Economic Explorations on the Potential Role of Agriculture and Forestry in Mitigating Greenhouse Gas Emissions: Findings and Research Directions

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Outline of Presentation

- Project Goals
- Modeling Approach
- Thoughts on role of Land based Agricultural & Forestry activities in GHG mitigation
- Research Results
- Challenges to squaring up agriculture/forest alternatives with others
- Future Directions and Challenges

For additional information see http://agecon.tamu.edu/faculty/mccarl/

Project Goals

- Study economically appropriate role of agriculture and forestry in GHG mitigation
- Examine the portfolio of Agricultural & Forestry GHG mitigation strategies and identify ones for further scrutiny
- Look at market and time conditions under which strategies dominate
- Bring in a full cost and GHG accounting
- Look at market effects and co benefits/ costs

Relevance of Ag & Forestry GHG Mitigation

- **Society is searching for low cost options.**
- **In the U.S. the first place they will look is in the energy sector where 80% of the emissions come from.**
- **They will only come to ag and forest if it is cheaper or otherwise attractive. Compliance costs estimated by EMF in range around near $100 per ton carbon for Kyoto implementation .**
- **Four AF roles w.r.t. GHG emission reductions**
  - Emission reducers
  - GHG sink - sequestration option
  - Substitute less emission intensive products
  - Passive sector subjected to higher input prices

Modeling approach - FASOMGHG

Strategy	Basic Nature	CO2	CH4	N2O
Afforestation	Sequestration	X		
Existing timberland/reforestation	Sequestration	X		
Deforestation	Emission	X		
Biofuel Production	Offset, Emiss.	X	X	X
Crop Mix Alteration	Emiss, Seq	X		X
Crop Fertilization Alteration	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 Change	Emission		X	X
Manure Management	Emission		X	X
Rice Acreage	Emission	X	X	X

Modeling approach - FASOMGHG

- Forest and agriculture sectors
- Sector linkage and land transfers
- GHG accounting
  - Forest carbon
  - Soil carbon
  - N2O
  - CH4
  - Fuel use carbon emissions
- 100 year time horizon in decade time steps
- 11 US regions

Modeling approach - FASOMGHG

- Considers saturation characteristics of both soils and forests (uses 30 years for ag soils, ATLAS growth and yield along with FORCARB carbon characteristics of forests from Forest Service)
- Land exchanges in response to GHG prices, plus all the agricultural activities by decade
- Product of dissertation by Heng-Chi Lee

Major findings

- Portfolio
- Dynamic role of strategies
- Potential measures
- Mitigation and Markets
- Dynamics and co benefits
- Policy Rules and Results

Major findings – Portfolio Results

Annuity equivalent

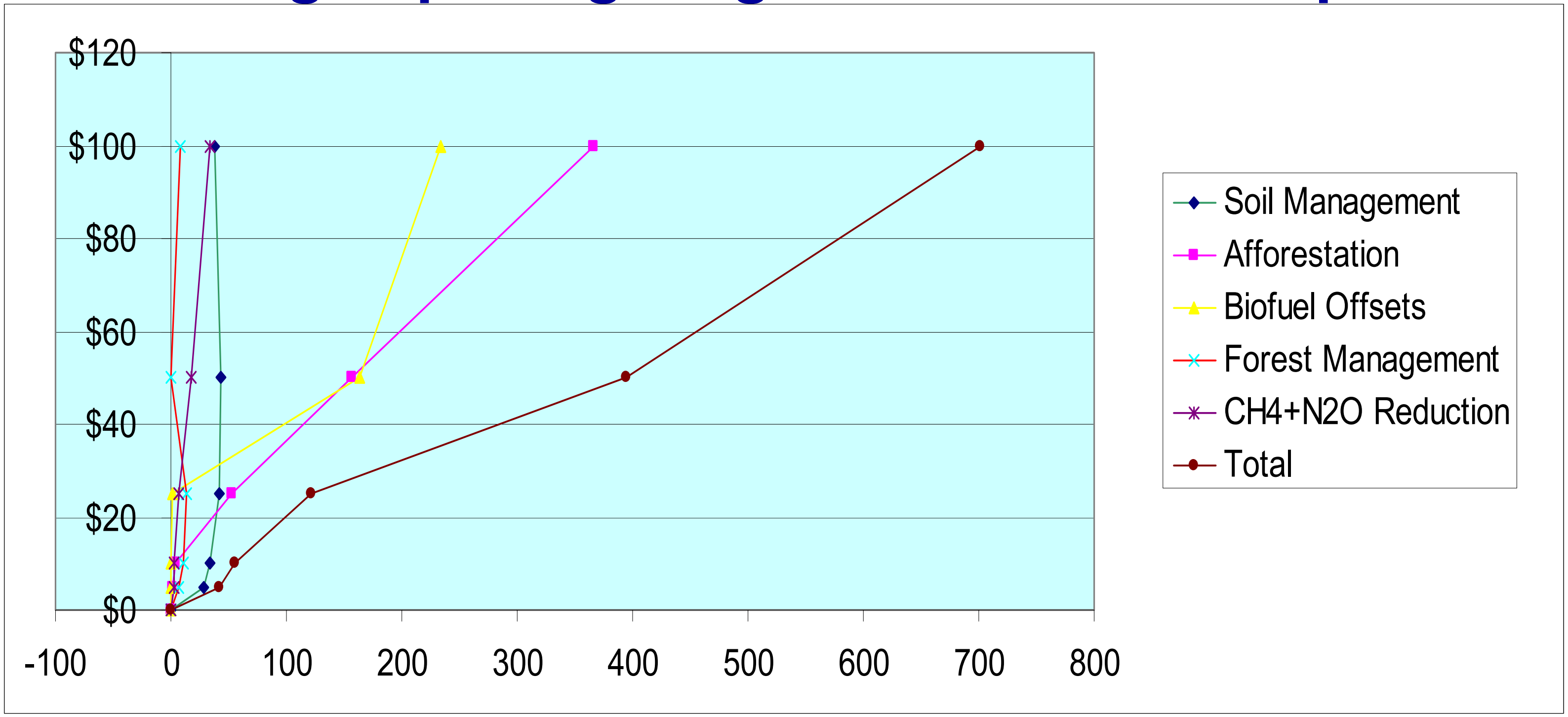
Millions of metric tons CE by source at alternative prices

