Assessing Economic Potential for GHG Offsets in US Agriculture and Forestry

Presented at Workshop on
Transition in agriculture and future land use patterns
LEI, Wageningen University

Bruce A. McCarl, Texas A&M University
Heng-chi Lee University of Western Ontario
Dhazn Gillig, Texas A&M University

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Other Collaborators

- Darius Adams, Oregon State
- Ralph Alig, USDA Forest Service
- Brian Murray, RTI
- Uwe Schneider, University of Hamburg
- Subhrendu Pattanayak, RTI
- Ben DeAngelo EPA
- Ken Andrasko, EPA
- Ron Sands, PNNL, Maryland
- Francisco Delachesnaye, EPA

Basic Components of Talk

Project Goals

Policy Context

Project Scope

Key Findings

Policy implications of results

Directions being Pursued

Project Goals

Examine the portfolio of land based GHG mitigation strategies and identify ones for further scrutiny considering Afforestation, Forest management, Biofuels, Ag soil, Animals, Fertilization, Rice, Grassland expansion Manure, Crop mix

Look at market and time conditions under which strategies dominate

Educate on needed scope of economic analysis

Bring in a full cost and GHG accounting

Look at market effects and co benefits/ costs

Policy Context

U.S. is outside of the context of Kyoto Protocol

U.S. has a largely voluntary policy to reduce GHG emission intensity by 18% by 2012. Intensity is emissions divided by GDP. This commitment is 1/6 the size of Kyoto obligation.

Many U.S. states proceeding unilaterally, Northeast, West Coast, Texas and others.

Virtually all U.S. companies have climate change offices and emissions are becoming of widespread concern

Chicago Climate Exchange is emerging but price low.

I think something will happen, but when?

GHG Offset Strategies in Analysis

Strategy	Basic Nature	CO_2	CH_4	N_2O
Afforestation	Sequestration	X		
Existing timberland	Sequestration	X		
Deforestation	Emission	X		
Biofuel Production	Offset	X	X	X
Crop Mix Alteration	Emiss, Seq	X		X
Crop Fertilization	Emiss, Seq	X		X
Crop Input Alteration	Emission	X		X
Crop Tillage Alteration	Emission	X		X
Grassland Conversion	Sequestration	X		
Irrigated /Dry land Mix	Emission	X		X
Enteric fermentation	Emission		X	
Livestock Herd Size	Emission		X	X
Livestock System Chg	Emission		X	X
Manure Management	Emission		X	X
Rice Acreage	Emission	X	X	X

Analytic Needs

Modeling Responses to GHG Incentives by Ag & Forests

- **Model/simulate relevant economic behavior and resource allocation decisions**
- **Critical to have as complete coverage as possible along key dimensions**
  - **Sectoral**
    - **Detail within sectors to identify activities by region, and time period**
    - **Market place phenomena as food is pushed out for carbon**
  - **Spatial**
    - **Heterogeneity of bio-physical and economic conditions (seq rates vary by > order of magnitude)**
    - **Resource competition, particularly for land within and across landscapes (among food, biofuel, forest, crops and pasture)**
  - **Temporal**
    - **Capture dynamic physical processes as they differ spatially (e.g., soil saturation, forest growth, climate change, forest stand carbon)**
    - **Capture dynamic economic processes (demand trends etc)**
- **Calibrated to real baseline data**
- **Validated by observed market phenomena**

Saturation of Sequestration
Ag Soils and Forests

Results – C accumulation vs. time with change from conventional till to no-till

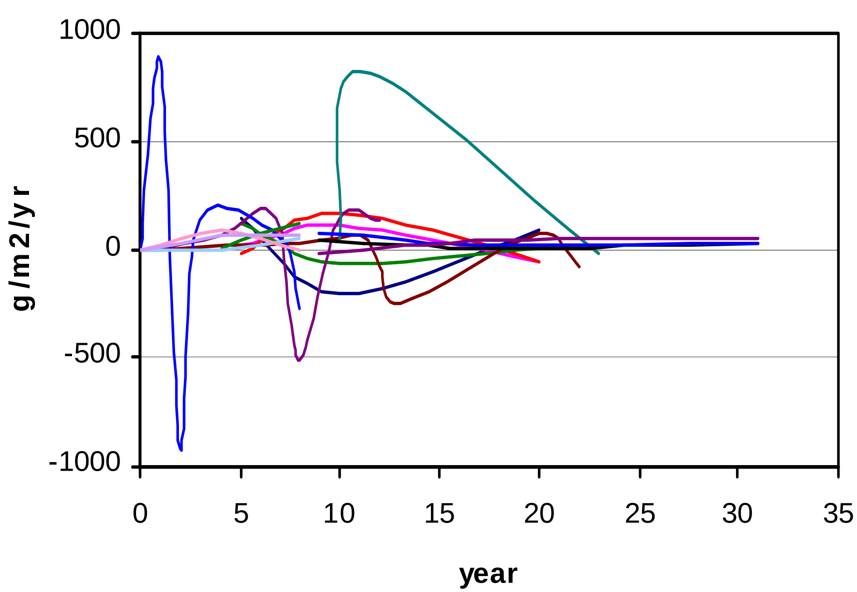
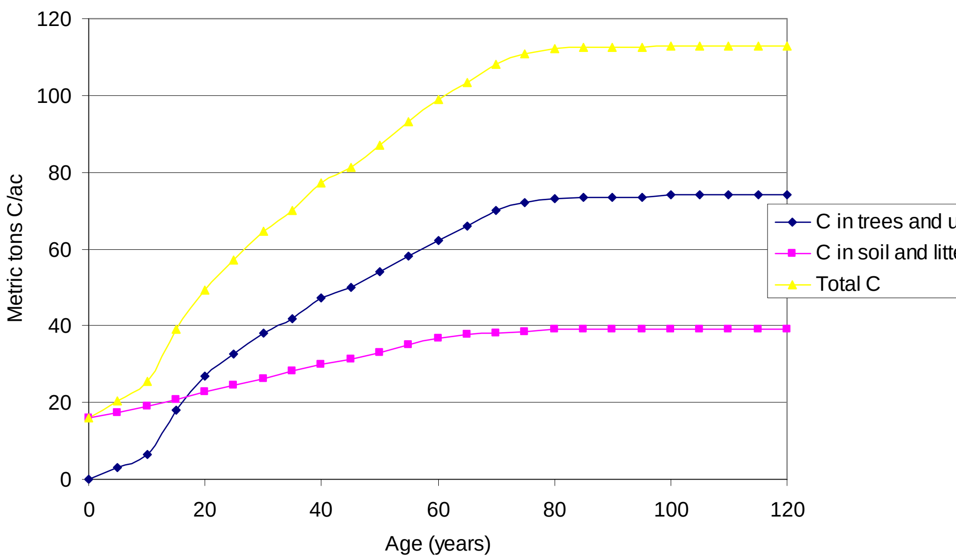


Figure 2. Cumulative Carbon sequestration in a Southeastern U.S. pine plantation
Source: Data Drawn form Birdsey (1996)



