Global forest investments and carbon neutrality in forest stocks

Brent Sohngen

Ohio State University

Modeling issues in forestry

- How do we measure carbon neutrality in forests and what affects it?
- How do different forests stack up around the world?
- Do investments in forests matter?

What is carbon neutrality in forests?

Forest ecosystem growth/drain equation:

$$\Delta S_{i,t} = -\sum_{a} \left(H_{i,a,t}\right)\left(\mathrm{V_{i,a,t}}\left(\mathrm{Z_{i,t}}\right)\right)\left(\mathrm{B}_a\right) + \sum\nolimits_{\mathrm{a}} \left(\mathrm{X_{i,a,t}}\right)\left(\mathrm{dV_{i,a,t}}\left(\mathrm{Z_{i,t}}\right)/\mathrm{d\,a}\right)\left(\mathrm{B}_a\right) - \delta_{i,t} S_{i,t}$$

Wood product pool:

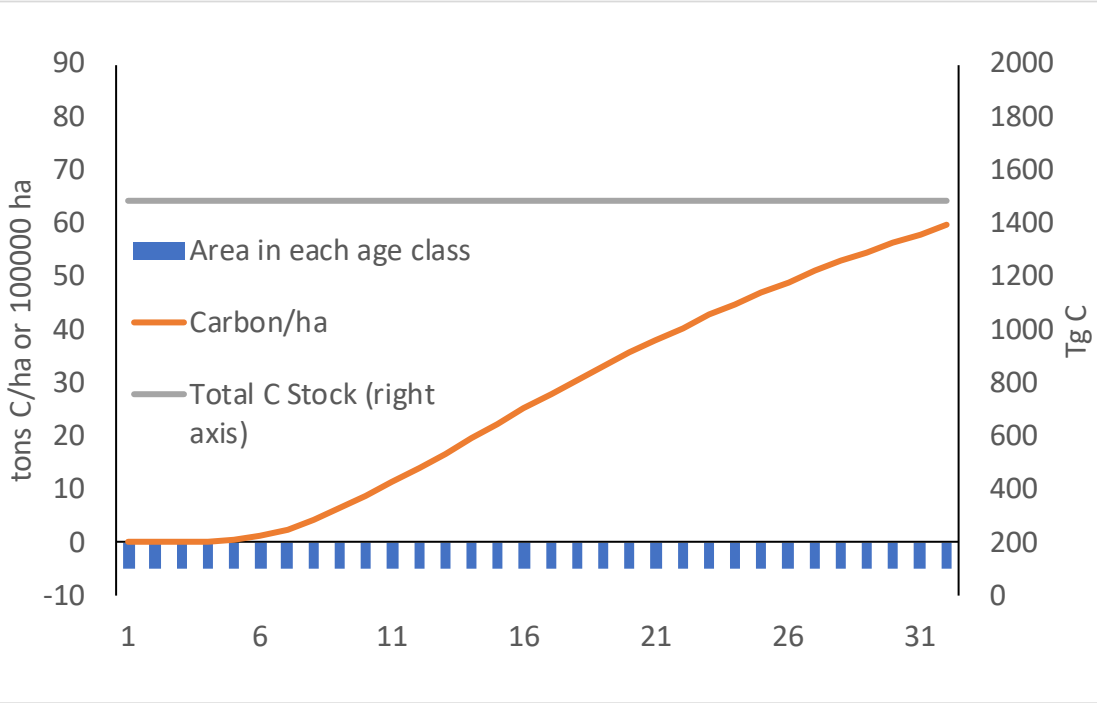
$$\Delta M_{it} = \sum\nolimits_{j} \left(\alpha_{ij} \sum_{a} \left(H_{i,a,t}\right)\left(\mathrm{V}_{i,a,t}\left(\mathrm{Z_{i,t}}\right)\right)\left(\mathrm{K}_a\right) - \lambda_{ij} L_{ijt} \right)$$

Conditions	Mathematical Outcome
Forest ecosystem removing C from atmosphere	$\Delta S_{i,t} \geq 0$
Forest sector removing C from atmosphere	$\Delta S_{i,t} + \Delta M_{i,t} \geq 0$

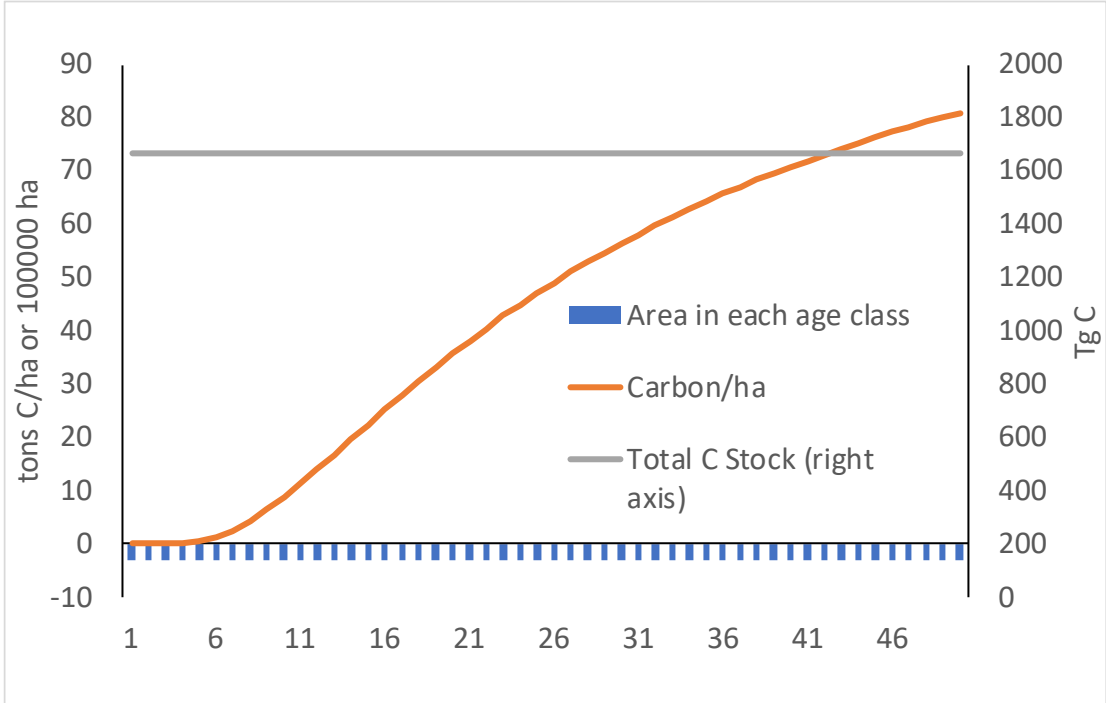
Sustainable forestry example

- Same forest type managed at 32-year or 50-year rotations

Faustmann
32-year rotations



MSY
50-year rotations



What affects carbon neutrality?

