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Economics of Greenhouse Gas Mitigation in Forestry and Agriculture: a National Assessment

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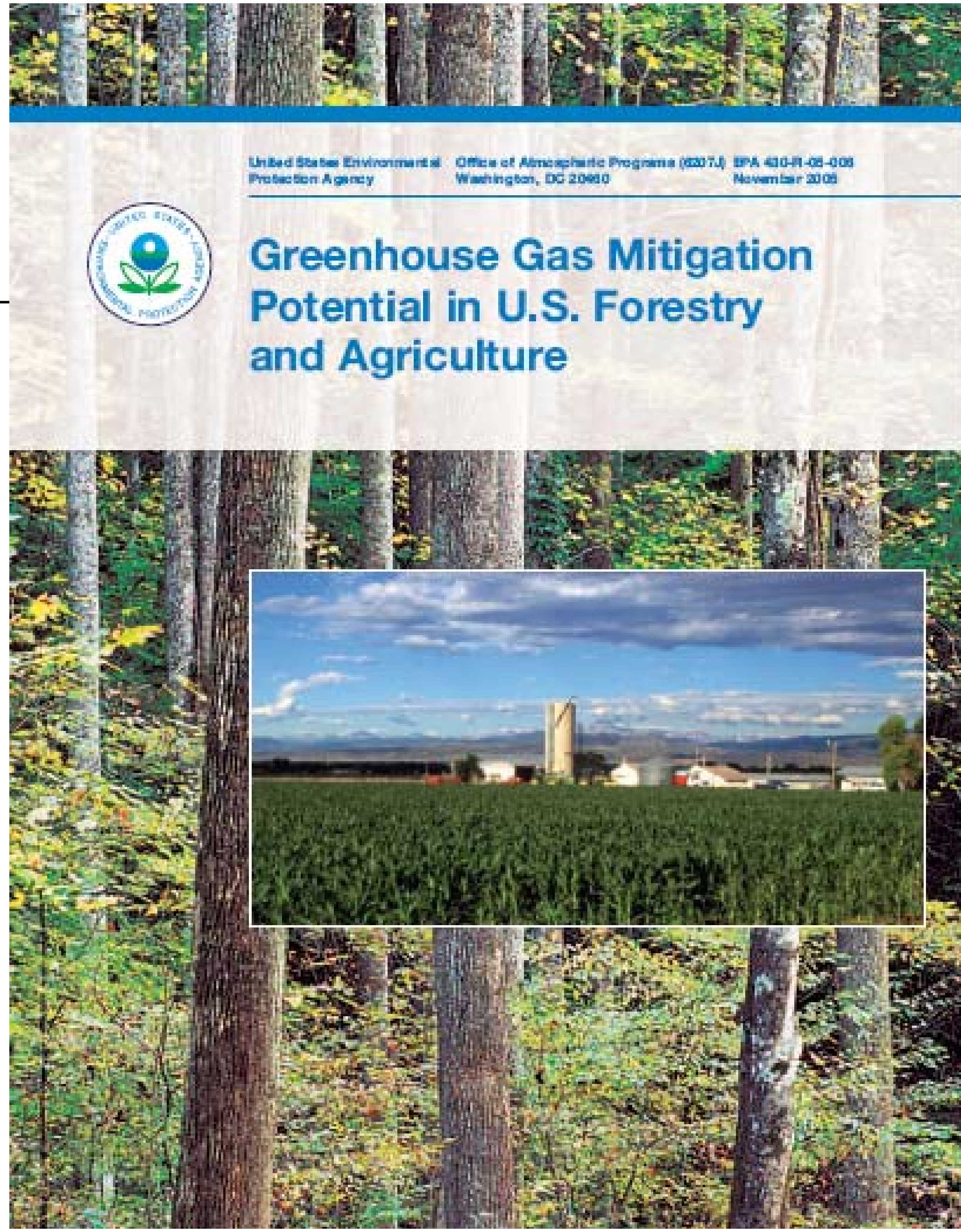
Funding and Collaborators

- **Primary Funding:** US EPA, Climate Change Division to RTI International
- **Collaborators**:
- ✓ Assessment Report team: Ken Andrasko & Ben DeAngelo (EPA), Brent Sohngen (RTI, Ohio State), Allan Sommer (USDA/NRCS), Kelly Jones (RTI),
- ✓ FASOMGHG team: Bruce McCarl (Texas A&M), Darius Adams (Oregon State), Ralph Alig (US Forest Service), Brooks Depro (RTI), Dhazn Gillig (American Express), Heng-chi Lee (U Western Ontario)



http://www.epa.gov/sequestration/greenhouse_gas.html

Central Questions

- What is the **total GHG mitigation potential** of the full suite of forestry and agricultural activities over time and at different costs?
- **How does the portfolio of forestry and agricultural activities change** over time and at different levels of GHG reduction incentives (or “GHG prices”)?
- What is the **regional distribution** of GHG mitigation opportunities within the United States?
- What are the implications of **carbon saturation and reversibility** (or duration)?
- How do **leakage and other implementation issues** affect GHG mitigation benefits?
- What are some of the **non-GHG environmental co-effects** of GHG mitigation activities?
- What appear to be the **top mitigation options**, nationally and regionally, taking GHG, economic, implementation, and other environmental factors into account?