	GHG Price ($/ton C)					
Activity	**$5**	**$10**	**$25**	**$50**	**$100**	**$200**
Soil Management	**28.7**	**33.7**	**41.5**	**43.0**	**37.8**	**27.0**
Afforestation	**1.0**	**3.8**	**53.0**	**156.3**	**366.2**	**358.2**
Forest Management	**7.0**	**11.2**	**12.9**	**-0.6**	**7.8**	**62.0**
Biofuel Offsets	**0.0**	**0.0**	**1.5**	**162.9**	**233.7**	**375.1**
CH4+N2O Reduction	**2.1**	**2.9**	**6.1**	**17.1**	**34.4**	**43.0**
Other Activities	**1.7**	**2.1**	**3.9**	**13.8**	**18.6**	**22.4**
Total	**42.4**	**55.5**	**121.7**	**394.9**	**700.8**	**890.7**

Sectors can make a difference

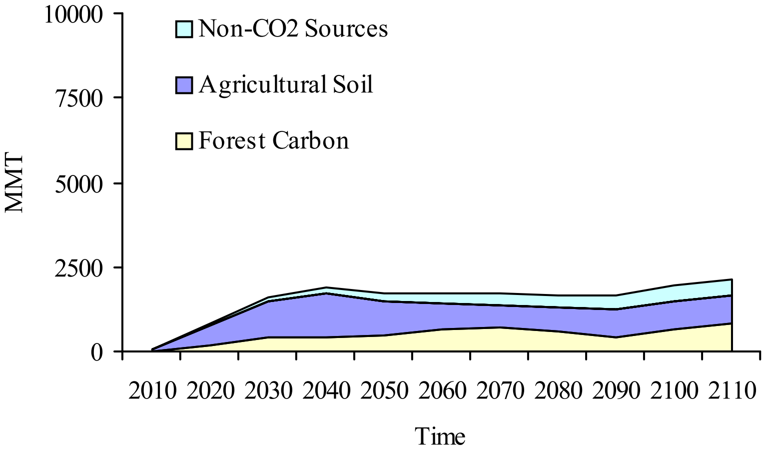
Major findings – Portfolio Results

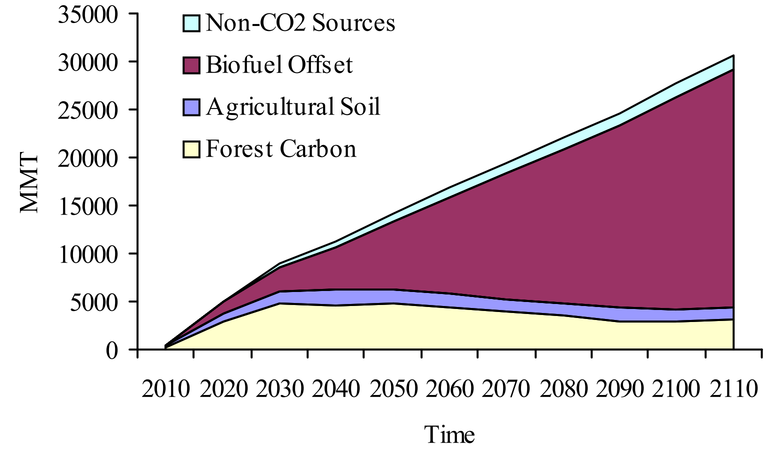
MMT arising at price giving $/tonne carbon equiv

