Is timber harvesting carbon neutral? And what about carbon fertilization?

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Modeling issues in forestry

- Emerging question about whether timber harvesting is carbon neutral.
  - “New” approach suggested by Peng et al. (2023)

- Some issues they raised
  - Economics doesn’t matter because it’s not even an economics problem
    - Economics is too complicated to model anyways.
    - Models include other things like carbon fertilization in their numbers.
    - The parameters of models are wrong
    - Models that capitalize future forests have only 1 response to higher demand → new forests.
  - Existing studies have ignored carbon emissions after harvesting.
  - Comparing fluxes after harvest versus a no harvest/natural counterfactual is the right approach.

- Climate impacts
  - The role of carbon fertilization on carbon flux and management

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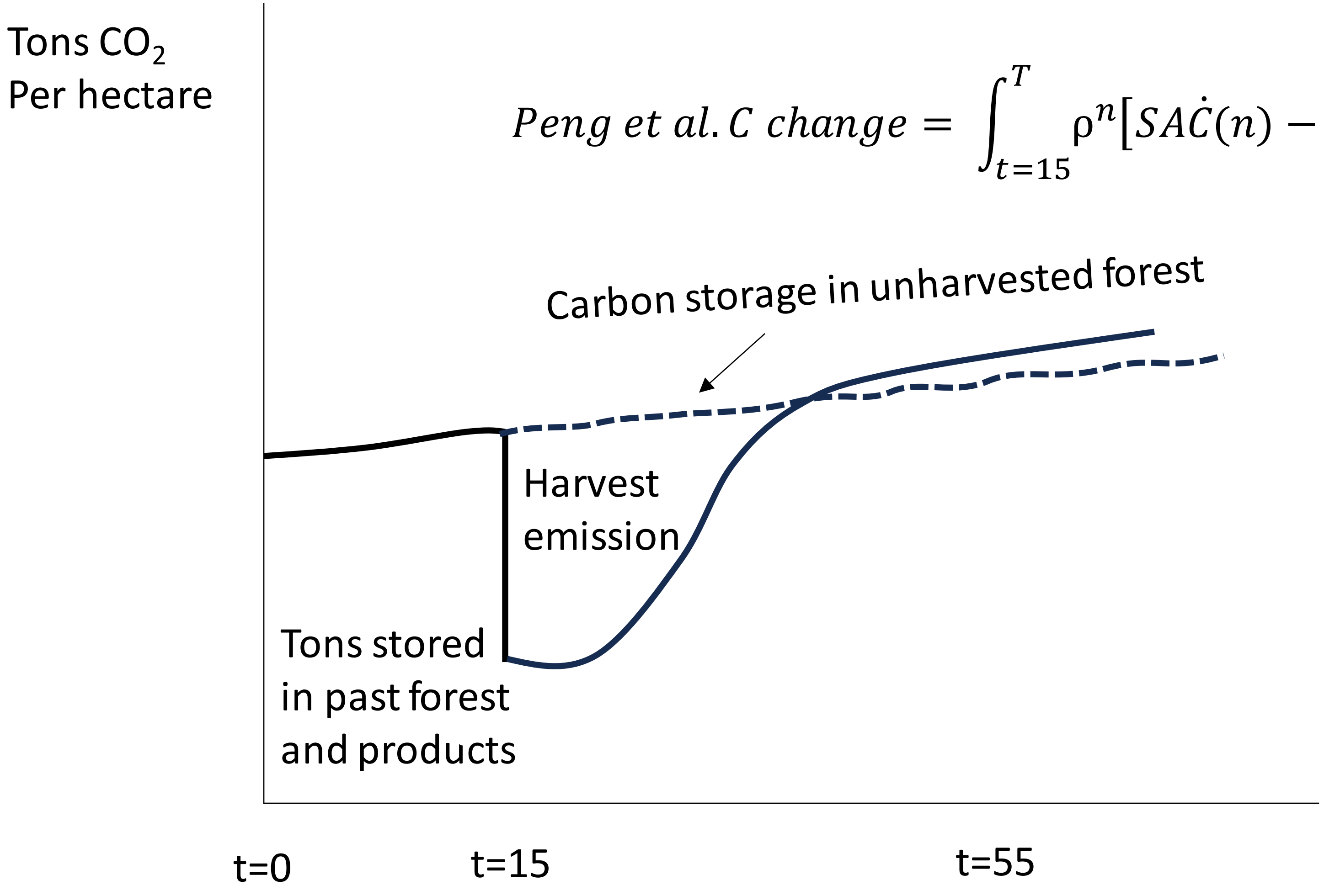
Comparison of harvested forest to set-aside forest.

