Insights from Agricultural GHG Offset studies

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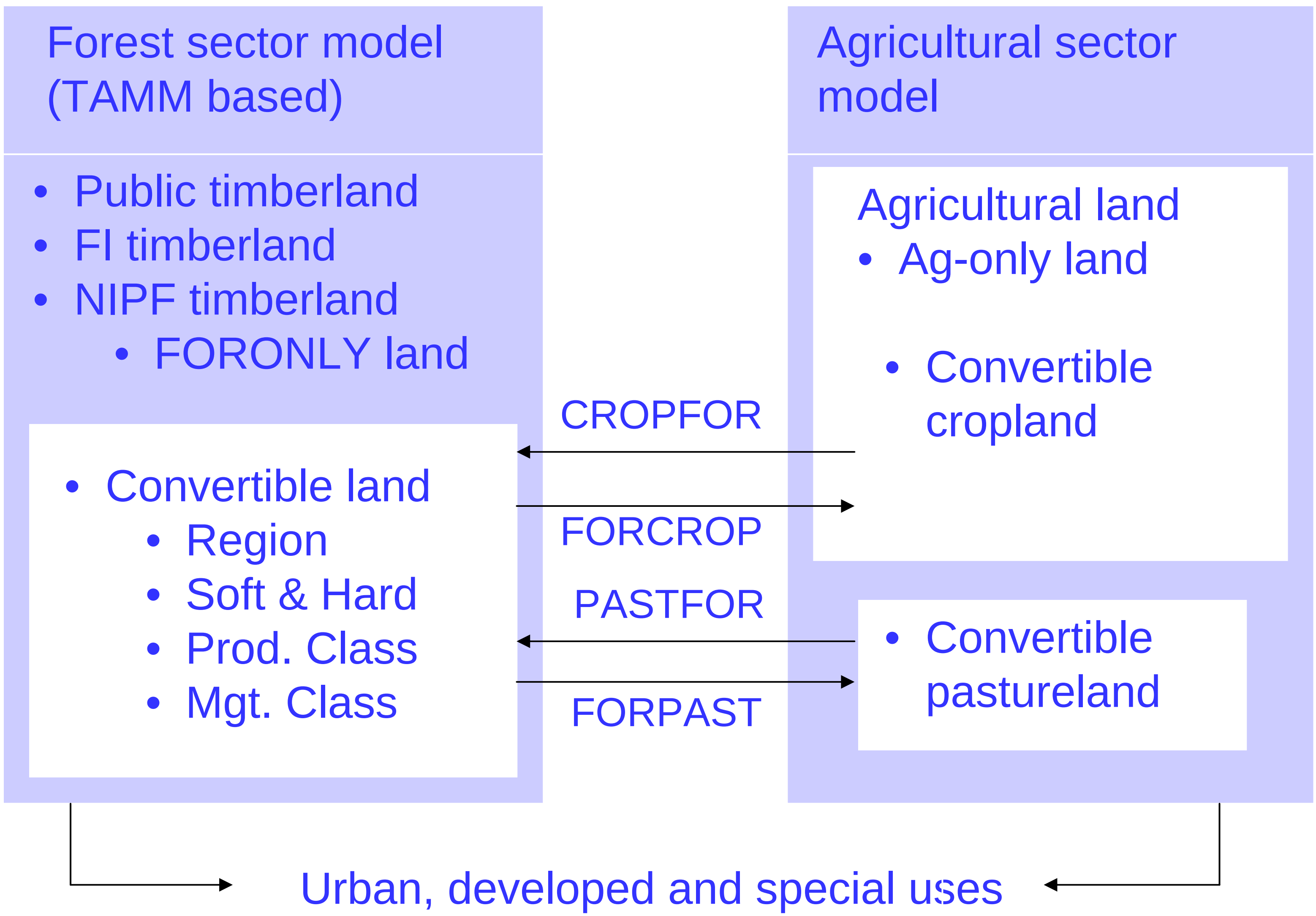
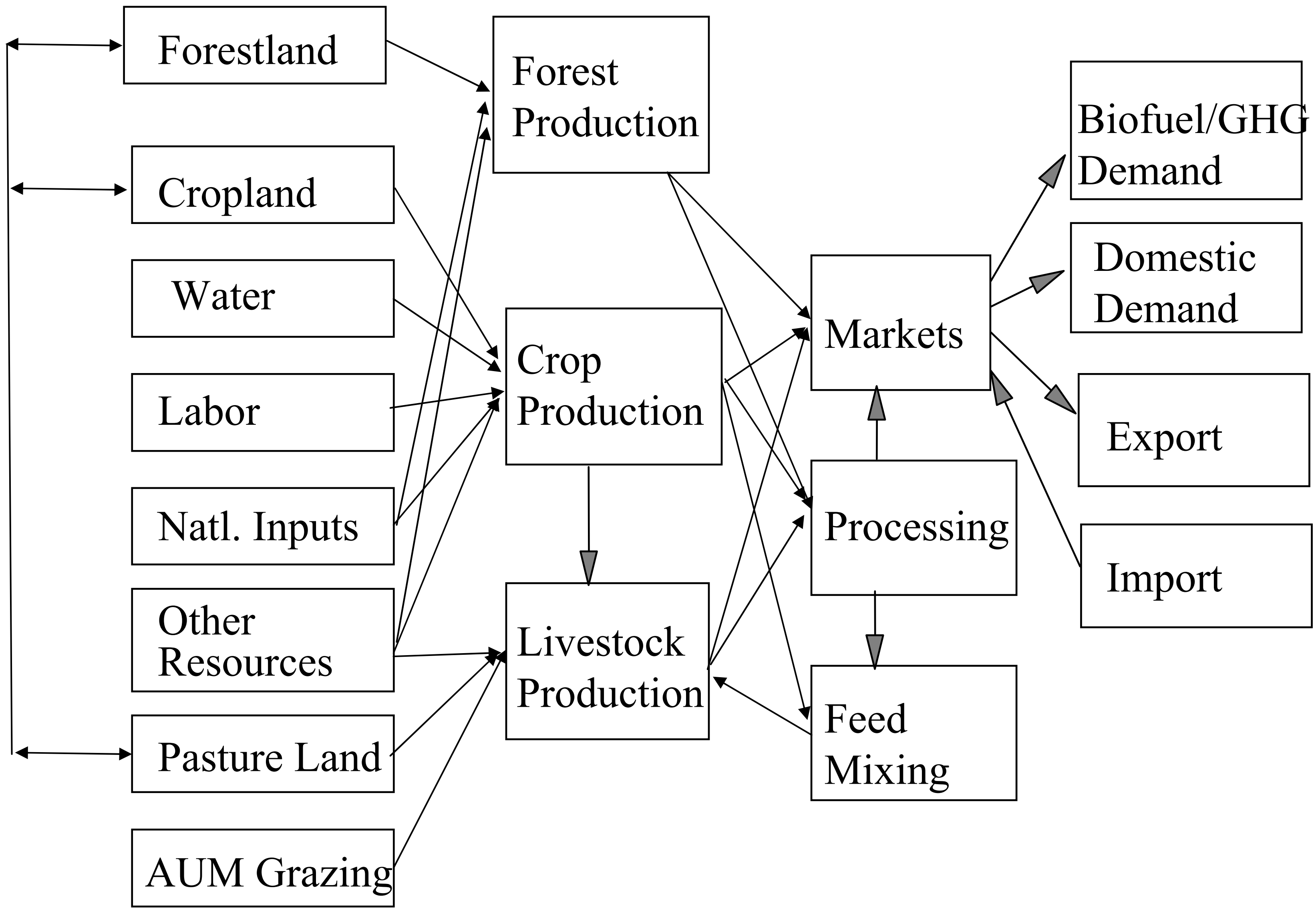
Paper/Study Objectives

- **Discuss insights from aggregate studies done on ag and forestry**
- **Address fungibility**
- **Provide backup material on model structure**

Basic Modeling



Basic Modeling



How are land-use and terrestrial GHG mitigation decisions currently modeled

Activity and GHG Coverage

Strategy	Basic Nature	CO_2	CH_4	N_2O
Afforestation	Sequestration	X		
Existing timberland/reforestation	Sequestration	X		
Deforestation	Emission	X		
Biofuel Production	Offset	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