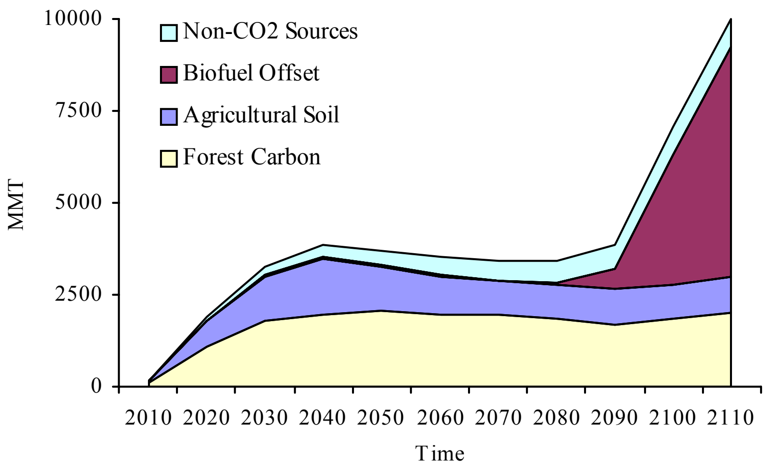


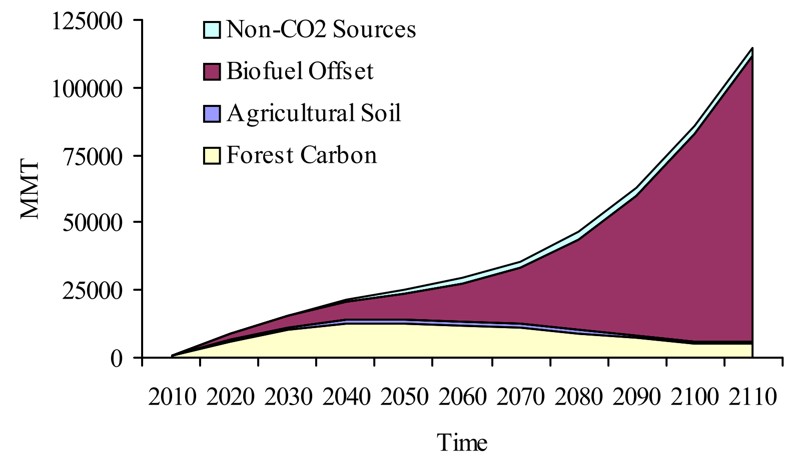
- Different strategies dominate at different price levels
- Soils are first but have limited capacity and then decline
- Small importance of CH4 and N2O

Major findings – Dynamic role of strategies









Source: Lee, Heng-Chi, **An Economic Investigation of the Dynamic Role for Greenhouse Gas Emission Mitigation by the U.S. Agricultural and Forest Sectors ,** PhD Dissertation, Texas A&M University,December 2002

Major findings – Dynamic role of strategies

Time from now	<$50/metric ton	>$50/metric ton
>30 years	Limited forest and afforest Non co2	Bio fuels Non co2
O to30 years	Ag soils Limited forest and afforest Non co2	Limited Ag soils Forest and afforest Biofuels Non co2