$$C\ change = \int_{t=15}^{T} \left[SA\dot{C}(n) - Har\dot{C}(n)\right] dn$$

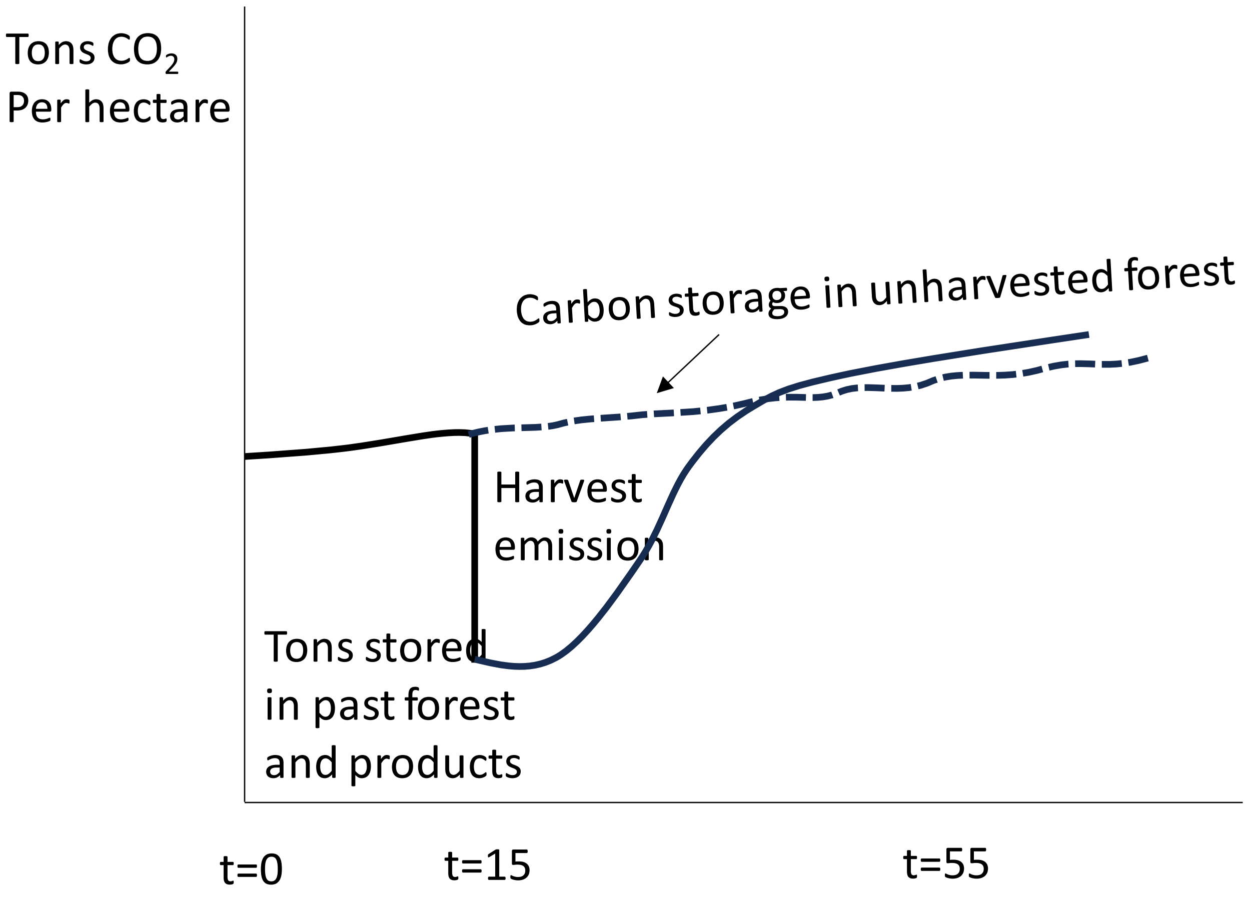
$$Peng\ et\ al.\ C\ change = \int_{t=15}^{T} \rho^{n}\left[SA\dot{C}(n) - Har\dot{C}(n)\right] dn$$



Some concerns about this approach

- Ignores hundreds of years of sustained yield forestry where stocks can be maintained at different levels, MSY or Faustmann being two clearly different ones.
- Normative assumptions ignored. All forests are treated the same, even ones that were planted for the express purpose of cutting.
- Focused entirely on existing stock, not future stock.
- Ignores market interactions.

Peng et al. approach:



Standard Approach:

$$\dot{S}_i = -\sum_j H_{ijt} \quad + G_{it}(S_{it}, Z_{it}) + g_{it} - \delta_{it} S_{it}$$