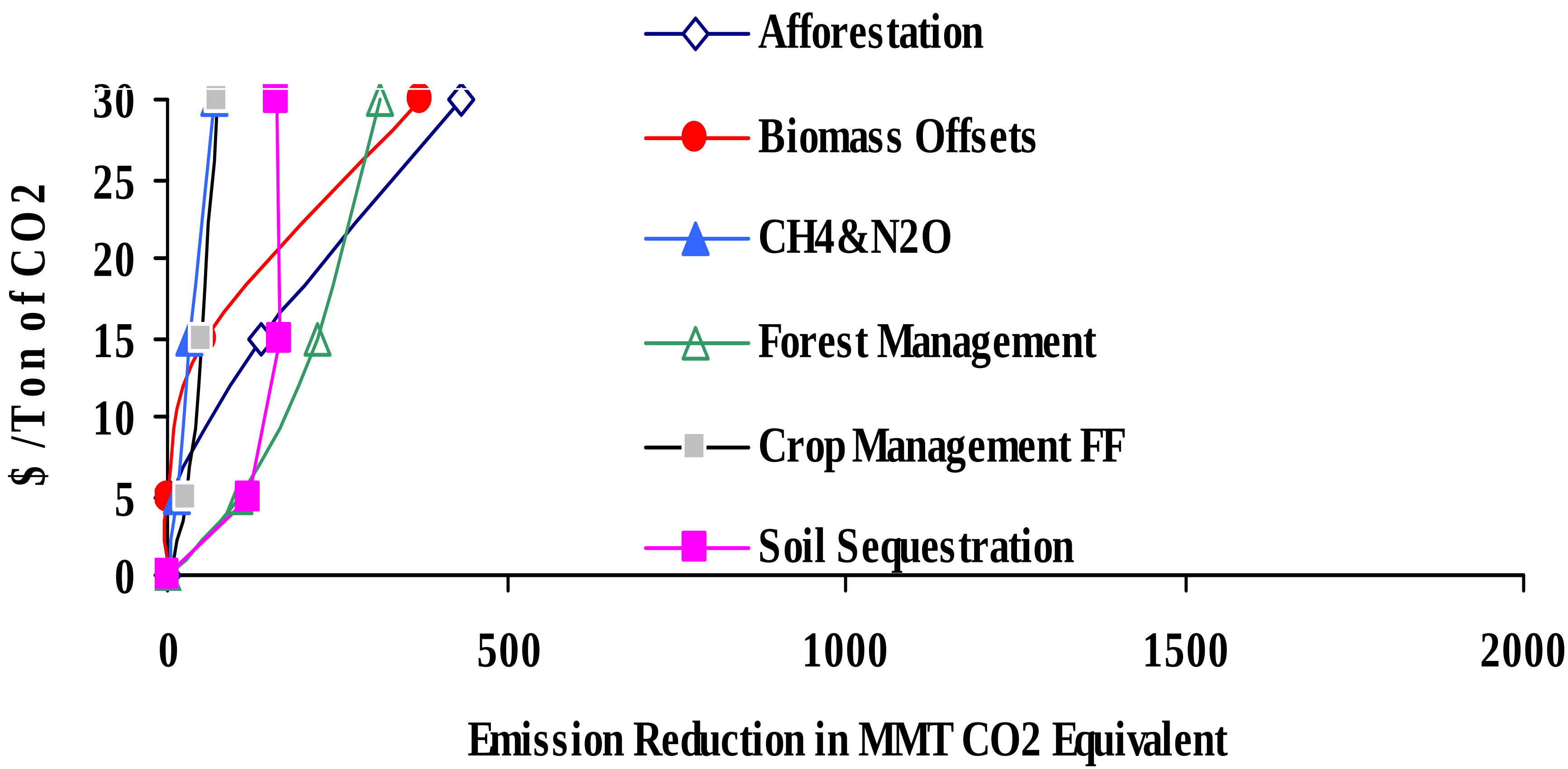
What issues might you consider?

Portfolio Complexity
Price dependence
Dynamics
Single strategy consideration
Value of economic framework
Economy wide perspective
Substitution with traditional production
– short and long run
Regional heterogeneity
Co-benefits
Fungibility

What issues might you consider?

Portfolio complexity and price dependence

MMt arising at an offset price giving $/tonne carbon equiv



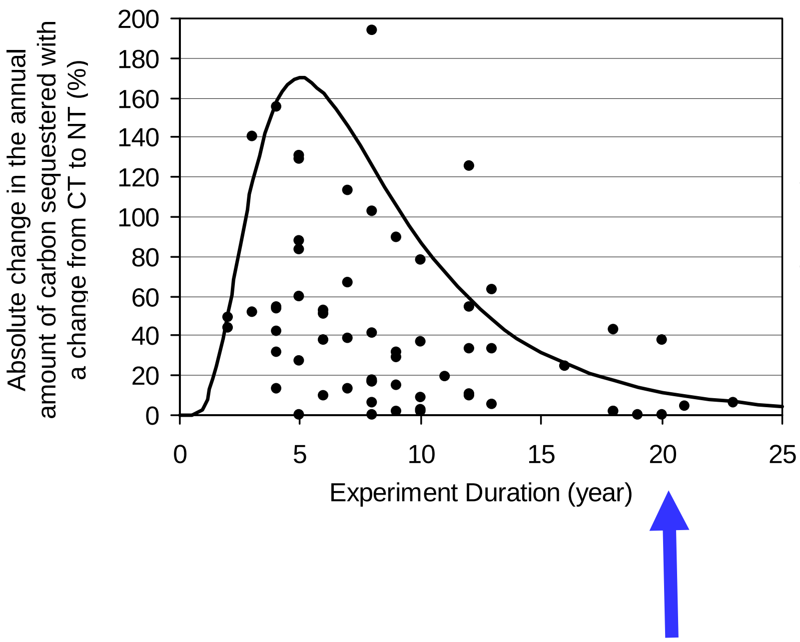
•Many contributions

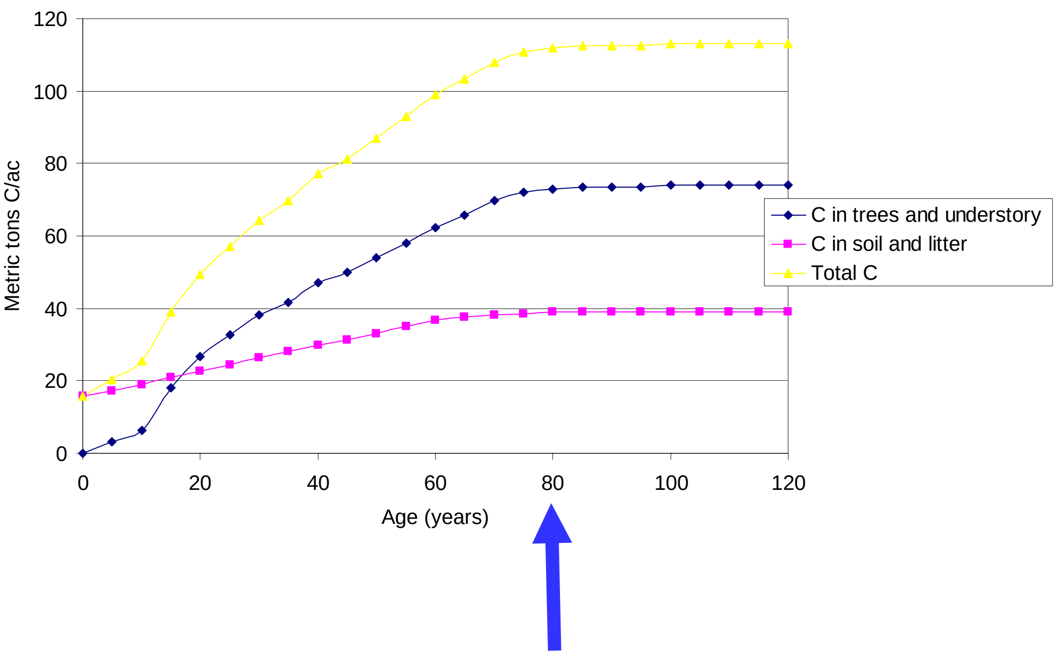
•Different strategies dominate at different price levels

What issues might you consider? Dynamics

Absolute Change in the Annual Rate of Carbon Sequestered Following a Change from Conventional Tillage (CT) to No-Till (NT) - West and Post

