Disentangling the Drivers of the U.S. Carbon Sink

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Introduction

The global terrestrial carbon sink has increased from 1.7±0.8 Pg C year-1 in the 1960s to 2.8±0.9 Pg C year-1 in the last decade.

Forests in the United States are estimated to be responsible for 12 percent of this total.

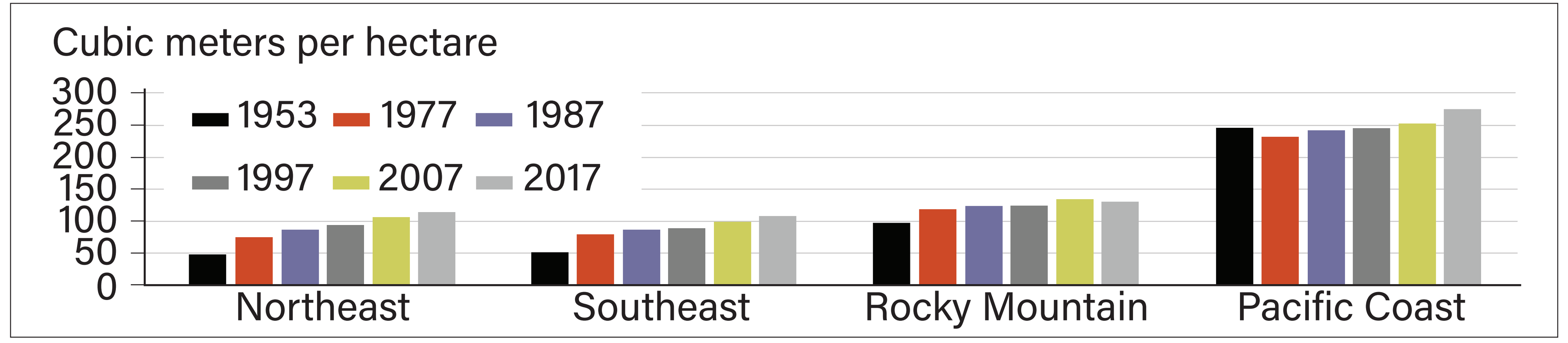
This can be partly attributed to increases in aboveground wood volume.

Between 1953 and 2017, wood volume increased by 67.5 m^3/ha in the Northeast, 56.5 m^3/ha in the Southeast, 33.3 m^3/ha in the Rocky Mountain, and 29.2 m^3/ha in the Pacific Coast region.

The extent to which key factors, such as elevated CO_2 and forest management, have driven these increases is not well understood.

Figure 1

Change in timberland wood volume per hectare by year and region



Source: Forest resources of 282 the United States, 2017." *General Technical Report-US Department of Agriculture, Forest 283 Service. Forest Service* (2019).

Objectives

This study aims to disentangle the effects of five key drivers: climate, CO_2, forest management, age composition, and area on aboveground wood volume in the 48 conterminous U.S. states.

Methods

We use historical observations of ten major U.S. forest groups over the past 60 years from the U.S. Forest Service's Forest Inventory and Analysis Program (USFS-FIA) and geolocated climate data from the PRISM Climate Group.

Our approach employs pooled regression analysis to create spatially and temporally explicit forest yield functions.

The impact of climate (i.e., changes in temperature and precipitation) is identified by linking wood volume in forest plots to climate data, which varies spatially and temporally.

Atmospheric CO_2 concentration, which varies only temporally, is isolated through time fixed effects and the fact that observations of the same type and age class of forests have experienced different exposure profiles over time.

Forest management is estimated by examining differences between naturally regenerated and planted stands of the same forest group.

