Cost of forest carbon sequestration as a response to climate change

in the presence of climate impacts

Alla Golub (Purdue University)
golub@purdue.edu

Brent Sohngen (Ohio State University)
sohngen.1@osu.edu

Yongyang Cai (Ohio State University)
cai.619@osu.edu

Thomas Hertel (Purdue University)
hertel@purdue.edu

John Kim (USDA Forest Service Pacific Northwest Research Station)
jbkim@fs.fed.us

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Cost of Forest Carbon Sequestration in the Presence of Climate Impacts

Alla Golub[1], Brent Sohngen[2], Yongyang Cai[2], Thomas Hertel[1], John Kim[3]

1 Purdue University, 2 Ohio State University, 3 USDA Forest Service

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Motivation

- Forest play a critical role in a long-term health of our planet and in meeting the goal of mitigating climate change
- Afforestation, reduction in deforestation and forest management are all mitigation options currently considered
- However, programs that increase carbon stored in forests are costly
  - Opportunity costs of holding land in forests
  - Costs of planting and managing trees
  - System-wide adjustment costs
- In addition, forests are expected to be themselves affected by climate change through impacts on forest growth rates, disturbance regime and shifts in where species can grow (IPCC 2014)
- Impacts of climate change on timber output, price and forest carbon stocks have been examined in the literature, but the question of how climate change affects mitigation costs has been unexplored

Goal

Analyze how impacts of climate change on forests affect cost of forest carbon sequestration

Approach

- Dynamic forward looking partial equilibrium (PE) model of global land use
- Maximize social planner's payoff that takes into account global population and per capita utility
- Population, income and climate are from "business as usual" scenario available in Shared Socio-economic Pathways data base (O'Neill et al. 2014, IIASA 2015)
- A global representative consumer derives utility from land-based (crop-based, livestock-based, wood products, energy) and other goods and services
- Consumer preferences are represented with An Implicit Directly Additive Demand System (Rimmer and Powell 1996)
- Production of the land-based consumption goods, as well as intermediate inputs required to produce these goods, are explicitly modeled within the PE framework; time path of the composite of all other goods and services is given exogenously
- To account for the heterogeneous effects of climate change, the global land endowment is split into biomes (Figure 1)
- Over time land can be converted between forests, crop and pasture uses; unmanaged forests can be accessed and converted to one of the production uses
- Forest vintages
- Biome specific timber yield functions for accessible and inaccessible forests are based on Tian at al. 2016
  - Accessible forest yield takes into account impacts of timber management on biophysical yield
- Given "business as usual" population, income, carbon concentration and temperature, global welfare is maximized to find the optimal age class of harvesting trees and optimal paths of the intensity of investments in forest management, area of managed and unmanaged forest, cropland and pasture, and other resource allocation

Data and calibration of climate impacts

- The data on climate change impacts on forests are obtained from the MC2 dynamic global vegetation model (DGVM) of Kim et al. (2017)
- MC2 employs climate scenarios developed using the MIT Integrated Global System Modeling (IGSM-CAM) framework (Paltsev et al. 2015, Monier et al. 2015)
- Calibrate biome specific climate impacts on forests
  - Changes in timber growth as a function of changes in CO_2 concentration (Figure 2a)
  - Dieback rate as a function of global surface temperature (Figure 2b)

Scenarios

- A. Without climate impacts (CI) on forests to obtain optimal path of forest carbon stocks in the absence of climate change
- B. Without CI and with carbon sequestration policy incorporated as a constraint on forest carbon stocks (lower bound, 5-20% higher than in A) to obtain cost of policy in the absence of climate impacts
- C. With the CI and the same lower bound on forest carbon stocks (in absolute terms) to obtain cost of policy in the presence of climate impacts