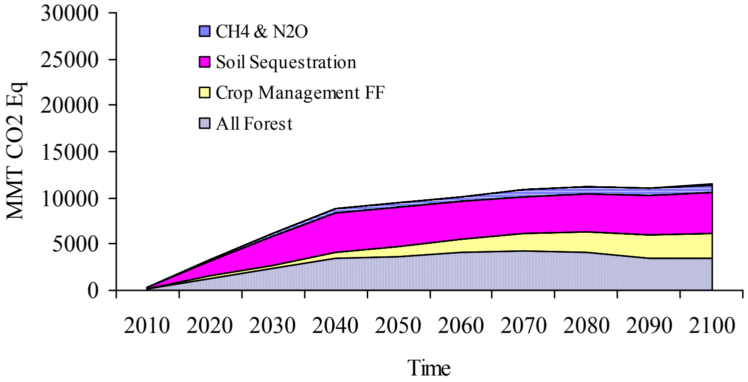
Carbon Accumulation on an Afforested Southeastern Pine Stand, to Saturation -- Birdsey



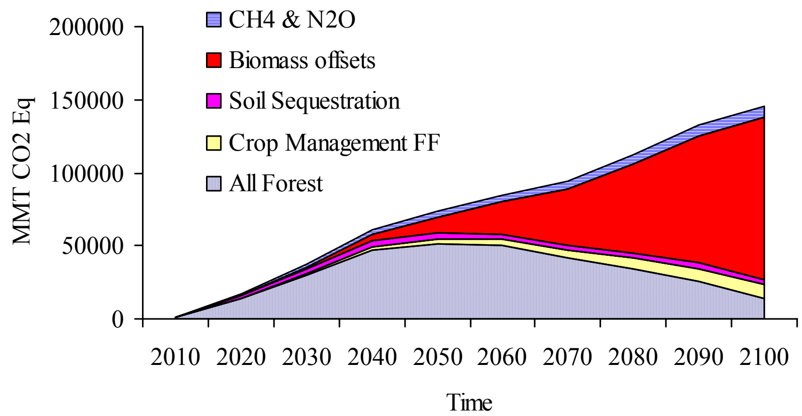


What issues might you consider?

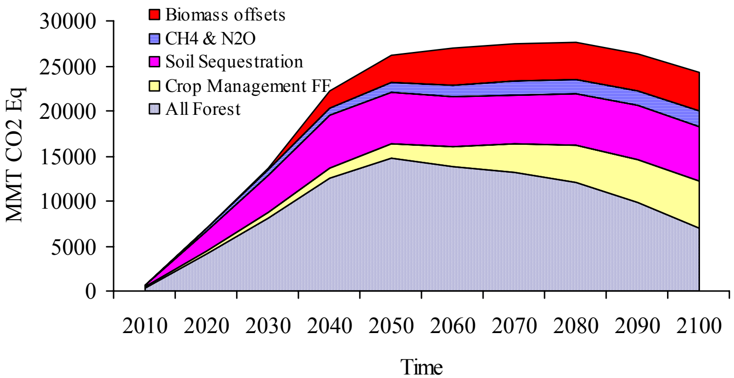
Dynamics



Cumulative Contribution at a $5 per tonne CO2 Price



Cumulative Contribution at a $50 Price



Cumulative Contribution at a $15 Price

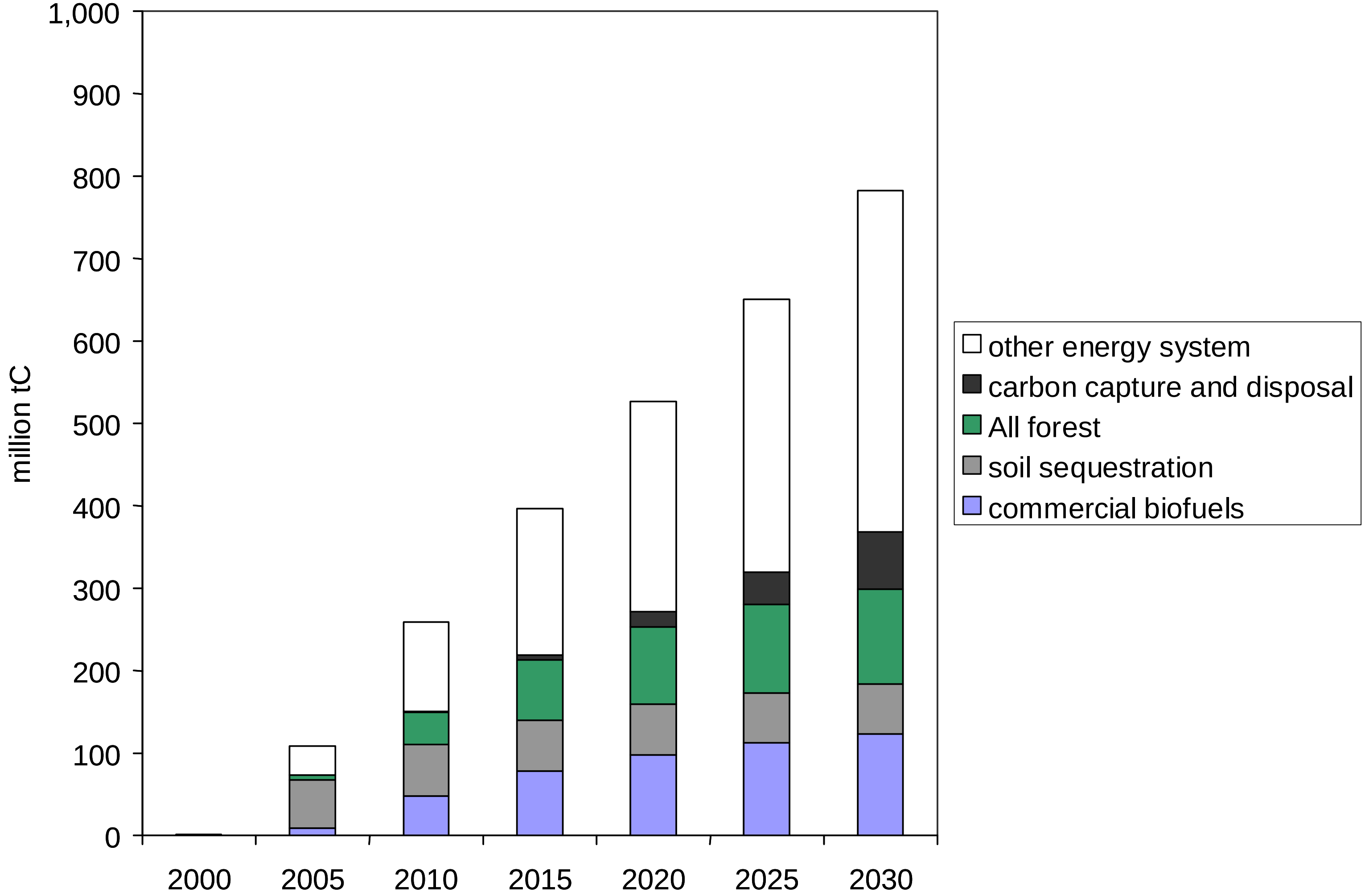
Note

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.

What issues might you consider?