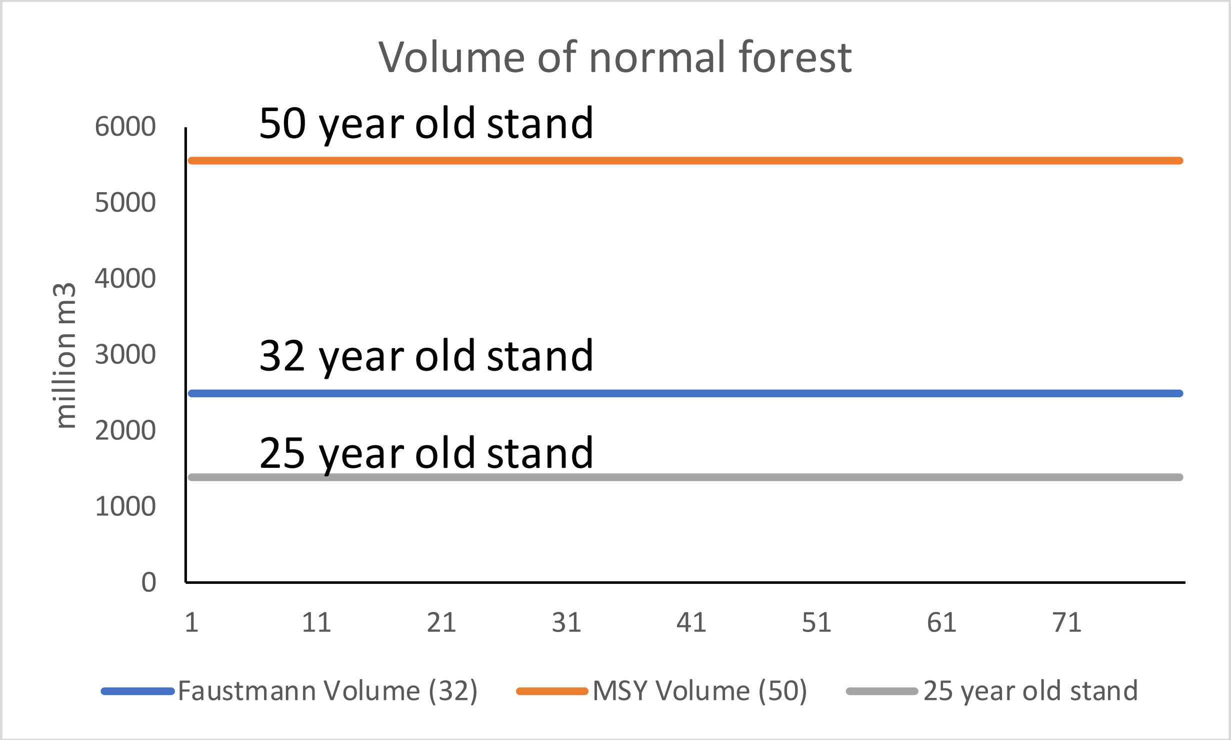
Normal Forest

from Sohngen and Sedjo (1996)

- Normal forest: forest with equal age classes of trees of some age
- Volume (m3/ha) =

  exp(7.82 – 52.9/age)
- r=4%
- Faustmann age = 32
- MSY age = 50
- Area = 16 million ha

	25	32	50
Ann. Harv. Vol. (mill m^3)	192	238.3	276.6
Ann. Harv. Area	640,000	500,000	320,000



Forestry models have analyzed the effect of demand and other shocks

Sohngen and Sedjo (1996)

- Demand shocks that increase consumption will reduce carbon and vice-versa.
- But, demand shocks that increase demand over time will increase stocks in optimal control models and reduce it in static models.

Instantaneous demand shock

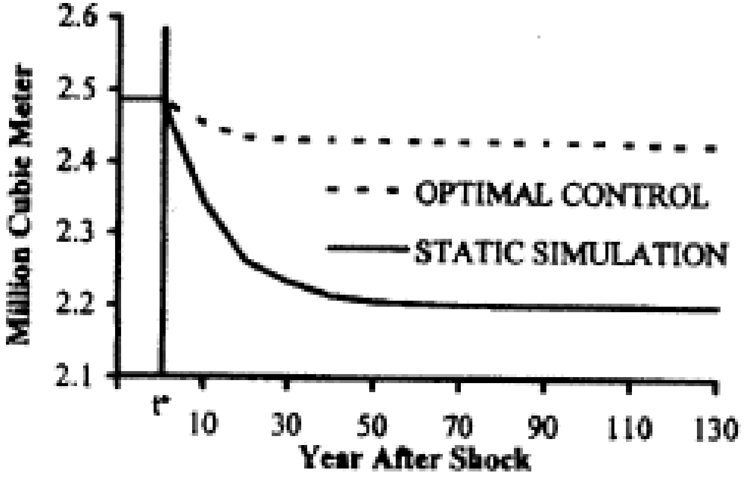


Figure 1. Comparison of price and inventory paths for the instantaneous demand shock scenario.

Slow demand build-up

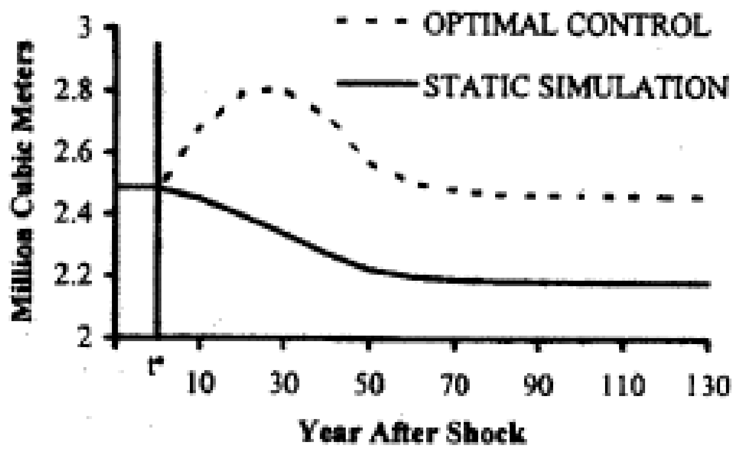


Figure 4. Comparison of price and inventory paths for the slow demand increase scenario.