West and Post, Oakridge NL

Note saturation by year 20

Birdsey et al, USFS, FORCARB

Note saturation by year 80

Major Results

Portfolio

Dynamic role of strategies

Potential measures

Mitigation and Markets

Dynamics and co benefits

Favored regional activity identification

Simultaneities with climate change

Ties to CGE

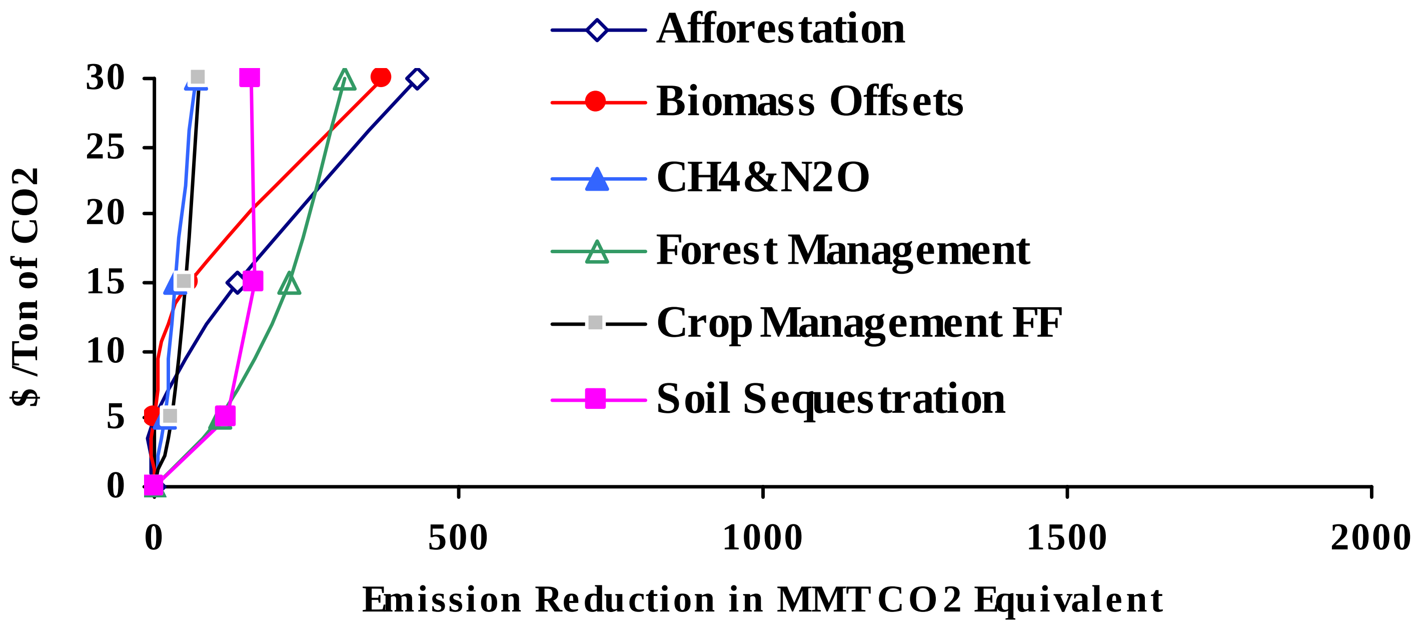
Portfolio Results

	5	15	30	50	80
Afforestation	2	110	450	845	1264
Soil Sequestration	120	153	147	130	105
Biomass Offsets	17	844	952	957	960
CH4&N2O	13	34	65	107	159
Forest Management	106	216	313	385	442
Crop Management FF	29	56	74	91	106
All Strategies	288	1413	2001	2514	3037

Sectors can make a difference

Source Lee, H.C., B.A. McCarl and D. Gillig, "The Dynamic Competitiveness of U.S. Agricultural and Forest Carbon Sequestration," 2003.

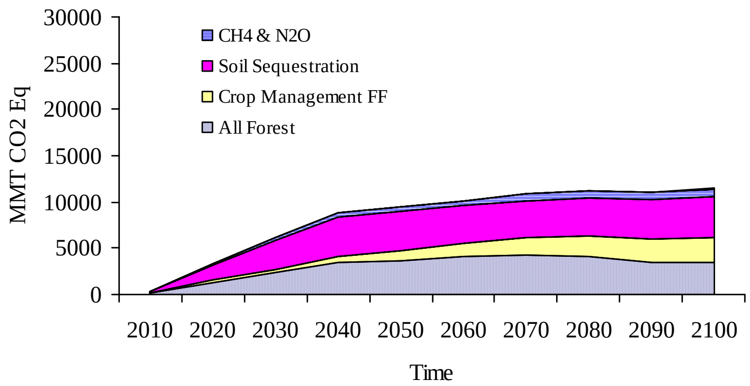
Portfolio Results



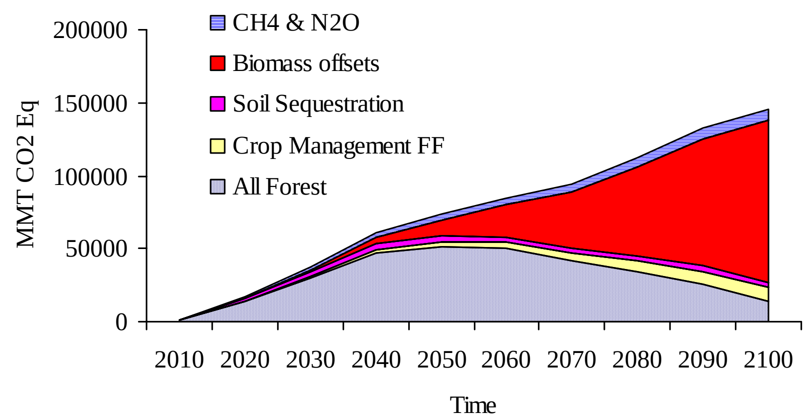
- Different strategies dominate at different price levels
  - Soils and forest management best at low prices
  - Biofuels and trees at higher prices
- Small importance of CH4 and N2O
- Biofuel Market penetration

Source Lee, H.C., B.A. McCarl and D. Gillig, "The Dynamic Competitiveness of U.S. Agricultural and Forest Carbon Sequestration," 2003.

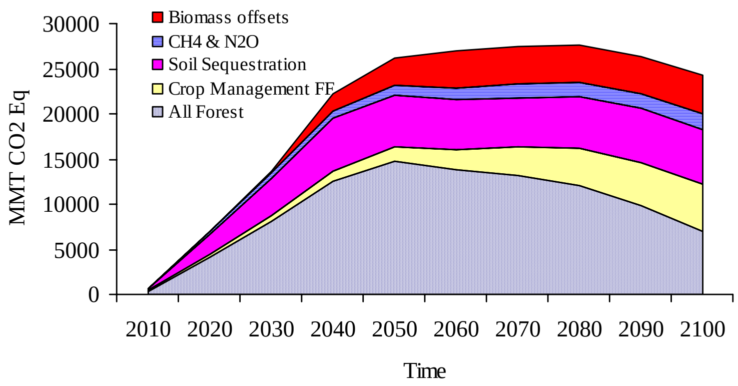
Dynamic Role of Strategies Results



Cumulative Contribution at a $5 per tonne CO2 Price



Cumulative Contribution at a $50 Price



Cumulative Contribution at a $15 Price

Note

Effects of saturation on sequestration
Growing nonco2 and biofuels

Source Lee, H.C., B.A. McCarl and D. Gillig, "The Dynamic Competitiveness of U.S. Agricultural and Forest Carbon Sequestration," 2003.

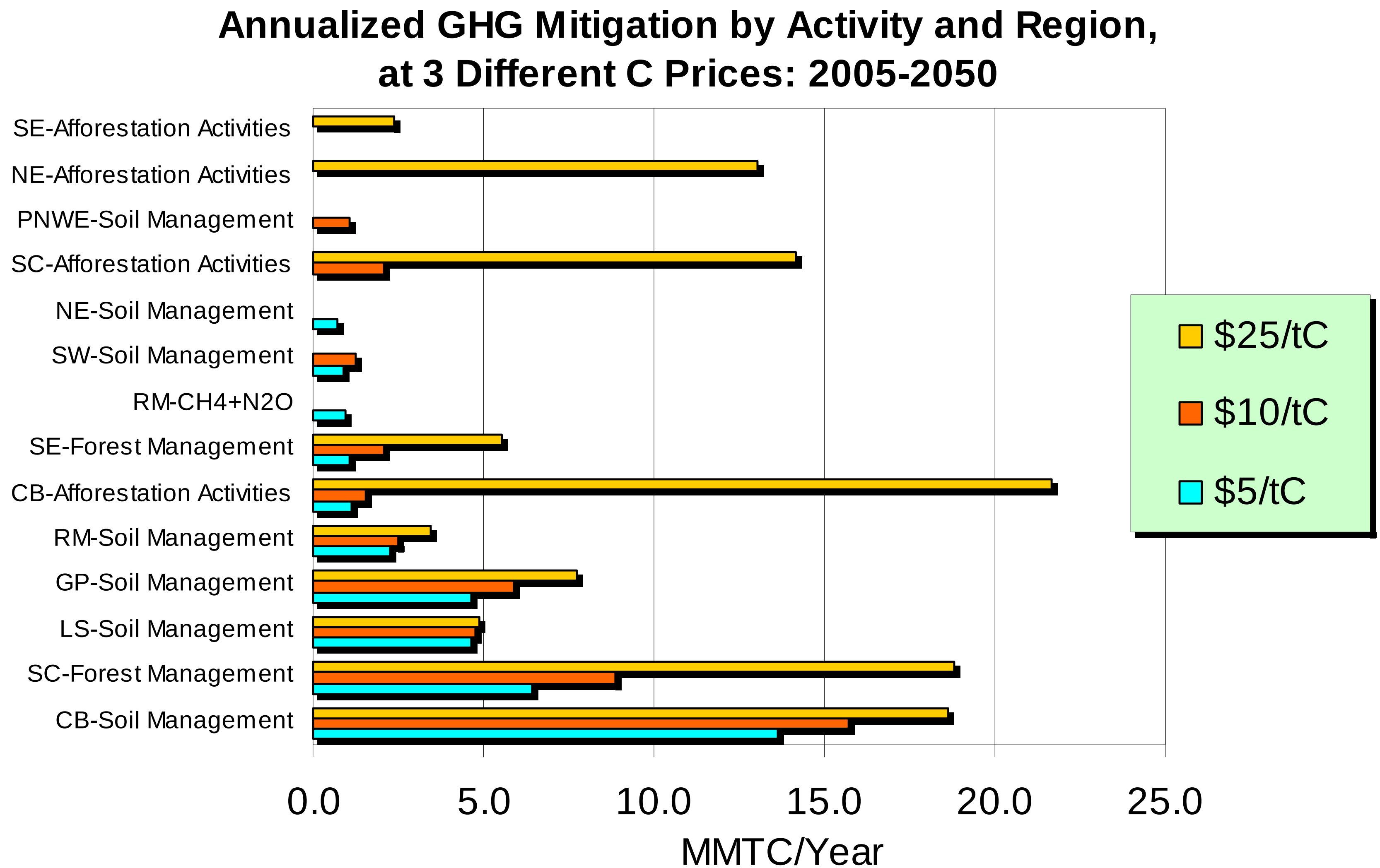
Dynamic Role of Strategies Results

Time from now	<$15/metric ton	>$15/metric ton
>30 years	Limited forest and afforest Non co2	Bio fuels Non co2
O to30 years	Ag soils Forest management Non co2	Limited Ag soils Forest and afforest Biofuels Non co2

