What is leakage, why does it matter, and how big is it?

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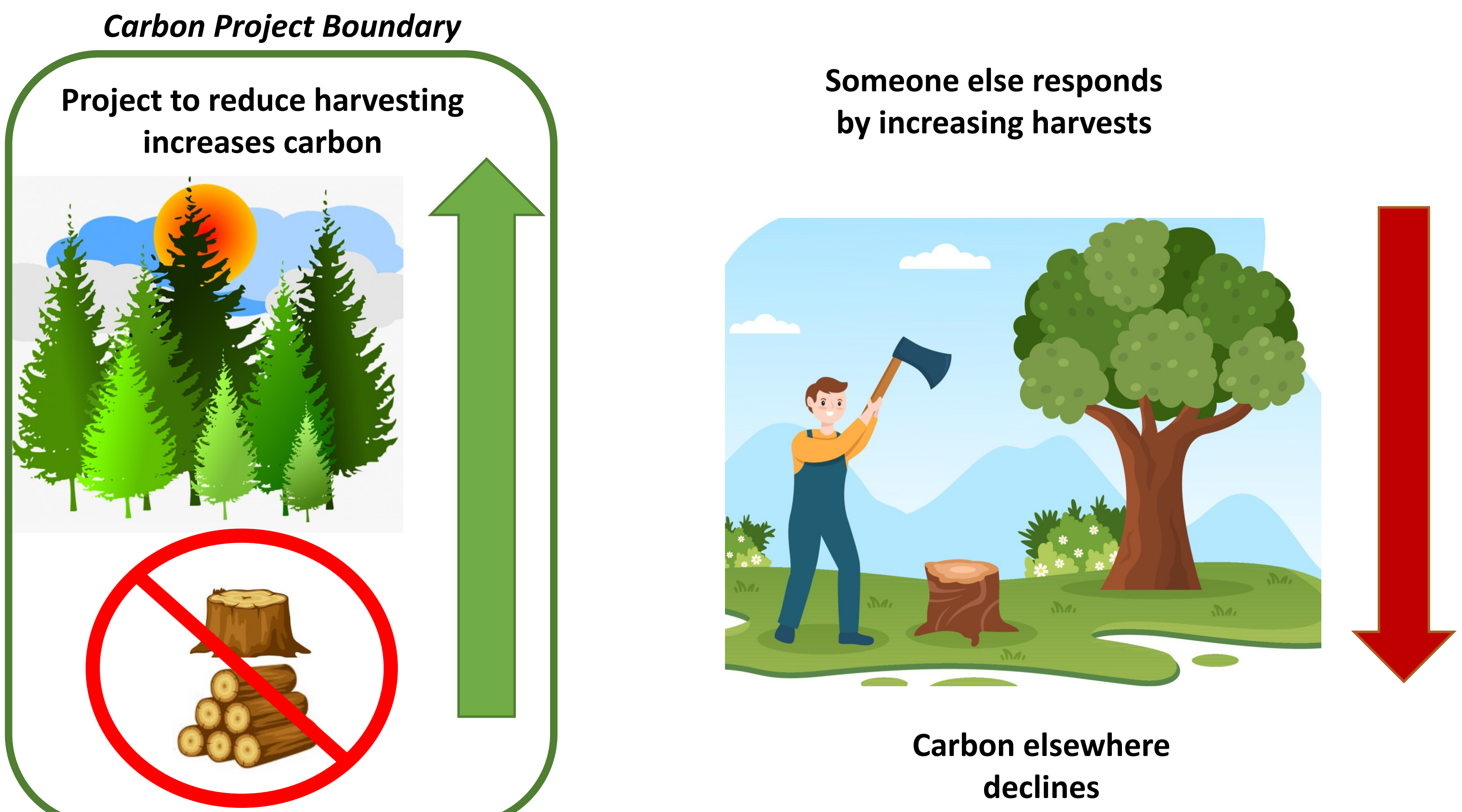
What is Leakage?



In economics, **leakage** is a classic **spillover**, where an economic or policy driver in one market or location creates an unintended consequence in another market or location as a result of market interactions (e.g., shifts in supply and/or demand for inputs or outputs).

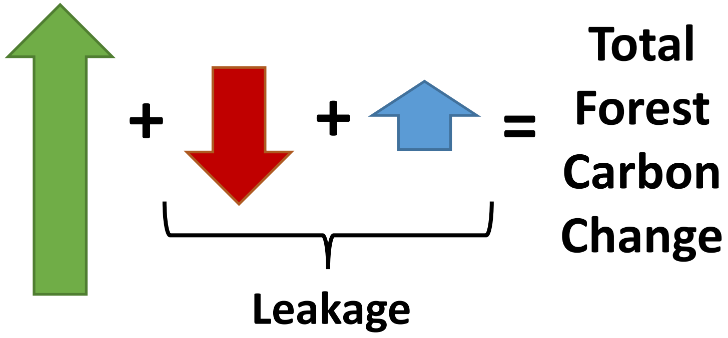
What is Leakage?

Carbon Project Boundary

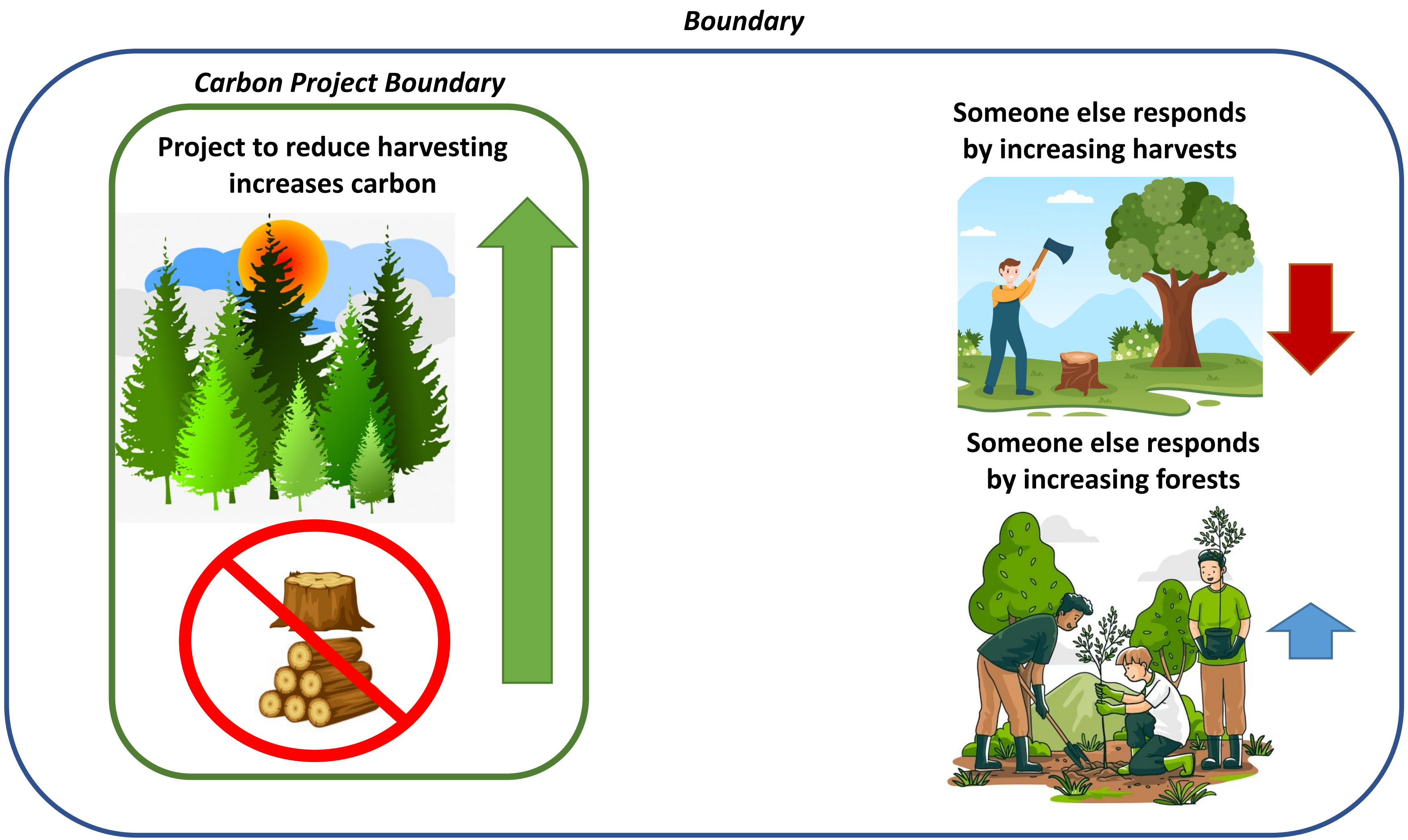
Project to reduce harvesting increases carbon