Keep in mind…

- Many forests are sustainable: 40-60% of the world's forests are derived from plantations that are sustainably managed.

- 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

Other problems with Peng *et al*.

- Policy recommendation of "new approach" is that wood harvests are not treated as carbon neutral under any circumstance. In a world where carbon matters, this is like adding a tax on emissions:
  - Net price to producers will be lower initially (taxed), but over time the market price of wood could rise when supply is constrained.
  - Forest land value will be lower
  - There will be less land in forests
  - Favero et al. (2020); Li et al. (2021)
- Treats forests like a car, as simple emitting source

$$\dot{S}_i = -\sum_j H_{ijt} + G_{it}(S_{it}, Z_{it}) + g_{it} - \delta_{it} S_{it}$$

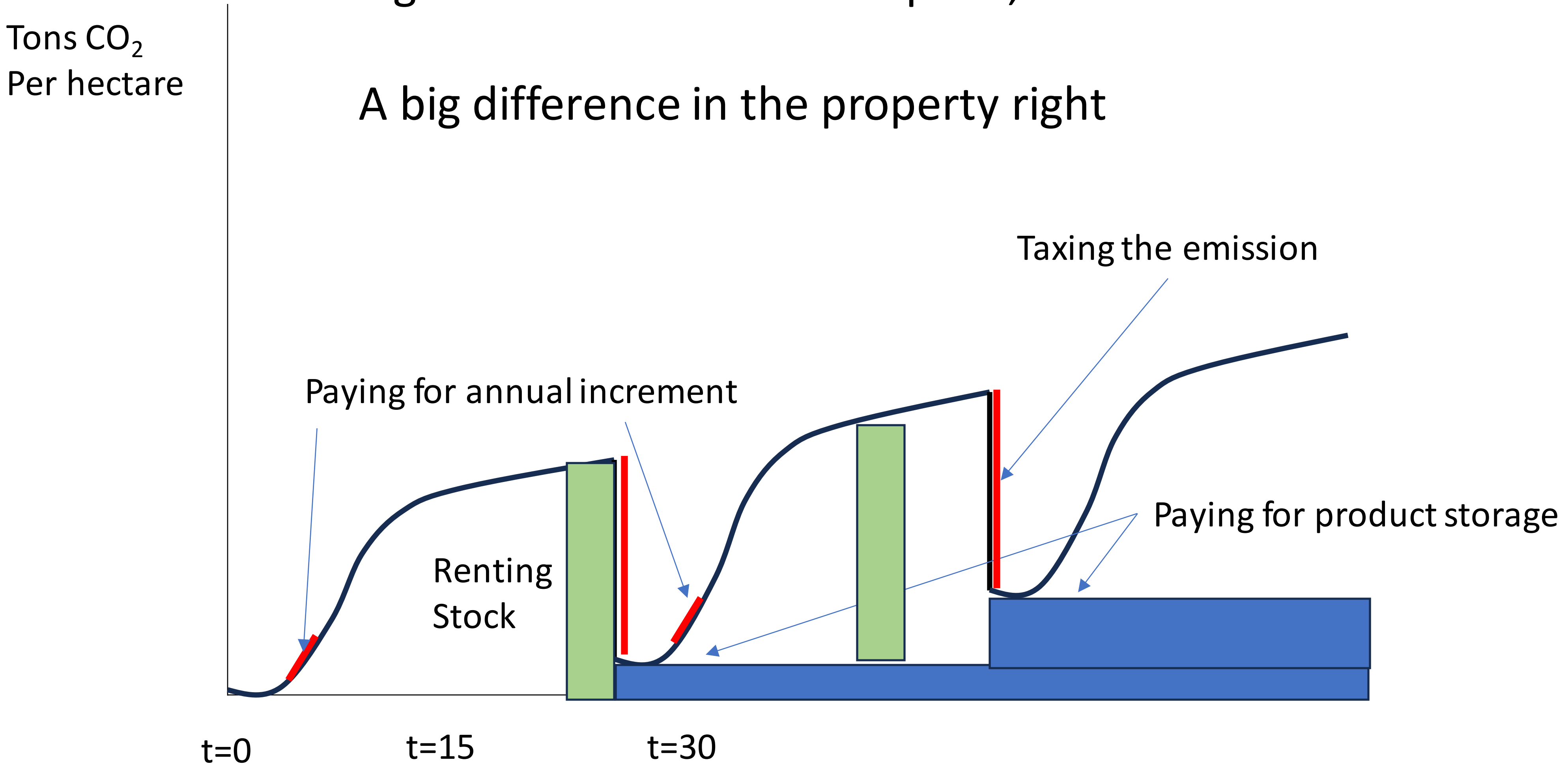
Would we ever reduce harvests for carbon?