Level of Price

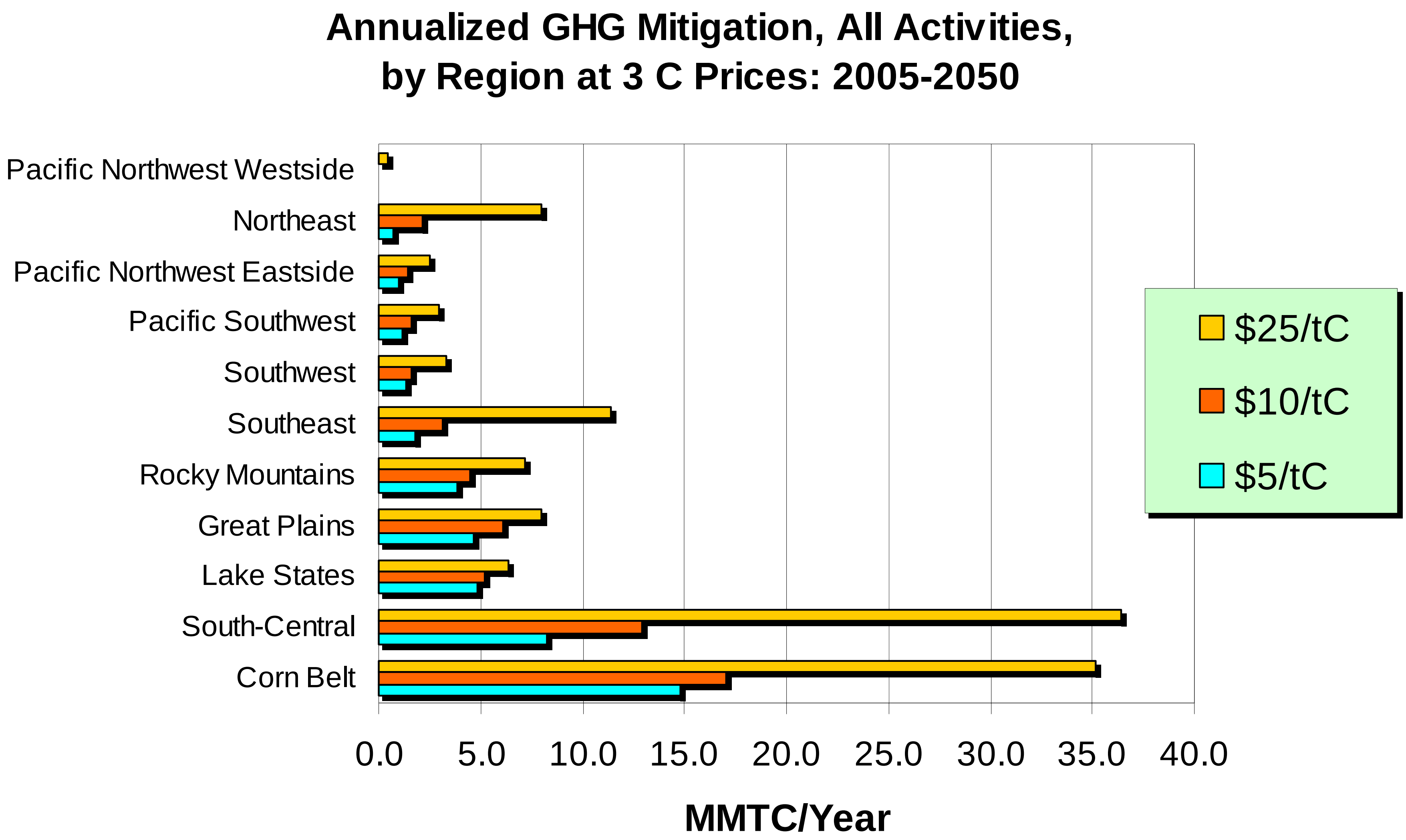
Source Lee, H.C., B.A. McCarl and D. Gillig, "The Dynamic Competitiveness of U.S. Agricultural and Forest Carbon Sequestration," 2003.

Opportunities By Region/Activity



Source: Pattanayak, S.K., A.J. Sommer, B.C. Murray, T. Bondelid, B.A. McCarl, and D. Gillig, "Water Quality Co-Benefits of Greenhouse Gas Reduction Incentives in Agriculture and Forestry," Report to EPA, 2002.

Regional Totals



Source: Pattanayak, S.K., A.J. Sommer, B.C. Murray, T. Bondelid, B.A. McCarl, and D. Gillig, "Water Quality Co-Benefits of Greenhouse Gas Reduction Incentives in Agriculture and Forestry," Report to EPA, 2002.

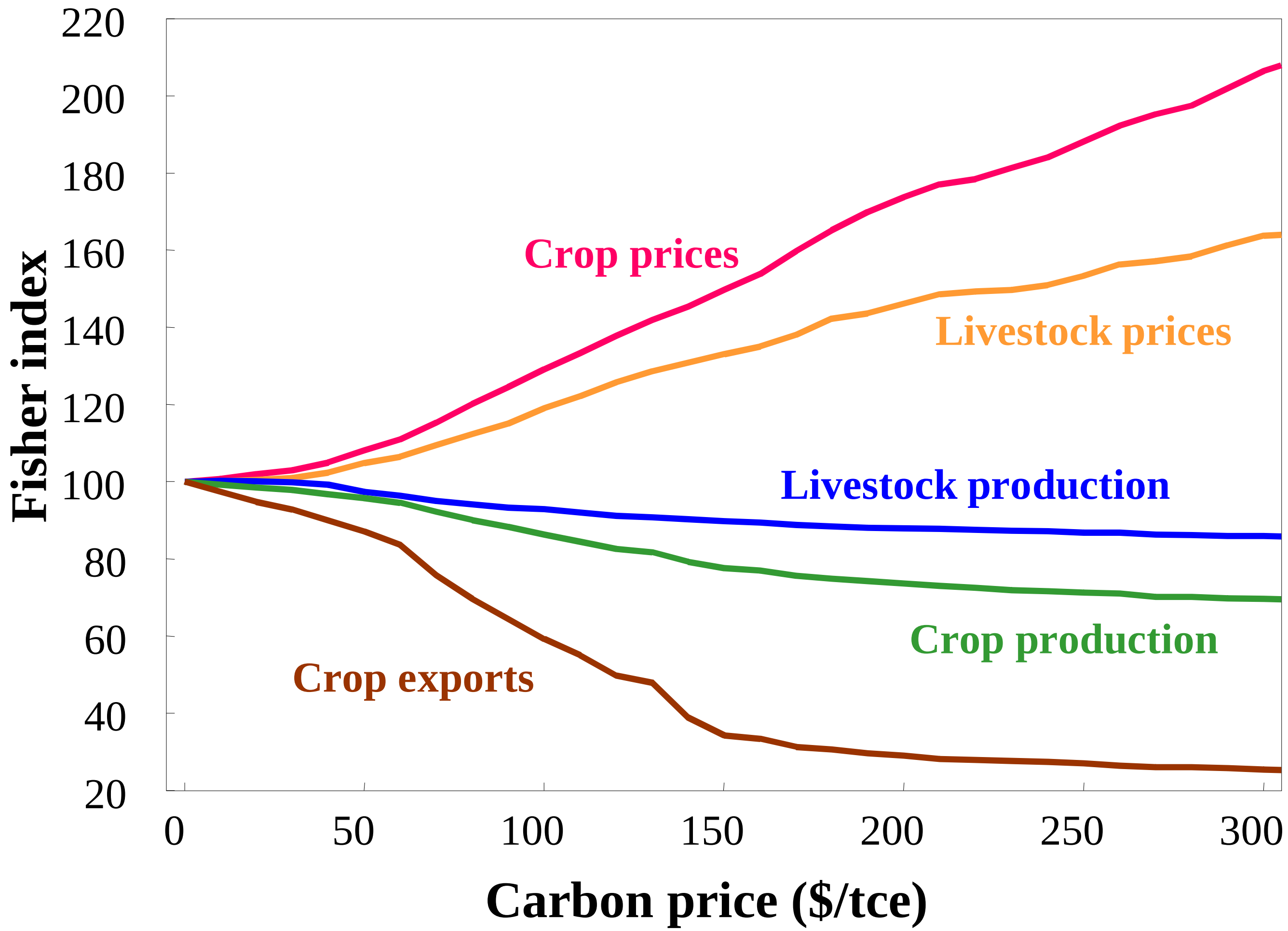
Regional Strategy Results

Largest opportunities by region and type

Region/Type	$5	$10	$25	$50	$100	$200
CB-Soil Management	1	1	3	7	10	
SC-Forest Management	2	2	2	6	7	9
LS-Soil Management	3	4	8			
GP-Soil Management	4	3	6	9		
RM-Soil Management	5	5	9			
CB-Afforestation Activities	6	8	1	3	1	1
SE-Forest Management	7	7	7		9	
RM-CH4+N2O	8					
SW-Soil Management	9	9				
NE-Soil Management	10					
SC-Afforestation Activities		6	4	5	5	6
PNWE-Soil Management		10				
NE-Afforestation Activities			5	4	8	
SE-Afforestation Activities			10	10		
SC-Biofuel Offsets				1	2	2
SE-Biofuel Offsets				2	4	4
LS-Afforestation Activities				8	3	7
NE-Biofuel Offsets					6	8
LS-Biofuel Offsets						3
CB-Biofuel Offsets						5
RM-Afforestation Activities						10

Source: Pattanayak, S.K., A.J. Sommer, B.C. Murray, T. Bondelid, B.A. McCarl, and D. Gillig, "Water Quality Co-Benefits of Greenhouse Gas Reduction Incentives in Agriculture and Forestry," Report to EPA, 2002.