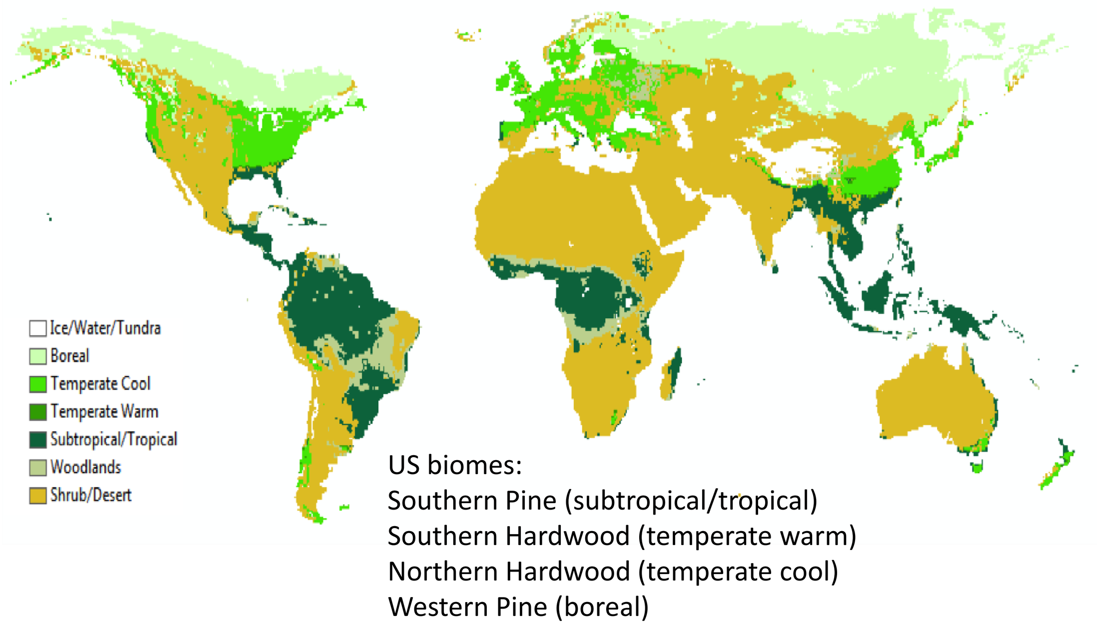

Figure 1 Forest biomes are areas with common ecological function

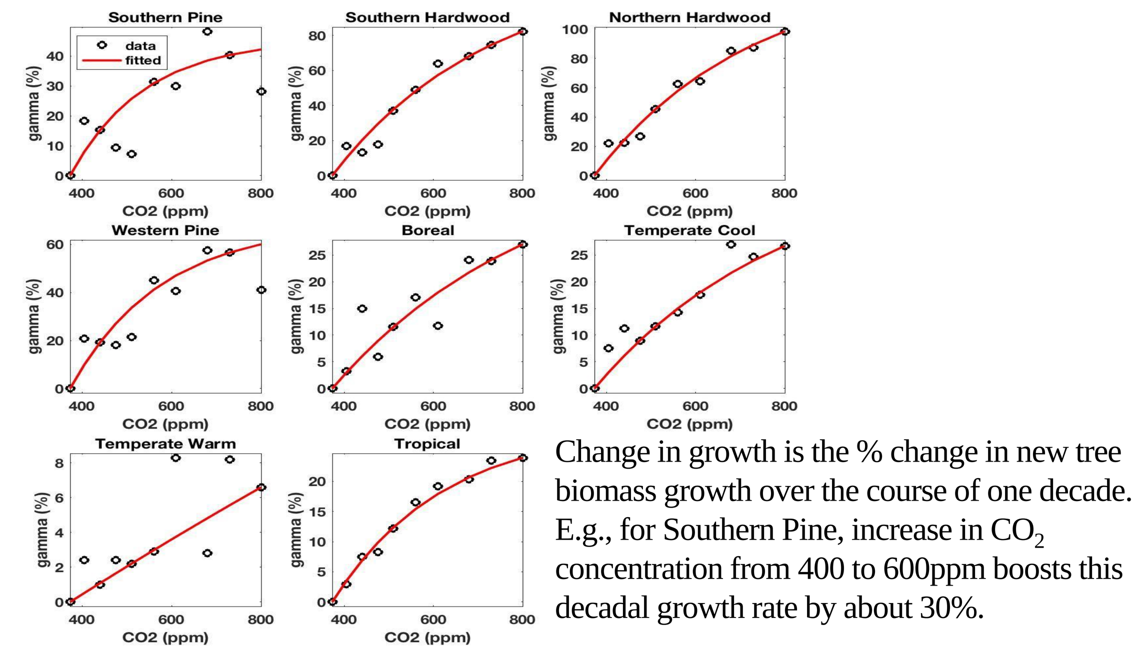

Figure 2a Biome specific climate impact on forest growth

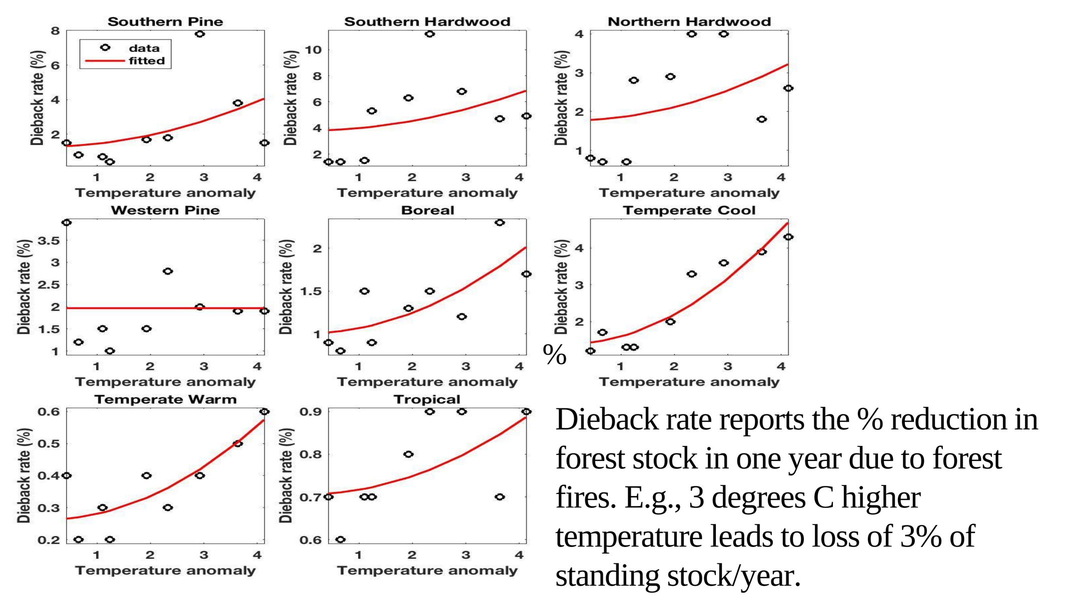

Figure 2b Biome specific climate impact on forest dieback