Someone else responds by increasing harvests

Someone else responds by increasing forests

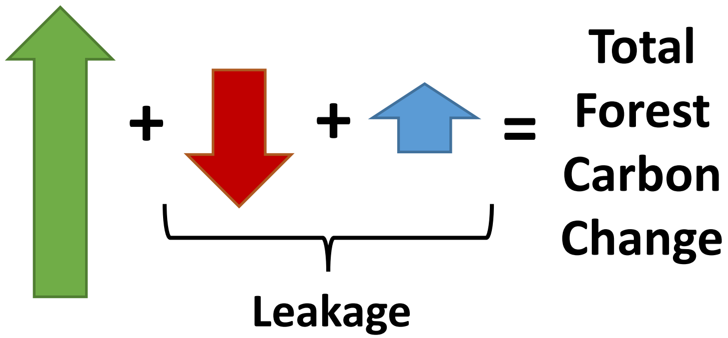


What is Leakage?



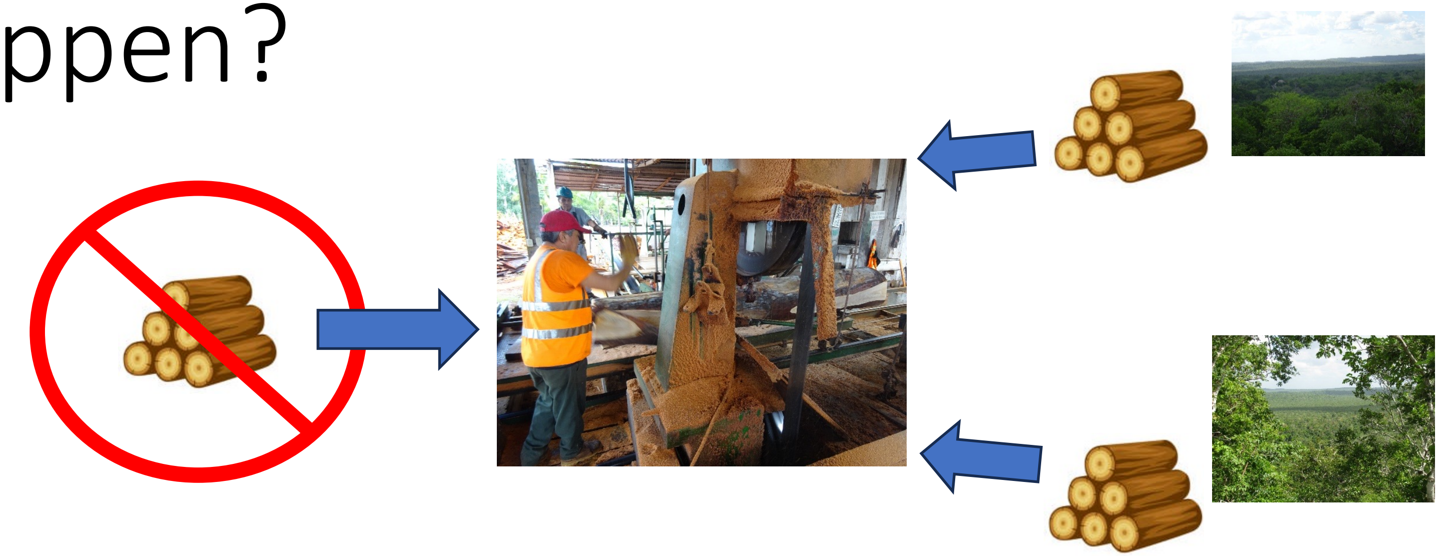
Three key points about leakage:

- An economic phenomenon.
- Can have both negative and positive effect.
- The boundary set for the problem matters.

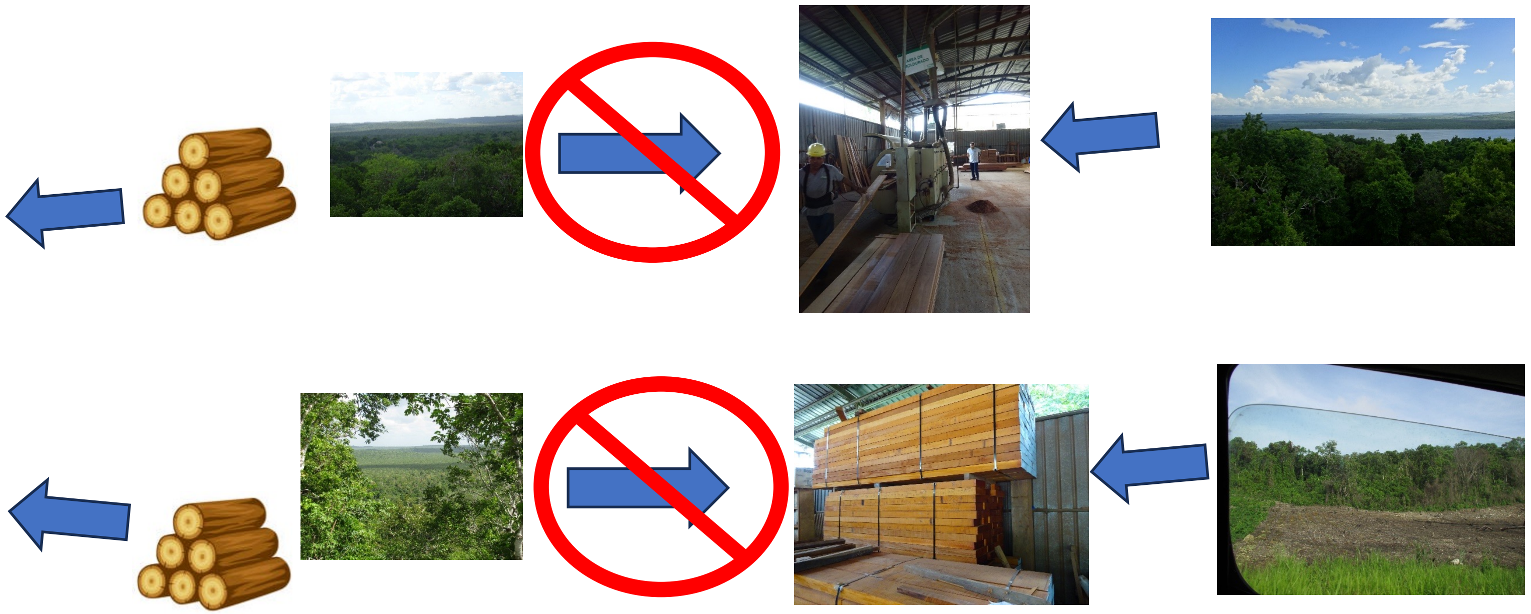


How does leakage happen?