GHG Mitigation and Ag-Markets

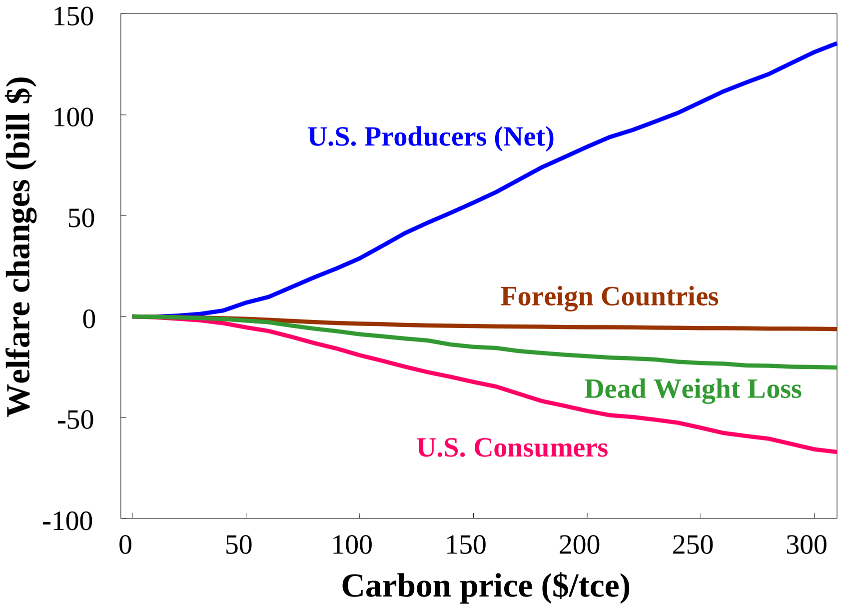


Tradeoff between carbon and traditional production –
ag prices rise, forest products fall

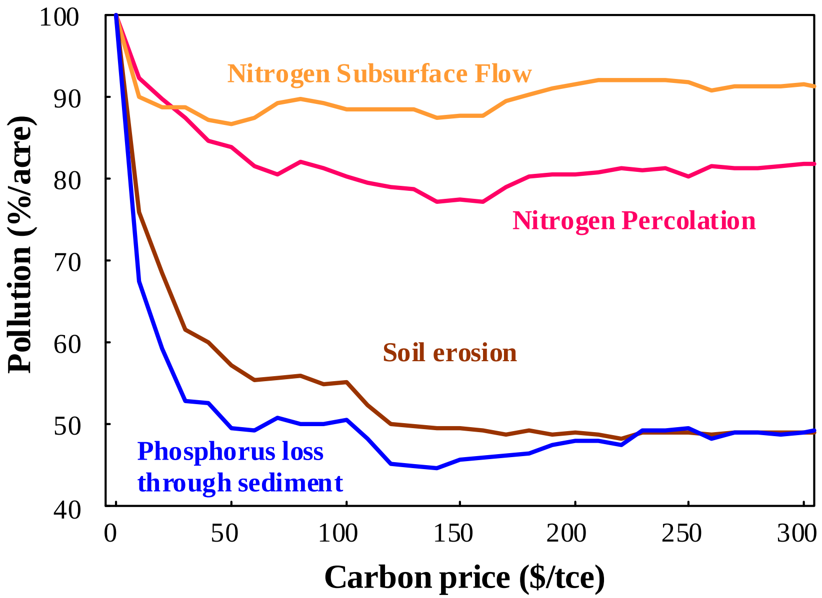
Source: Pattanayak, S.K., A.J. Sommer, B.C. Murray, T. Bondelid, B.A. McCarl, and D. Gillig, "Water Quality Co-Benefits of Greenhouse Gas Reduction Incentives in Agriculture and Forestry," Report to EPA, 2002.

Results: Co-Benefits, Economic & Envir.

Ag-Sector Welfare



Multi-environmental Impacts



- Producers gain & Consumers lose
- Exports reduced
- Environmental gains
- High prices erode co-benefits due to intensification

- Some co-benefits do not saturate over time but continue to be accrued (erosion, runoff, farm income).
- Ecosystem gains in habitat may saturate

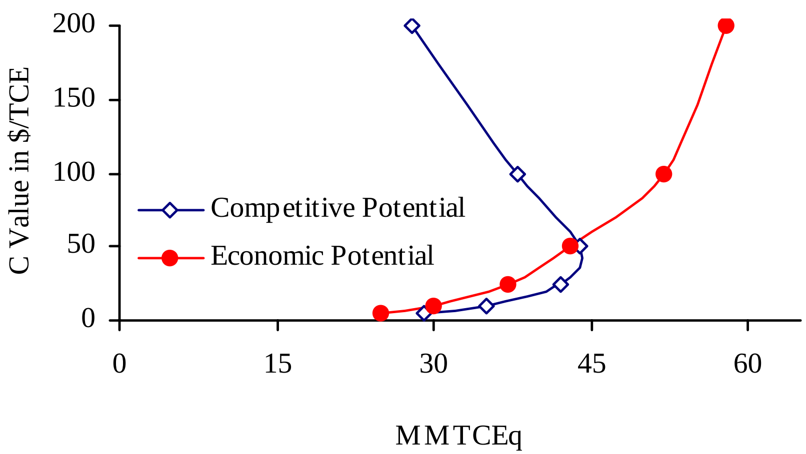
Source: Pattanayak, S.K., A.J. Sommer, B.C. Murray, T. Bondelid, B.A. McCarl, and D. Gillig, "Water Quality Co-Benefits of Greenhouse Gas Reduction Incentives in Agriculture and Forestry," Report to EPA, 2002.

Co-Benefits: Water Quality Changes

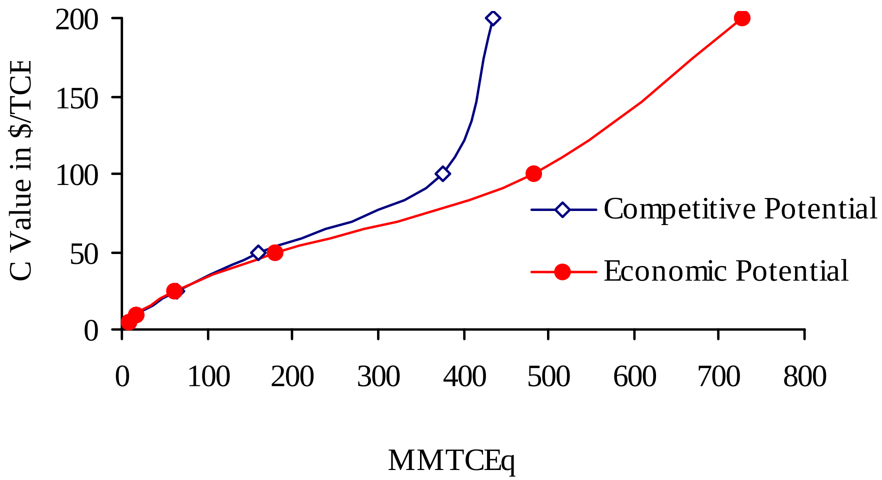
Preliminary Results, at $25/tC

Source: Pattanayak, S.K., A.J. Sommer, B.C. Murray, T. Bondelid, B.A. McCarl, and D. Gillig, "Water Quality Co-Benefits of Greenhouse Gas Reduction Incentives in Agriculture and Forestry," Report to EPA, 2002.