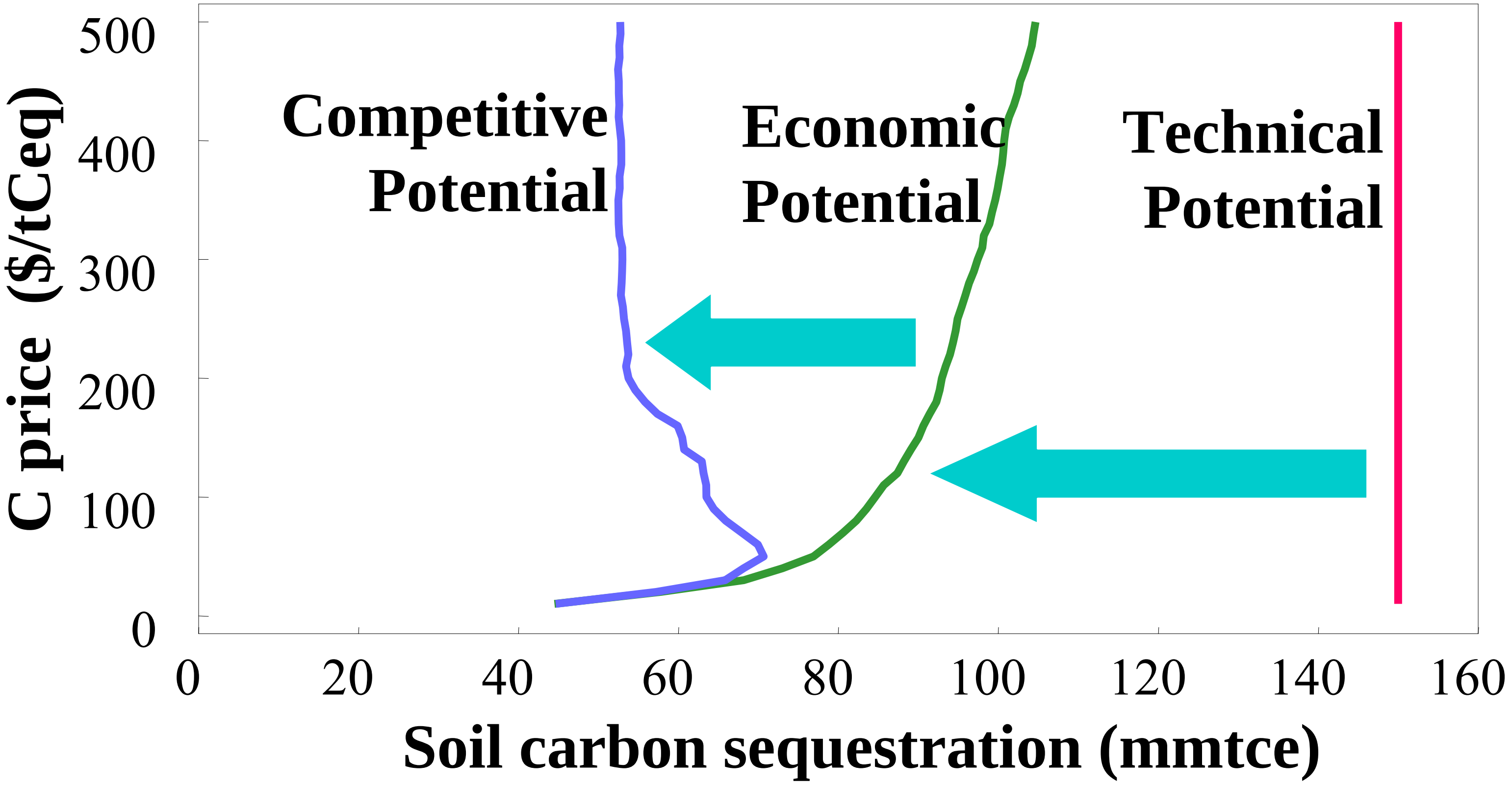
Economy wide perspective



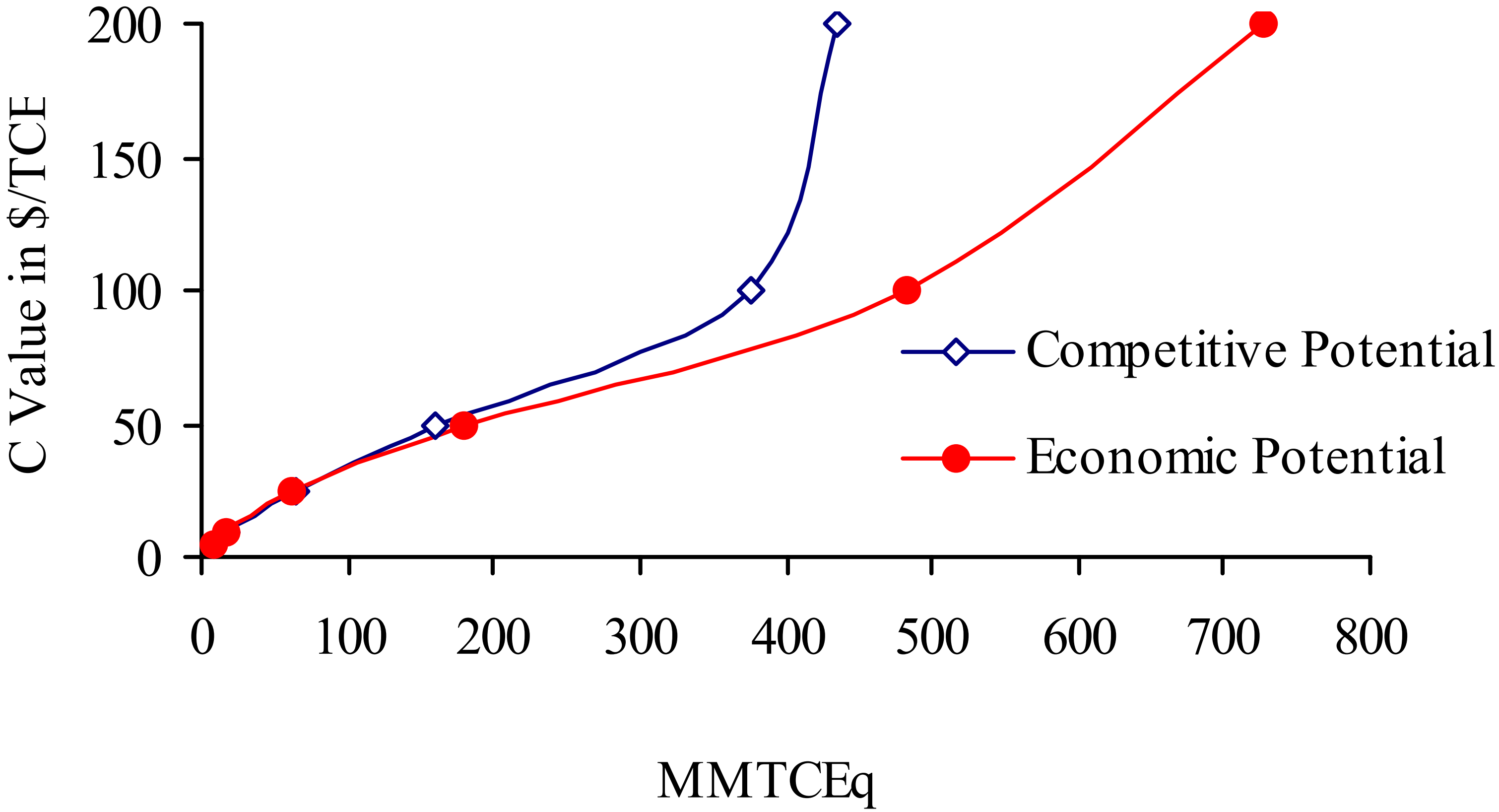
What issues might you consider?

Assessing potential and value of economics

Example: U.S. ag soil potential:



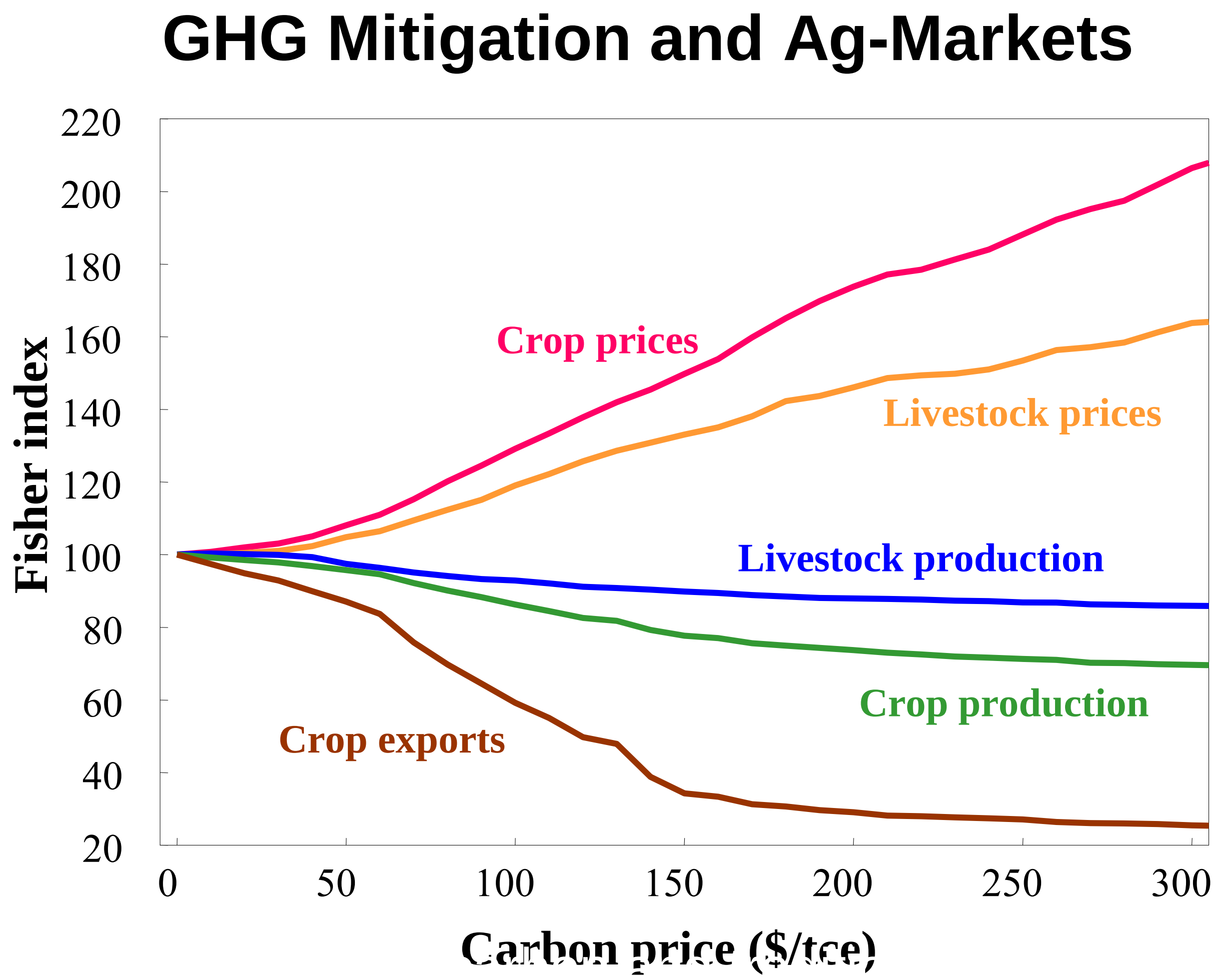
What issues might you consider?
Assessing potential and value of economics



Annual Carbon Sequestration in Forest Sector

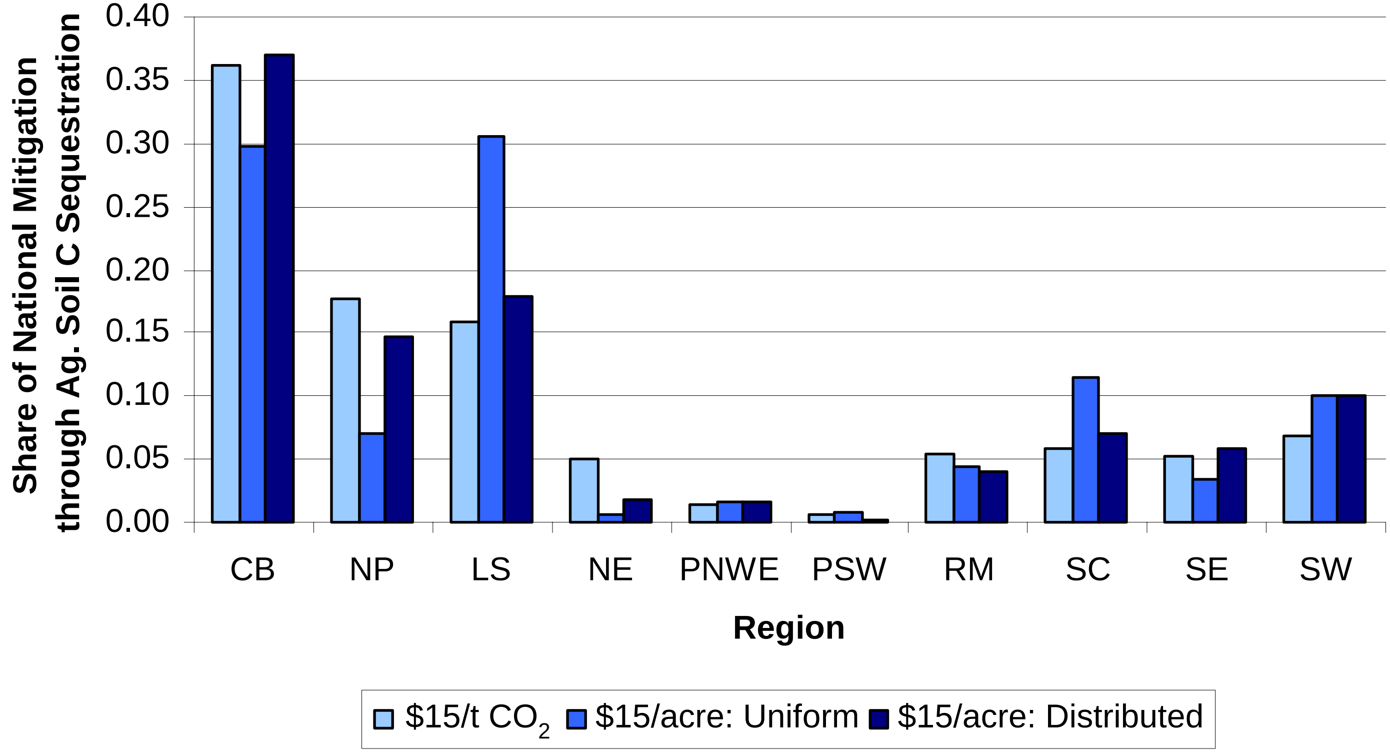
What issues might you consider?