- Direct displacement



- Market displacement



Some points on leakage in “no harvest” case

- Leakage can only happen if at some point, the tree harvested would not have been harvested that period.
  - Otherwise, loggers, traders, and mill owners are just trading trees that would have been harvested anyways.

- **No tree is free**: If a tree taken off the market leads to an actual ***increase*** in harvest elsewhere, prices went up.

- Most often, leakage implies taking a tree from a **future harvest**.

- A price increase leads to **new investments** as well.

PNW public harvest restrictions in 1990

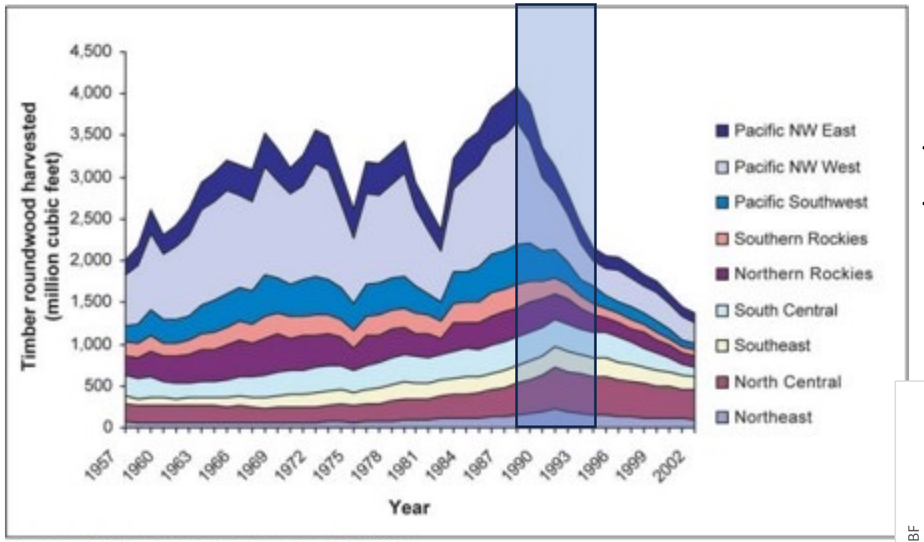
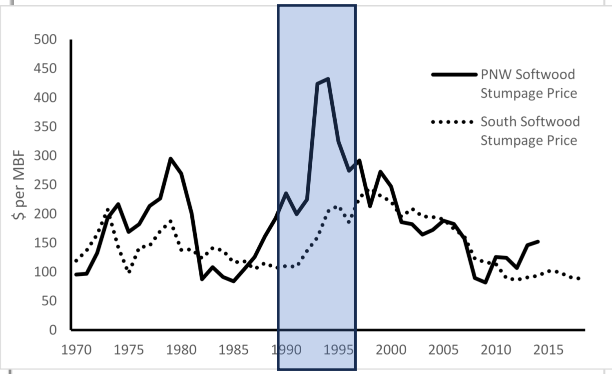


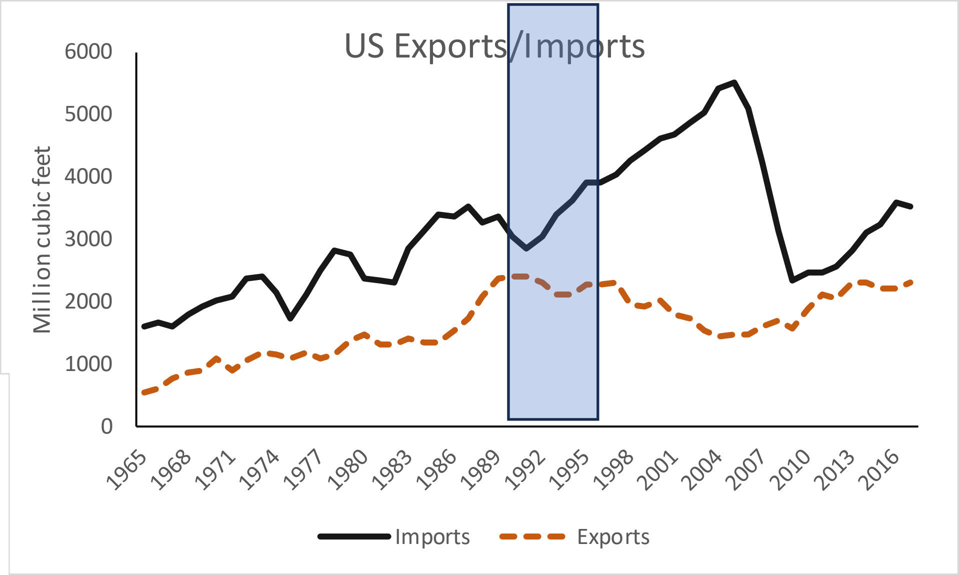
Figure 7—Total public harvest, by region, 1957-2002.

-50%
-2,000 mcf

+30%
+1000 mcf

+125%





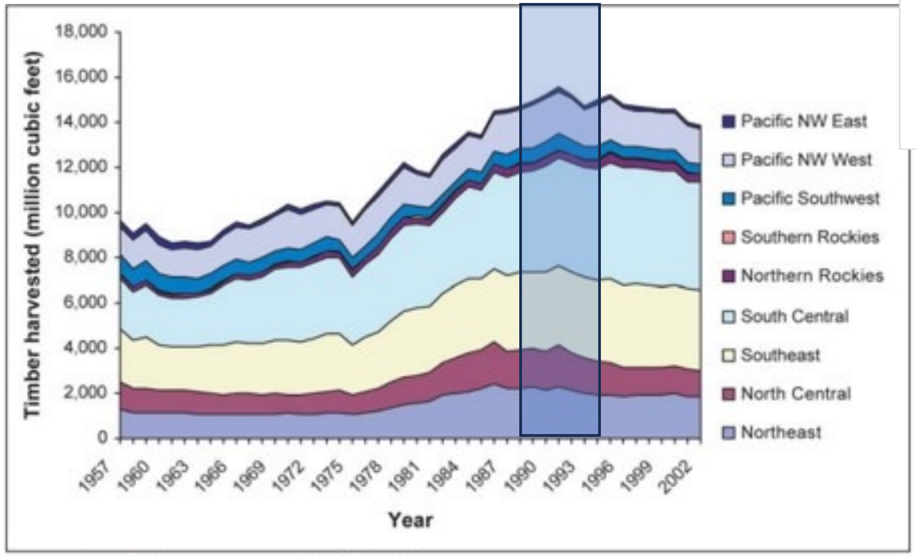
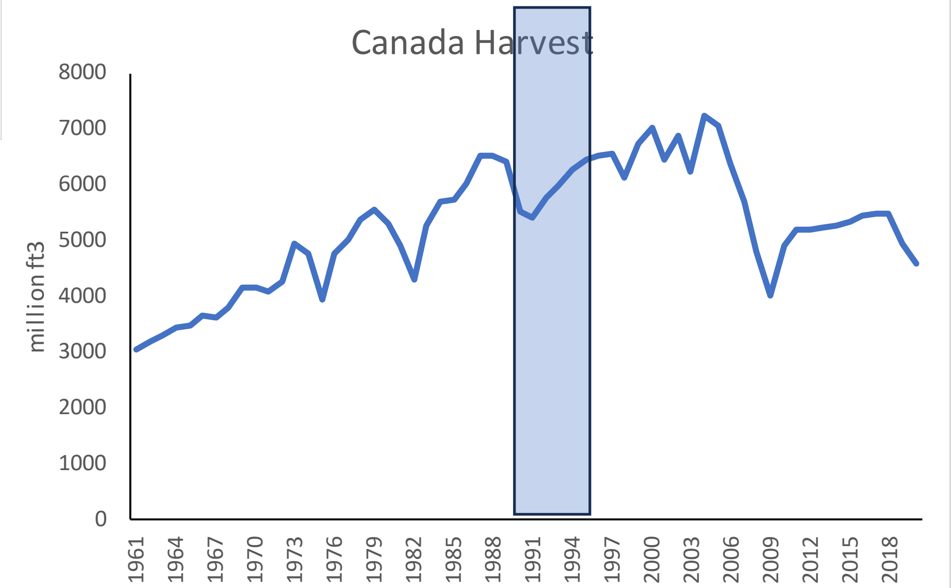


Figure 9—Total private harvest, by region, 1957-2002.

