PNAS Nexus, 2023, **2**, 1–4
https://doi.org/10.1093/pnasnexus/pgad345
Advance access publication 21 November 2023
Brief Report

Near-term investments in forest management support long-term carbon sequestration capacity in forests of the United States

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Edited By: Yannis Yortsos

Abstract

The forest carbon sink of the United States offsets emissions in other sectors. Recently passed US laws include important climate legislation for wildfire reduction, forest restoration, and forest planting. In this study, we examine how wildfire reduction strategies and planting might alter the forest carbon sink. Our results suggest that wildfire reduction strategies reduce carbon sequestration potential in the near term but provide a longer term benefit. Planting initiatives increase carbon sequestration but at levels that do not offset lost sequestration from wildfire reduction strategies. We conclude that recent legislation may increase near-term carbon emissions due to fuel treatments and reduced wildfire frequency and intensity, and expand long-term US carbon sink strength.

Keywords: natural climate solutions, climate mitigation, forest carbon projections, climate legislation

Significance Statement

Nature based climate solutions and investments in forest management can help protect communities, improve forest resilience, and improve forest carbon sequestration rates. However, the scope, scale, and timing of the management actions have different carbon consequences in the near-term versus longer-term. Our results suggest that nature based climate solutions can increase forest carbon sequestration, but gains may not be realized for decades.

Introduction

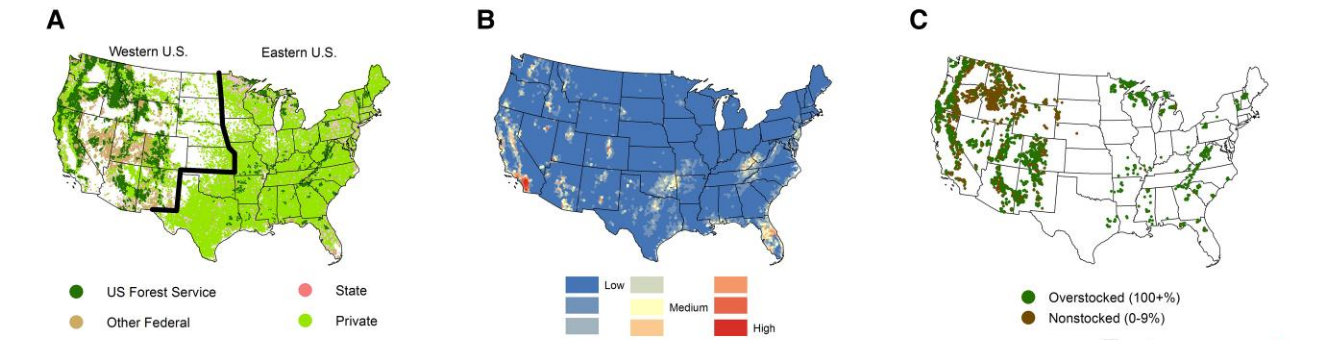
Forests are the largest terrestrial carbon sink [1], and the sink strength is influenced by biological and social dynamics including forest growth, disturbance, management, land use change, and policy [2]. Recent evaluations of forest carbon dynamics in the United States [3] and projections of future forest carbon [4, 5] indicate that the net sink strength is declining and future contributions from forests are uncertain due to biological and social drivers [4, 6]. As US climate legislation is enacted and management strategies are implemented to act on those policies, it is critical to analyze their potential effects on forest carbon and other ecosystem services.

The 2021 Infrastructure Investment and Jobs Act (IIJA; P.L:117-58) and the 2022 Inflation Reduction Act (IRA; P.L:117-169) include important forest-climate components; each allocated billions of dollars for management activities to perform forest restoration, increase planting, combat wildfires, and develop climate-smart forestry approaches. Forest management activities relevant to IIJA and IRA either remove carbon [7], add carbon [7, 8], or avoid carbon loss [9]. These activities impact carbon futures differently depending on the scale and the time frame examined. In this study, we examined the potential carbon consequences of the US Department of Agriculture Forest Service (USFS) planting and fuel reduction strategies to implement the IIJA policies [10].

USFS strategies [10] align with natural climate solutions [11], including tree planting on an additional 1.6 million ha of USFS forest land with inadequate tree cover or regeneration (nonstocked) and forest fuel treatments on an additional 8.1 million ha of USFS land and 12.1 million ha of non-USFS land in the western United States over the next 10 years. The IIJA policy-driven management actions to protect communities and increase forest resilience aim to affect >7% of the 283 million ha of forest [3] in the United States.