Results

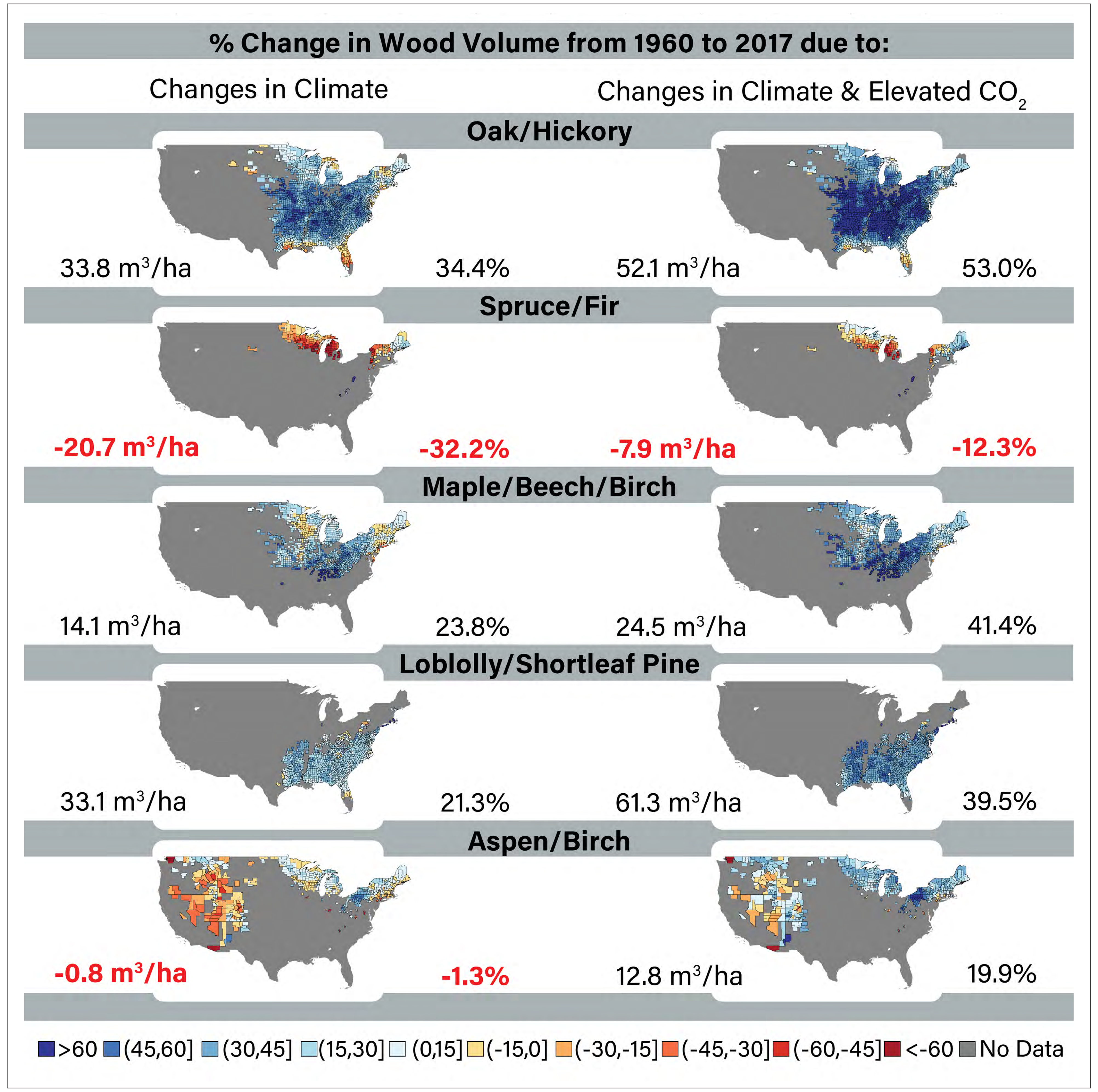
From 1960 to 2017, the impact of elevated CO_2 on 50-year-old trees was shown to be significant ($P < 0.01$) and uniformly positive for all forest groups.

The impact of changes in climate was also significant ($P < 0.01$), but in some parts of the range for virtually every forest group the negative effects of changes in climate are large enough to negate the benefits from elevated CO_2.

In particular, for spruce/fir negative climate effects largely overwhelmed the positive impact of elevated CO_2 across most of its range.

Figure 2

Estimated change in wood volume from 1960 to 2017 in 50-year-old stands, by county and forest group and based on observations of naturally regenerated stands aged 1 to 100



Note: The numerical values in the bottom left of each pane detail the mean county impact in cubic meters per hectare and the values in the bottom right of each pane detail the mean percentage change.