+20%
+500 mcf

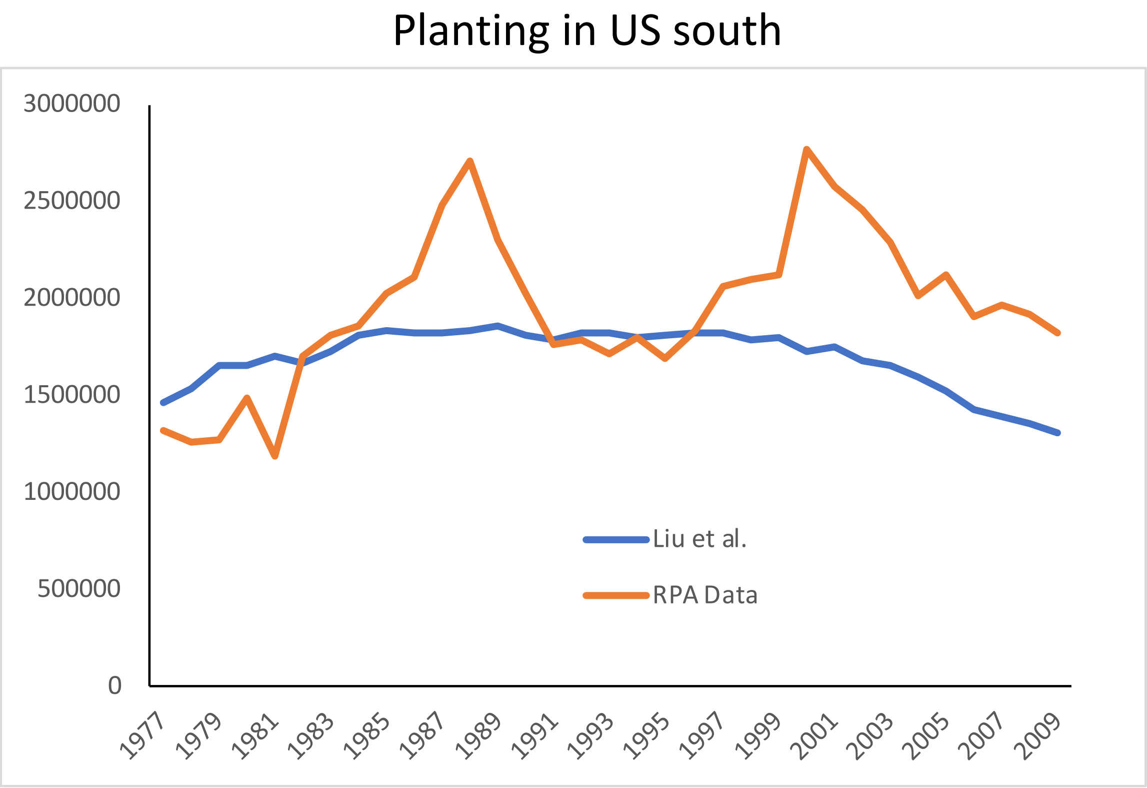
+20%
+1000 mcf

Harvest leakage
was substantial
Wear and Murray (2004)



What about planting?

- Estimates suggest that 1.8 million additional hectares were planted in 1989 – 1996 period in the US south
  - Amounts to 5.2% of total hectares today.
- This could increase the flux by 16 million tons CO_2/yr today.



To evaluate leakage, modelers should

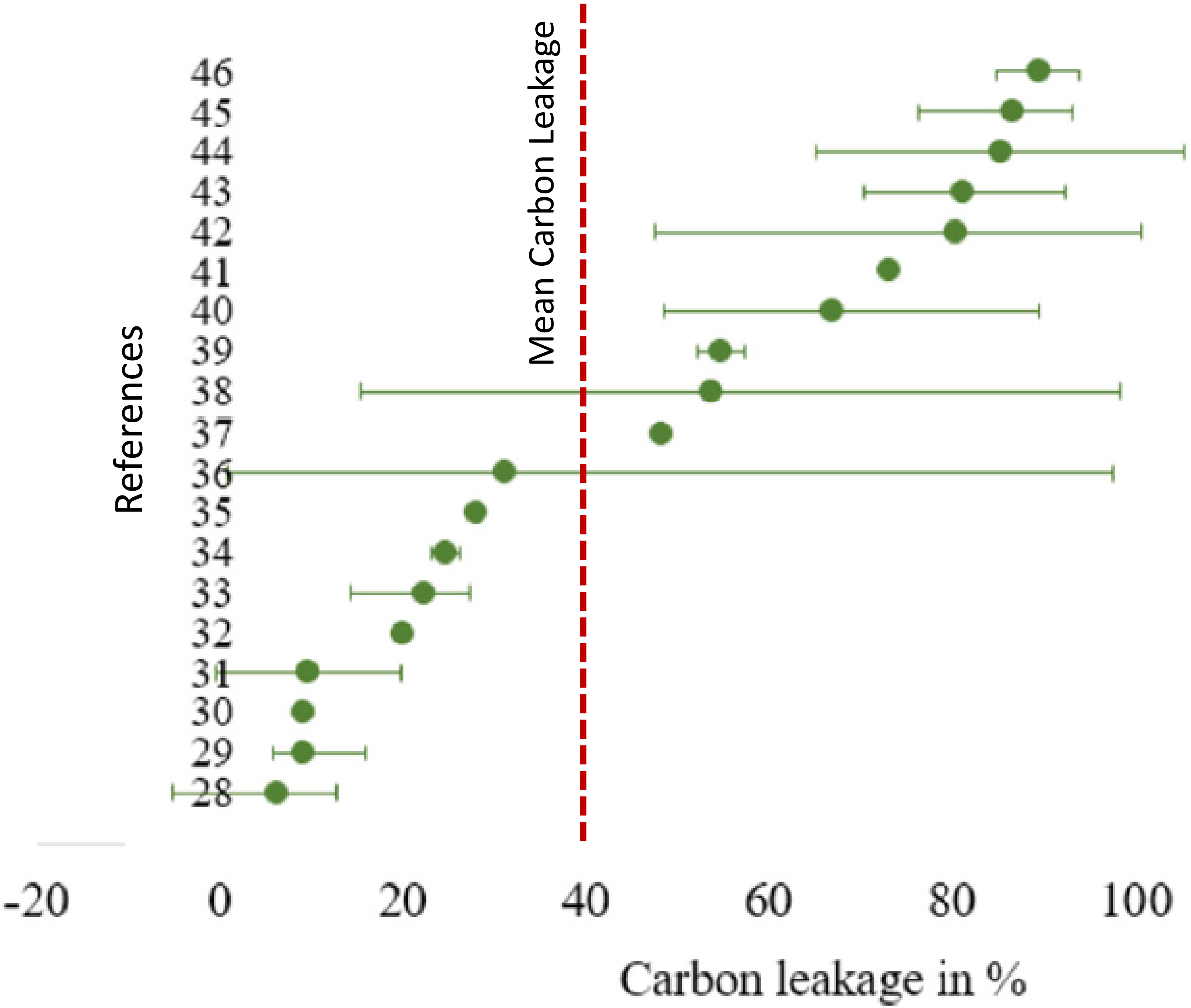
- Account for space ➔ including more forests is better.