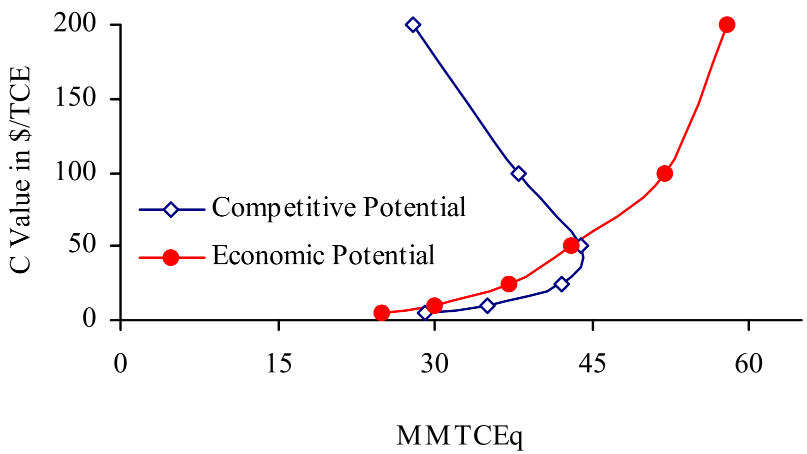
Level of Price

Major findings – Potential measures

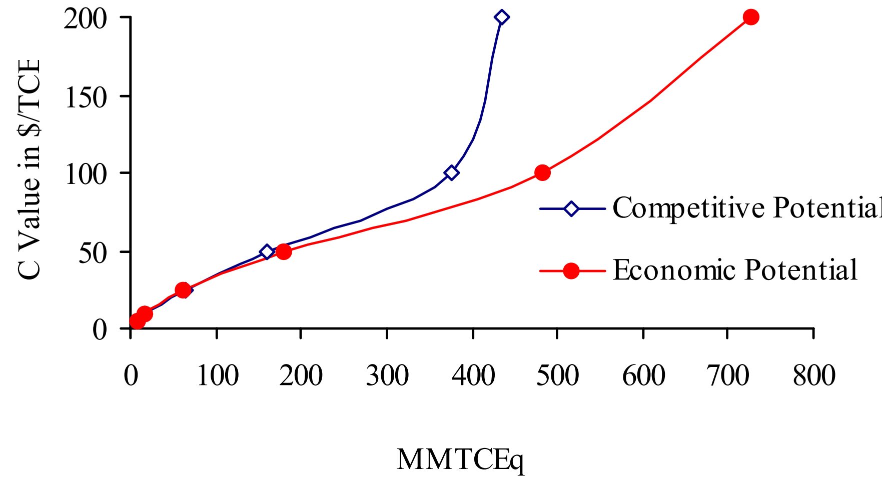
- Many estimates of potential have been generated, most are based on technical aspects of practices without economic concern
- But practice adoption costs money and foregoes income
- Also strategies may be competitive

Major findings – Potential measures

- **Economic vs competitive potential**



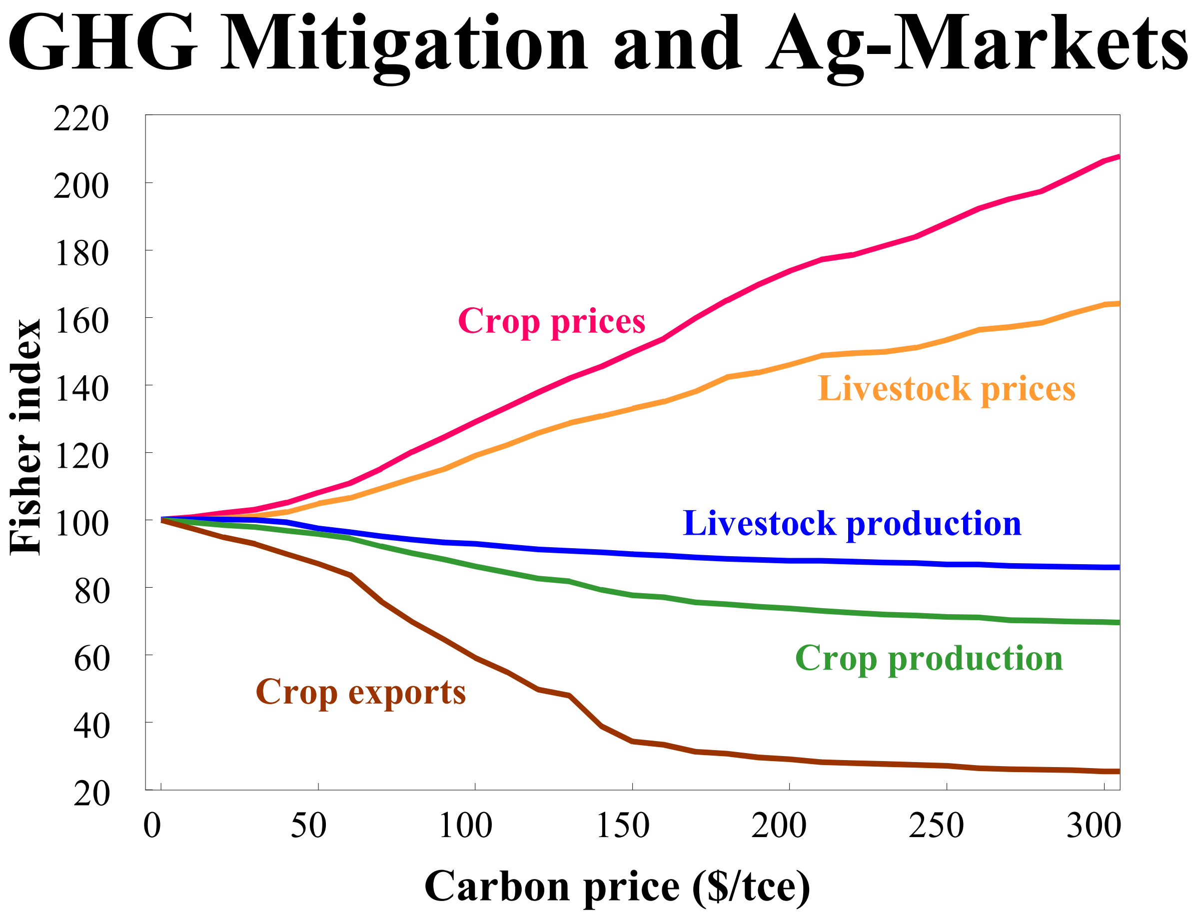
Annual Soil Carbon Sequestration on Crop Land