Assessing potential and value of economics



What issues might you consider?
Regional heterogeneity

Regional Shares of Agricultural Soil Carbon Sequestration



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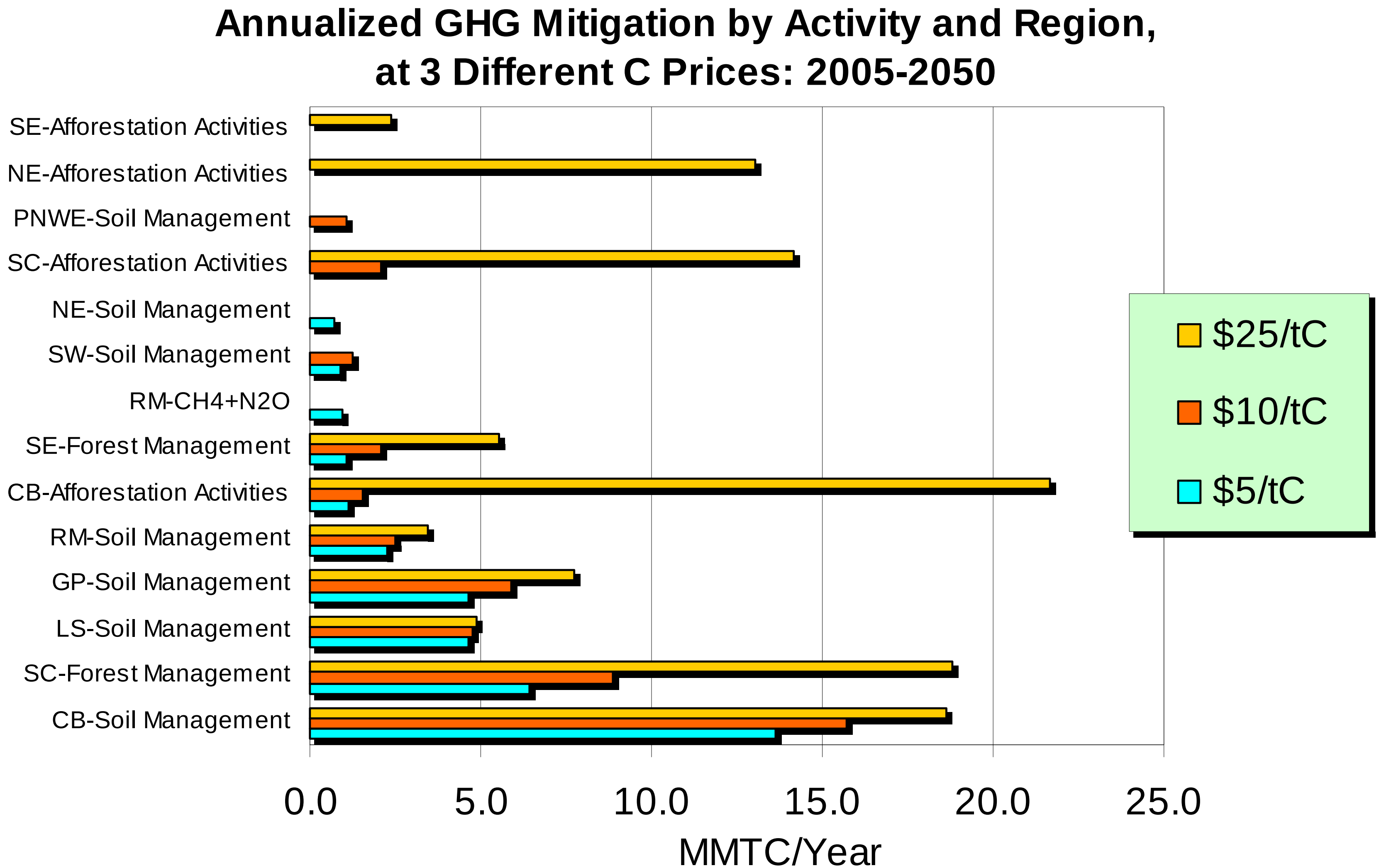
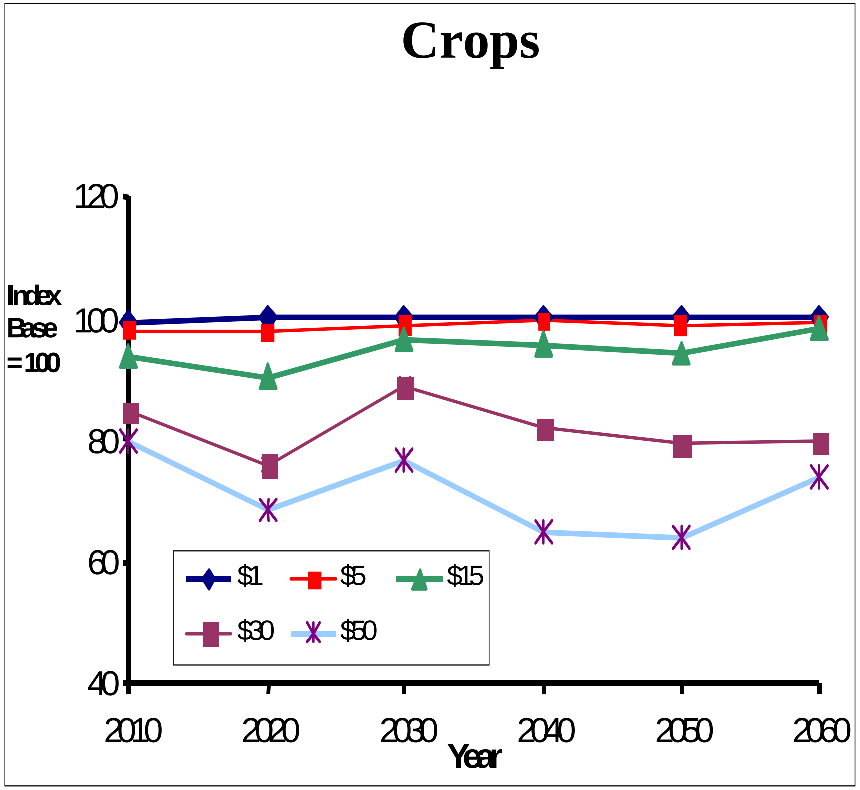
Regional heterogeneity

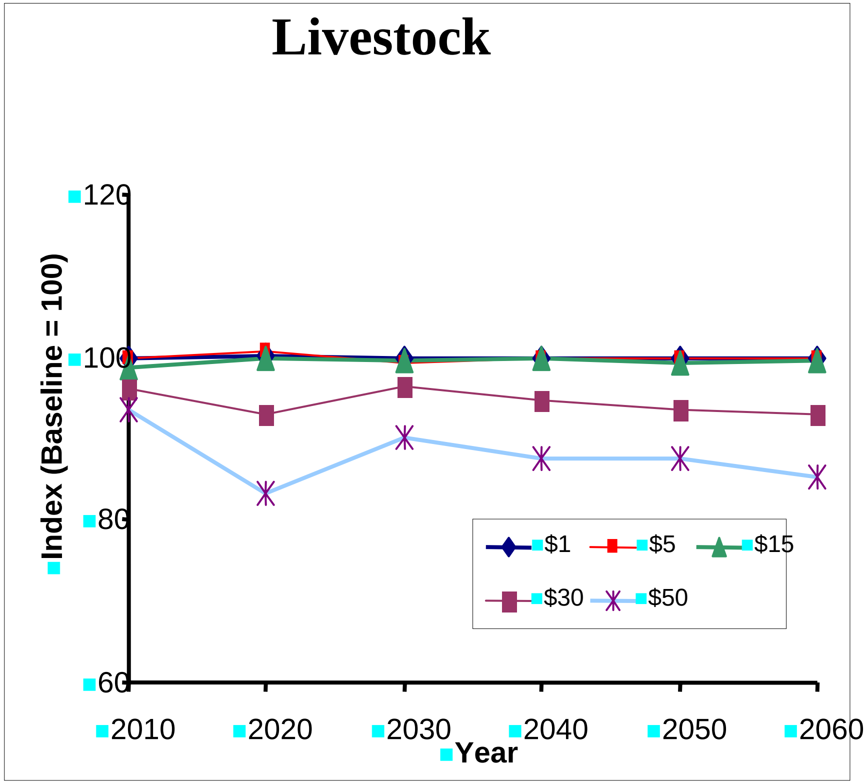


What issues might you consider?