- Account for costs ➔ no forest is free to harvest, especially one that was not intended to be harvested.
  - Marginal opportunity costs
  - Marginal harvesting costs
  - Marginal access costs
  - Marginal transportation costs

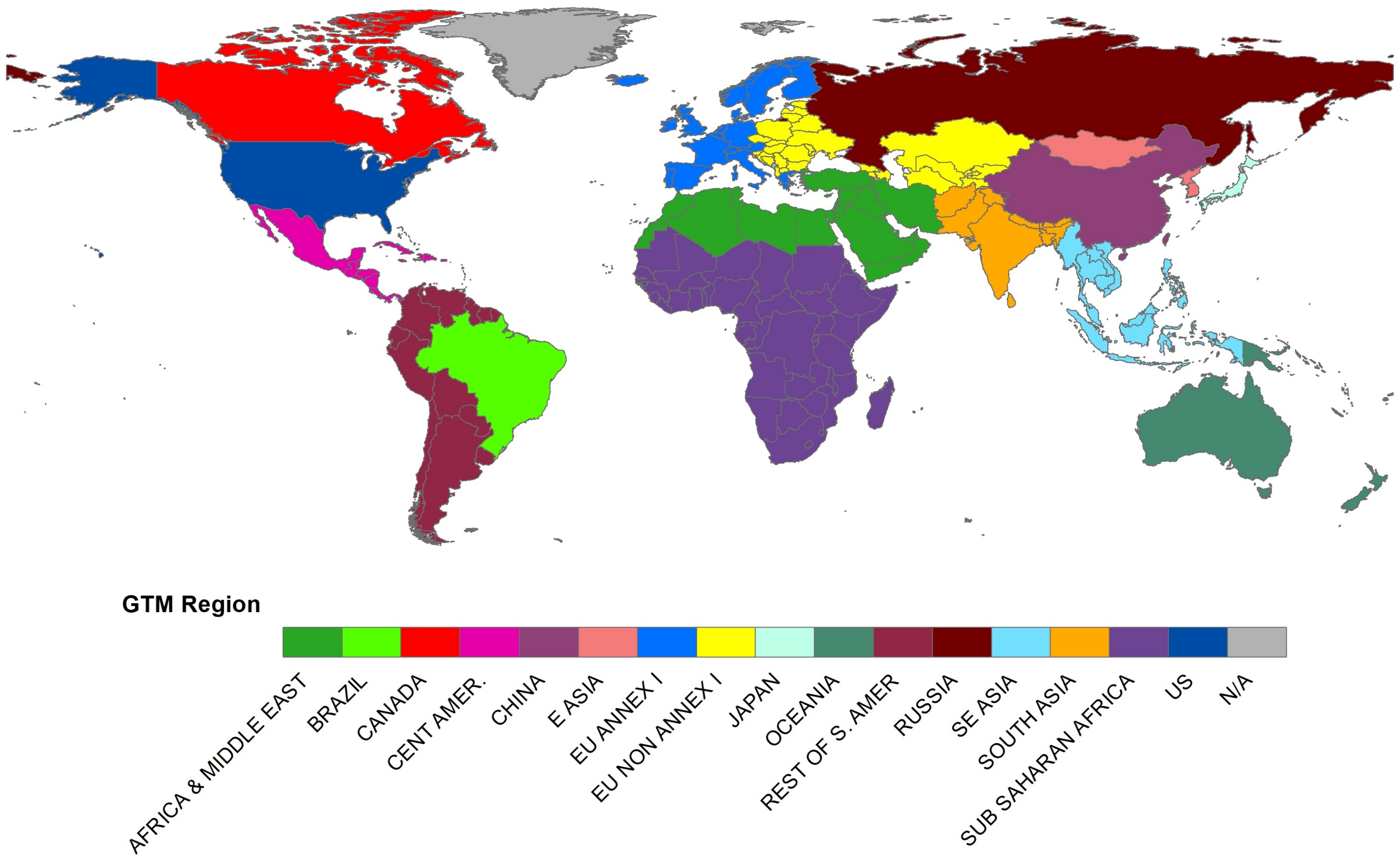
- Account for time
  - ➔Moving forests across time is costly
  - ➔Some leakage happens further in the future because prices have increased.
  - ➔Some leakage, or reduction in leakage, happens because people invest in forests.

Range of leakage estimates (Pan et al., 2020)

[28] Baylis et al. (2013)
[29] Kuik (2014)
[30] Alix-Garcia et al. (2012)
[31] Fortmann et al. (2017)
[32] Kim et al. (2014)
[33] Acosta-Morel (2011)
[34] Sohngen and Brown (2004)
[35] Meyfroidt and Lambin (2009)
[36] Murray et al. (2004)
[37] Zech and Schneider (2019)
[38] González-Equino et al. (2017)
[39] Sun and Sohngen (2009)
[40] Wear and Murray (2004)
[41] Jadin et al. (2016)
[42] Gan and McCarl (2007)
[43] Kallio et al. (2018)
[44] Kallio and Solberg (2018)
[45] Nepal et al. (2013)
[46] Hu et al. (2014)



This analysis with Global Timber Model



- 300+ land classes in 16 regions. Each region represented by multiple forest types / species
- Each forest type is defined by yield curve, age class distribution, management and harvest costs, land rental, etc.
- Forward looking agents,
- Run over 200 years

GTM Leakage Scenarios

2 ‘project type’ scenarios run across various forest biomes:

1. **Extended rotation (i.e., deferred harvests).** Increase in rotation length, implemented via changing the optimum harvest age of harvest for a given forest type (e.g., US Southern Pine) by 10 years.

2. **Forest set-asides (i.e., permanent conservation).** Decrease the total area of forest available for management and harvest via reducing the ‘accessible’ forest acreage