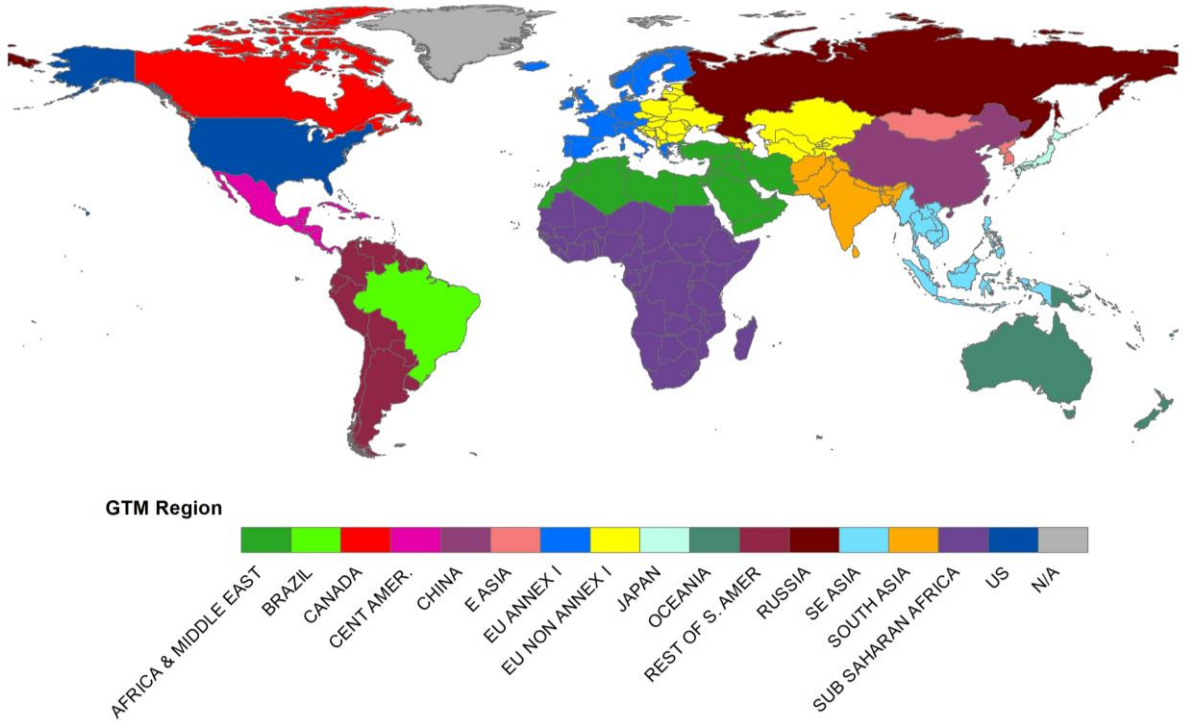
- Type of forest
  - Old growth: $\Delta S_{i,t} < 0$
  - Second growth: $\Delta S_{i,t} \leq \text{or} > 0$
  - Plantations: $\Delta S_{i,t} < 0$
- Harvesting
- Regeneration and management inputs.
- Distribution of wood products
- Carbon fertilization and climate impacts
  - Change in growth
  - Increased disturbance

Assessment of carbon neutrality in the Global Timber Model (GTM).

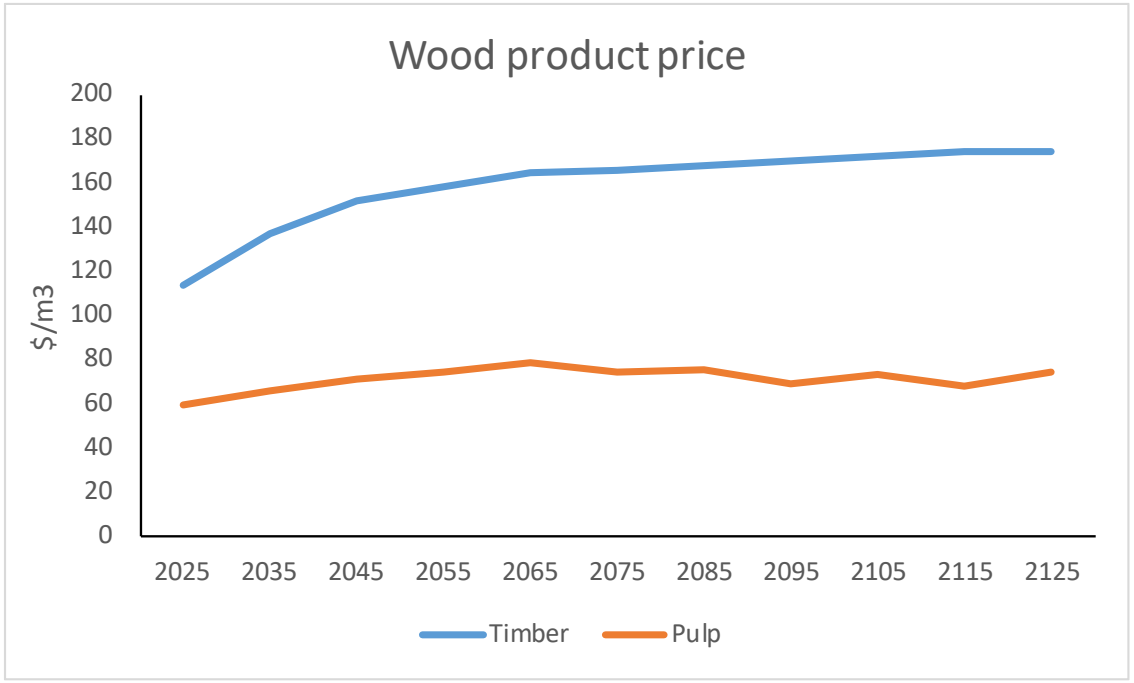
- GTM is a dynamic optimization model of the global forest sector
  - Includes all forests, 300+ land classes in 16 regions.
  - Old growth/inaccessible
  - Second growth, low intensity management
  - Plantations