- Tax and Subsidy: $Max_t \frac{\left(PVe^{-rt} + \int_0^T P^C \alpha \dot{V} e^{-rn} dn - P^C(1-\beta)Ve^{-rt} - C\right)}{(1-e^{-rt})}$
    - Van Kooten et al. (1995)
    - Subsidy for carbon withdrawal from atmosphere, tax for emission into atmosphere.
- Rental: $Max_t \frac{\left(PVe^{-rt} + \int_0^T R^C \alpha V e^{-rn} dn + P^C \beta V e^{-rt} - C\right)}{(1-e^{-rt})}$
    - $R^C = P^C(1\text{-}\exp(-r+n))$
    - Sohngen and Mendelsohn (2003)
    - Rental subsidy for holding carbon out of atmosphere and payment for permanent pickling.

Difference between tax/subsidy v rental is distributional.

Same efficiency outcomes (e.g., same rotation age for a given timber and carbon price, but

A big difference in the property right



Economic evaluation – carbon rental

- Augmented Faustmann: $Max_t \frac{\left(PVe^{-rt}+\int_0^T R^C \alpha V e^{-rn} dn + P^C \beta V e^{-rt} - C\right)}{(1-e^{-rt})}$
  - $R^C = P^C(1\text{-exp}(\text{-}r\text{+}n))$

$$\dot{P}V + P\dot{V} + R^C\alpha V + (\dot{P}c)\beta V + P^C\beta\dot{V} =$$

$$rPV + rP^C\beta V + r\left(\frac{\left(PVe^{-rt} + \int_0^T R^C \alpha V e^{-rn} dn \ + \ P^C\beta V e^{-rt} - C\right)}{(1 - e^{-rt})}\right)$$

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)

Evaluate the MB/MC of harvesting

$$\dot{P}V + P\dot{V} + R^{C}\alpha V + (\dot{P}c)\beta V + P^{C}\beta\dot{V} =$$

$$rPV + rP^{C}\beta V + r\left(\frac{\left(PVe^{-rt} + \int_{0}^{T} R^{C}\alpha V e^{-rn}dn \; + \; P^{C}\beta V e^{-rt} - C\right)}{(1 - e^{-rt})}\right)$$

Forest price changes = 0.4% per year
Carbon price changes 3%/yr
Initial carbon price = $15 and $100

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

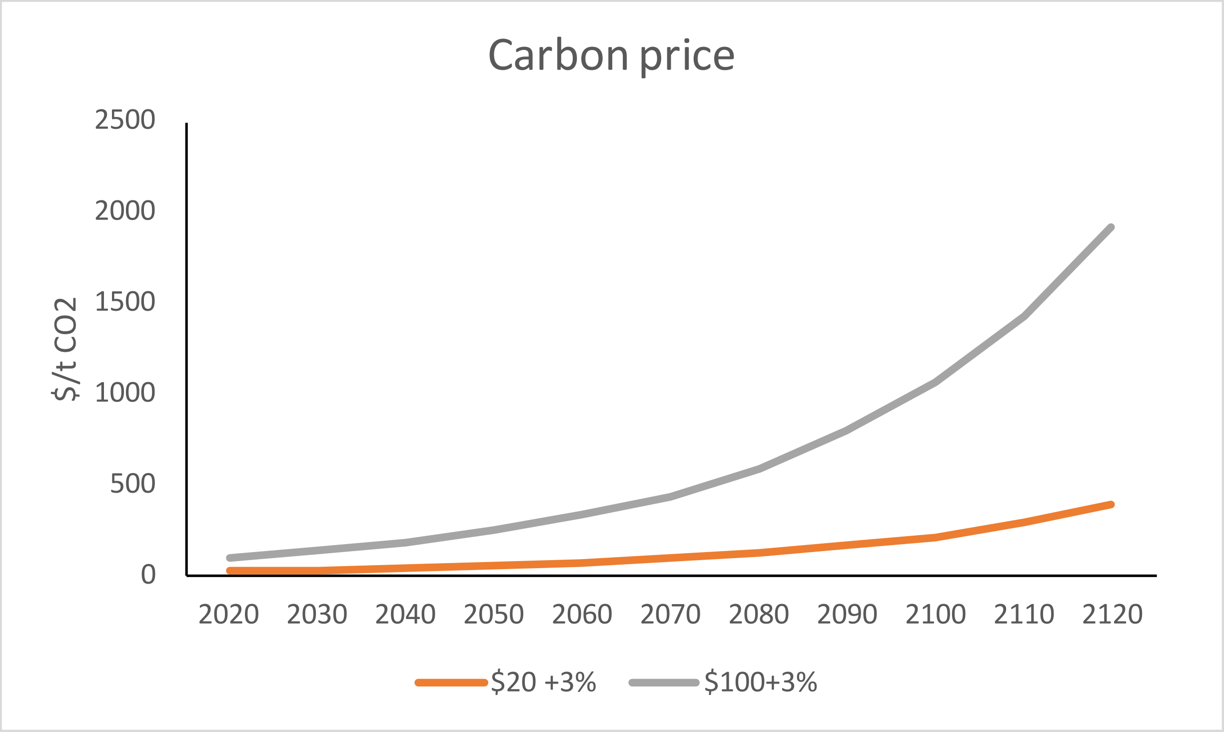
	MB>MC (Hold)	MB<MC (Harvest)
US	52	23
CHINA	10	0
BRAZIL	10	0
CANADA	36	0
RUSSIA	14	0
EU ANNEX I	9	0
EU NON ANNEX I	4	0
SOUTH ASIA	5	0
CENTRAL AMERICA	12	0
REST OF SOUTH AMERICA	10	0
SUB-SAHARAN AFRICA	8	0
SE ASIA	10	0
OCEANIA	10	0
JAPAN	2	0
AFRICA MIDDLE EAST	8	0
EAST ASIA	21	0