Source: Authors' calculations using data from NOAA, USFS, and the PRISM group.

Examining the impact in the U.S. Southeast from 1974 to 2017, we find that the total increase in wood volume from all five drivers is 2.66 billion m^3 with elevated responsible for 28.6 percent, changes in age composition for 19.7 percent, management for 19.2 percent, changes in climate for 16.3 percent, and changes in forest area for 16.3 percent.

Table 1

Estimated impact of key drivers on change in wood volume (in million cubic meters) in U.S. Southeast from 1974 to 2017

	Loblolly/Shortleaf	Slash/Longleaf	Oak/Hickory
Elevated CO_2	374.9	148.4	237.5
Climate	145.7	21.4	266.7
Age Composition	141.9	125.7	256.4
Area	427.5	-100.5	107.1
Management	455.8	56.2	
Sum of Impacts	**1,545.7**	**251.2**	**867.7**

States are AL, AR, FL, GA, LA, MS, NC, OK, SC, TN, TX, & VA.

Examining the impact in the U.S. Northeast from 2005 to 2017, we find that wood volume decreased by 51.4 million m^3 with elevated CO_2 and changes in age composition increasing wood volume by 136.1 and 16.9 million m^3, respectively, and changes in area and climate decreasing volume by 118.9 and 85.5 million m^3, respectively.

Table 2

Estimated impact of key drivers on change in wood volume (in million cubic meters) in U.S. Northeast from 2005 to 2017 Model

	Maple/Beech/Birch	Oak/Hickory	Spruce/Fir
Elevated CO_2	63.9	47.1	10.8
Climate	-28.0	-35.4	-11.3
Age Composition	-86.9	69.8	6.5
Area	-31.3	-71.5	-0.1
Sum of Impacts	**-82.2**	**10.0**	**5.9**

	Elm/Ash/Cottonwood	Oak/Gum/Cypress	Oak/Pine
Elevated CO_2	4.9	1.3	8.0
Climate	-4.9	-1.2	-4.6
Age Composition	13.7	1.3	12.4
Area	6.2	-4.7	-17.5
Sum of Impacts	**19.9**	**-3.2**	**-1.7**

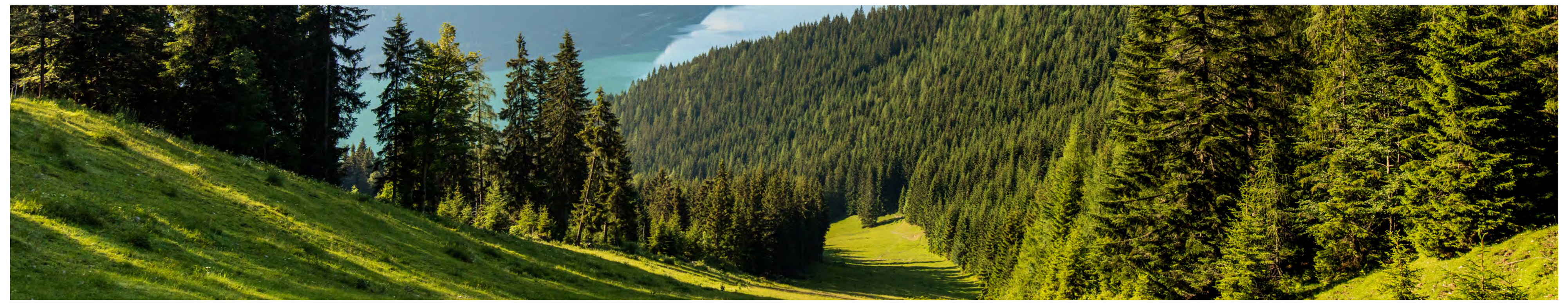
States are AL, AR, FL, GA, LA, MS, NC, OK, SC, TN, TX, & VA.

Conclusions

Our model results show that for all 10 forest groups in our study elevated CO_2 has had a positive impact on wood volume.

Changes in climate have had mixed results, and in some parts of the range of each forest group the negative effects were large enough to negate the benefits from elevated CO_2.

Future research, therefore, will be needed to determine whether elevated CO_2's positive impact can continue to offset the negative impacts from the changes in climate.



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