Implementation rates: 2-50% of eligible forest type forest area

Enrollment from 2020-2100+

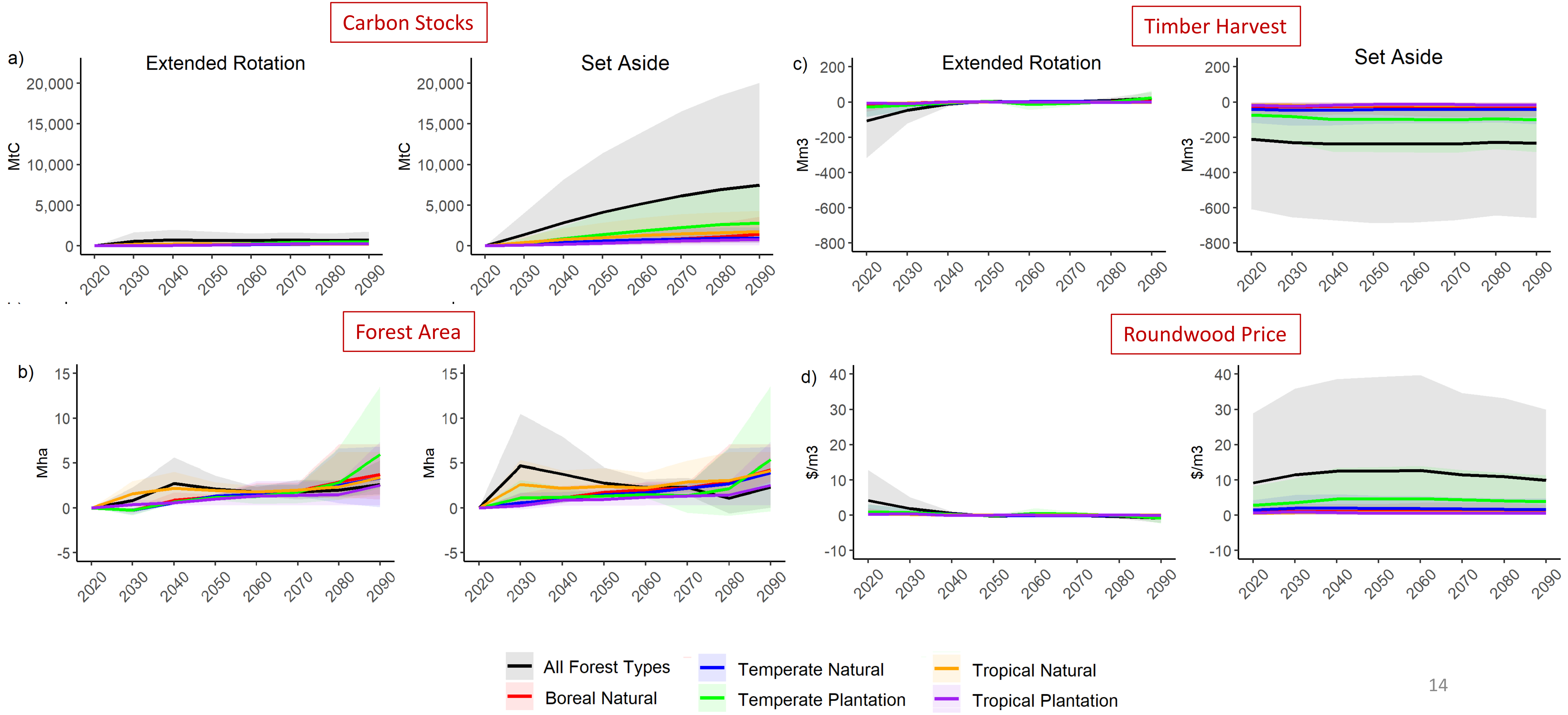
Measure over 10 to 80-year timeframes

No Forest Carbon Policy – Global Baseline

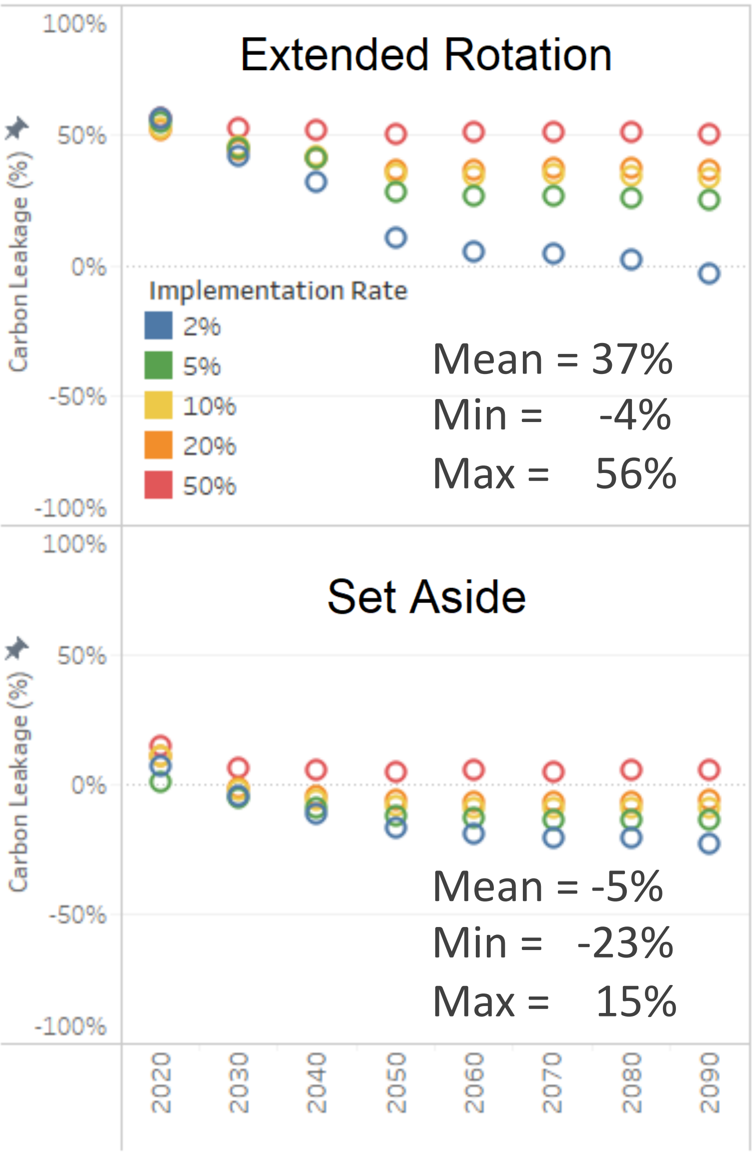
Year	Forest Area (Mha)	Forest Carbon Stock (GtC)	Annual Forest C Flux* (MtC/yr)	Annual Timber Harvest (Mm3/yr)	Roundwood Price ($/m3)
2020	3,899	957	-239	2,259	$86
2030	3,911	959	-467	2,354	$103
2040	3,866	964	-634	2,461	$114
2050	3,837	970	-761	2,568	$119
2060	3,818	978	-817	2,608	$124
2070	3,806	986	-870	2,797	$121
2080	3,803	995	-958	2,826	$124
2090	3,801	1,004	-920	3,062	$120
2100	3,800	1,013	-911	3,168	$122
Annual Change	-1.2	0.73	-8.4	11	$0.45
Annual Change (%)	-0.03%	0.1%	1.7%	0.4%	0.4%

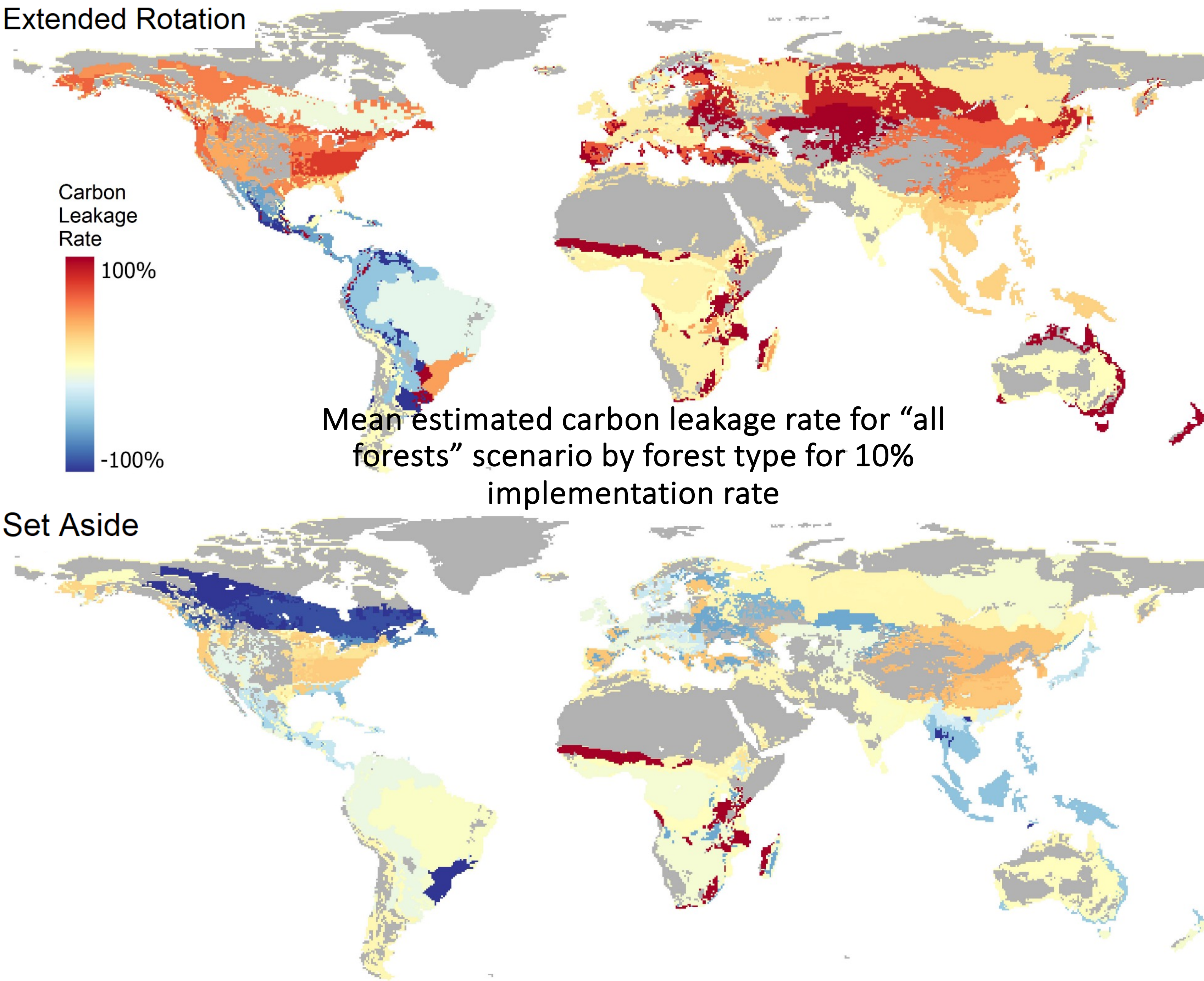
*Negative number indicates net increase in forest carbon sequestration (i.e., larger carbon sink)