Economic vs competitive potential



Annual Soil Carbon Sequestration on Crop Land



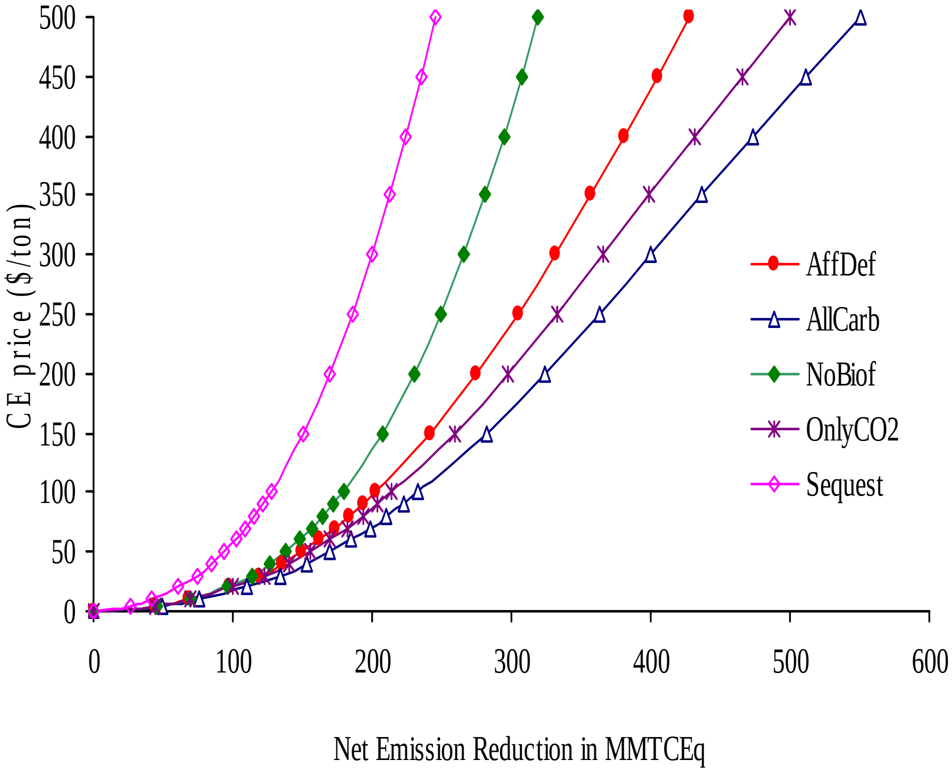
Annual Carbon Sequestration in Forest Sector

Economic potential is how much one would get if this was the only strategy employed

Competiive potential is how much one gets when other strategies are possible

Technical potential of ag soils is at 140 MMT

Implementation policy and response (from Non dynamic model)

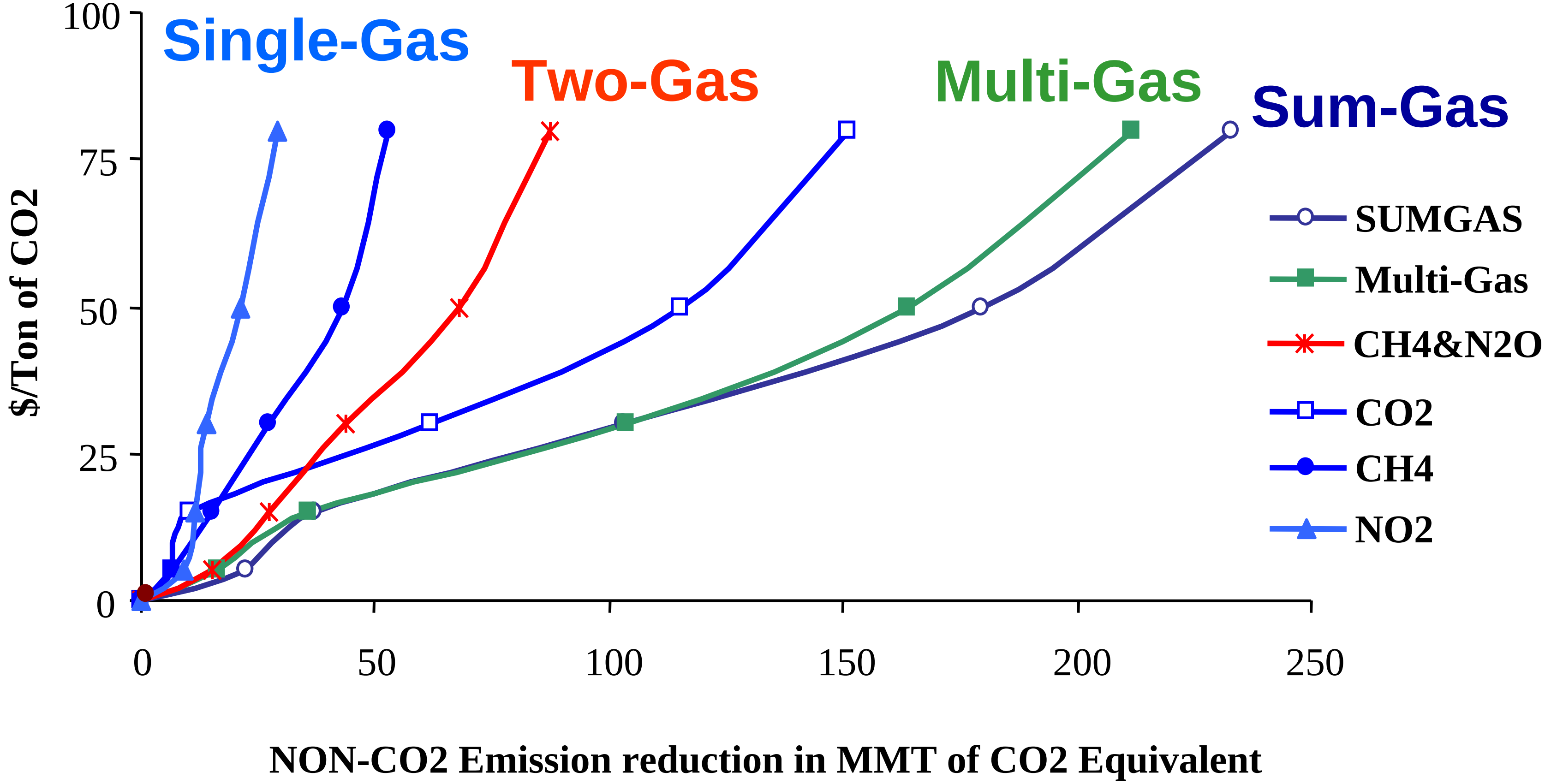


Affdef -- afforestation and deforestation only
Allcarb -- all forestry and ag
Nobiof -- no biofuels
OnlyC02 -- no non co2 gasses
Sequest -- ag soils only

Allowed activity can make a big difference in ag potential

Source : Gillig, D., B.A. McCarl, and R.D. Sands, "Integrating Agricultural and Forestry GHG Mitigation Response into General Economy Frameworks: Developing a Family of Response Functions," Mitigation and Adaptation Strategies for Global Change, forthcoming, 2003.

Looking at opportunities in isolation



Results do not add up due to competition and complementarity

Single opportunity approach generates overestimate of total mitigation potential

Ties to CGE Results

Developed response functions from model

To do this ran model multiple times

under alternative levels for

carbon equivalent price,

agricultural commod. demand - domestic & export

fuel price

Yielding data on simultaneous production of

GHG offsets

AF commodity price and quantity

AF sectoral performance

Then we fit functions to those data to encapsulate the results

Source : Gillig, D., B.A. McCarl, and R.D. Sands, "Integrating Agricultural and Forestry GHG Mitigation Response into General Economy Frameworks: Developing a Family of Response Functions," Mitigation and Adaptation Strategies for Global Change, forthcoming, 2003.

Ties to CGE Results

Estimated functions

Quantity of GHG emissions and sinks.

Emissions of CO_2, CH_4, and N_2O (broken out to avoid double counting)

Sinks for CO_2 (did CH_4 but should not use?)

Ag Production, exports, imports and price

Fisher index tot ag production, exports, imports and price changes

Biofuel production

Land Use, allocation and valuation.

Acres crops, biofuels, pasture and forest, and choice of tillage practices.

Welfare distribution.

consumers' producers' and foreign interests.

Levels of environmentally related items -

use of crop land, irrig. water; nitrogen, phosphorus, potassium, pesticides, fossil fuels, water and wind erosion.

Source : Gillig, D., B.A. McCarl, and R.D. Sands, "Integrating Agricultural and Forestry GHG Mitigation Response into General Economy Frameworks: Developing a Family of Response Functions," Mitigation and Adaptation Strategies for Global Change, forthcoming, 2003.

Ties to CGE Results

Functional form

$$Y_k = A_k \prod_i x_i^{\beta_{ki}} \varepsilon_k$$

where

A_k is the intercept term associated with the *k*th response function

β_{ik} is a vector of parameters associated the vector **x** of signals.

The base functions with all of the independent variables held at the base level

1 for carbon price , 100 for the others

That depicts the ASMGHG output under a

zero carbon price

1997 energy price,

1997 domestic demand,

1997 export demand levels.