Annual Carbon Sequestration in Forest Sector

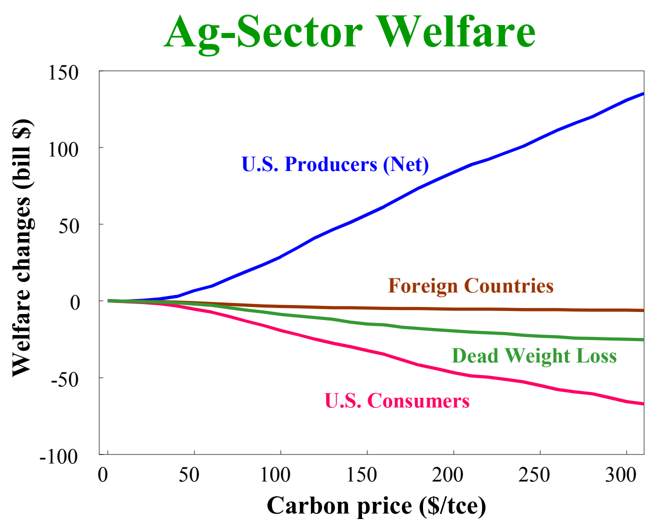
- **Economic potential is how much one would get if this was the only strategy employed**
- **Competitive potential is how much one gets when other strategies are possible**
- **Technical potential often overstates what can be achieved (above TP of ag soils is at 140 MMT)**

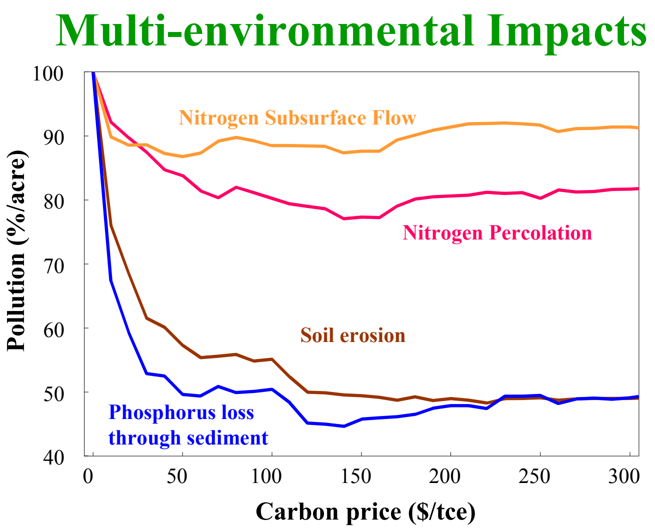
Results – Mitigation and Market Effects



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

Results – Co Benefits, Economic, and Environment

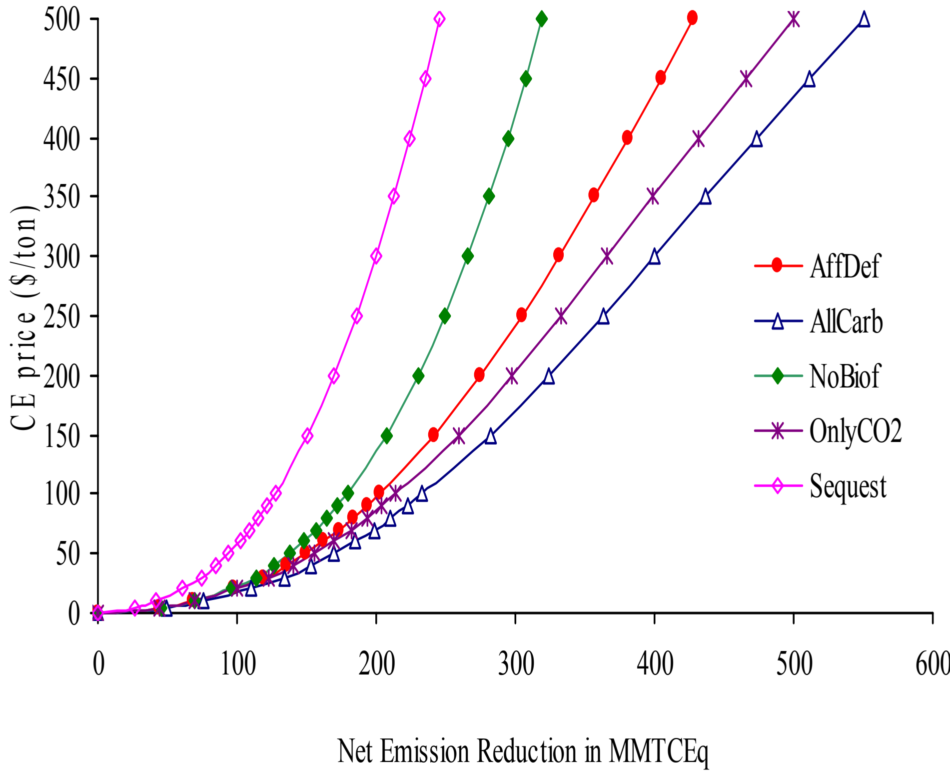




- Producers gain & Consumers lose
- Exports reduced
- Environmental gains
- High prices erode co-benefits due to intensification
- Some co-benefits do not saturate over time but continue to be accrued (erosion, runoff, farm income).
- Ecosystem gains in habitat may saturate