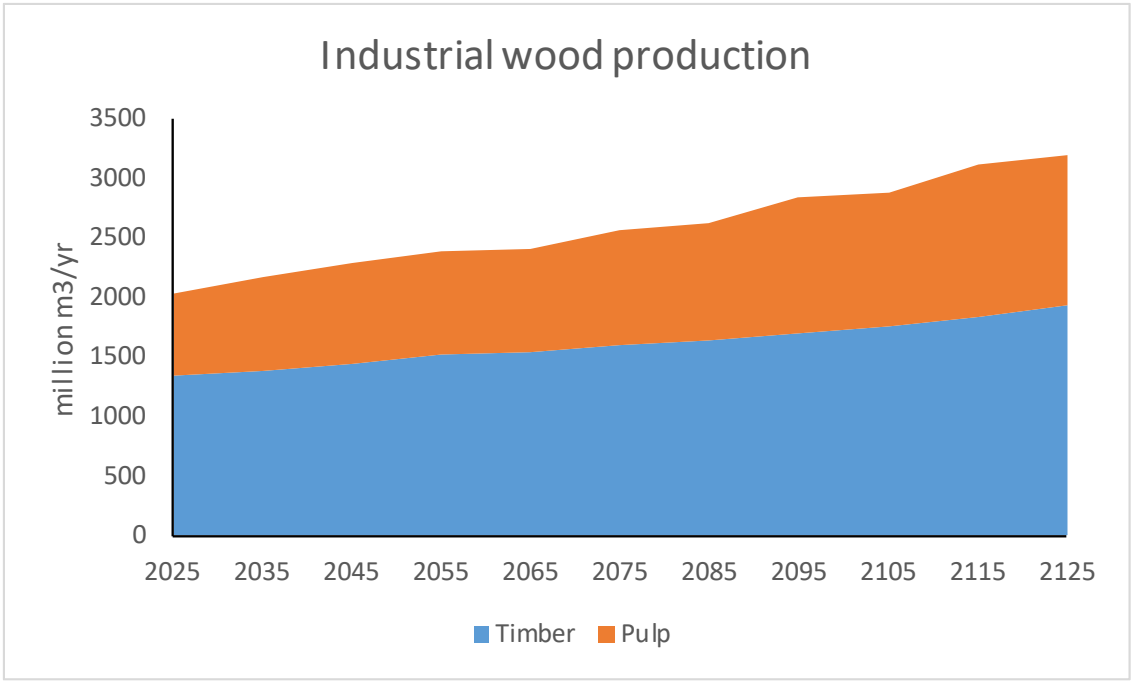
- Global market
  - Global demand for sawtimber and pulpwood with quality adjustment factors to adjust value of wood in each location.
  - Implies trade of wood products is frictionless
  - Demand elasticity = -1.0
  - Income elasticity ~ 0.9

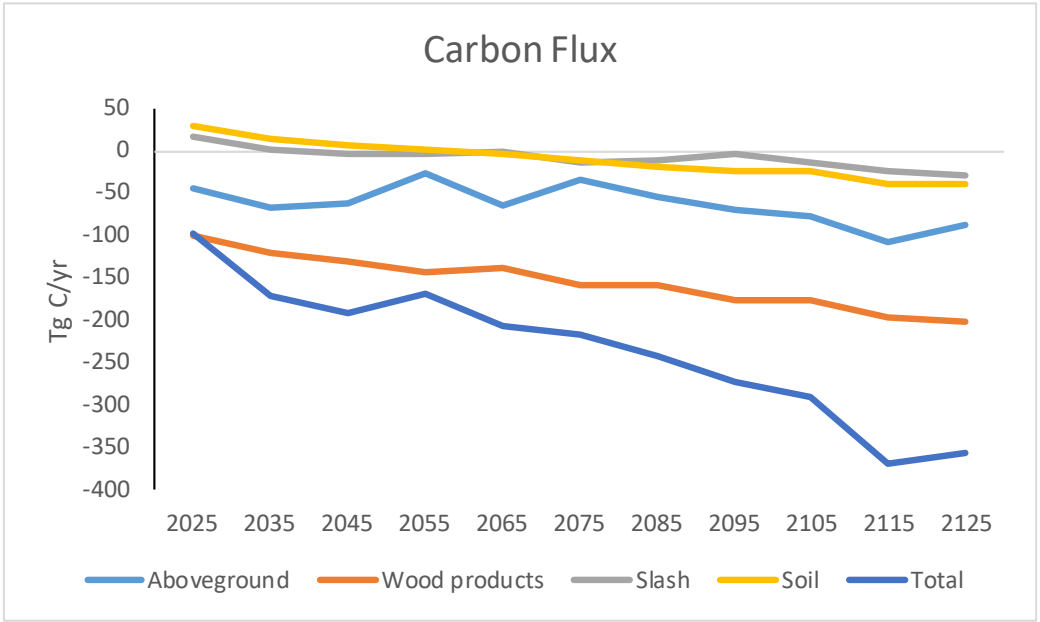
- Land rental functions for each land class, with land supply elasticity = 0.3, so a 10% increase in land rents will increase land area in the forest type by 3%.