Mitigation Options in Forestry and Agriculture: Sequestration, Emissions Reduction and Biofuels

Sequest-ration

Strategy	Mitigation Activities	Target GHG
Afforestation	Convert agricultural lands to forest	CO_2
Forest management	Lengthen timber harvest rotation Increase forest management intensity Forest preservation Avoid deforestation	CO_2
Agricultural soil carbon sequestration	Crop tillage change Crop mix change Crop fertilization change Grassland conversion	CO_2

Emissions reduction

Fossil fuel mitigation from crop production	Crop tillage change Crop mix change Crop input change Irrigated/dry land mix change	CO2
Agricultural CH4 and N2O mitigation	Crop tillage change Crop mix change Crop input change Irrigated/dry land mix change Enteric fermentation control Livestock herd size change Livestock system change Manure management Rice acreage change	CH4 N2O

Biofuels

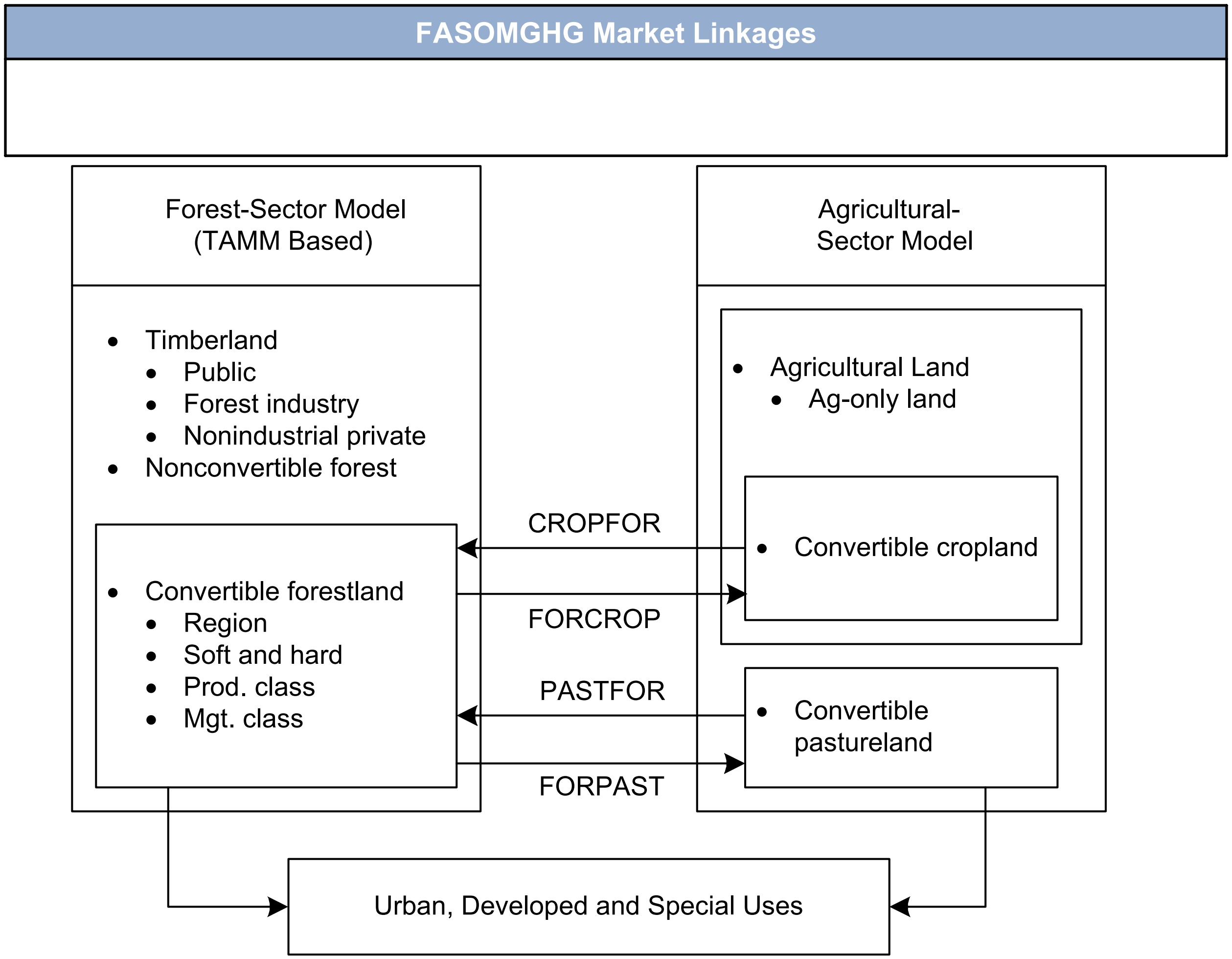
Biofuel offsets	Produce crops for biofuel use	CO2

Opportunity cost: Determinant of mitigation supply

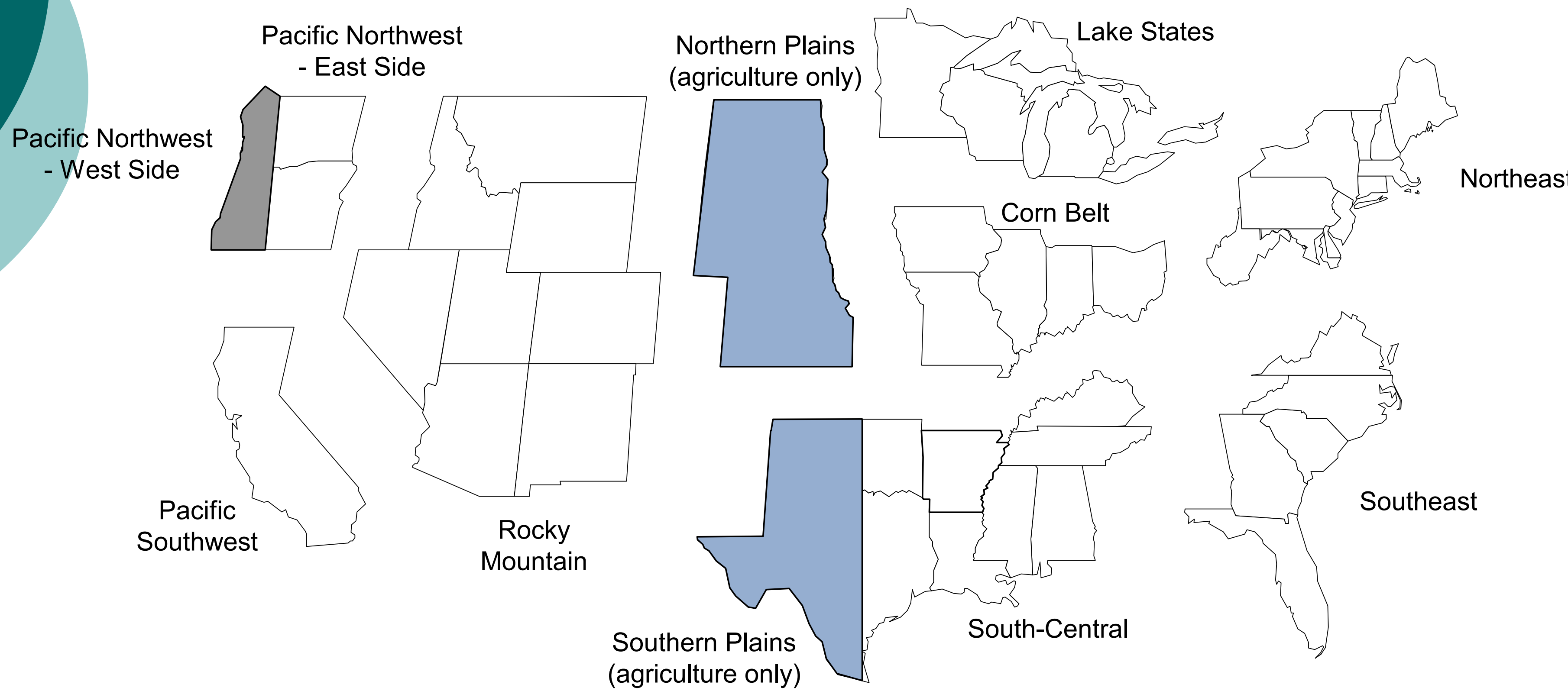
- **Practice 1 (High emitting)**
  - Net income = $100/ac/yr
- **Practice 2 (Low emitting)**
  - Net income = $80/ac/yr
  - Sequesters (or reduces emissions) = 1 ton CO_2/yr
- **Will adopt Practice 2 (mitigate) if paid at least $20/ton CO_2**