Ties to CGE Results

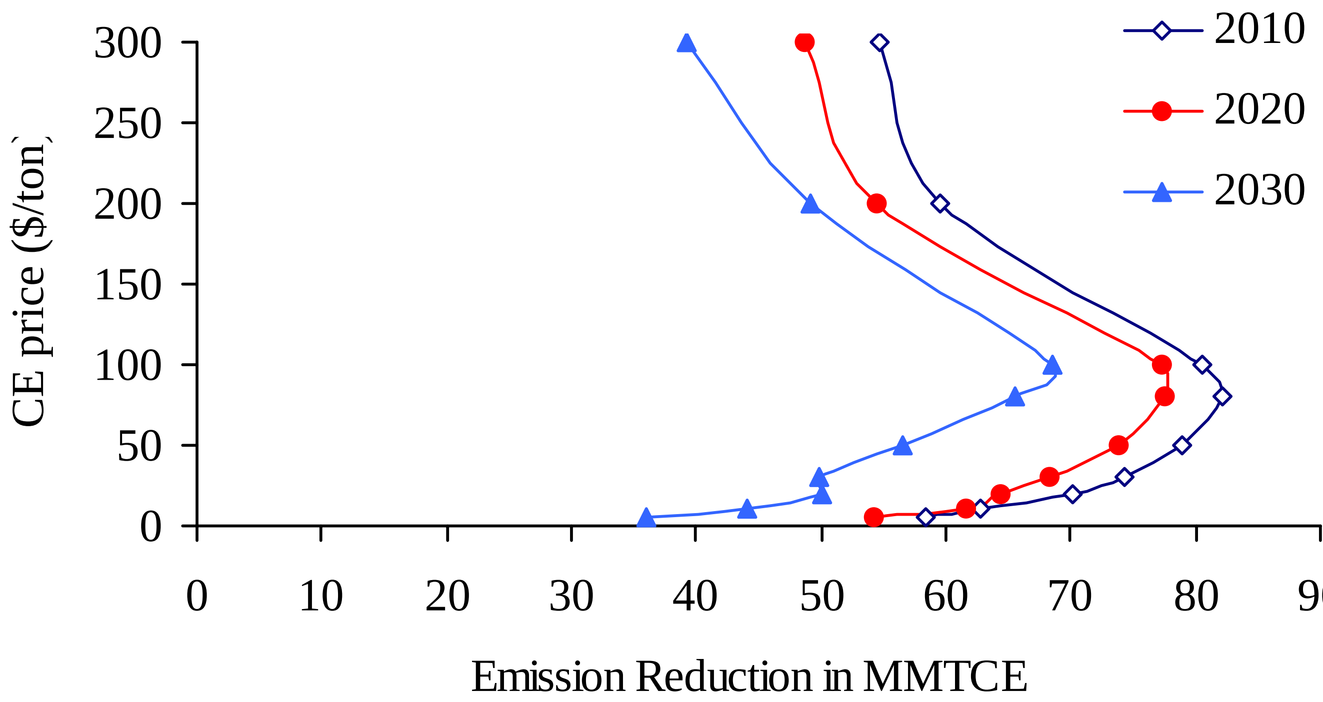
Dependent Variables	Intercept	Carbon Price	Agriculture Demand	Exports	Fuel Price	R^2
GHG Accounts:						
CO2 source emissions [a]	19.6450	-0.1725	0.1844	-0.0322*	0.0904	0.879
CO2 nonag emissions [b]	0.603	-0.076	0.395	0.245	0.236	0.901
CH4 source emissions	85.3070	-0.0742	0.0303*	-0.0252*	-0.0428	0.785
N2Osource emissions	9.9328	-0.0653	0.1477	0.0886	0.0975	0.763
CO2 sinks [c]	7.6185	0.5122	-0.1824	0.0866*	0.2752	0.918
CO2 offsets from biofuel	0.00001	3.4568	-0.9853*	-1.2428*	0.2849	0.733
Agricultural Prices and Production:						
Price	12.9690	0.1309	0.1208	0.1365	0.1086	0.685
Production	72.1472	-0.0642	0.0810	0.0106*	0.0147*	0.732
Exports	2.4464	-0.1826	-0.2640	1.2012	-0.0194*	0.589
Imports	18.2478	0.0197	0.3122	0.0129*	0.0324	0.603

* Marks insignificant coefficients

Source : Gillig, D., B.A. McCarl, and R.D. Sands, "Integrating Agricultural and Forestry GHG Mitigation Response into General Economy Frameworks: Developing a Family of Response Functions," Mitigation and Adaptation Strategies for Global Change, forthcoming, 2003.

GHG Abatement and US Agriculture: Generating Data for Integrated Assessment (I)

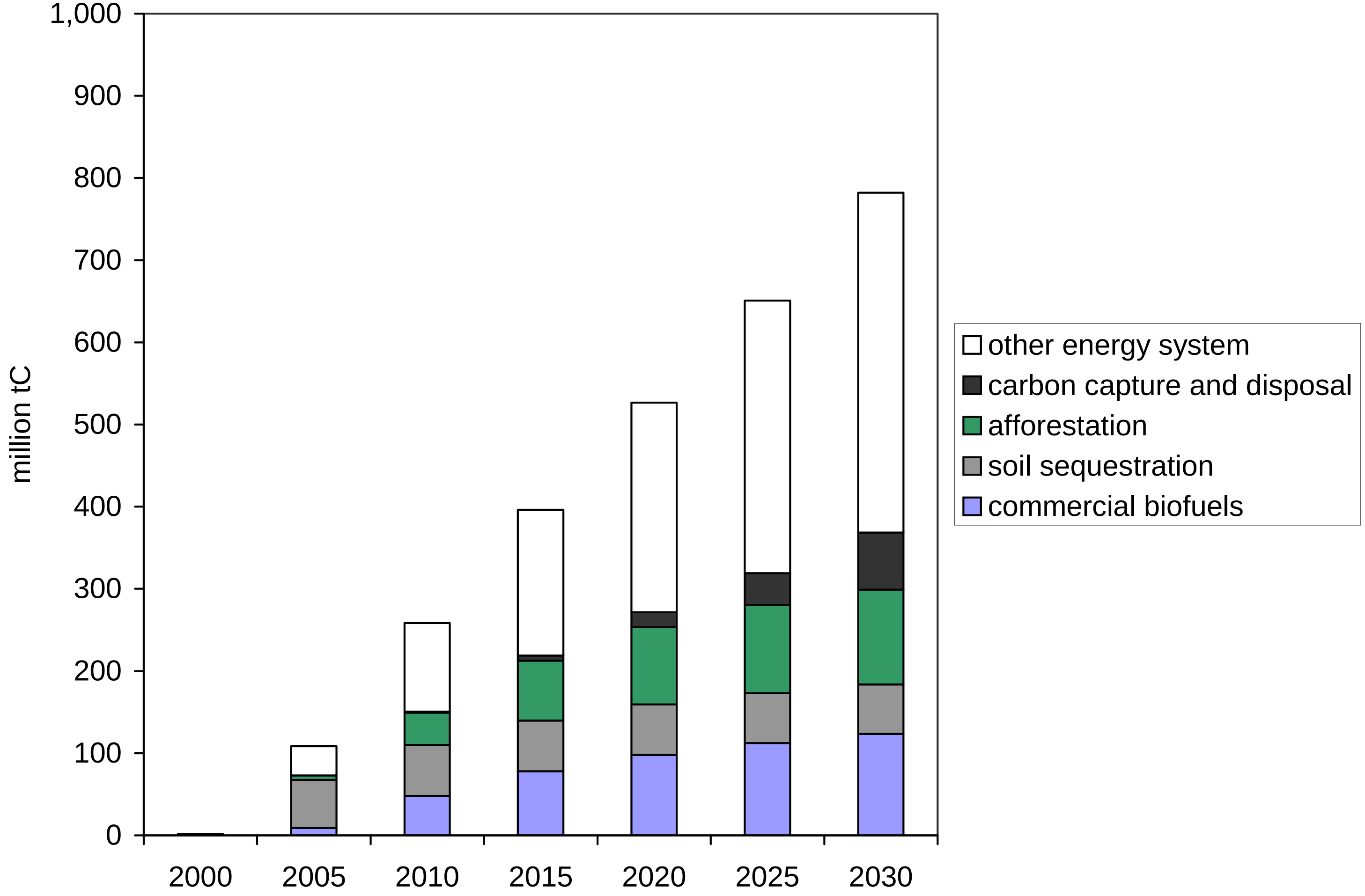
Dynamics and saturation
Ongoing estimation attempts
Reductions from Agricultural Tillage



Source : Gillig, D., B.A. McCarl, and R.D. Sands, "Integrating Agricultural and Forestry GHG Mitigation Response into General Economy Frameworks: Developing a Family of Response Functions," Mitigation and Adaptation Strategies for Global Change, forthcoming, 2003.

SGM CGE Model

Composition of U.S. Emissions Reductions (remain at year 2000 emissions)



From Sands, R.D., B.A. McCarl, and D. Gillig, "Assessment of Terrestrial Carbon Sequestration Options within a United States Market for Greenhouse Gas Emissions Reductions," Presented at the Second Conference on Carbon Sequestration , Alexandria, VA, May 7, 2003.