Forest Carbon Policy Scenario Impacts
Change from Baseline



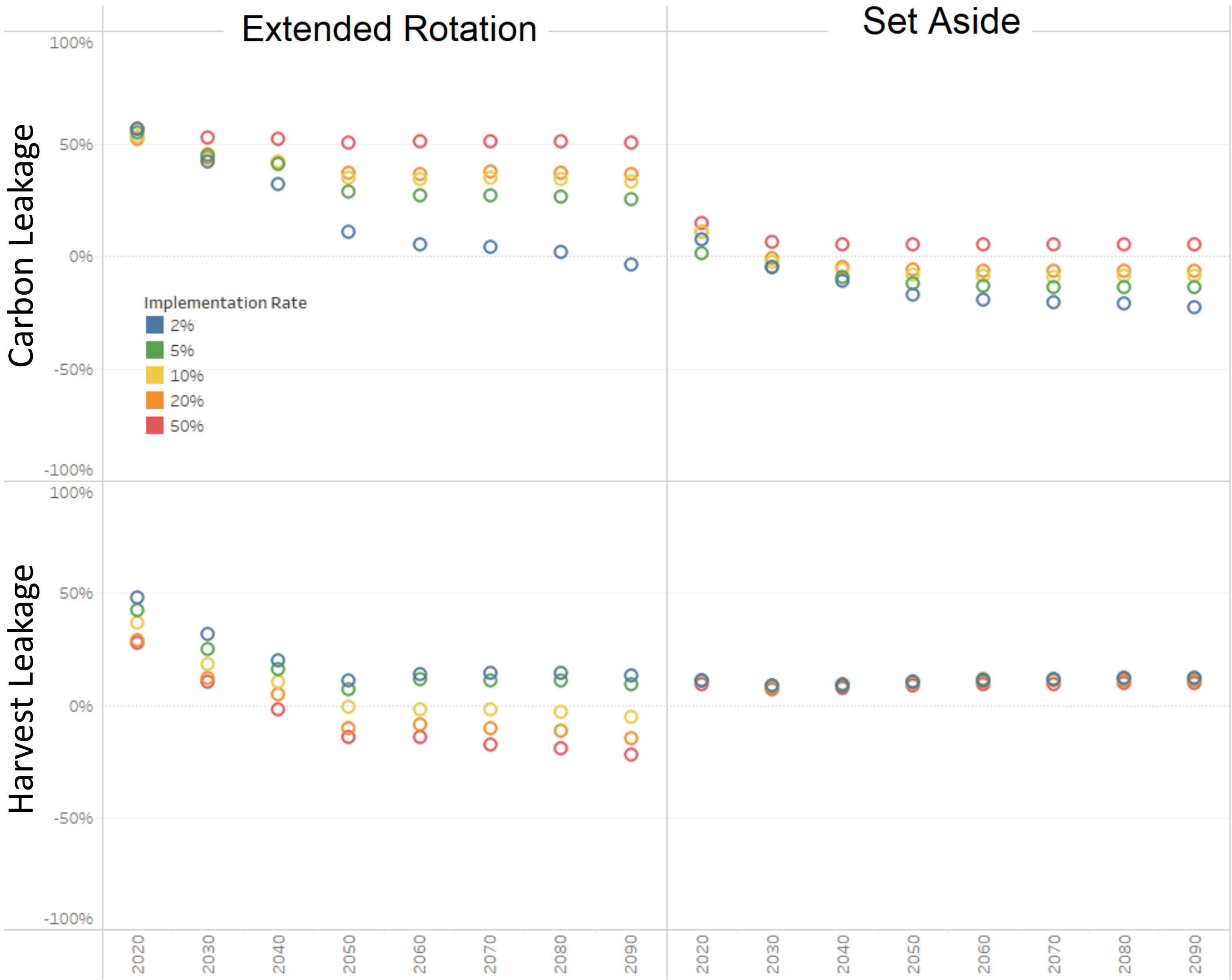
Global Carbon Leakage





Mean estimated carbon leakage rate for “all forests” scenario by forest type for 10% implementation rate

Carbon vs. Harvest Leakage



Leakage Estimates Summary Stats
(All implementation rates)

Scenario	Metric	Carbon Leakage	Harvest Leakage
Extend Rotation	Mean	37%	7%
	Min	-4%	-22%
	Max	56%	48%
Set Aside	Mean	-5%	10%
	Min	-23%	7%
	Max	15%	12%

Carbon v. Harvest Leakage Correlation

Scenario	2%	5%	10%	20%	50%
Extend Rot.	0.92	0.94	0.99	0.99	0.94
Set Aside	-0.45	-0.50	-0.37	0.06	0.06

Forest carbon projects have the potential to create leakage, which is driven by four major factors

FOREST TYPE & REGION

Forest carbon leakage is higher in regions and forest types with high intensity forestry production, as those systems produce more volume per unit area. Therefore, a forest carbon project in more intensively-managed forest removes more volume from the market, leading to the harvest of increasingly inefficient trees.

Scenario	Leakage
Extended Rotation, 10% enrollment, 50-yr time horizon, **Temperate Plantation Forest Biome**	+40%
Extended Rotation, 10% enrollment, 50-yr time horizon, **Tropical Natural Forest Biome**	-27%

MEASURED TIME HORIZON

Forest carbon leakage is lower when measured over a longer time period, as landowners respond to project-induced market shocks with long-term shifts in management timing and intensity.

Scenario	Leakage
All Forests, Extended Rotation, 10% enrollment, **20-yr measured time horizon**	+49%
All Forests, Extended Rotation, 10% enrollment, **50-yr measured time horizon**	+42%
All Forests, Extended Rotation, 10% enrollment, **80-yr measured time horizon**	+39%

PROPORTION ENROLLED

As the proportion of land enrolled in a carbon project increases, the number of unencumbered trees available for harvest decreases. Carbon leakage is higher where there is a higher proportion of forests enrolled in a carbon project because it forces the harvesting of more costly, less productive areas. Thus, higher project implementation rates results in less efficient market responses.

Scenario	Leakage
All Forests, Extended Rotation, 50-yr time horizon, **2% enrollment**	+29%
All Forests, Extended Rotation, 50-yr time horizon, **20% enrollment**	+42%

FOREST CARBON PROJECT TYPE

Forest carbon leakage varies based on the practice applied, as each creates different market signals. These signal stimulate investment in forests with high carbon and product yield. The management response is larger for set asides than extended rotations because they cause timber to permanently leave the market.