Global Timber Model

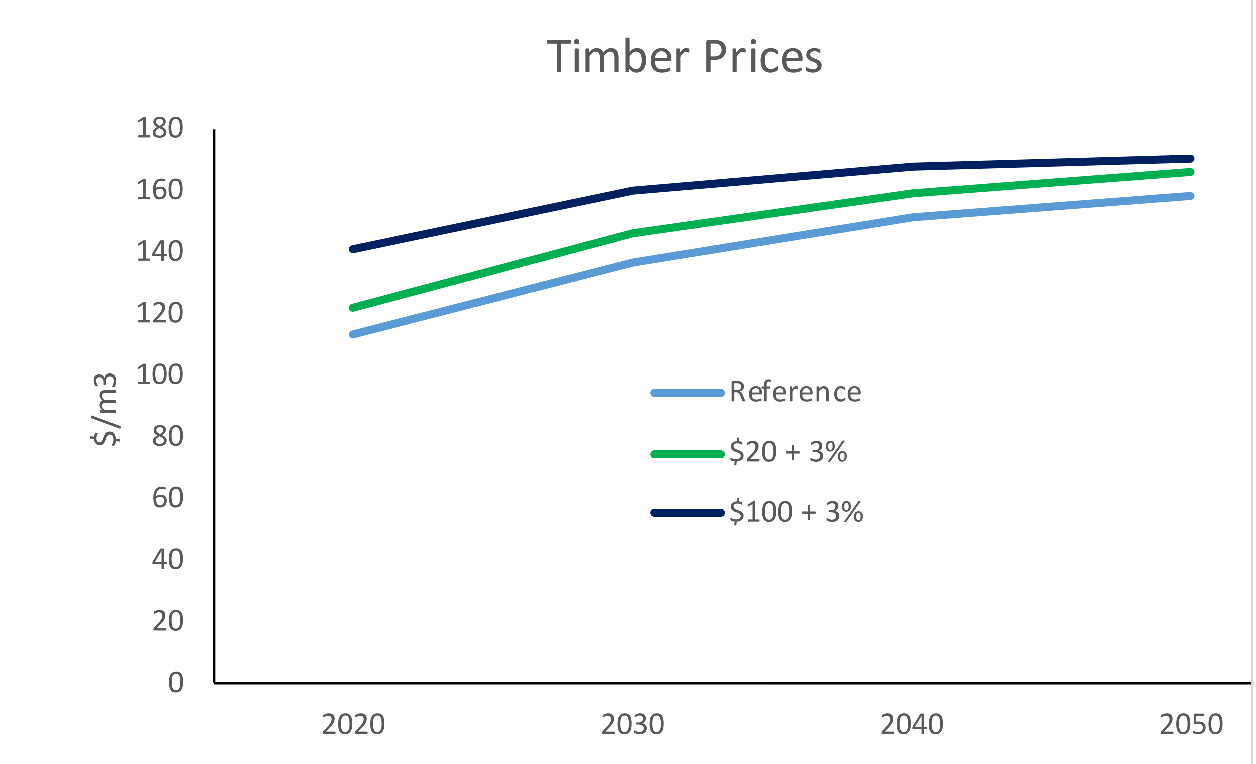
- Global market
  - Global demand for sawtimber and pulpwood with quality adjustment factors to adjust value of wood in each location.
  - Implies trade of wood products is frictionless
  - Demand elasticity = -1.0
  - Income elasticity ~ 0.9
- Land rental functions for each land class, with land supply elasticity = 0.3, so a 10% increase in land rents will increase land area in the forest type by 3%.