- Economic analysis requires a model that **captures the simultaneous effects of land use, management adoption decisions, and market feedback**
  - FASOMGHG (McCarl et al): A sector market model

FASOMGHG Model links commodity markets and land use



FASOMGHG Regions



Simulating Effects of a GHG Price for Forest and Agricultural Practices

Note: CO_2 being traded for ~$30/ton
In EU trading system

Prices Paid for GHG Mitigation
($1-50 per t CO_2)

FASOMGHG
Economic Model of US Forest and Agriculture Sector

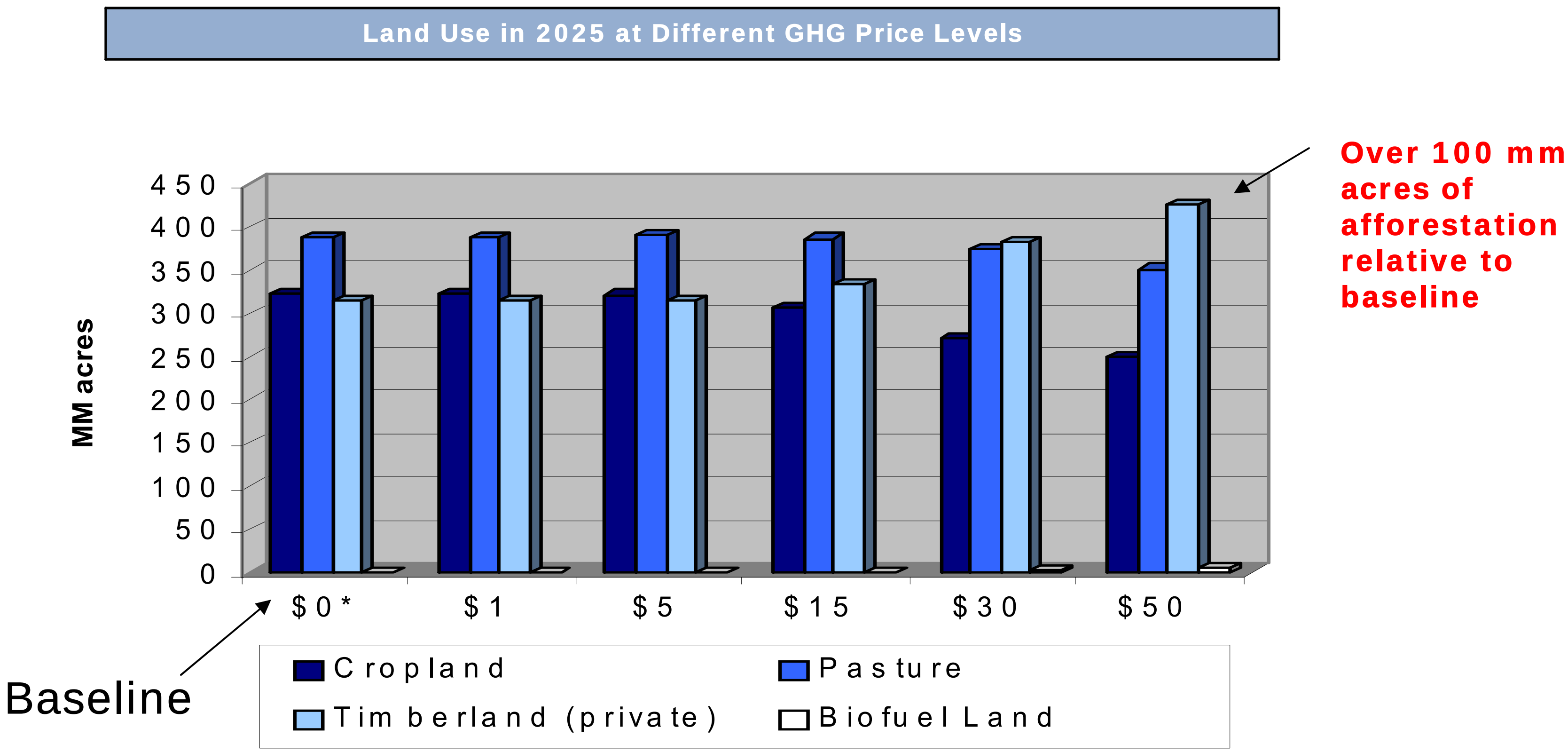
GHG Mitigation by
- Sector
- Activity
- Region
- Time Period