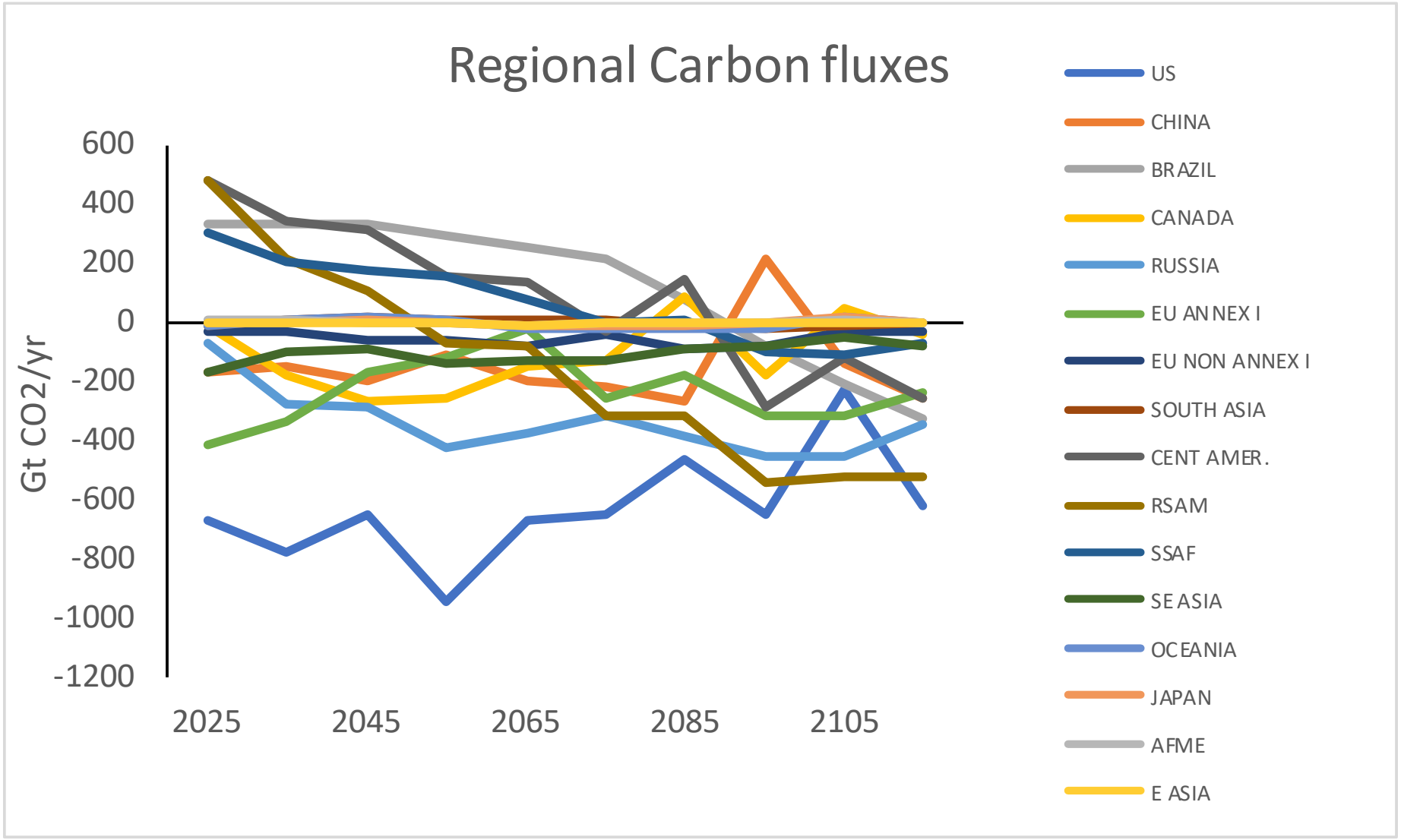
Dynamic baseline





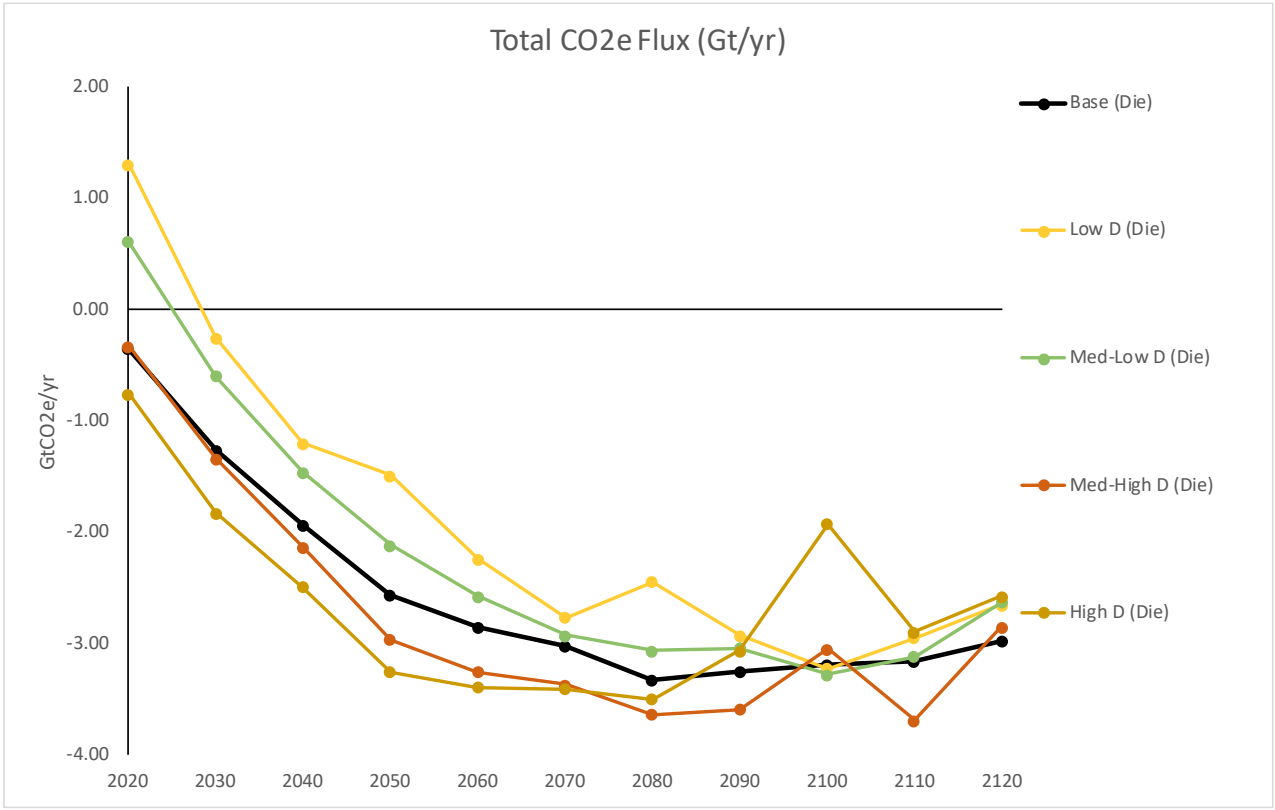


Regional Carbon flux



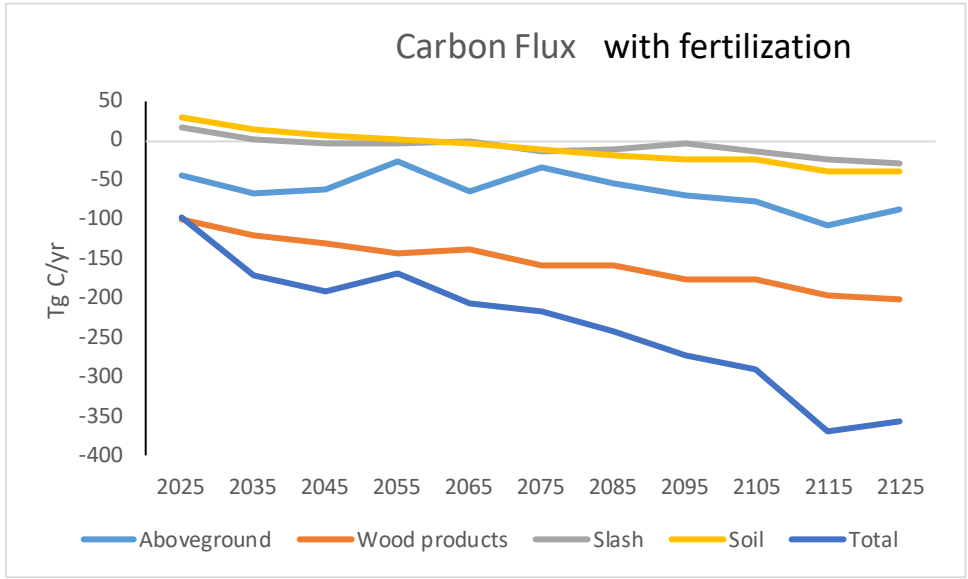
Harvest impacts on flux?