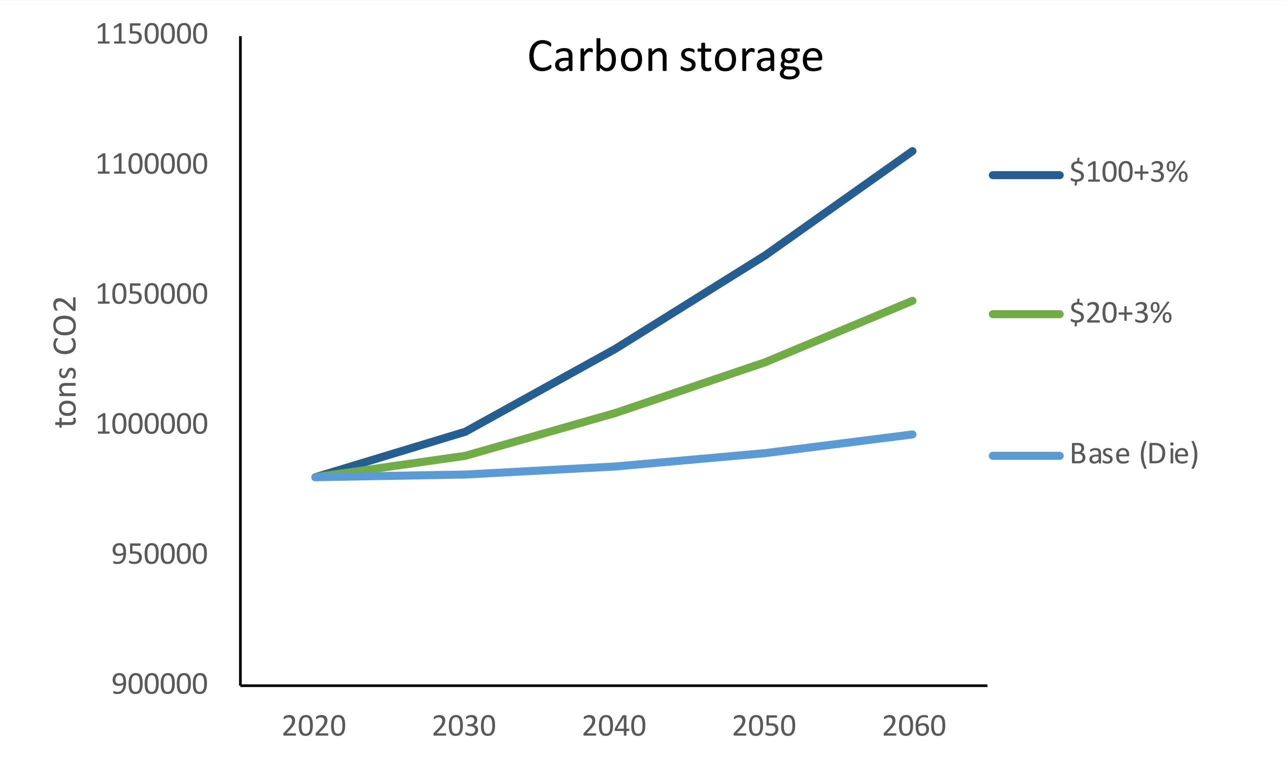
Dynamic analysis - Global Timber Model

- 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.



Dynamic Analysis





With carbon pricing ➔
Higher prices
Smaller annual harvest globally

Carbon storage includes:
Aboveground C
Slash C
Soil Organic C
Market C

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%**

Carbon fertilization

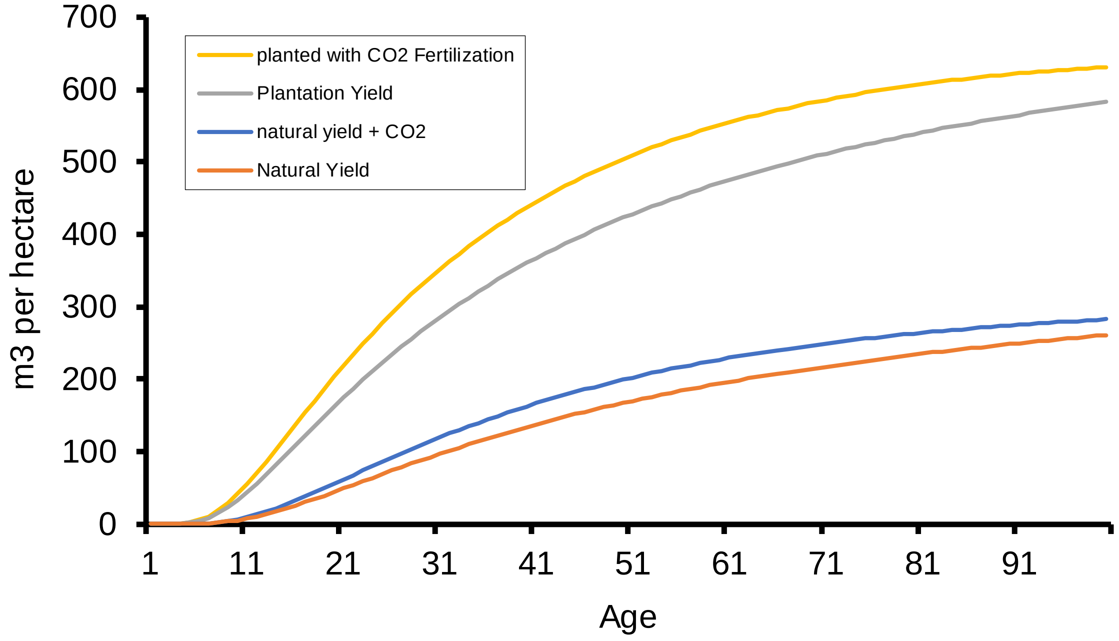
- US effects (Davis et al., 2022)
  - 1% increase in lifetime CO_2 leads to 1.3% increase in wood volume
  - Between 1985 and 2015