Non-GHG Co-effects
- Erosion
- Nutrients
- Pesticides

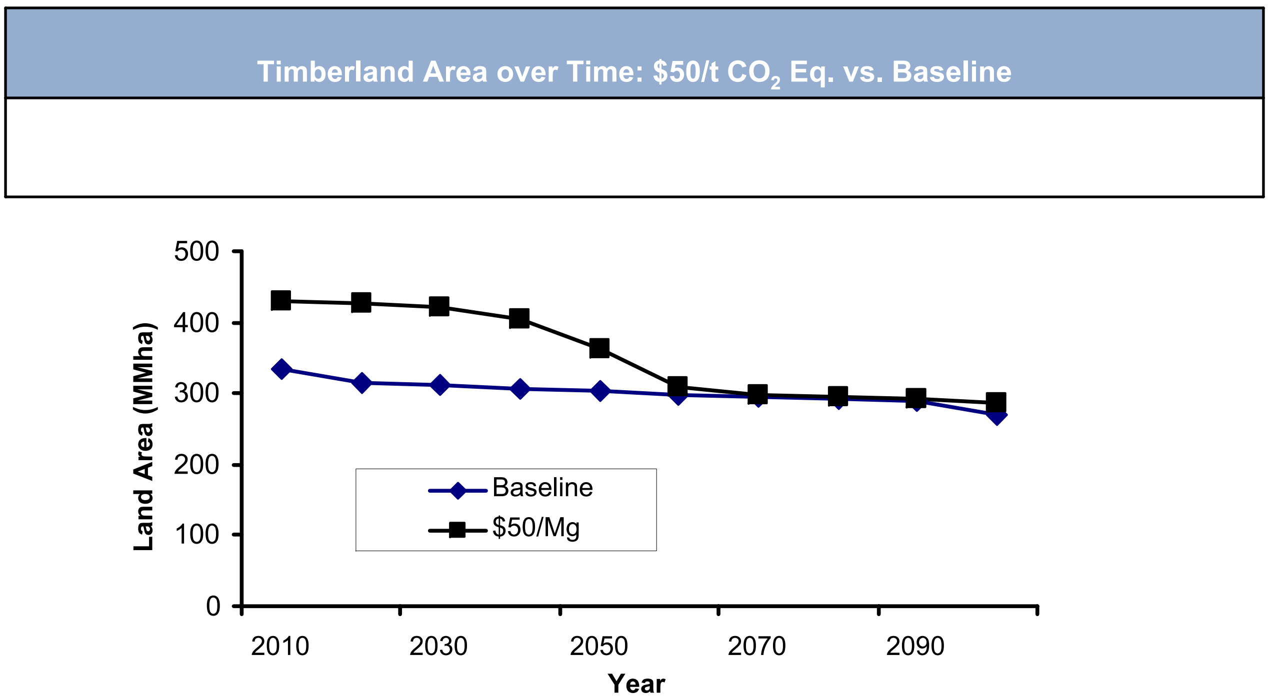
Key results

- **GHG reduction incentives** can generate **substantial mitigation** from the U.S. forest and agriculture sectors **especially in the first few decades.**
- **If GHG prices rise over time**, however, GHG mitigation is shown to **start low and increase** over time.
- The **optimal portfolio and timing** of mitigation strategies are affected by the GHG price levels
- **Agricultural CH4 and N2O mitigation** is a relatively small but steady part of the mitigation portfolio
- Mitigation potential is likely to have a **regional, uneven distribution**
- **If** a national GHG mitigation quantity in a given year is an objective, but **economic incentives do not continue** after that date, then carbon sequestered in previous decades is likely to be **reversed**
- **Leakage** of GHG benefits from management activities in one region to other regions **may be significant** in scenarios where only selected activities (e.g., afforestation) are eligible for inclusion in a mitigation scheme
- **Large changes in land use** and production due to mitigation activities can have substantial **non-GHG environmental co-effects**
- Several **key issues related to the design** of an incentive system can affect the magnitude, timing, and duration of GHG benefits and cost