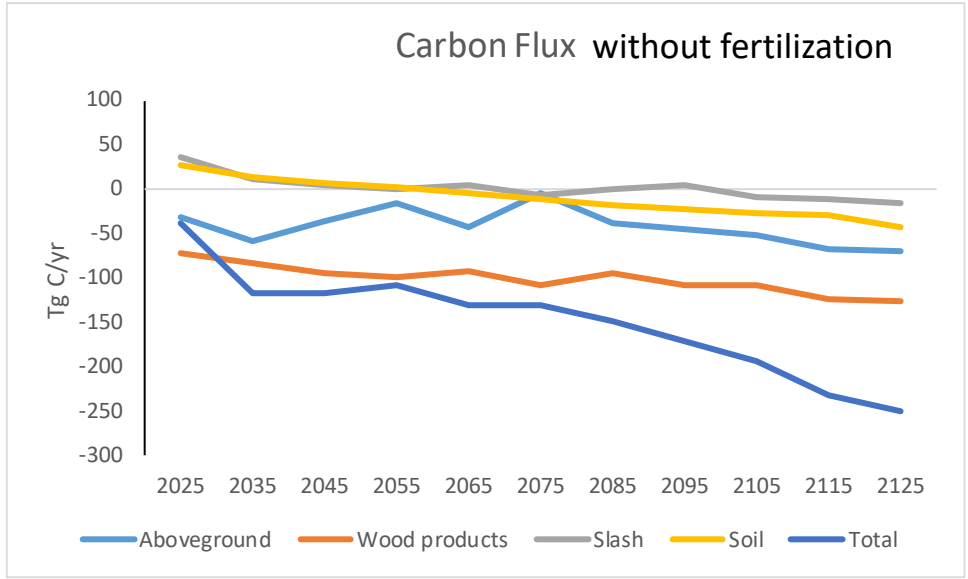
- Assess a deviation of timber harvesting over time on carbon flux.
- All else equal
- Higher demand increases flux and vice-versa.
- Suggests globally more wood consumption increases carbon flux into forests.
- Each 1 m^3 of additional wood harvest leads to about 1 ton of additional flux out of the atmosphere, but this diminishes over time.



Carbon fertilization?

- Carbon fertilization lowers sawtimber prices 5-8%, and pulpwood prices 12-25%
- Carbon fertilization increases wood production 10-20%
- Carbon fertilization increases carbon flux 30-40%

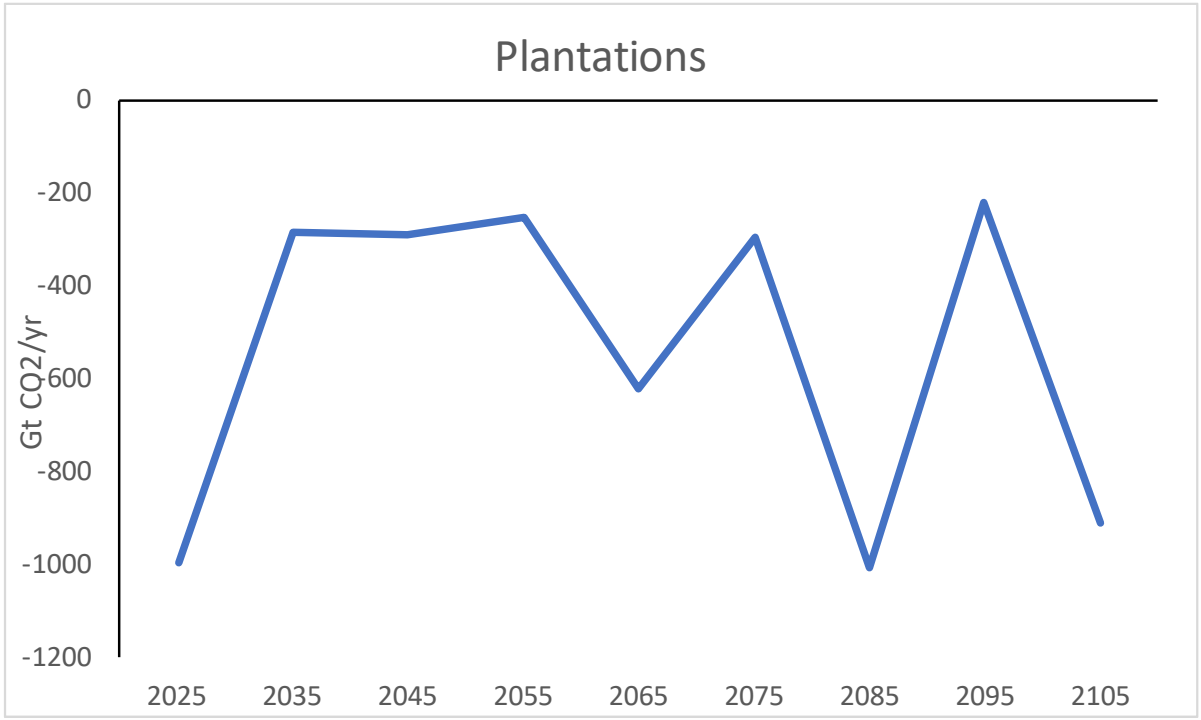




Plantation investments are critical for carbon flux

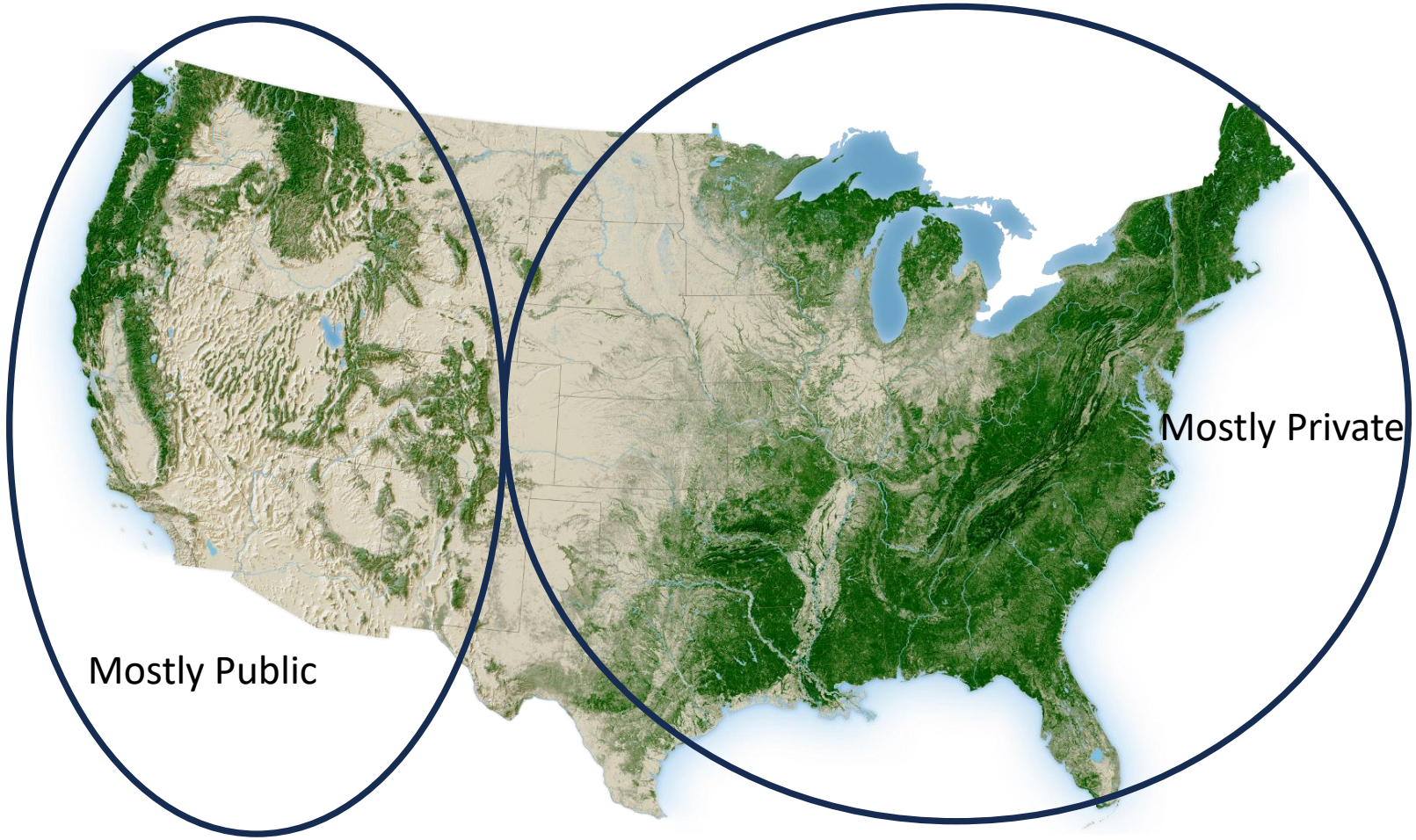
- Plantations sequester 540 Gt CO_2 per year this century, amounting to 58% of the total carbon flux in forests.
- Add 10.5 million hectares by 2050 and 20.1 million hectares by 2100.
- Investments increase from around $1.5 billion/yr to $3.8 billion/yr in 2050 and $6.8 billion/yr by 2100.