Substitution with traditional production – short and long run

Production Quantity Index over Time

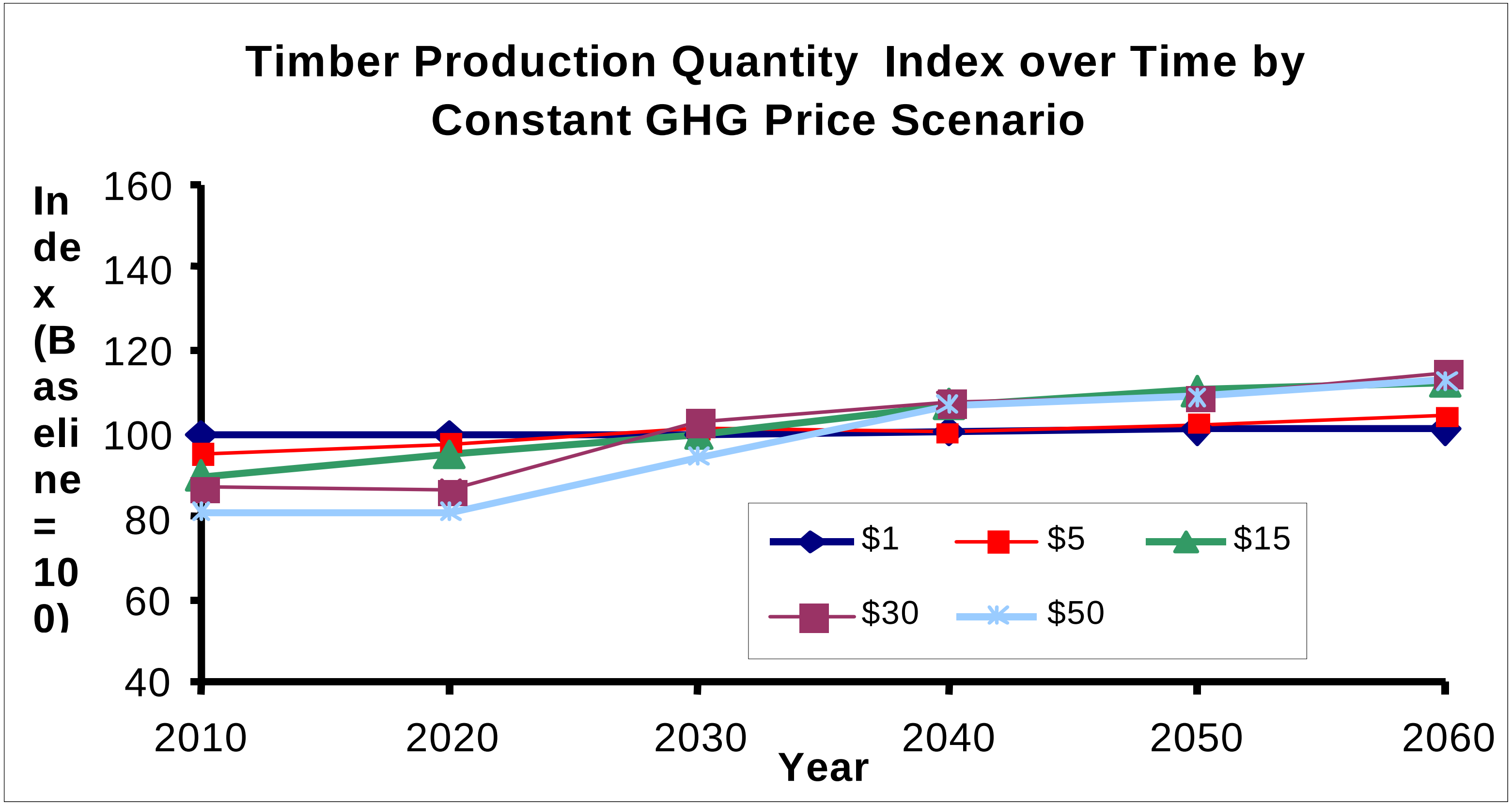




Substitutes

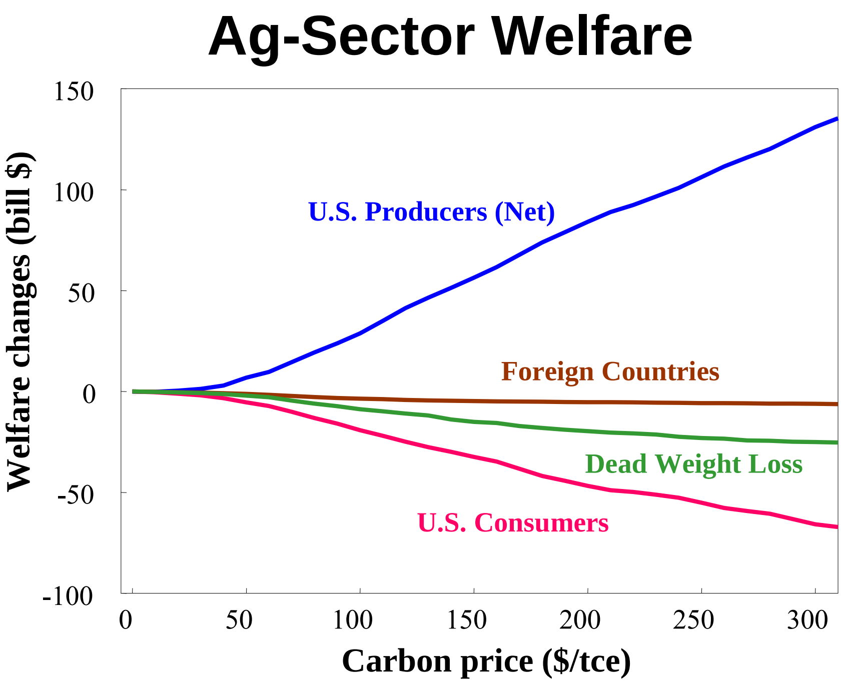
What issues might you consider?

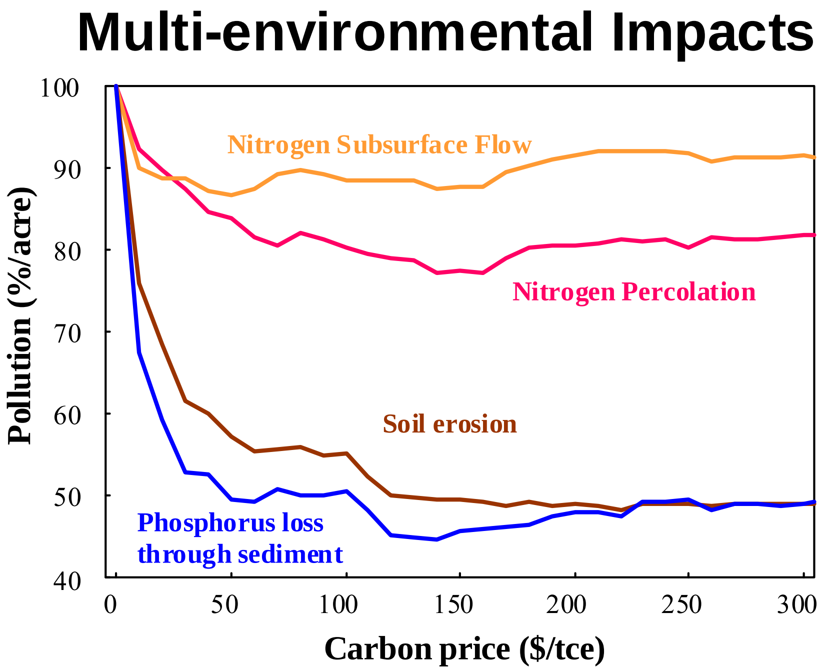
Substitution with traditional production – short and long run



Near term Substitutes, Long Run Complement

What issues might you consider?
Co-benefits





Gain here but lose in energy sector

Probably should ignore for now

What issues might you consider?
Fungibility

A number of concepts have arisen that are likely to differentially characterize the contribution of alternative possible offsets within the total regulatory structure. These involve:

- Permanence
- Additionality
- Leakage
- Uncertainty

General concern price may differentiate based on characteristics like a grading standard

What issues might you consider?
Fungibility

Grading standards

#2 yellow corn, CD plywood,
long staple cotton

Receive a price premium/discount depending upon product characteristics and consumer cost of using

GHG offsets may have consumer cost effects being not fully claimable due to

- Permanence
- Additionality
- Leakage
- Uncertainty

What issues might you consider?

Fungibility- How do we derive price discount?

$$\text{CurCostPerTon} = \frac{\text{PresValueCostOfOffset}}{\text{QuantityOffsetToday}}$$

$$\text{PresValueCostOfOffset} = \sum_{t=0}^{T} \frac{\text{PriceOffsetInYear}_t \ \text{QuantityOffsetInYear}_t + OtherCost_t}{(1+\text{D}isc)^t}$$

$$\text{QuantityOffsetToday} = \sum_{t=0}^{T} \frac{\text{QuantityOffsetInYear}_t}{(1+\text{D}isc)^t}$$

$$\text{CurCostPerTon} = \frac{\sum_{t=0}^{T} (\text{Pr}\,iceOffset * QuantityOffsetInYear_t + OtherCost_t)/(1+Disc)^t}{\sum_{t=0}^{T} QuantityOffsetInYear_t/(1+Disc)^t}$$

Note I have a non constant price variant

What issues might you consider?

Fungibility- How do we derive price discount?

To derive price discount for permanence etc add some terms (Pdiscount, buyback and claimable offsets) then equate a perfect perpetual offset with an imperfect one

$$\mathrm{CurCostPerTon}_{\mathrm{perfect}} = \frac{\sum_{t=0}^{T} (\mathrm{OffsetPr} * \mathrm{QOffset}_t * (1 - \mathrm{PDiscount}) - \mathrm{OffsetPr} * \mathrm{Buyback}_t + \mathrm{OthCost}_t)/(1+\mathrm{Disc})^t}{\sum_{t=0}^{T} \mathrm{ClaimQuanOffset}_t / (1+\mathrm{Disc})^t}$$

$$\mathrm{QOffset} = \mathrm{QOffset}_t$$

$$\mathrm{PDiscount} = 0$$

$$\mathrm{Buyback}_t = 0$$

$$\mathrm{OthCost}_t = 0$$

$$\mathrm{ClaimQuanOffset}_t = \mathrm{QOffset}$$

$$\mathrm{CurCostPerTon}_{\mathrm{perfect}} = \mathrm{OffsetPr}$$

$$\text{implies} \quad \mathrm{CurCostPerTon}_{\mathrm{perfect}} = \mathrm{CurCostPerTon}_{\mathrm{imperfect}}$$

What issues might you consider?