GHG economic incentives change the way that land is allocated



Land use change is not necessarily permanent



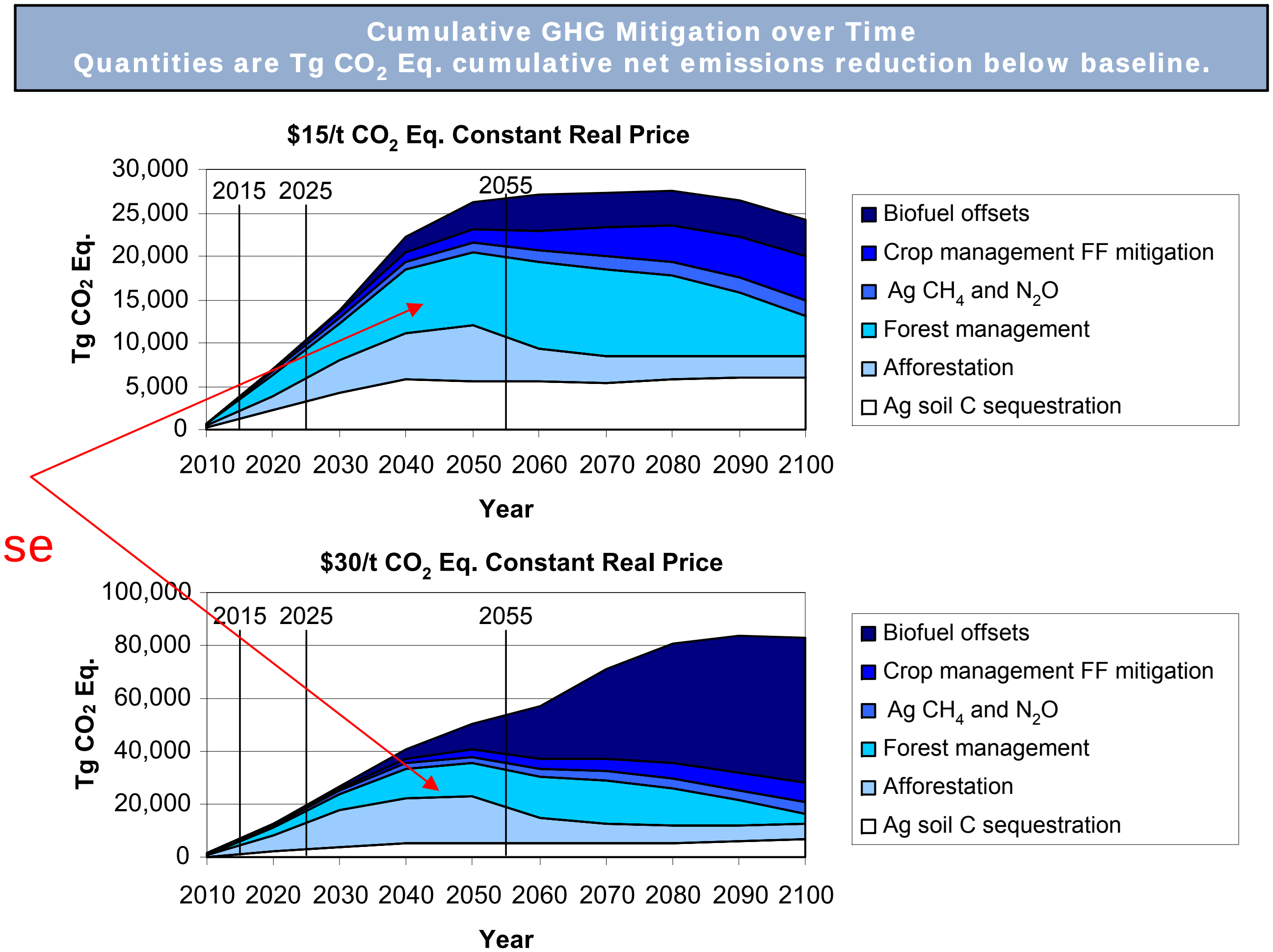
National GHG Mitigation Totals by Key Activity:

Annualized Averages, 2010–2110

	GHG Price ($/ ton CO_2)				
Activity	**$1**	**$5**	**$15**	**$30**	**$50**
Afforestation	0.0	2.3	137.3	434.8	823.2
Forest management	24.8	105.1	219.1	314.2	384.8
Agricultural soil carbon sequestration	62.0	122.7	168.0	162.4	130.6
Fossil fuel mitigation from crop production	20.5	31.9	53.1	77.6	95.7
Agricultural CH_4 and N_2O mitigation	9.4	15.2	32.0	66.8	110.2
Biofuel offsets	0.0	0.1	57.2	374.6	560.9
All Activities	116.8	277.3	666.7	1,430.4	2,105.4

Cumulative mitigation peaks, reverses (sequestration dynamics)

C reversal through harvesting and land use reversion



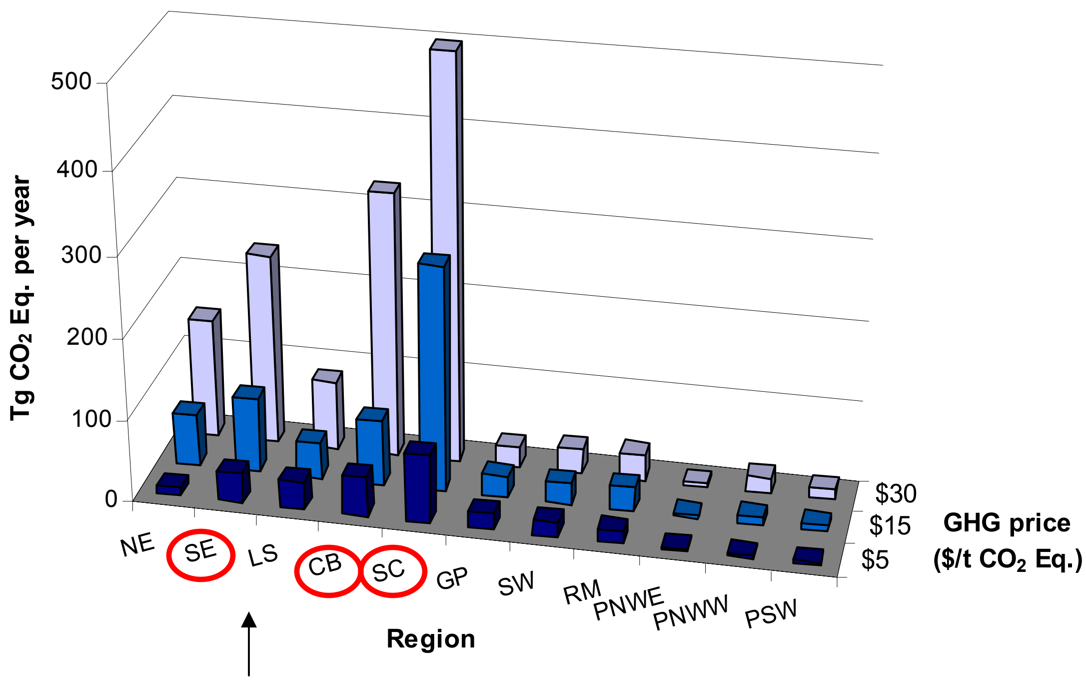
Opportunity Matrix

	Low price	*High Price*
Short-run	**Aricultural Soil C Sequestation** **Forest management**	**Afforestation**
Long-run	**Forest management**	**Afforestation** **Biofuels**

Issue: Forest management can be difficult to measure, monitor, and compare to baseline

Potential is not uniform across regions

Total Forest and Agriculture GHG Mitigation by Region
Quantities are Tg CO2 Eq. per year net emissions reduction below baseline, annualized over the time period 2010–2110.