Scenario	Leakage
All Forests, **Extended Rotation,** 50-yr time horizon, 10% enrollment,	+42%
All Forests, **Set Asides,** 50-yr time horizon, 10% enrollment,	-3%

Positive leakage (+X%) indicates that leakage detracts from overall project mitigation

Negative leakage (-Y%) indicates project activities create additional spillover benefits

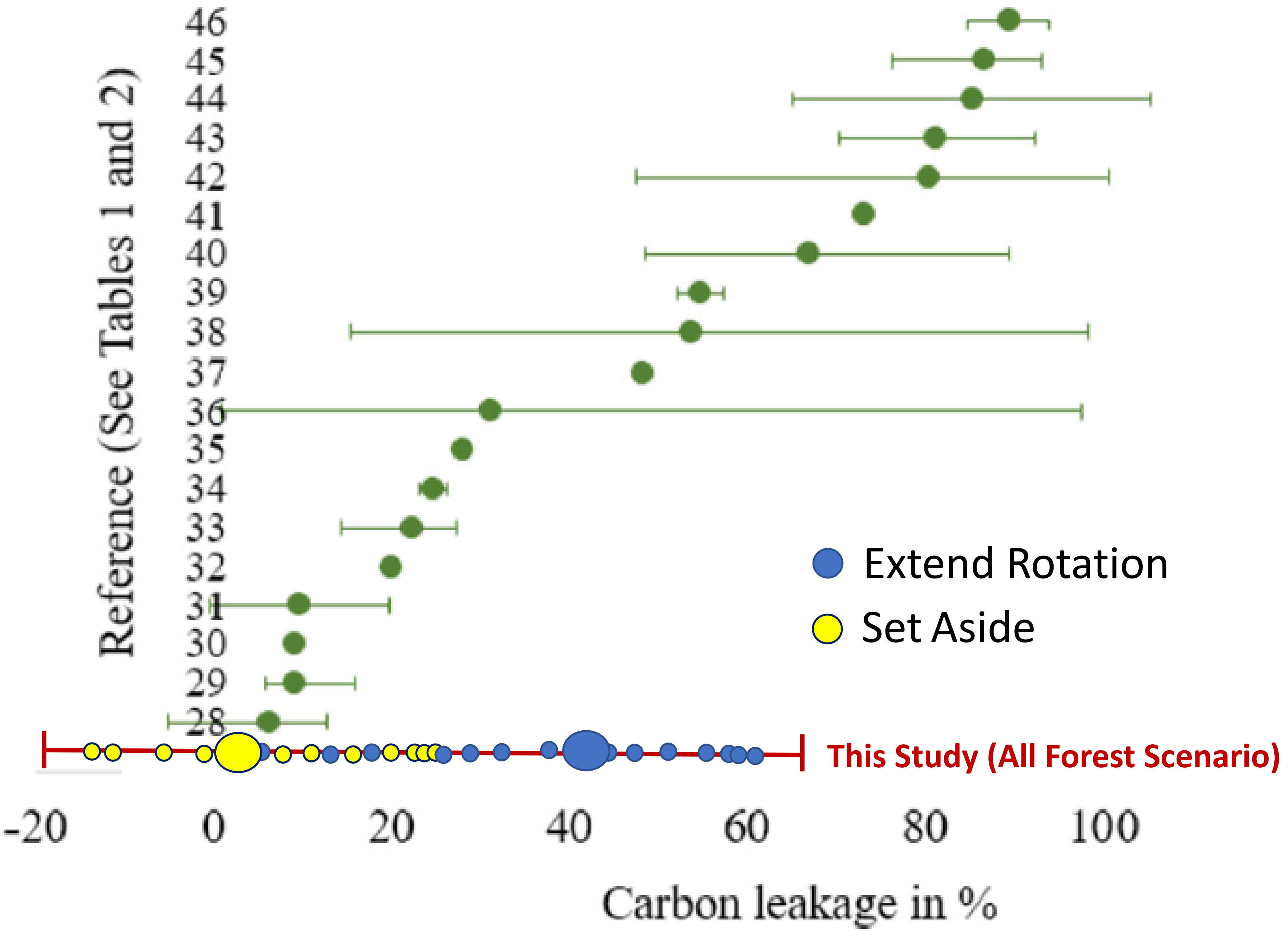
Discussion

- GTM forward-looking optimization model, rational agents
  - Early adjustments in anticipation of future conditions

- Model responds to harvest reductions via mix of *intensification* (e.g., improved management) and *extensification* (i.e., afforestation)
  - Changes in areas already heavily forested w/existing infrastructure

- What is the 'right' leakage policy scenario to model?
  - Forests across the globe have potential to enroll → 'all forests'
  - Start with lower implementation but then ramp up over time?

Pan et al (2020) Carbon Leakage Meta Analysis



This Leakage Study Estimates

Scenario	Metric	Carbon Leakage
Extend Rotation	Mean	37%
	Min	-4%
	Max	56%
Set Aside	Mean	-5%
	Min	-23%
	Max	15%

Leakage Estimation Summary

- Leakage rates highly variable across projects and implementation rates
  - Many instances of ‘negative’ leakage → positive spillovers
  - Higher implementation → larger market signal and response to harvest/price shocks
- Leakage rates often decline over time-length of measurement
  - Non-project forests can ‘mitigate’ leakage impacts, but takes time
- Set asides have lower leakage rates → higher price change drives more investment in management of non-project forests
  - Mix of intensive and extensive actions
- Carbon and harvest leakage rates weakly negatively correlated
  - Suggests we should not combine for project leakage deduction

What the 'Right' Rate for *Global* Carbon Leakage?

<u>'Current'</u> forest carbon project implementation and coverage:

- Extended rotation: +15% to +35%
- Set asides: -15% to -10%

<u>Optimistic</u> about global forest carbon market growth and coverage:

- Extended rotation: +35% to +40%
- Set asides: -5% to 0%

Want to learn more?

Daigneault, A., Sohngen, B., Belair, E., Ellis, P. (2023). "A Global Assessment of Regional Forest Carbon Leakage." Preprint available on Research Square.

https://www.researchsquare.com/article/rs-3596881/v1

Preprint includes links to detailed results and model.

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Biological Sciences - Article

A Global Assessment of Regional Forest Carbon Leakage

Adam Daigneault, Brent Sohngen, Ethan Belair, Peter Ellis

This is a preprint; it has not been peer reviewed by a journal.

https://doi.org/10.21203/rs.3.rs-3596881/v1

Abstract

Globally, improved forest management (IFM) practices are recognized as powerful, low-cost natural climate solutions, but carbon leakage may reduce project efficacy, and uncertainty about the impact of leakage may result in underinvestment in improved forest management. While some carbon project protocols deduct predicted leakage impacts before issuing credits, the methods and rates applied are extrapolated from a small amount of evidence. This paper applies a data-driven approach to quantify project-level forest leakage impacts at regional and global scales. We use a dynamic global forest sector model to estimate the leakage effects of two forest carbon project interventions under varying implementation rates and conditions: extended rotations and permanent set asides. We then apply statistical methods to identify key drivers of varying leakage estimates. We find that leakage is considerably lower than expected—carbon leakage rarely passes 50% and is often negative—especially in the tropics and for set asides. However, rates vary considerably by policy design and are influenced by the project type, measurement period, project implementation rate, and dynamic market and ecological response to harvest schedule changes. The regionalized, condition-specific leakage estimates from this paper provide the most detailed global assessment of carbon project leakage yet assembled. These data provide an evidence base from which to discount forest management carbon projects where needed and can help ensure accurate accounting of IFM interventions' net climate benefit.

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