Results – Policy Rules and Results

Implementation policy and response (from ASM summary)



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

Rules make a difference

Generating dynamic response for integrated assessment

Developed response functions from model using **FASOMGHG**

To do this ran model multiple times under alternative levels for

- carbon equivalent price
- agricultural commodities demand
- domestic
- exports
- fuel price

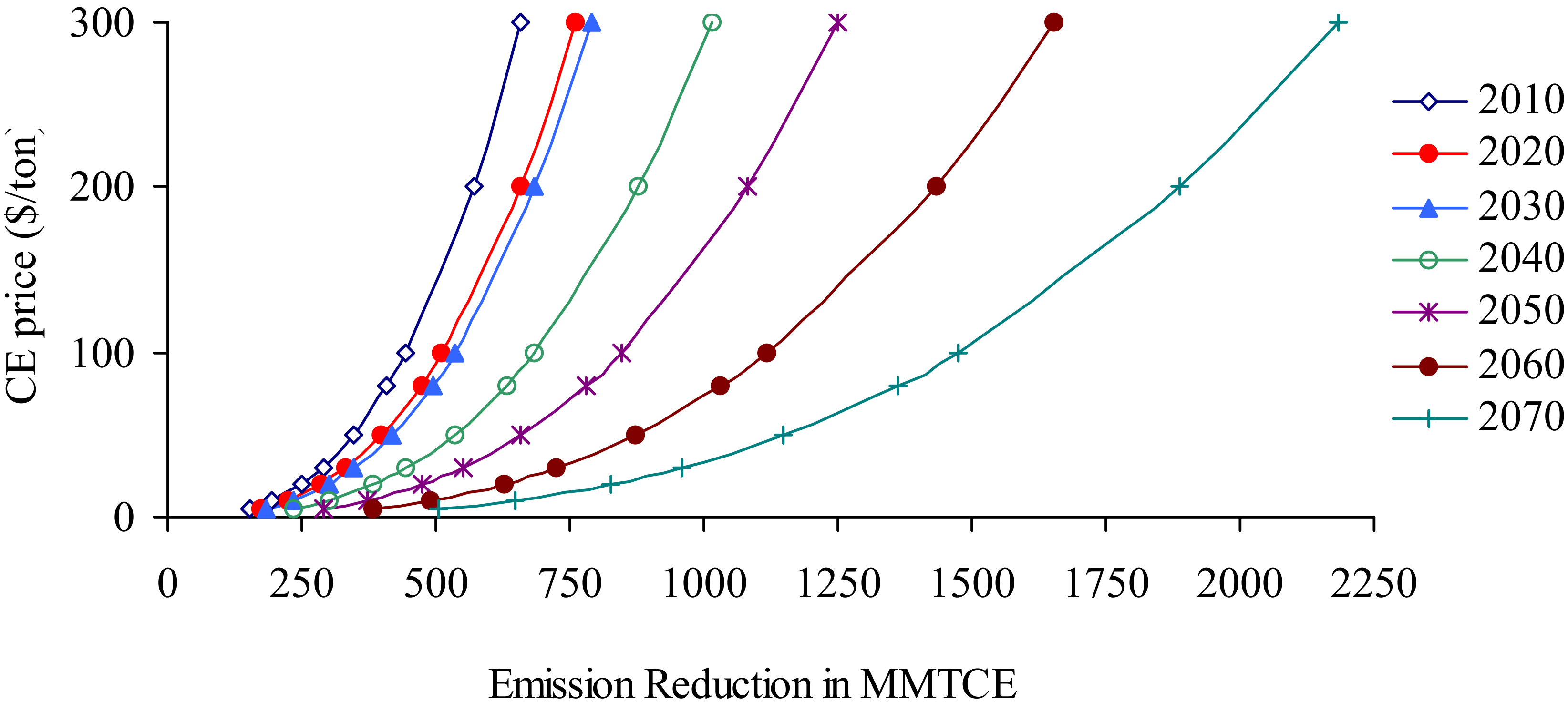
Yielding data on simultaneous production of

- GHG offsets
- AF commodity price and quantity
- AF sectoral performance

Then we fit functions to those data to encapsulate the results

Generating Dynamic Data for Integrated Assessment

Some results



Omitted Factors – Full Cost of Carbon

Carbon will cost money to produce, sell, and measure, govt may help

Not all carbon may be saleable

$$\text{Private cost per ton} = \frac{(PDC + PAIC + MTC - GC)}{QGHGO * DISC}$$

where DISC = (1-ADD)*(1-LEAK)*(1-UNCER)*(1-PERM)

Omitted Factors – Full Cost of Carbon

$$\text{Private cost per ton} = \frac{(PDC + PAIC + MTC - GC)}{QGHGO * DISC}$$

PDC – Cost producer incurs to switch from current practices

PAIC - Cost to get producer to adopt above PDC in terms of incentive to get trained bear extra risk etc.