We use data from >130,000 national forest inventory (NFI) plots to clarify the potential effects of planting and increased fuel management on carbon trajectories in the conterminous United States

Competing Interest: The authors declare no competing interest.
Received: August 3, 2023. **Accepted:** October 11, 2023



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Fire Fuel High Treatment (FHT) 2022-2032	Fire Fuel Low Treatment (FLT) 2022-2032	Planting	Shared Socioeconomic Pathway 2: U.S. characteristics	Representative Concentration Pathway 8.5 climate models and U.S. classification
Remove 10-50% of the live basal area and/or 90% of the dead fuel weight.	Remove 10-25% of the live basal area and/or 90% of the dead fuel weight.	Reforestation of 1.6 million ha of non-stocked USFS land.	Medium U.S. population growth	CNRM-CM5 (Wet)
			Medium U.S. economic growth rate	IPSL-CM5A-MR (Dry)
Treat 8.1 and 12.1 million ha of USFS and other forest land respectively based on fireshed priority areas.	Treat 8.1 and 12.1 million ha of USFS and other forest land respectively based on fireshed priority areas.		Medium bioenergy demand	HadGEM2-ES (Hot)
			Mixed focus on renewables and fossil fuels for energy	MRI-CGCM3 (Least warm)
			Medium trade openness	NorESM1-M (Middle)

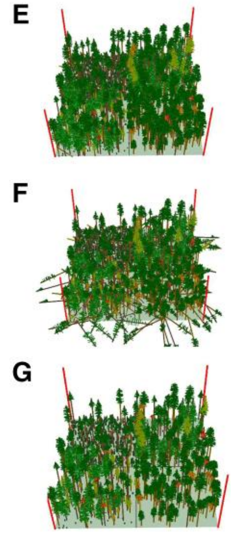

Fig. 1. A) Forested NFI plot locations (approximate) and ownership. B) illustrates fire sheds [12] used to identify western forest fuel treatment locations [7]. C) The fuel treatments within priority fire sheds targeted overstocked and fully stocked USFS land and in other ownerships. Nonstocked USFS land was targeted for planting. D) Projections were based on two different fuel-treatment levels, planting, and five different climates under Shared Socioeconomic Pathway 2. The fuel treatments apply a tree basal area reduction and/or dead fuel weight reduction; E) depicts a western forest stand with 46 m^2 ha^{-1} of basal area, thinned to 23 m^2 ha^{-1}, displaying cut and unutilized trees F) and the resulting forest without cut trees G).

(Fig. 1). We constructed 30-year projections of the NFI based on Shared Socioeconomic Pathway 2 [13] and five general circulation models under Representative Concentration Pathway 8.5 to assess forest carbon stocks and fluxes associated with two fuel treatment levels and one planting scenario (Fig. 1, SI Appendix). The results highlight the potential effects of recent policies on the capacity of forests to sequester and store carbon and underscore the long-term nature of forest investments.

Results

In 2019, there were 19,362 MMT of aboveground forest carbon (aboveground live vegetation, deadwood, and litter pools; Fig. 2A) increasing at 132 MMT yr^{-1}. Tree planting, even on low-productivity sites, adds carbon to the forests, and under the planting scenario, the results suggest that 5 MMT of carbon will be added to US forests by the year 2032 from seedling establishment and growth (Fig. 2B).

Fuel treatments are designed to temporarily reduce carbon from forests through thinning, prescribed fire, or other mechanical means, and under a fuel high-treatment (FHT) scenario (Fig. 1D), 288 MMT of aboveground carbon will be removed from western forests by 2032 (Fig. 2B). Under a fuel low-treatment (FLT) scenario (Fig. 1D), 194 MMT of carbon will be removed (Fig. 2B). The fuel-treatment scenarios have two additional short-term (2022–2032) effects: (i) lost sequestration potential from live tree removal and (ii) decreased wildfire carbon emissions (Fig. 2B).

Carbon emission mitigation potential is an important measure of policy impact. We define mitigation potential as the difference in net annual carbon flux between the baseline (no planting or additional fuel treatments) and each scenario (FHT, FLT, planting). Our results suggest that planting leads to a positive mitigation potential that increases over time, ranging from +0.5 MMT yr^{-1} in 2032 to +1.6 MMT yr^{-1} in 2050 (Fig. 2C).