Carbon flux in plantations and their products



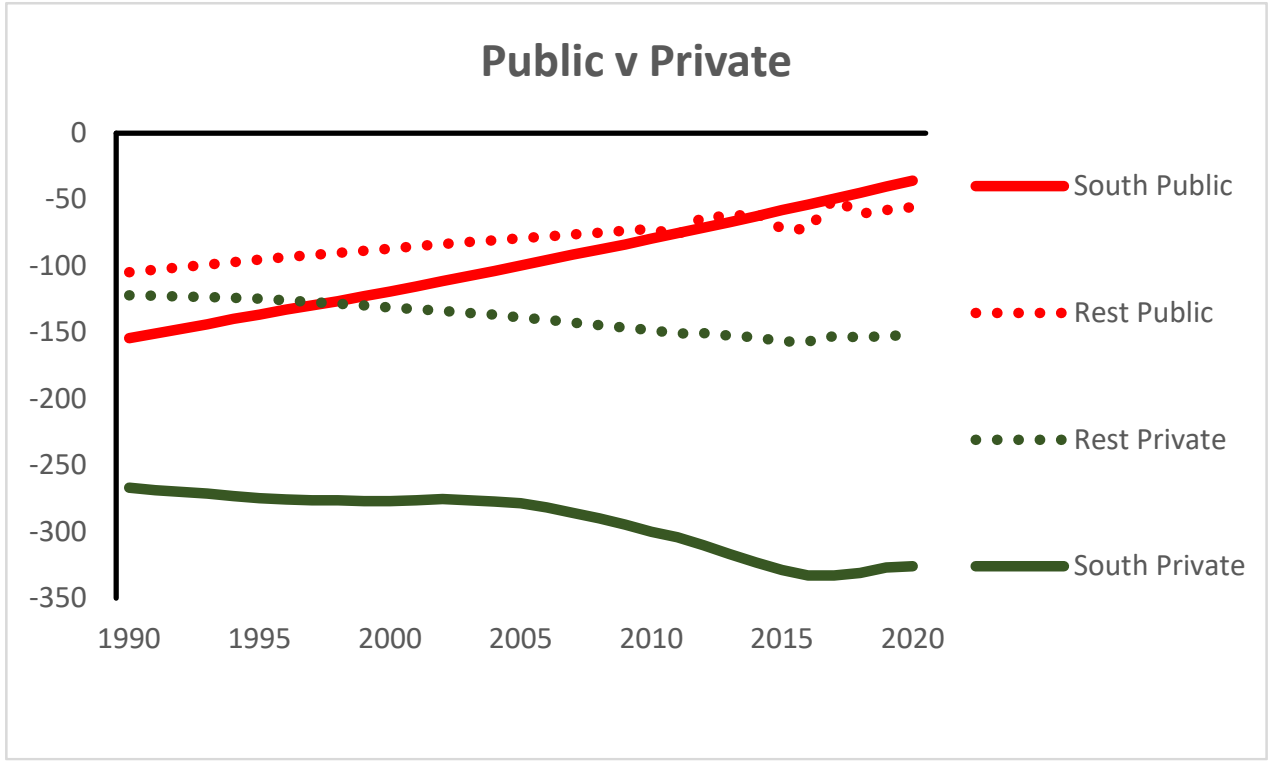
How about the US?

22 million hectares of plantations in Southern and Pacific Northwestern US.
38 million hectares of second growth, less intensively managed forests
215 million hectares of low intensity managed forests, old growth, and reserved forests



US forest carbon flux

- Flux on private forests has strengthened while flux on public forests has declined.
  - Specifically the flux has increased in the US south, where the most intensive management happens.
- Private forests constitute 63% of the land and 84% of the flux.
  - 80% of harvesting
- Public forests constitute 37% of the land and 14% of the flux.
  - 20% of harvesting.



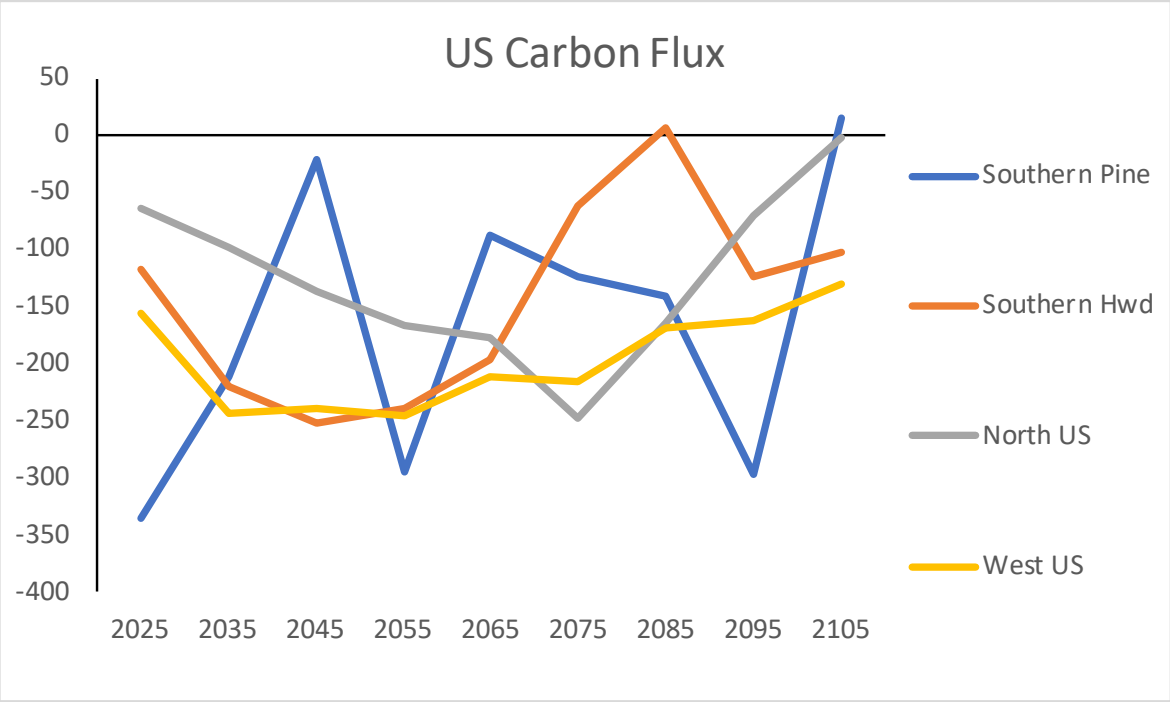
Domke et al. (2022)

