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. The authors calculated the present value using a process economists call discounting.

N-3. Carbon impacts from afforestation and reforestation of U.S. forests, 2017[4]

Study's Focus	Calculate annual economic benefits for the nation from afforestation on about 12 million acres of private lands in the eastern U.S. and reforestation on about 9 million acres of public lands in western states, through 2050.
Findings	Carbon sequestration resulting from these actions would yield economic benefits totaling about $6,300 per acre. This number represents their core assumption, that changes in climate would cause economic damages corresponding to 2015 expectations for the social cost of carbon dioxide ($SCCO_2e$). If the negative effects of climate change prove to be more severe, the benefits from the forest-based carbon sequestration that would follow afforestation and reforestation would be as high as $19,000 per acre.
Discussion	Applying the most recent estimate of the $SCCO_2e$, by Ricke, et al (2018), raises the expected benefit about tenfold, to about $63,000 per acre. This research also raises the estimate for the benefit, if climate change proves to be more severe than expected, to about $120,000 per acre. This information suggests that, on average, planting trees (afforestation or restoration) in the conterminous U.S. would yield carbon-related benefits of about $63,300 per acre, with a significant likelihood that the benefits would exceed $120,000 per acre.

N-4. Cost of forest-based carbon sequestration, 2005[5]

Study's Focus	Synthesize the literature to analyze the true opportunity costs of using land for forest-based carbon sequestration.
Findings	The sequestration of 270 million metric tons (MMt) of CO_2e/yr can be accomplished at a cost of $7.50–$22.50 per ton. The cost rises to $9–$27 for the sequestration of 450 MM CO_2e/yr.
Discussion	Even if adjusted upward for inflation since 2005, these costs fall far short of the economic benefits from carbon sequestration. The most recent estimates of the $SCCO_2e$, by Ricke, et al (2018) are $417/Mt CO_2e for the expected value of the benefits, and $800/Mt CO_2e if climate change proves to be more damaging than expected.

N-5. Carbon-credit payments and harvest-rotation age: a meta analysis, 2018[6]

Study's Focus	Review studies from around the world to ascertain the extent to which higher carbon-credit payments induce landowners to extend the harvest-rotation age.
Findings	On average, an increase of 1% in the carbon payment can induce landowners to increase rotation age 0.16%.
Discussion	

[4] Bluffstone, R., J. Coulston, R.G. Haight, J. Kline, S. Polasky, D.N. Wear, and K. Zook. 2017. Chapter 3: Estimated Values of Carbon Sequestration Resulting from Forest Management Scenarios. The Council on Food, Agricultural and Resource Economics (C-FARE) Report No. 0114-301c.
[5] Stavins, R.N., and K.R. Richards. 2005. The cost of U.S. forest-based carbon sequestration.
[6] Ning, Z, and C. Sun. 2014. Carbon sequestration and forest rotation age: a meta-analysis.

N-6. Carbon impacts from extending the harvest-rotation age for forests in different regions of the U.S., 2009[7]