Results for the fuel-treatment scenarios suggest a negative mitigation potential in the near-term largely due to the removal of live trees. In the longer term, projections suggest a positive, but small, mitigation potential largely due to increased growth of thinned stands and reduced fire mortality. Under the FHT scenario, in 2032, projections suggest a −31 MMT yr^{-1} mitigation potential, indicating that forests would have less net annual carbon accumulation with the fuel treatments. Conversely, by 2050, the FHT fuel treatments may lead to a +6 MMT yr^{-1} mitigation potential (about 4.5% of current flux). These results highlight that carbon accumulation through net forest growth is unlikely to offset carbon removal and loss of sequestration potential from fuel treatments in the near term. In the longer term, the treatments may lead to small increases in annual accumulation rates due to avoided wildfire emissions and improved growth in thinned forests. However, the projected cumulative 2022–2050 carbon sequestered under the FLT and FHT scenarios is 200 and 310 MMT less, respectively, than the baseline (Fig. 2D), indicating a reduced capacity of US forests to offset emissions from other sectors over the projection period.

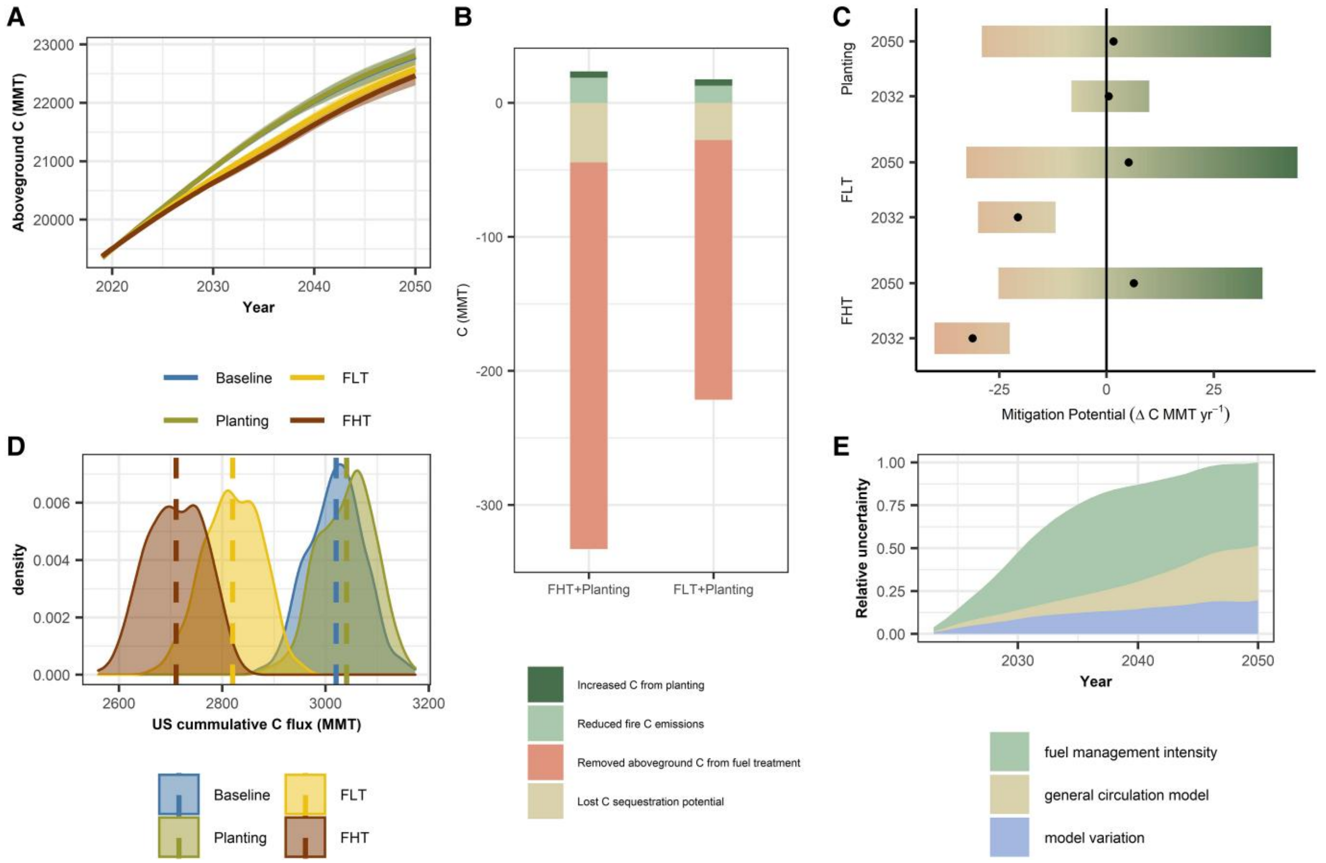

Fig. 2. Historic and projected US aboveground carbon stocks for the baseline, FLT, and FHT scenarios A) from 2019 to 2050, with shaded areas displaying model and climate variability. B) The effects of the fuel treatments and planting from 2022 to 2032. Projected US forest mitigation potential under FLT, FHT, and planting scenarios in 2032 and 2050 (C; length of each bar indicating model and climate variability). The distribution of projected cumulative aboveground carbon sequestration in 2050 for the United States under baseline, planting, FLT, and FHT scenarios D). In E), uncertainty components show variability driven by the forest projection model, alternative general circulation models, and fuel management intensity (FLT vs. FHT).

Discussion

Forest management activities impact carbon futures differently depending on the scale of the activities and the time frame examined. Our results suggest that the IIJA fuel treatment effects outweigh the planting effects, leading to a decrease in expected annual flux through 2032 (negative mitigation potential) and less cumulative carbon sequestered over the projection period. Yet, annual flux is projected to increase after 2032 because of the IIJA fuel treatments, demonstrating the potential longer term benefit of these treatments on forest carbon. Policies put in place through the IRA offer additional funding for fuel reductions, forest restoration, and climate-smart forestry. Management activities associated with forest restoration generally call for a mixture of cutting/thinning and planting [7], and the impact on carbon futures will depend on both the scale and the mixture of the activities, in addition to the utilization of cut material to make long-lived wood products that store carbon in the long term [14].