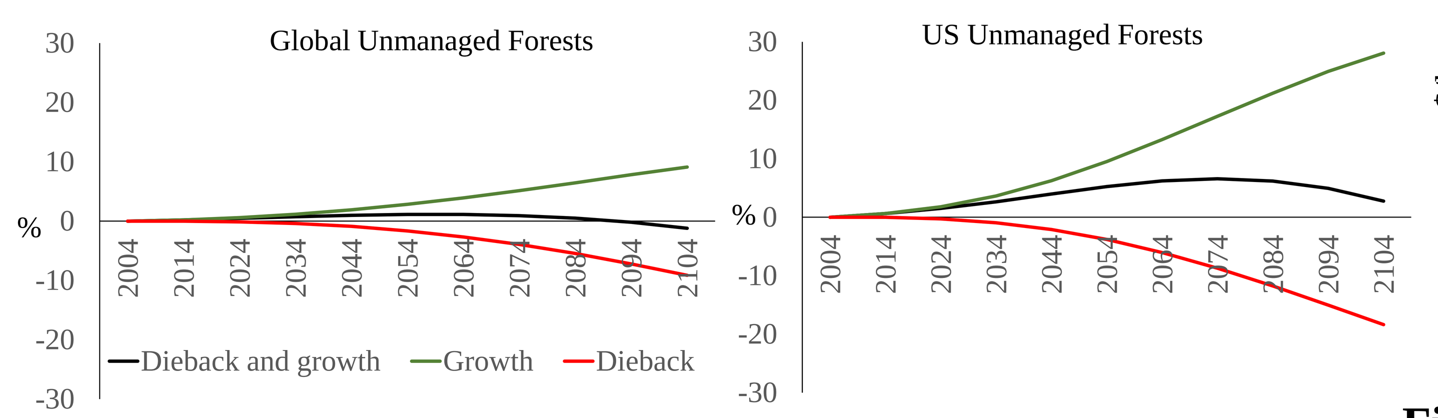

Figure 3 Changes in unmanaged forest carbon stock in US and globally. The changes are due to impacts of climate change on forest growth and dieback, together and separately, % change relative to without climate impacts scenario. No change in unmanaged forest area.