Opportunities primarily in the eastern US

Top 10 region/activity combinations shift with GHG price

		GHG Constant Price Scenario ($/t CO_2 Eq.)				
Region	**Activities**	**$1**	**$5**	**$15**	**$30**	**$50**
SC	Forest management	1	1	1	3	3
CB	Agricultural soil carbon sequestration	2	2	4	7	10
LS	Agricultural soil carbon sequestration	3	3	6		
GP	Agricultural soil carbon sequestration	4	5	7		
SW	Fossil fuel mitigation from crop production	5	7			
RM	Agricultural soil carbon sequestration	6	8			
SC	Fossil fuel mitigation from crop production	7	6	8	10	
NE	Agricultural soil carbon sequestration	8	9			
CB	Fossil fuel mitigation from crop production	9	10			
CB	Agricultural CH_4 and N_2O mitigation	10				
SE	Forest management		4	3	6	8
SC	Afforestation			2	1	2
NE	Biofuel offsets			5	4	5
RM	Afforestation			9		
SW	Agricultural soil carbon sequestration			10		
CB	Afforestation				2	1
SE	Biofuel offsets				5	4
SC	Biofuel offsets				8	6
CB	Biofuel offsets				9	7
LS	Afforestation					9

Pay per Acre vs per Ton (Paying for "Practice vs Performance")

Table 6-7: Per-Acre vs. Per-Tonne Payment Approaches for Afforestation: 2015 and 2010–2110 Annualized

	Payment Scenario		
	$15/t CO_2 Eq.	**$100/Acre Uniform**	**$100/Acre Productivity Based**
Year 2015			
GHG mitigated (Tg CO_2 Eq. per year)	88.8	23.5	89.9
Net afforestation (MM acres)	10.1	5.1	11.3
Over 2010–2110 projection period (annualized)			
GHG mitigated through afforestation (Tg CO_2 Eq. per year)	137.4	41.9	68.6
Value of GHG payments (billion $ per year)	$1.36	$0.79	$1.06

Most efficient — Least efficient — More efficient

Leakage is focused primarily in the forest sector

Leakage Estimates by Mitigation Activity at a GHG Price of $15/t CO_2 Eq.
All quantities are on an annualized basis for the time period 2010–2110.

Selected Mitigation Activities	A GHG Effects of Targeted Payment (Tg CO_2 Eq.)	B Net GHG Effects of All Activities (Tg CO_2 Eq.)	C Indirect GHG Effects from Nontargeted Activity[a] (Tg CO_2 Eq.)	D Leakage Rate[b] (%)
Afforestation only	137	104	–33	24.0
Afforestation + forest management	338	348	10	–2.8
Biofuels	84	83	–1	0.2
Agricultural management	230	231	1	–0.1
Agricultural soil carbon	154	145	–9	5.7

[a]Indirect effects: C = (B – A).
[b]Leakage rate: D = –(C/A) * 100; rounding occurs in table.
Note: Negative leakage rate in D refers to beneficial leakage (i.e., additional mitigation outside the selected activity region, also called positive leakage).

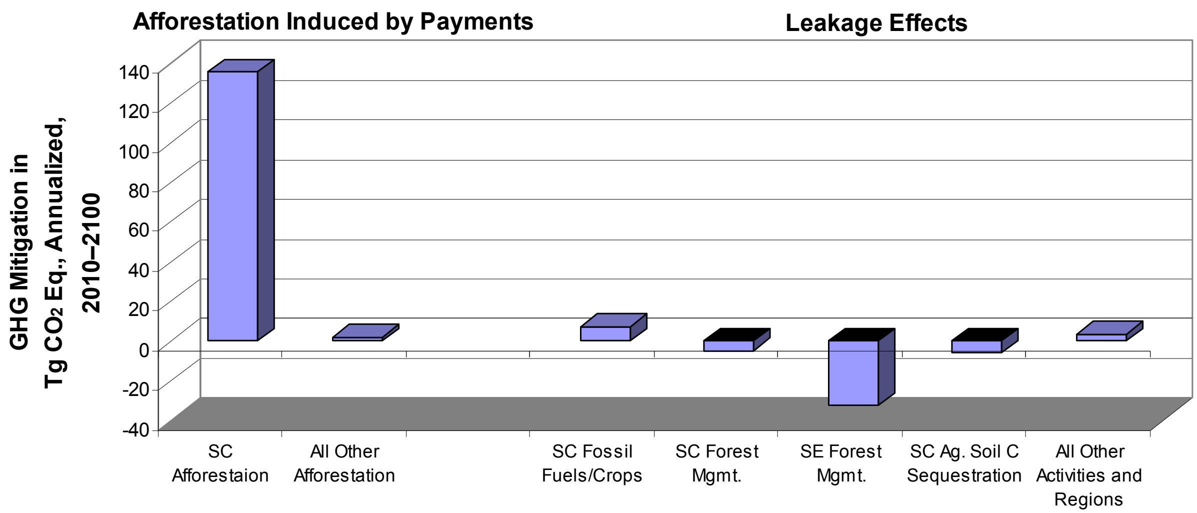
Worth considering

Fairly minimal

When you combine incentives within the forest sector, leakage disappears

Leakage occurs across regions and activities

Regional Leakage Flows for Afforestation-Only Payment Scenario: $15/t CO_2 Eq.
Note: Negative sign (e.g., South-Central Forest Mgmt.) is leakage, and positive sign is beneficial leakage (i.e., additional mitigation outside targeted activity region).