https://doi.org/10.2737/FS-RU-382

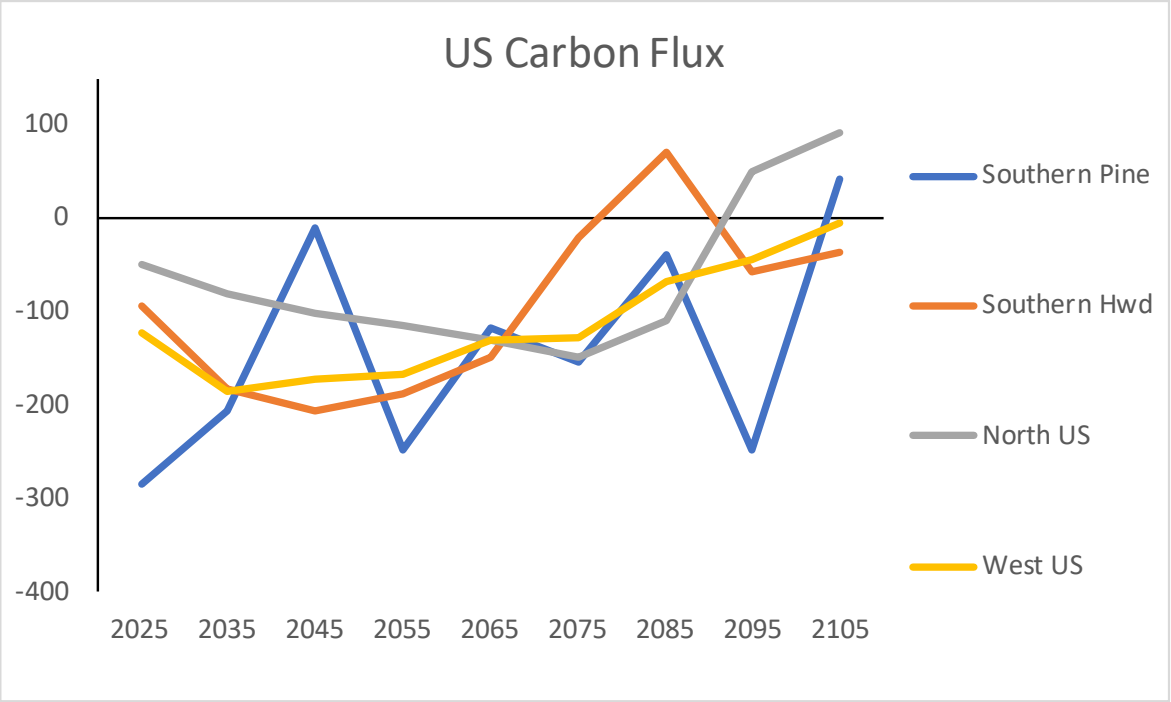
Looking forward in the United States

22 million hectares of plantations in Southern and Pacific Northwestern US.
38 million hectares of second growth, less intensively managed forests
215 million hectares of low intensity managed forests, old growth, and reserved forests

With carbon fertilization



Without carbon fertilization



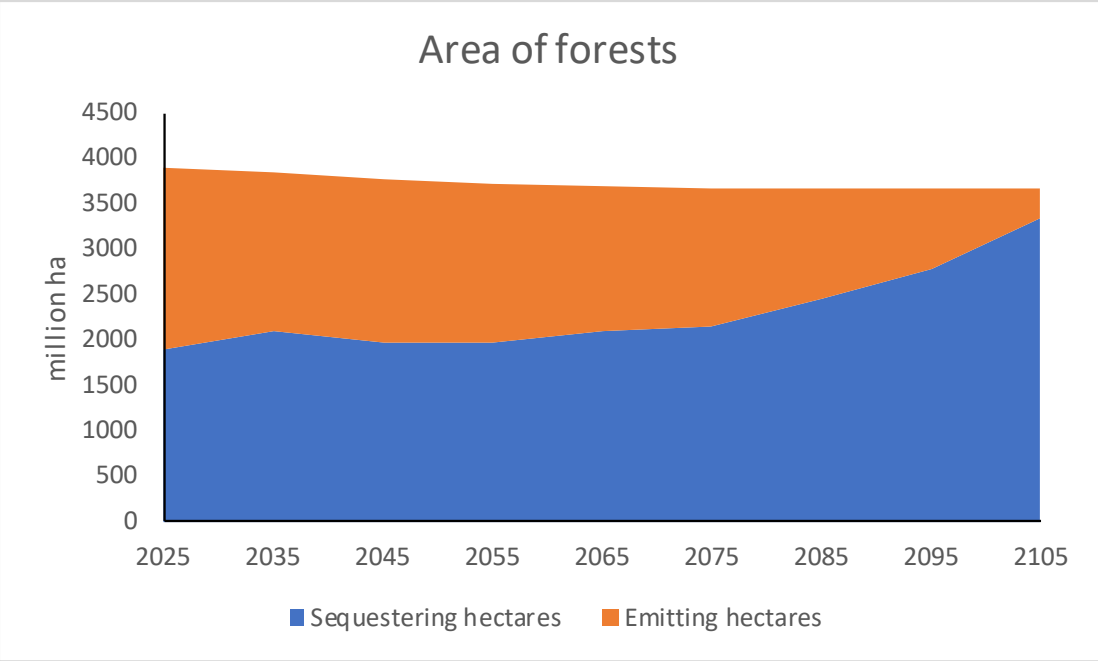
Keep in mind…

- Many forests are sustainable: 40-50% of the world's harvests are derived from plantations that are sustainably managed.

- 1.9 billion hectares are removing carbon from the atmosphere
- 2.0 billion hectares are emitting carbon to the atmosphere

- Many managed tropical systems are sustainable or could be
  - Malaysia, Guatemala, Costa Rica, Vietnam

- Some forests are not:
  - Old growth
  - Canada
  - Some tropical harvests
  - Deforestation supplies wood to markets, but isn't forestry



Would we ever reduce harvests for carbon?