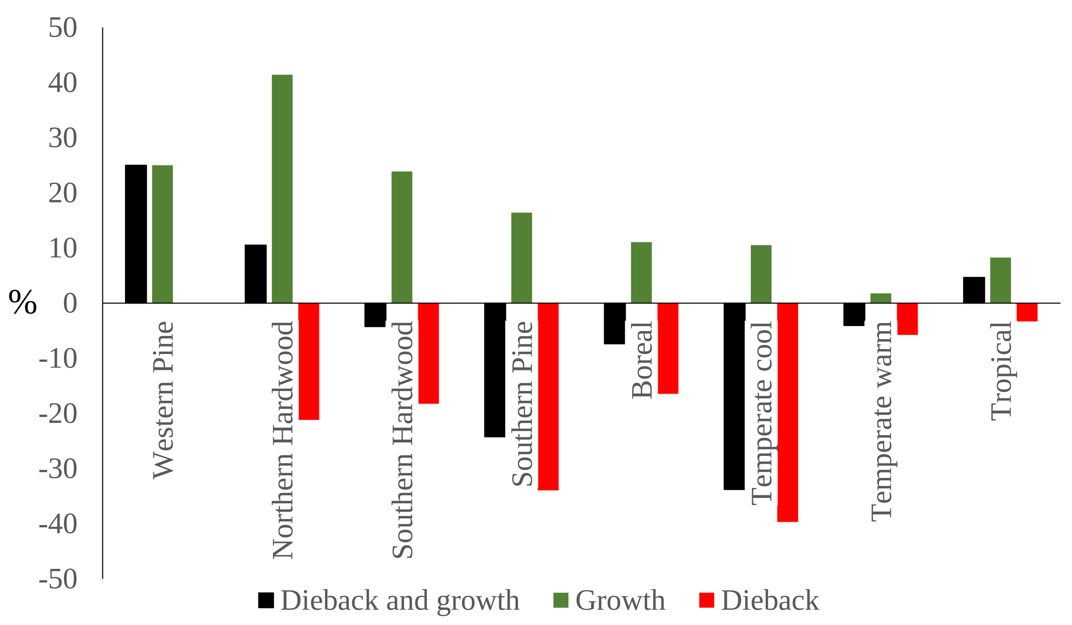

Figure 4 Biome changes in unmanaged forest carbon stock. The changes are due to impacts of climate change on forest growth and dieback, together and separately, % change relative to without climate impacts scenario. No change in unmanaged forest area.