Change in	25 yrs	40 yrs	75 yrs
Lifetime carbon	13%	12%	8%
Volume change	17%	15%	11%

  - By 2050, expect another 14 – 17% increase in CO2 concentration, with attendant increase in volume
- Canada effects (Oh et al., 2024)
  - 1% increase in lifetime CO_2 leads to 0.9% increase in wood volume

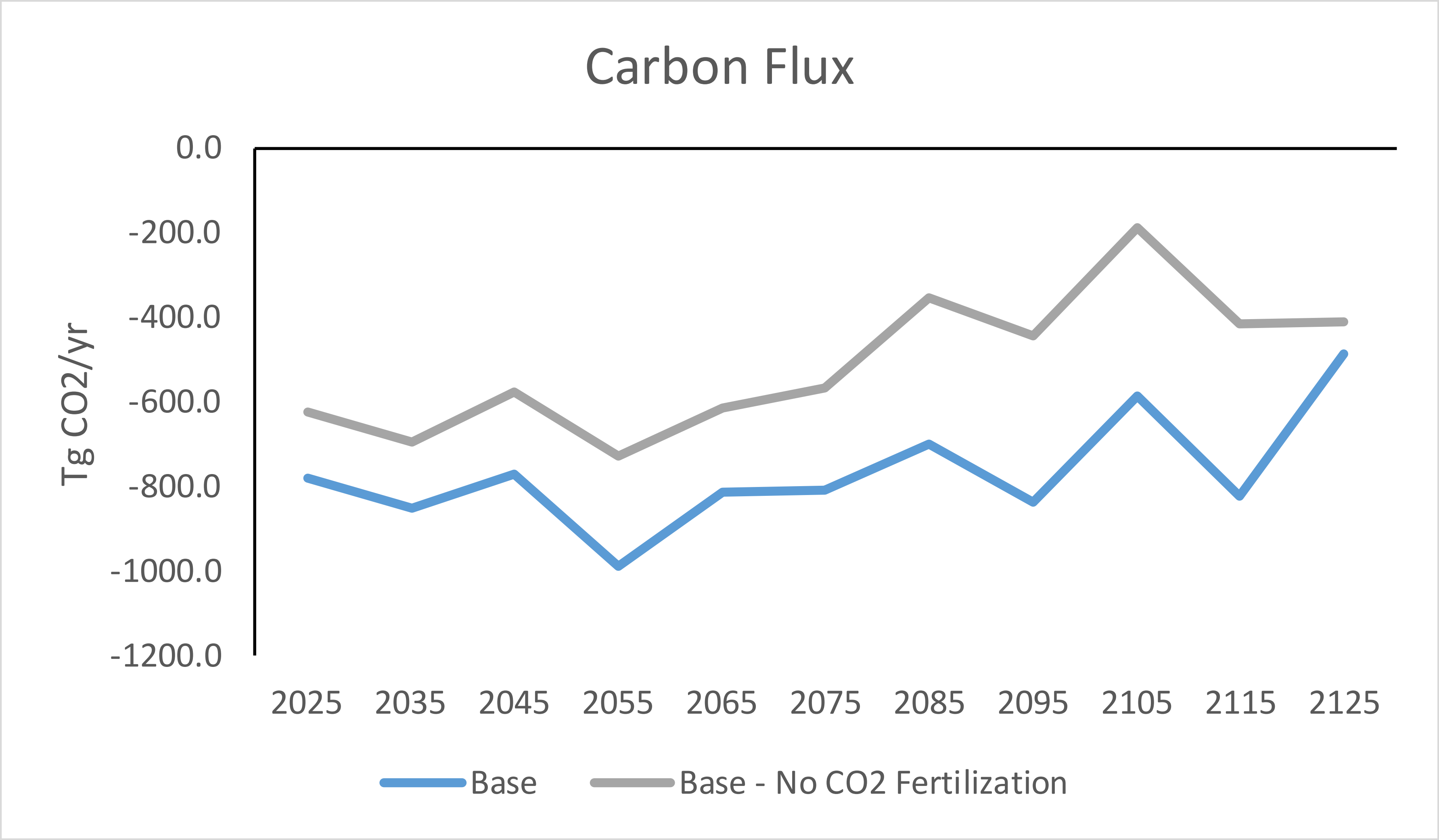
Carbon fertilization on young stands

- Carbon fertilization effect is proportionally the same for natural and managed stands, but potentially has its largest effect on managed short-rotation stands.



	Volume 1970	Volume 2020	Gain
Natural Stand (even-aged 1 – 100)	147.5	170.1	22.7
Plantation (even aged 1-30)	112.0	140.3	28.2

Effects of CO2 fertilization in projections with GTM



Can carbon prices compensate?