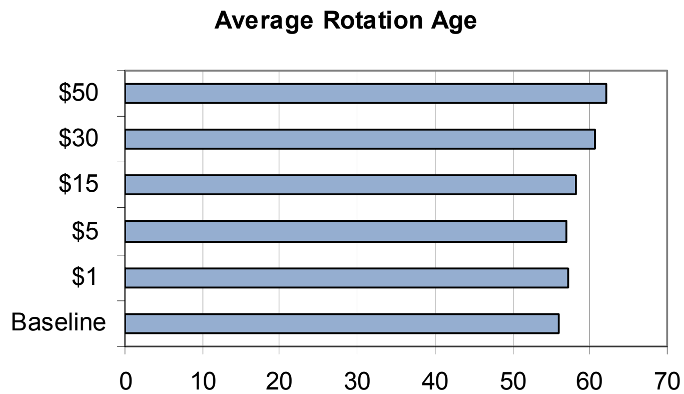


Environmental Co-effects of Forest Carbon Sequestration Strategies

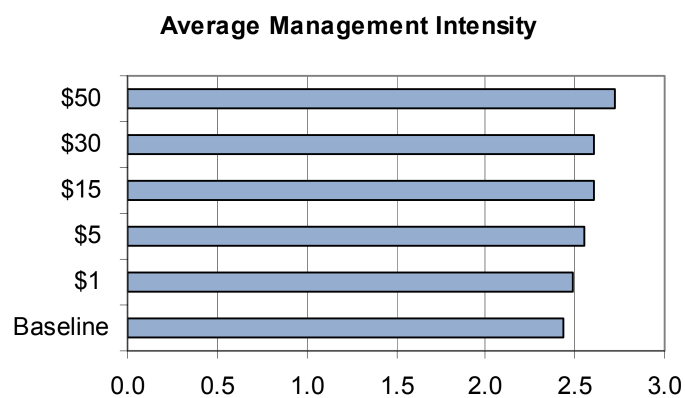
- ✓Forest Structure/Habitat
- ✓Water quality
- ✓Water quantity

GHG Pricing Effects on Forest Structure

Effect of GHG Prices on Forest Management Variables, 2015



Carbon prices lengthen timber rotations



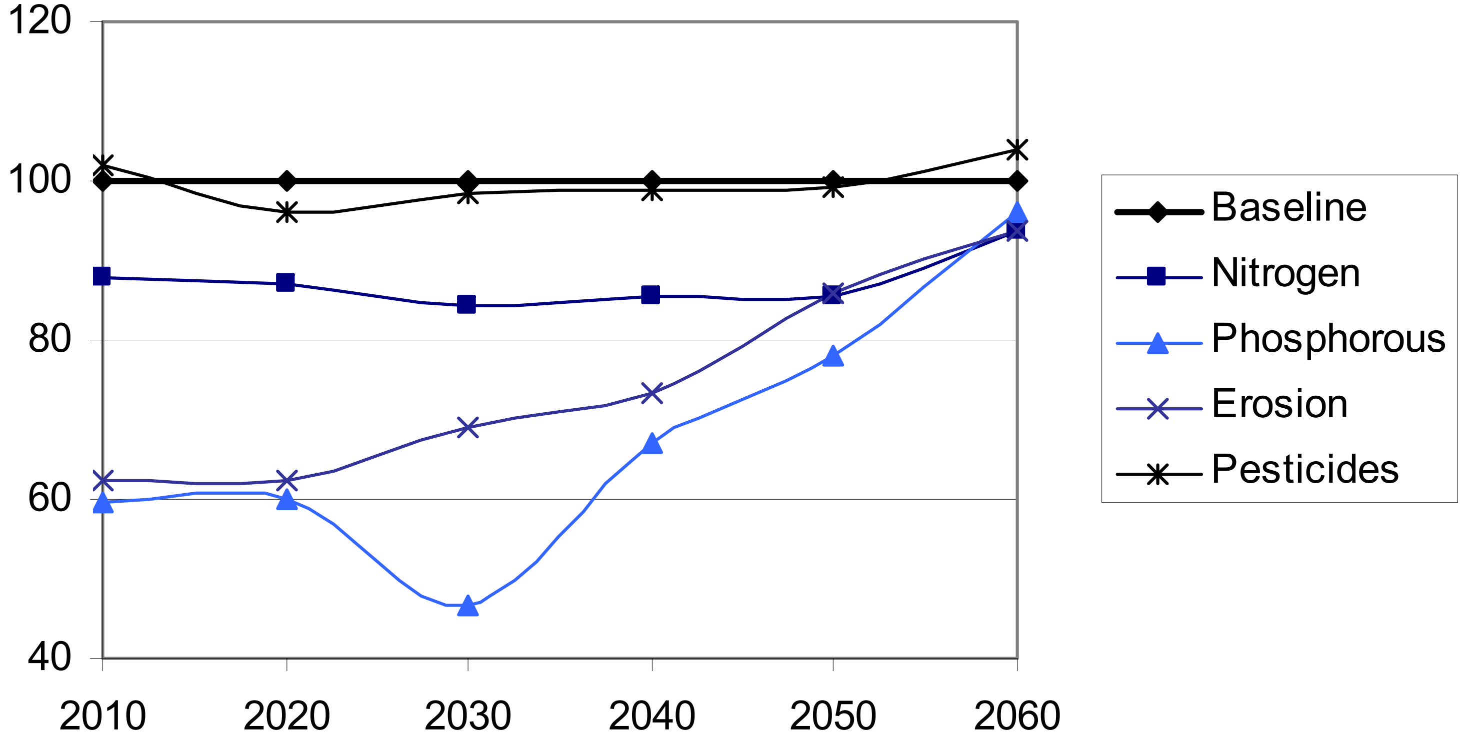
Carbon prices increase management intensity (plantations, silvicultural inputs)

GHG Mitigation and Water Quality Co-benefits

Changes in land use to sequester carbon can reduce erosion, nutrient runoff, and pesticide use to the benefit of water quality