- Use database for the Global Timber Model to assess marginal benefits and marginal costs of waiting to harvest.
  - Contains data on 244 forest and management types globally, ranging from intensively managed plantations to inaccessible types in all regions
- Use initial prices, costs and yields, unadjusted for climate change.
- Data from Daigneault et al. (2023)

Do the marginal benefits of waiting ever get big enough to suggest not harvesting?
Carbon price = $15/t CO2

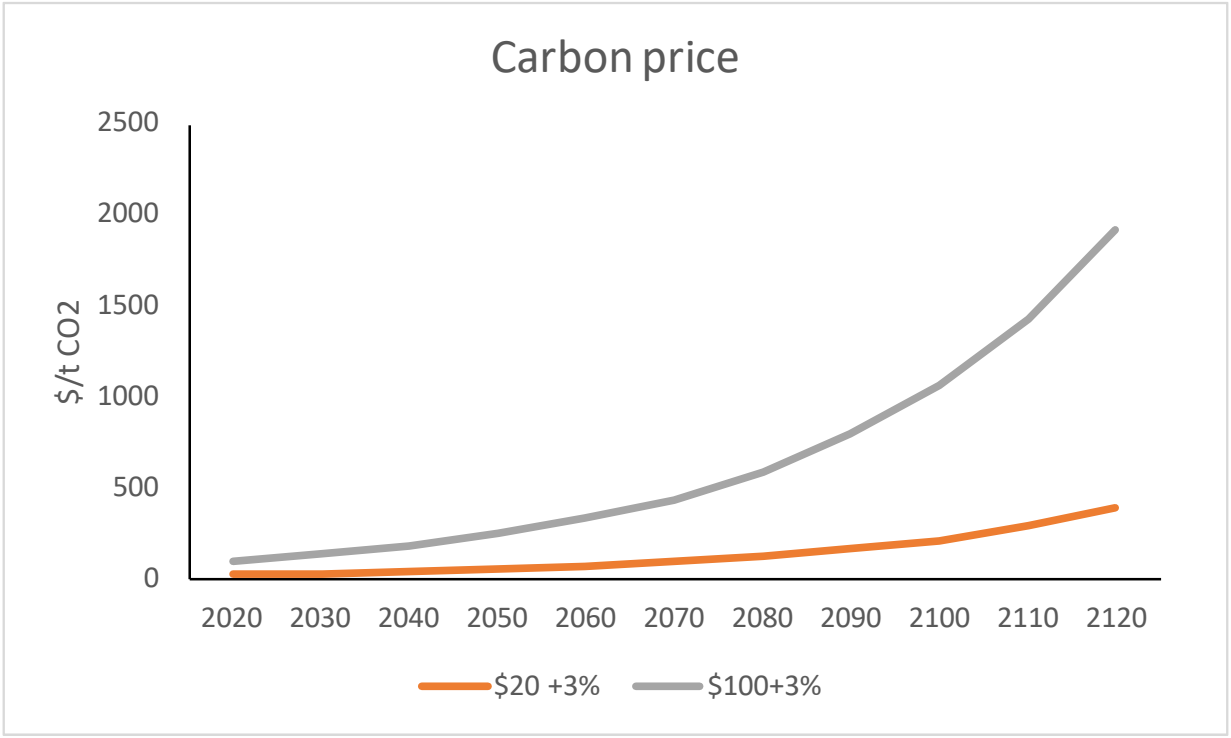
	MB>MC (Hold)	MB<MC (Harvest)
US	49	26
CHINA	6	4
BRAZIL	9	1
CANADA	18	18
RUSSIA	12	2
EU ANNEX I	3	6
EU NON ANNEX I	4	0
SOUTH ASIA	5	0
CENTRAL AMERICA	12	0
REST OF SOUTH AMERICA	10	0
SUB-SAHARAN AFRICA	8	0
SE ASIA	6	4
OCEANIA	8	2
JAPAN	2	0
AFRICA MIDDLE EAST	8	0
EAST ASIA	12	9

Do the marginal benefits of waiting ever get big enough to suggest not harvesting?
Carbon price = $100/t CO2

	MB>MC (Hold)	MB<MC (Harvest)
US	52	23
CHINA	10	0
BRAZIL	10	0
CANADA	36	0
RUSSIA	14	0
EU ANNEX I	9	0
EU NON ANNEX I	4	0
SOUTH ASIA	5	0
CENTRAL AMERICA	12	0
REST OF SOUTH AMERICA	10	0
SUB-SAHARAN AFRICA	8	0
SE ASIA	10	0
OCEANIA	10	0
JAPAN	2	0
AFRICA MIDDLE EAST	8	0
EAST ASIA	21	0

Dynamic analysis - Global Timber Model

- Carbon managed by renting carbon in forest stocks and paying for carbon stored permanently in wood product pools.
- Consider $20 + 3%, and $100 +3%.
- Assess what happens to wood products, forest management, and carbon storage.



Effect on Harvest Volume

	$20 +3%		$100+3%	
	2020	2050	2020	2050
US	0.1%	14.2%	-5.1%	24.1%
CHINA	-4.2%	-24.5%	-7.8%	-56.8%
BRAZIL	-14.9%	-2.0%	-57.1%	16.6%
CANADA	0.3%	-0.3%	1.5%	-1.7%
RUSSIA	-8.1%	2.7%	-42.2%	-21.4%
EU ANNEX I	-7.8%	5.9%	-7.5%	12.8%
EU NON ANNEX I	0.0%	-1.1%	0.0%	20.6%
SOUTH ASIA	-10.4%	-4.4%	-87.1%	-65.8%
CENTRAL AMERICA	-39.5%	-20.3%	-78.0%	-23.6%
REST OF SOUTH AM.	-32.9%	-47.3%	-82.4%	-40.4%
SUB-SAHARAN AFRICA	-75.2%	-61.2%	-76.3%	-92.2%
SE ASIA	-18.0%	-41.3%	-72.7%	-52.0%
OCEANIA	-0.9%	11.6%	-4.9%	-46.5%
JAPAN	-26.5%	-5.1%	-83.1%	-56.4%
AFME	-44.7%	-40.6%	-73.0%	-68.5%
E ASIA	0.0%	-15.5%	-29.6%	-28.8%
Total	-10.2%	-6.8%	-28.7%	-13.2%

Conclusion

- Forests are sequestering carbon in many places around the world where sustainable yield forestry is practiced
  - Most forests in Europe, many in the US, and an increasing number in the tropics.

- Forests are also sequestering carbon because of the investments foresters have made in timber.
  - Accounts for perhaps 50-60% of the total carbon flux from the atmosphere into forests.
  - The US gets most of its sequestration from what is happening in managed forests.

- Some harvesting is definitely unsustainable and leading to carbon emissions on net.
  - Old growth harvesting and deforestation in the tropics.