MTC- Transactions cost to assemble, measure, monitor, certify, sell, carbon

GC- Government cost share

Red terms omitted above

Omitted Factors – Full Cost of Carbon

$$\text{Private cost per ton} = \frac{(\text{PDC} + \text{PAIC} + \text{MTC} - \text{GC})}{\text{QGHGO} * \text{DISC}}$$

QGHGO	Nominal quantity of offsets
ADD	Discount for what would have been done in baseline.
LEAK	Leakage discount
UNCER	Uncertainty discount
PERM	Permanence discount

where DISC = (1-ADD)*(1-LEAK)*(1-UNCER)*(1-PERM)

Red terms omitted above

Directions & Challenges

- Other costs of strategies (assembly, brokerage, measurement, etc.)
- Discounts for leakage, saturation, uncertainty additionality
- Dynamic response functions from FASOMGHG
- Better ag carbon – Century, EPIC
- Better forest carbon
- Better non-CO2
- Improved animal emission accounting & management
- Updated forest inventory and growth
- CGE

For More

- http://agecon.tamu.edu/faculty/mccarl/model.html
- http://agecon.tamu.edu/faculty/mccarl/mitigate.html
- http://agecon.tamu.edu/faculty/mccarl/climchg.html

Supplementary Material is on pages that follow

Modeling approach - FASOMGHG

- Merger of:
  - log-level forest sector model (substantial detail on the forest inventory) and
  - multi-commodity agriculture sector model (substantial detail on cropping and livestock production options)
  - with interaction at the land base level
- Optimizing intertemporal, quasi-spatial market model
- Simulates resource management decisions, commodity production-consumption, trade and prices

Modeling approach - FASOMGHG

FASOMGHG depicts production, consumption and international trade in 11 U.S. regions of 22 traditional and 3 biofuel crops, 29 animal products, and more than 60 processed products.

FASOM simulates market and trade equilibrium in the U.S. and 28 major foreign trading partners.

Solutions reveal commodity and factor prices, levels of production, export and import quantities, GHG emissions management strategy adoption, resource usage, and environmental impact indicators.

Environmental impacts include levels of greenhouse gas emission or absorption for carbon dioxide, methane, and nitrous oxide; surface, subsurface, and ground water pollution for nitrogen and phosphorous; and soil erosion.

Estimation data

180 systematic scenarios of independent variables

10 alternative carbon equivalent prices

- \$1, \$5, \$10, \$20, \$30, \$50, \$80, \$100, \$200, and \$300 per ton

3 levels of fuel prices for ethanol and energy

- 80%, 100%, 120% of base levels

3 levels of domestic demand

- 90%, 100%, 110% of base 1997 levels

2 levels of export demand

- 100%, 110% of base 1997 levels

Another 15 random scenarios from the ranges above for each of the 4 items to build degrees of freedom.

Same scenarios in all decades.

Generating dynamic response for integrated assessment

Estimated Functions

Quantity of GHG emissions and sinks.

Emissions of CO2, CH4, and N2O (broken out to avoid double counting)

Sinks for CO2

Ag&Forest Production, exports, imports and price

Fisher index agricultural production, exports,import levels and prices

Biofuel production

Land Use, allocation and valuation.

Acres for crops, biofuels, pasture and forest, land rental rates, and choice of tillage practices

Welfare distribution.

Agricultural and forest sector welfare for consumers', producers', and foreign interests

Levels of environmentally related items -

Use of crop land, irrigated water; nitrogen, phosphorus, potassium, pesticides, and fossil fuels levels of water and wind erosion

Generating dynamic response for integrated assessment

Functional form

$$\mathbf{Y_{kt}} = \mathbf{A_k}\, e^{\alpha_t D_t} \prod_i \mathbf{x_i}^{\beta_{ki}} \varepsilon_k$$

where

A_k =	an intercept term associated with the *k*th response function
β_{ik} =	a vector of estimated parameters associated the vector **x** of signals
D_t =	a decadal dummy variable
α_t =	a multiplicative shift in the dependent variable when we are in decade *t*
t =	years where t = 2010-9 is designated as the base and
D_t =	2,3, 4, 5, 6, and 7 represents years 2020-9, 2030-9, 2040-9, 2050-9, 2060-9, 2070-9, respectively

The base functions are for a year during 2010-2019 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