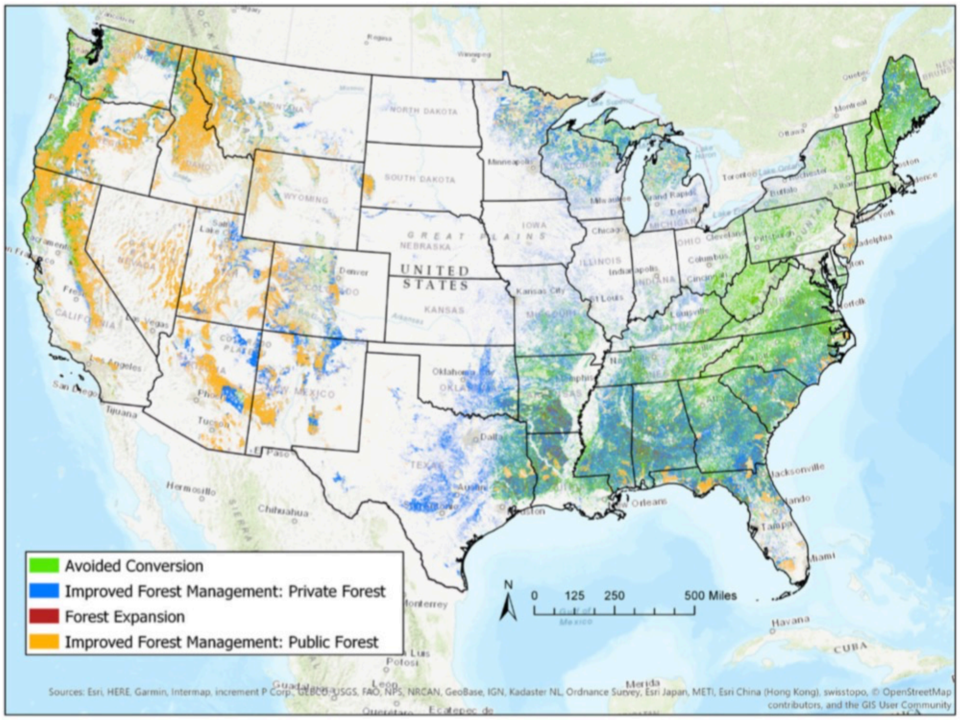
Study's Focus	For 46 different forest types in the conterminous U.S., estimate the amount of additional forest carbon (live tree, standing and down deadwood, understory, forest floor, and wood products) that would be sequestered by extending the harvest-rotation age by 5 years or 100 years.
Findings	All regions show an increase in carbon sequestration with longer rotations. The westside of the Pacific Northwest would generate the greatest level of carbon per hectare. The highest sequestration, aggregated over an entire ecosystem, occurs in the PNW West, South Central, and Northeast regions.
Discussion	For six forest ecosystems, researchers compared the additional carbon that would be sequestered and the amount of timber that would be forgone from a 100-year extension of the rotation age. These findings, multiplied by $417/Mt$CO_2$, the most recent estimate of the SCCO_2e by Ricke, et al (2018), suggest the timber prices that would be needed for the lost value of the logs to exceed the value of the carbon benefits: (per m³ / per thousand board feet*) Pacific Northwest Douglas-fir: $1,300 / $3,000 Southeast Loblolly-Shortleaf Pine $900 / $2,100 Northeast Maple-Beech-Birch $1,600 / $3,700 Pacific Southwest Fir-Spruce-Mtn. Hemlock $4,100 / $9,700 N Lake States Aspen Birch $2,700 / $6,400 Rocky Mtn. South Ponderosa Pine $4,000 / $9,500 The timber prices would have to be roughly twice as great to exceed the climate-related benefits if climate change proves to cause damages higher than general expectations. This information strongly suggests that extending the harvest-rotation age for plantations across the U.S. would generate carbon-related benefits that likely would exceed the value of the forgone timber production. *Assumes 1 m^3 = 424 board feet.

	per m^3	per thousand board feet*
Pacific Northwest Douglas-fir:	$1,300	$3,000
Southeast Loblolly-Shortleaf Pine	$900	$2,100
Northeast Maple-Beech-Birch	$1,600	$3,700
Pacific Southwest Fir-Spruce-Mtn. Hemlock	$4,100	$9,700
N Lake States Aspen Birch	$2,700	$6,400
Rocky Mtn. South Ponderosa Pine	$4,000	$9,500

[7] 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.

N-7. Achieving forestry goals for deep carbonization, 2018[8]

<table>
<tr><td>Study's Focus</td><td>Compile relevant literature to describe the costs of the climate-smart forestry practices necessary to contribute to an 80% reduction in economy-wide GHG emissions by 2050, and the spatial distribution of these practices across the conterminous U.S.</td></tr>
<tr><td>Findings</td><td>Carbon sequestration through land management (forestry and agriculture) declined nearly 10% from 1990, to 745.4 million metric tons (MMt) CO_2e in 2016. Forest sequestration declined from 789.7 to 745.5 MMt CO_2e. Land management can sequester an additional 150–800 MMt CO_2e per year for a carbon price of \$10–\$50/tCO_2e. Opportunities for forest sequestration— avoiding conversion of forests to other uses, expansion of forests onto lands currently under different uses, and improved management of private and public forests—exist across the conterminous U.S.:



Source: Map created by Kendall DeLyser, April 30, 2018. Projection: USA Contiguous Albers Equal Area Conic USGS Version</td></tr>
<tr><td>Discussion</td><td></td></tr>
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[8] Aggarwal, A., D. ARostegui, K. DeLyser, B. Hewett, et al. 2018. Achieving the Mid-Century Strategy goals for deep carbonization in agriculture and forestry.