Reduced runoff

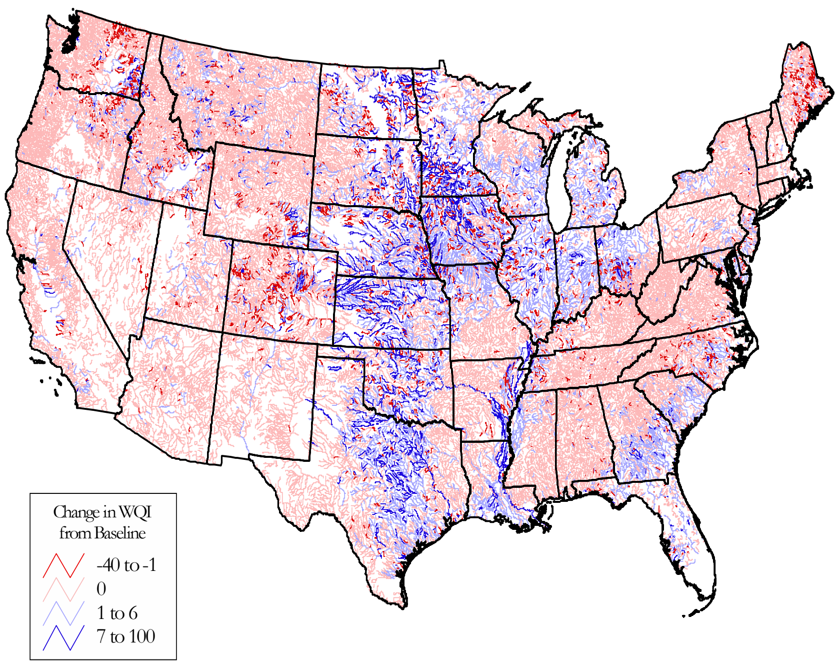
Pollutant Loading Effects Over Time of a $15 / t CO_2 Eq. GHG Price
Note: All values indexed to a baseline value of 100.



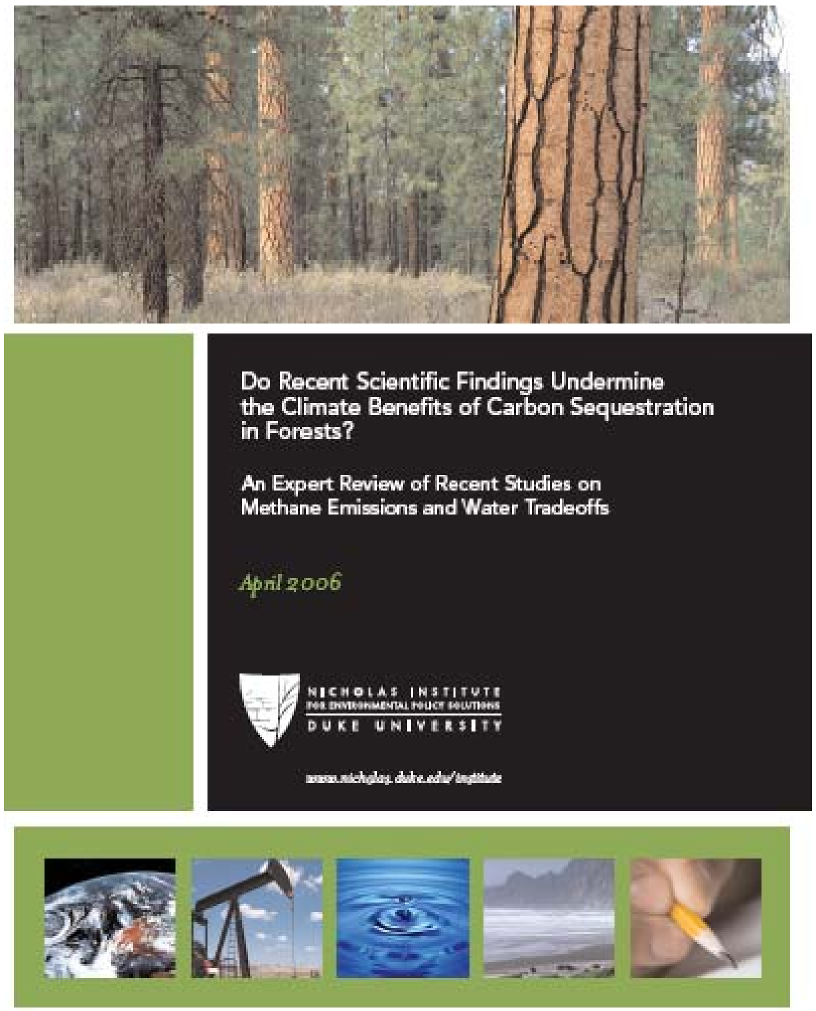
Changes in Water Quality Index (WQI):

$50/Tonne C (~$15/tonne CO_2)

- Linked national FASOMGHG model with RTI national water quality model (NWPCAM) to simulate water quality effects of GHG mitigation in Ag/land use
- Found overall improvements in water quality nationally and in most regions
- Pattanayak et al, 2005 Climatic Change



Do Recent Findings Undermine the Value of Forest Carbon Sequestration?



Water stresses from plantations

R.B. Jackson, E.G. Jobbagy, R. Avissar, S.B. Ray, D.J. Barrett, C.W.Cook, K.A. Farley, D.C. le Maitre, B.A. McCarl, and B.C. Murray.Dec 2005. Trading water for carbon with biological carbon sequestration. Science. 310:1944-1947.

Methane emissions from plants/trees

Keppler, J.T.G. Hamilton, M.Bras, and T. Rockmann. Jan 2006.Methane emissions from terrestrial plants under aerobic conditions. Nature. 439:187-191.

Conclusion: Both studies, while important, do not substantially undermine sequestration as a mitigation strategy

http://www.env.duke.edu/institute/methanewater.pdf

Summary

- Carbon sequestration in forests and agriculture have tremendous biophysical potential to offset GHG emissions
- Cost per ton is less than many alternatives for emission reduction
- The mitigation portfolio changes with the GHG price
  - Lower Prices: Ag and Forest C management
  - Higher Prices: Afforestation and Biofuels
- Most C sequestration opportunities concentrated in the South and Midwest
- Policy design matters
  - Per ton vs per acre
  - Targeted programs can cause leakage which undermines net benefits
- Opportunity for water quality co-benefits
  - But other mitigation options in the energy sector have co-benefits too
- Recent scientific findings about some (-) plantation co-effects do not substantially undermine value of forest C sinks as a mitigation strategy
- More work needed on policy scope and implementation

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