Preliminary Leakage Estimates from Regional Projects

Afforestation Program Leakage Results, as % (rounded)

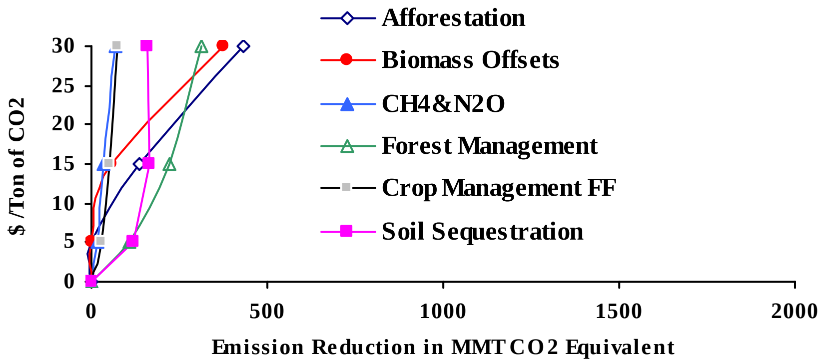
Northeast	23
Lake States	18
Corn Belt	30
Southeast	40
South-central	42

Avoided Deforestation Leakage Results, as % (rounded)

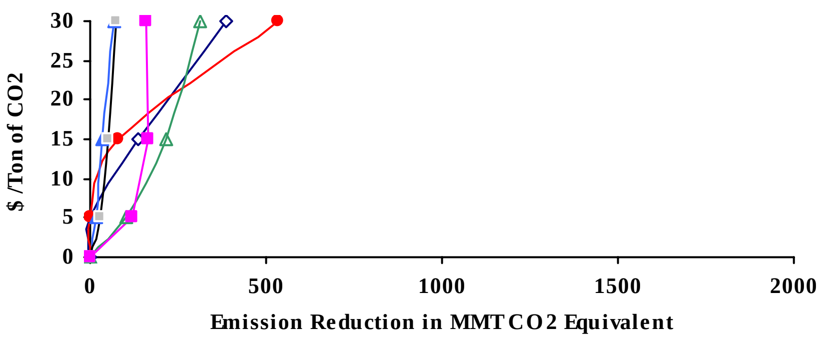
	No Harvesting	**Harvesting Allowed**
Pacific Northwest-East Side		8
7		
Northeast	43	41
Lake States	92	73
Corn Belt	31	–4
South-central	28	21

Source: Murray, B.C., B.A. McCarl, and H.C. Lee, "Estimating Leakage From Forest Carbon Sequestration Programs," Land Economics, forthcoming February, 2004.

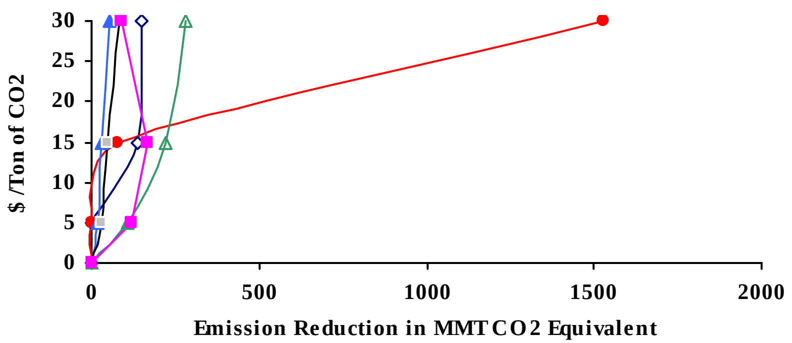
Biofuels and Market Penetration



(a) 50% of energy crops contribution



(b) 100% of energy crops contribution



(c) No-Limit energy crops contribution

Lot of potential depends on mkt penertration

General Policy Observations Based on Studies

- Forests and agriculture can provide cost-effective means for obtaining sizable near-term increments in stored carbon
- Regardless of flux target, cost effective policies may involve both portfolio of ag and forest alternatives including ag soils, non co2, biofuels, afforestation
- Biofuels appears to be most sustainable long term item
- Sequestration saturates ag soils 20 years or so , forests 30-40 in aggregate
- GHG mitigation competes with food and exports
- GHG mitigation supports rural incomes at expense of consumers and exports
- Substantial environmental quality cobenefits can arise
- Leakage via unintended (and unregulated) adjustments in land use between forest and ag sectors in response to a sequestration policy can be substantial
- Sequestering substantial additional amounts of carbon via afforestation of agricultural lands may have only modest economic welfare impacts on the agriculture sector
- Efforts to increase forest C could have a different geographic and species focus than previous studies suggest

Directions being Pursued

Other Costs of Strategies
Discounts for leakage, saturation, uncertainty additionality
Dynamic response functions from FASOM
Better ag carbon – Century, EPIC
Better forest carbon
Better non CO2
Biofuels
Improved animal emission accounting and management
Updated forest inventory and growth
CGE

Appendix: A Modeling Approach: FASOMGHG

- **F**orest and **A**gricultural **S**ector **O**ptimization **M**odel with GHG effects (CO_2, CH_4, N_2O)
- Examines land-based GHG strategies
- Considers saturation characteristics of both soils and forests (uses 30 years for ag soils, FORCARB model for forest soils and growth/yield characteristics of forests from USDA Forest Service)
- 100 year model, decadal time-step
- Land exchanges in response to GHG prices, plus all the agricultural activities by decade

Appendix: Model Structure: FASOMGHG Dimensions (I)

- **Sectoral**
  - Forest — 8 log and chip markets
  - Agriculture
    - **22 traditional** and **3 biofuel** crops
    - **29 animal products**
    - **60+ processed** products
  - GHG — 3 markets C, N2O, CH4
  - Land is allocated between sectors based on relative rents and suitability
- **Regional/trade**
  - 11 regions within the US
  - 28 major foreign trading partners for some ag
  - Excess supply/demand for rest of ag and forest

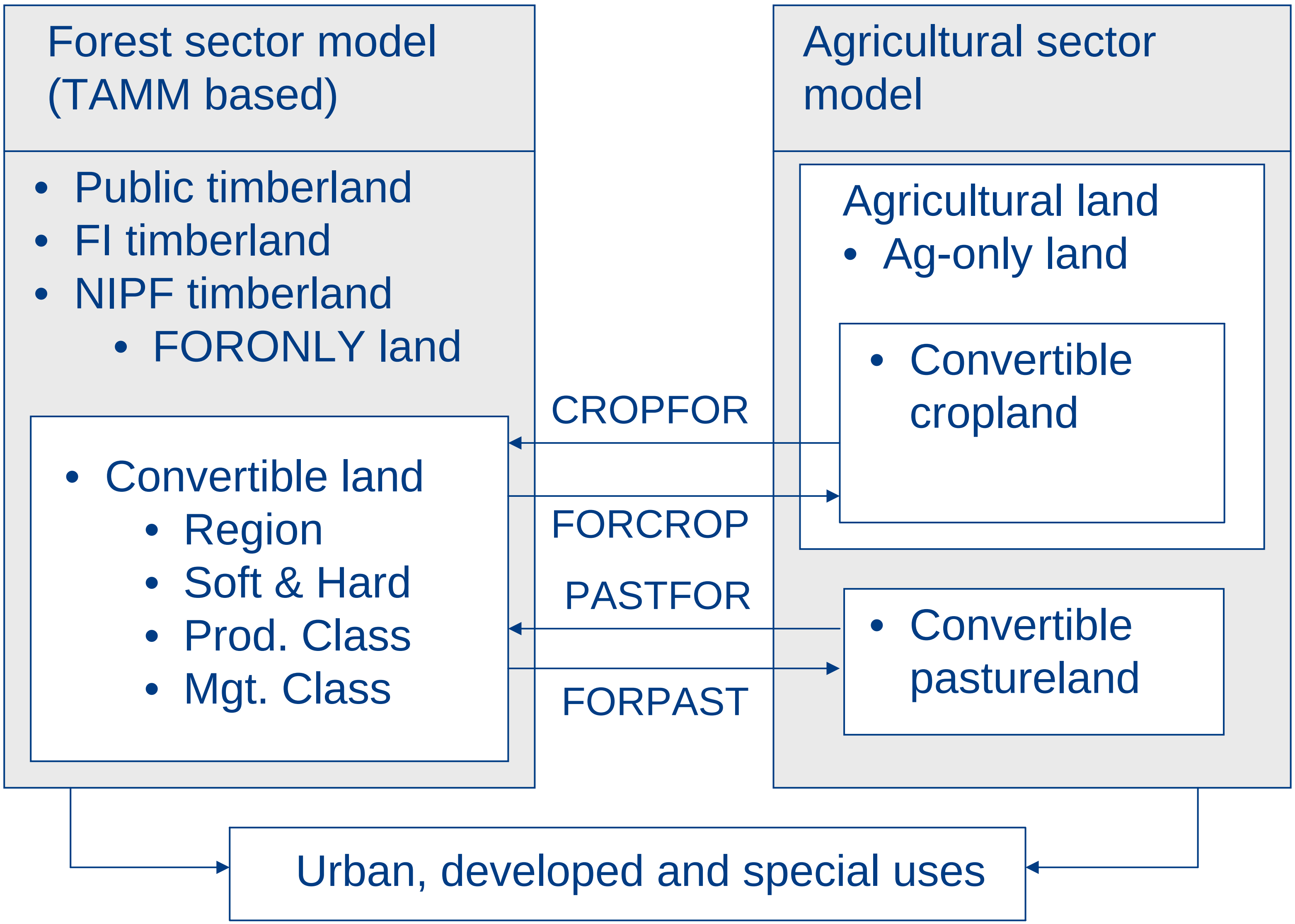
Appendix: Constrained Optimization Problem

- Objective Function: Maximize NPV of sum of producer and consumer surpluses
  - Across Ag and Forest sectors
  - Over time (100 yrs)
  - Including GHG payments
- Constraints
  - Total Production = Total Consumption
  - Tech Input/output relationships hold
  - Land use balances