Generating dynamic response for integrated assessment

Dependent Variables:	2010	2020	2030	2040	2050	C Price	AgDem	Fuel P	Exports	R^2
GHG Accounts:										
CO2 other source emissions[a]	581.41	567.06	571.78	556.99	533.88	-0.122	0.054	-0.557	0.013*	0.765
CO2 soil and grass emissions[b]	21.17	22.95	12.75	37.72	39.27	-0.037	0.026*	-0.357	0.184*	0.629
CH4 source emissions	322.67	314.70	317.32	309.11	296.29	-0.105	0.048	-0.435	0.011*	0.722
N2O source emissions	5.98	5.91	6.23	6.54	6.66	-0.127	0.075	0.345	0.021*	0.687
CO2 offset from biofuel	0.19	0.25	0.38	0.59	0.82	0.355	-0.466	1.336	0.261	0.678
Tree carbon seq.	2.38	1.61	0.54	0.47	0.22	0.224	-0.094*	1.101	-0.143*	0.592
AgSoil carbon seq.	66.23	68.93	73.06	23.87	17.56	0.022	-0.007*	-0.086	0.029*	0.932
Agricultural Prices and Production:										
Price	8.32	9.51	9.80	9.26	8.40	0.109	0.001*	0.494	0.007*	0.814
Production	127.67	109.13	97.84	93.87	93.99	-0.129	0.077	-0.076	0.026*	0.752
Exports	1632.39	1607.20	1942.42	2181.68	2231.55	-0.210	-0.123	-1.834	1.291	0.749
Imports	13.07	13.51	13.74	13.62	13.63	0.012	0.284	0.135	0.014*	0.806
Forest Prices and Production:										
Price	121.44	109.74	95.40	93.18	82.96	0.051	-0.026*	0.063	-0.046*	0.701
Production	88.45	96.34	99.84	102.06	102.97	-0.017	0.011*	-0.027	0.028*	0.463
Exports	65.79	65.00	69.78	74.96	73.80	0.001*	0.016*	-0.009*	0.075*	0.204
Imports	67.29	53.95	37.05	26.78	19.79	0.127	-0.061*	0.120	0.144*	0.457

* Asterisk indicates insignificant from zero at a 0.10 significant level based on a one-tail test.

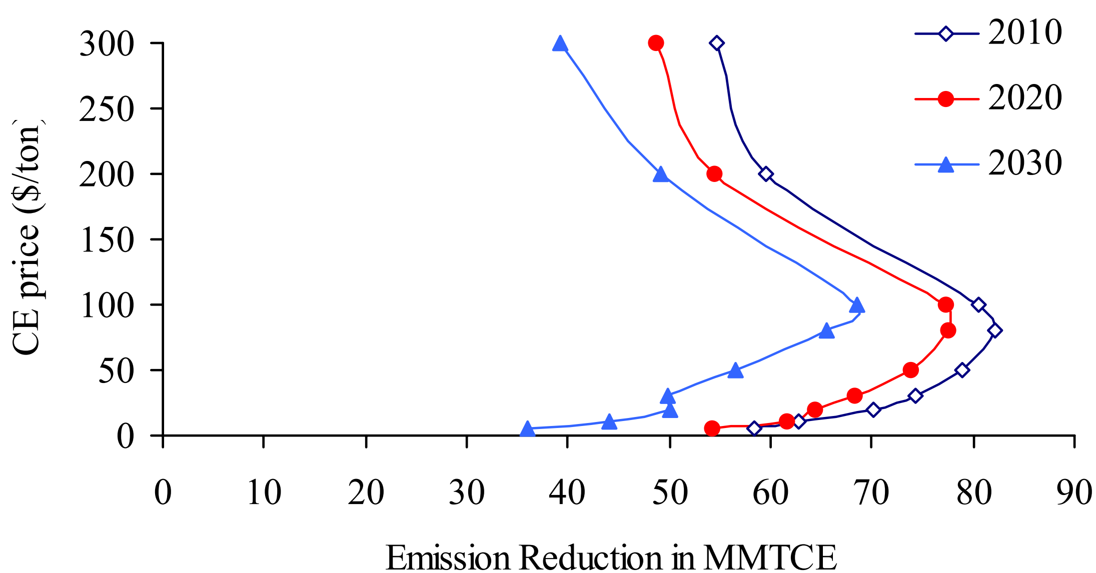
[a] CO_2 source emissions arise from the use of fuel, fertilizer manufacture, pesticide manufacture, and irrigation pumping.

[b] CO_2 source emissions arise from more intense tillage and changes in soil organic matter, and grassland development.

[c] The 4th order polynomial function is used to estimate the agricultural soil carbon sequestration.

GHG Abatement and US Agriculture: Generating data for Integrated assessment

Dynamics and saturation
Ongoing estimation attempts
Reductions from Agricultural Tillage



Source: **D. Gillig, B.A. McCarl and R.D. Sands Integrating Agricultural and Forestry Response to GHG Mitigation into General Economy Frameworks: Developing a Family of Response Functions using FASOM*, Draft manuscript, TAMU,2002.**