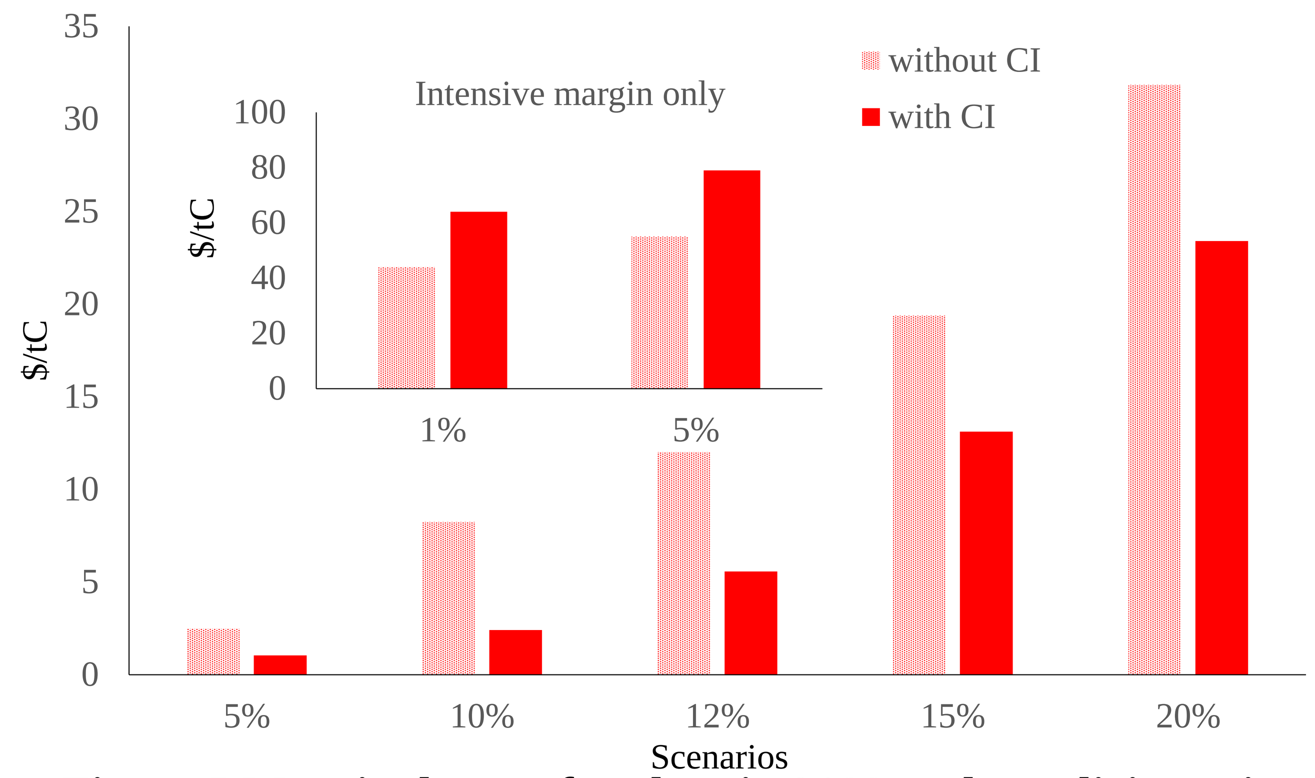

Figure 5 Marginal cost of carbon in 2100 under policies to increase forest carbon stocks 5 -20% by the end of the 21st century, with and without climate impacts on forests. "Intensive margin only" allows to increase forest carbon stocks only by changing timber management and rotations.

Figure 6 Changes in land use in 2100 under policies to increase forest carbon stocks 5-20% by the end of the 21st century, with and without climate impacts on forests

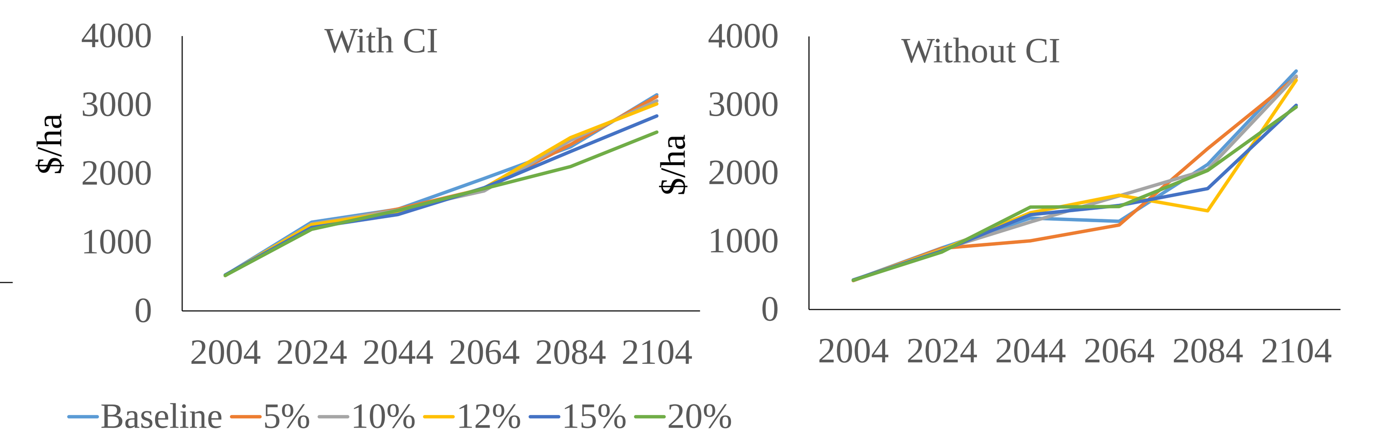

Figure 7 Optimal timber management intensity in US South Pines under policies to increase forest carbon stocks 5-20% by the end of the 21st century, with and without climate impacts

Preliminary conclusions

- Main vehicle to achieve a given forest carbon sequestration target in this analysis is conversion of pasture lands to managed forests
- This conversion results in intensification of livestock production, and smaller reduction in livestock output, relative to reduction in pasture
- Expansion of managed forests is smaller when climate impacts are taken into account
- Marginal costs of forest carbon sequestration are relatively low in this analysis, due to assumption of availability of cheap pasture lands
- Climate impacts on forests lower the cost of achieving a given carbon sequestration target
- However, when the carbon stocks can be increased on intensive margin only, costs are higher when climate impacts are taken into account
- Optimal management intensity is largely unaffected by climate impacts, with intensities being somewhat smaller at higher forest carbon sequestration targets

References

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