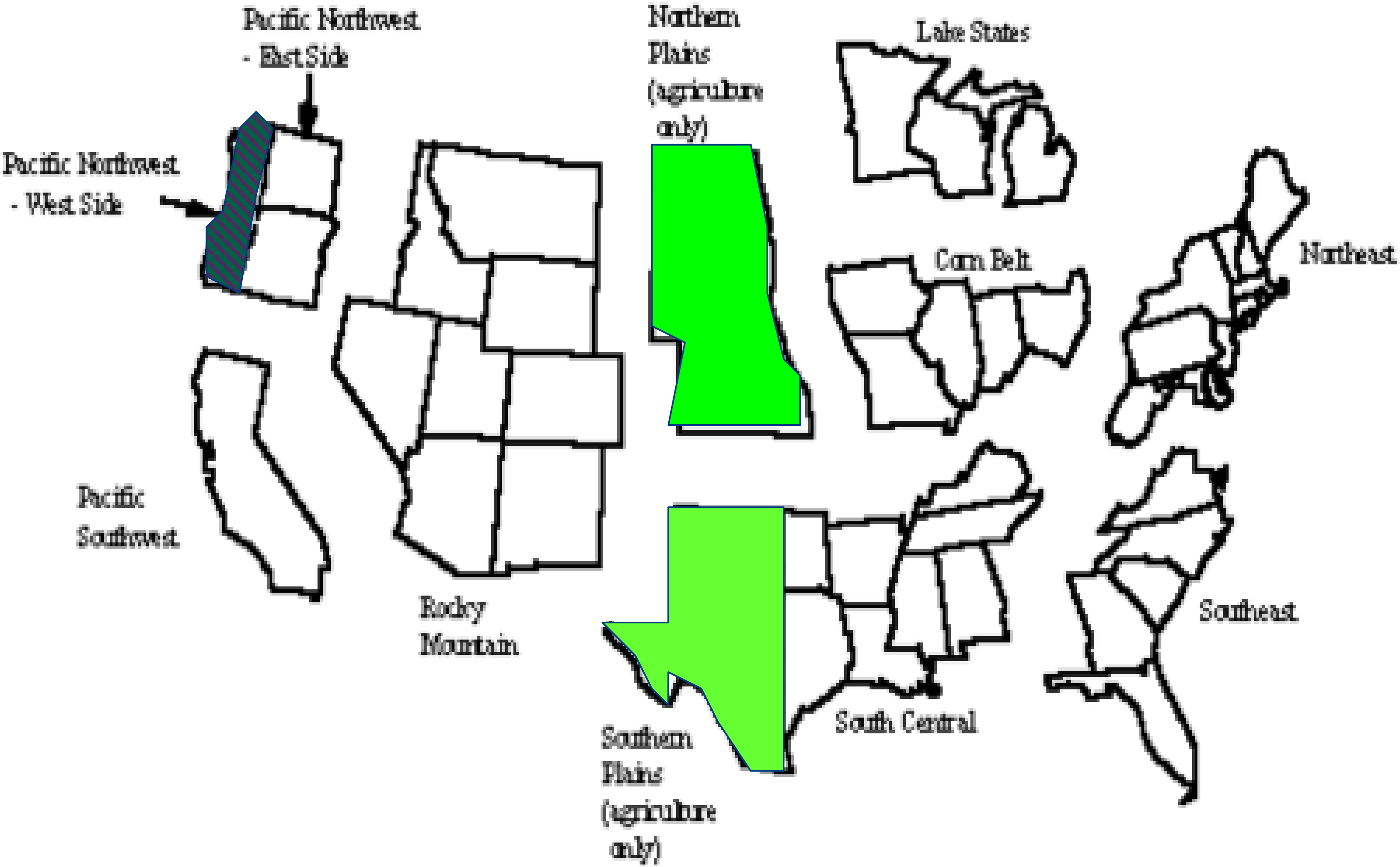
Appendix: Condensed Tableau of MP Model

	FOREST SECTOR		LAND TRANSFER		AGRICULTURE SECTOR			CARBON	
	FOREST CONSUMPTION	FOREST PRODUCTION	LAND FROM FOREST TO AG	LAND FROM AG TO FOREST	AG PRODUCTION	AG CONSUMPTION	AG INPUT SUPPLY	GHG INCENTIVE	
OBJECTIVE – NPV VALUE MAX	+INTEGRAL UNDER DEMAND	-COST	-TRANSFORM COST		- COST	+INTEGRAL UNDER DEMAND	- COST	+PRICE	
FOREST HARVEST	+1	- PRODUCTION							≤ 0
FOREST LAND BALANCE		+1	-1	+1					≤ FL
AG OUTPUT					+PRODUCTION	+1			≤ 0
AG LAND BALANCE			+1	-1	+1				≤ AL
AG INPUTS					+USE		-W		≤ AV
AG > FOR LAND MAX			+1	-1					≤ AFMAX
FOR > AG LAND MAX			-1	+1					≤ FAMAX
CARBON AND OTHER GHG		Δ GHG IN FOREST			Δ GHG IN AG			+1	≤ 0

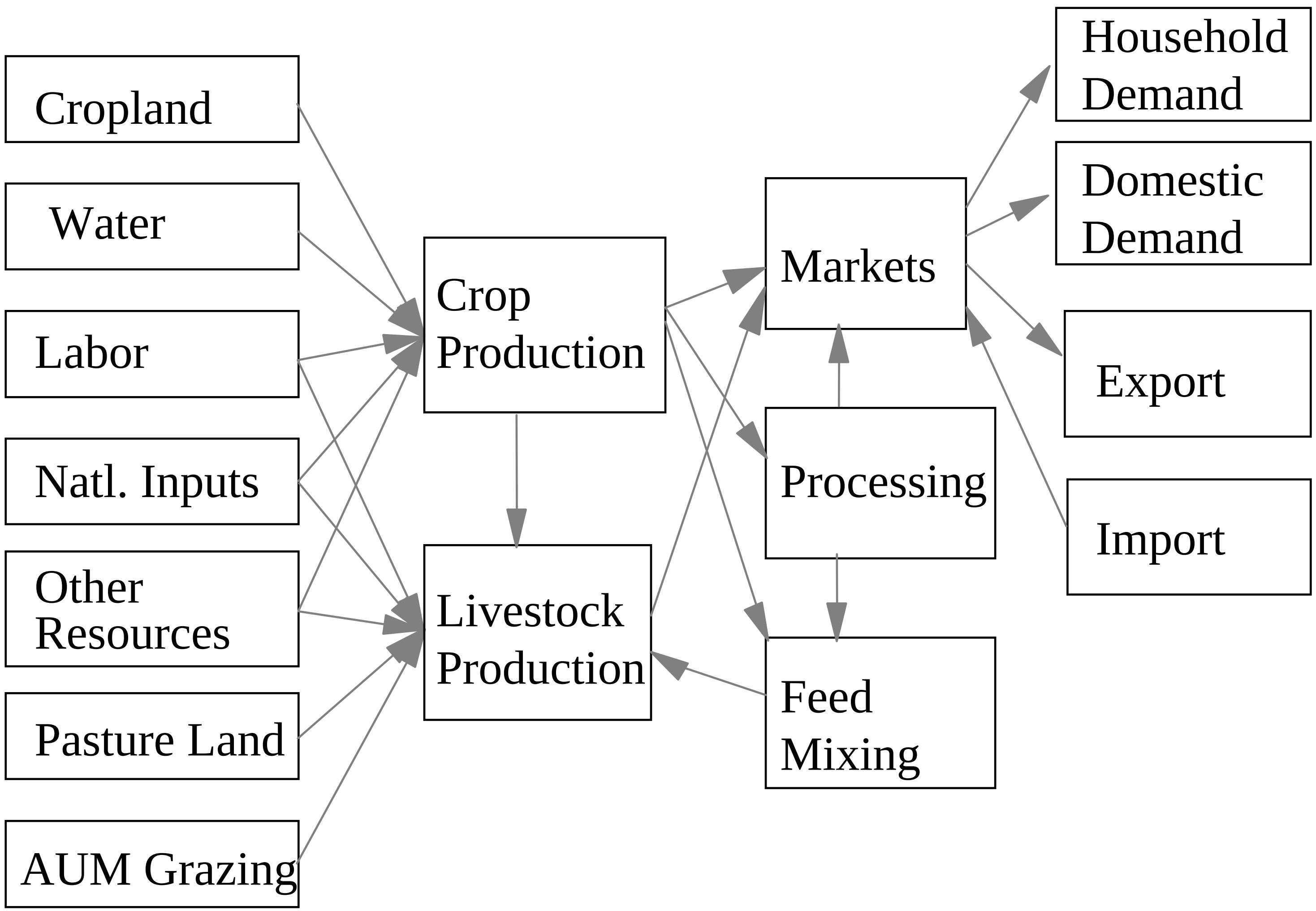
Appendix: Cross-sector Land Interaction



Appendix: Forest Part of FASOMGHG Regional Definition



Appendix: Agricultural Sector Model Structure



Appendix: Foreign Regions in FASOMGHG