Biomass removed during fuel treatments was assumed to be an emission. The lack of roundwood receiving facilities in the western region, coupled with the questionable adequacy of the wood removed during fuel treatment, suggests that meaningful shifts in US harvested wood carbon stocks and stock change are unlikely, and hence, any potential forest products arising from the fuel treatment were not accounted for. However, wood product innovation and market investments through climate-smart forestry goals may lead to uses for biomass removed during fuel management and restoration activities (i.e. contribution to carbon stored in harvested wood products) or mitigation in other sectors (e.g. biomass for energy) [14].

The USFS fuel reduction strategy is principally focused on protecting communities and improving forest resilience [10], which is the requisite for long-term sustainability. Our results suggest that this strategy would be successful on these terms—they would reduce tree mortality from wildfire (i.e. less intense fires) and increase net forest growth after 2032 in the western United States. However, the strategy may also result in decreased cumulative net carbon sequestration, affect annual flux rates differently in the near term vs. long term, and have a range of additional influences on other ecosystem services.

Materials and methods

The US NFI identifies the starting conditions for this research. Projections of the NFI are based on the USFS Forest Dynamics Model [15] (SI Appendix).

Acknowledgments

The authors thank Jim Vose, Dave Wear, and two anonymous reviewers for their helpful comments. This research was supported by the U.S. Department of Agriculture.

Supplementary Material

Supplementary material is available at *PNAS Nexus* online.

Funding

D.M.W. and E.B.B. were funded by the USDA Forest Service through agreements 21IA11330180032 and 22JV11330180058, respectively. This research was supported by the U.S. Department of Agriculture.

Author Contributions

J.W.C. designed the study and the research. J.W.C. and D.M.W. analyzed the data. J.W.C., G.M.D., E.B.B., C.B.O., and D.M.W. wrote the paper.

Data Availability

The USFS Forest Dynamics Model requires US NFI data, climate data, and land use change projections. The US NFI is available at https://apps.fs.usda.gov/fia/datamart/datamart.html. The climate data used are available at http://thredds.northwestknowledge.net:8080/thredds/reacch_climate_CMIP5_macav2_catalog2.html. Land use change projections are available at https://doi.org/10.2737/RDS-2023-0026. Fire shed data are available at https://www.fs.usda.gov/rds/archive/catalog/RDS-2020-0054. Projection results will be made available at https://www.fs.usda.gov/rds/archive/.

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