Price discount -- Permanence case

$$CurCostPerTon_{impermanent} = \frac{\sum_{t=0}^{T} (OffsetPr * (1 - discount) * (QOffset_t - Buyback_t) + OthCost_t) / (1 + Disc)^t}{\sum_{t=0}^{T} ClaimQuanOffset_t / (1 + Disc)^t}$$

$OffsetPr$	$\text{is discounted} = OffsetPr * (1 - PermDiscount)$
$QOffset_t$	varies with t
$Buyback_t$	<> 0 if leasing or if project reverses
$OthCost_t$	<> 0
$ClaimQuanOffset_t$	$= QOffset_t$
$CurCostPerTon_{perfect}$	$= CurCostPerTon_{imperfect}$

$$OffsetPr = \frac{\sum_{t=0}^{T} (OffsetPr * ((1 - PermDiscount) * QOffset_t - Buyback_t) + OthCost_t) / (1 + Disc)^t}{\sum_{t=0}^{T} ClaimQuanOffset_t / (1 + Disc)^t}$$

implies $$PermDiscount = \frac{\sum_{t=0}^{T} (Buyback_t + MainCost_t / PriceOffset) / (1 + Disc)^t}{\sum_{t=0}^{T} QuanOffset_t / (1 + Disc)^t}$$

What issues might you consider?

Price discount -- Permanence case

$$\text{PermDiscount} = \frac{\sum_{t=0}^{T} (\text{Buyback}_t + \text{MainCost}_t / \text{PriceOffset}) / (1+\text{Disc})^t}{\sum_{t=0}^{T} \text{QOffset}_t / (1+\text{Disc})^t}$$

When is discount zero

No Buyback

No Maintenance cost

25 year lease with 100% buyback – 48% price discount

Maintenance at 10% of cost -- 36%

What issues might you consider?
Fungibility - Other Cases

$$\text{UncertaintyDisc} = Z_{\alpha} * \text{CV}$$

$$\text{AdditionalityDisc} = \frac{\sum_{t=0}^{T} \text{QuanOffset}_t * \text{ProportionAdditional}_t / (1+\text{Disc})^t}{\sum_{t=0}^{T} \text{QuanOffset}_t / (1+\text{Disc})^t}$$

$$\text{LeakageDisc} = \frac{\sum_{t=0}^{T} \text{QuanOffset}_t * (1-\text{ProportionLeakage}_t) / (1+\text{Disc})^t}{\sum_{t=0}^{T} \text{QuanOffset}_t / (1+\text{Disc})^t}$$

$$\text{PricetoOffsetProducer} = \text{Offsetprice} * (1-\text{PermDisc}) * (1-\text{UncerDisc}) * (1-\text{AddDisc}) * (1-\text{LeakDisc})$$

What issues might you consider?

Fungibility - Other Cases

$$\text{ProportionAdditional} = \frac{\text{WithProjectOffsets - BaselineOffsets}}{\text{WithProjectOffsets}}$$

$$\text{ProportionLeaking} = \frac{e * C_{ot}}{[e - E * (1 + P)]\, C_{pr}}$$

e is the price elasticity of supply for off project producers.

E is the price elasticity of demand for commodity produced.

Cot is GHG emissions per unit of increased commodity production outside project.

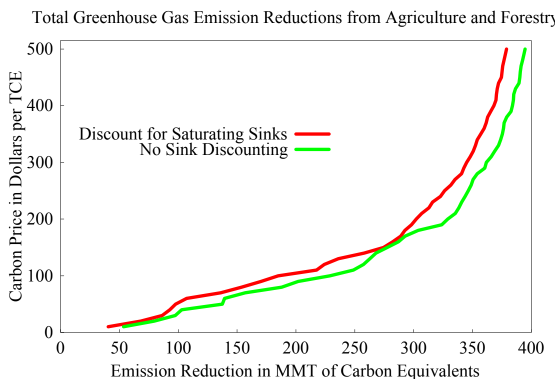
Cpr is GHG offsets per unit of reduced commodity production in project.

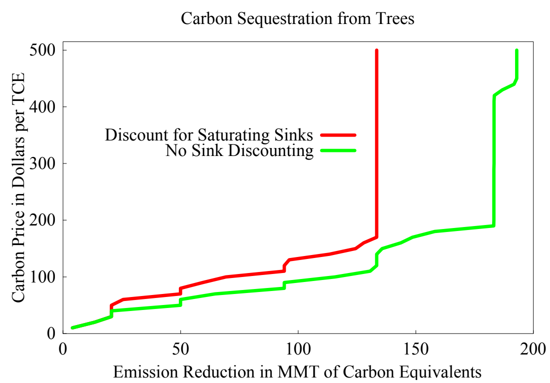
P is relative market share and is quantity of commodity produced by project divided by market amount produced.

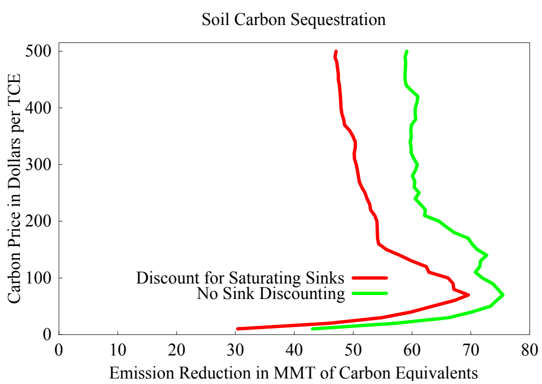
What issues might you consider?

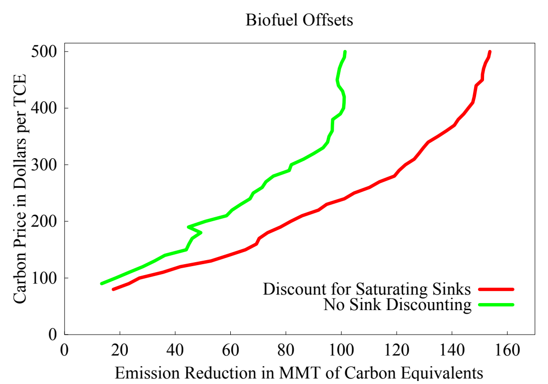
Fungibility - Aggegate

FASOM handles permanence, domestic additivity, domestic leakage, some uncertainty, Back to ASM permanence only









What issues might you consider?
Fungibility

Beaumont through Columbus Texas area has historically produced rice. In 1985, 600,000 acres. In 2000, 214,000 acres. Policy, environment and markets are applying pressure. Today, many rice producers are in quest of new opportunities. Trees, other crops and pasture provide possible alternatives to some.

$$\text{PricetoOffsetProducer} = \text{Offsetprice} * (1 - \text{PermDisc}) * (1 - \text{UncerDisc}) * (1 - \text{AddDisc}) * (1 - \text{LeakDisc})$$

	Perm	Add	Leak	Uncer	All	Saleable
Rice to crops	30%	12%	32%	10%	62%	**38%**
Rice to pasture	50%	4%	17%	10%	64%	**36%**
Rice - trees(pulp)	30%	1%	16%	10%	48%	**52%**
Rice - trees (saw)	10%	1%	16%	10%	33%	**67%**

Not additive

So What

Ag and forest have low cost opportunities

Type of response depends on price, place and time

Permanence is an issue but may bridge to future

Watch out for non economic estimates

Suports farm prices and incomes

Co benefits but double edged

Fungibility can be a problem

A Supplementary Appendix
Some Modeling Details

Forest products

SWSAWTLOGWOODS	SWPULPLOGWOODS	SWFUELLOGWOODS	
HWSAWTLOGWOODS	HWPULPLOGWOODS	HWFUELLOGWOODS	
SWSAWTLOGMILL	SWPULPLOGMILL	SWFUELLOGMILL	
HWSAWTLOGMILL	HWPULPLOGMILL	HWFUELLOGMILL	
SLUM	SPLY	SWMISC	SRESIDUES
HLUM	HPLY	HWMISC	HRESIDUES
OSB			
SPWOOD	HPWOOD	HWPULP	SWPULP
AGRIFIBERLONG	AGRIFIBERSHORT	OLDNEWSPAPERS	OLDCORRUGATED
WASTEPAPER	PULPSUBSTITUTE	HIGDEINKING	NEWSPRINT
UNCFREESHEET	CFREESHEET	UNCGROUNDWOOD	CGROUNDWOOD
TISSUE	SPECIALTYPKG	KRAFTPKG	LINERBOARD
CORRUGMED	SBLBOARD	RECBOARD	CONSTPAPER
DISPULP	SWKMPULP	HWKMPULP	RECMPULP
CTMPMPULP			

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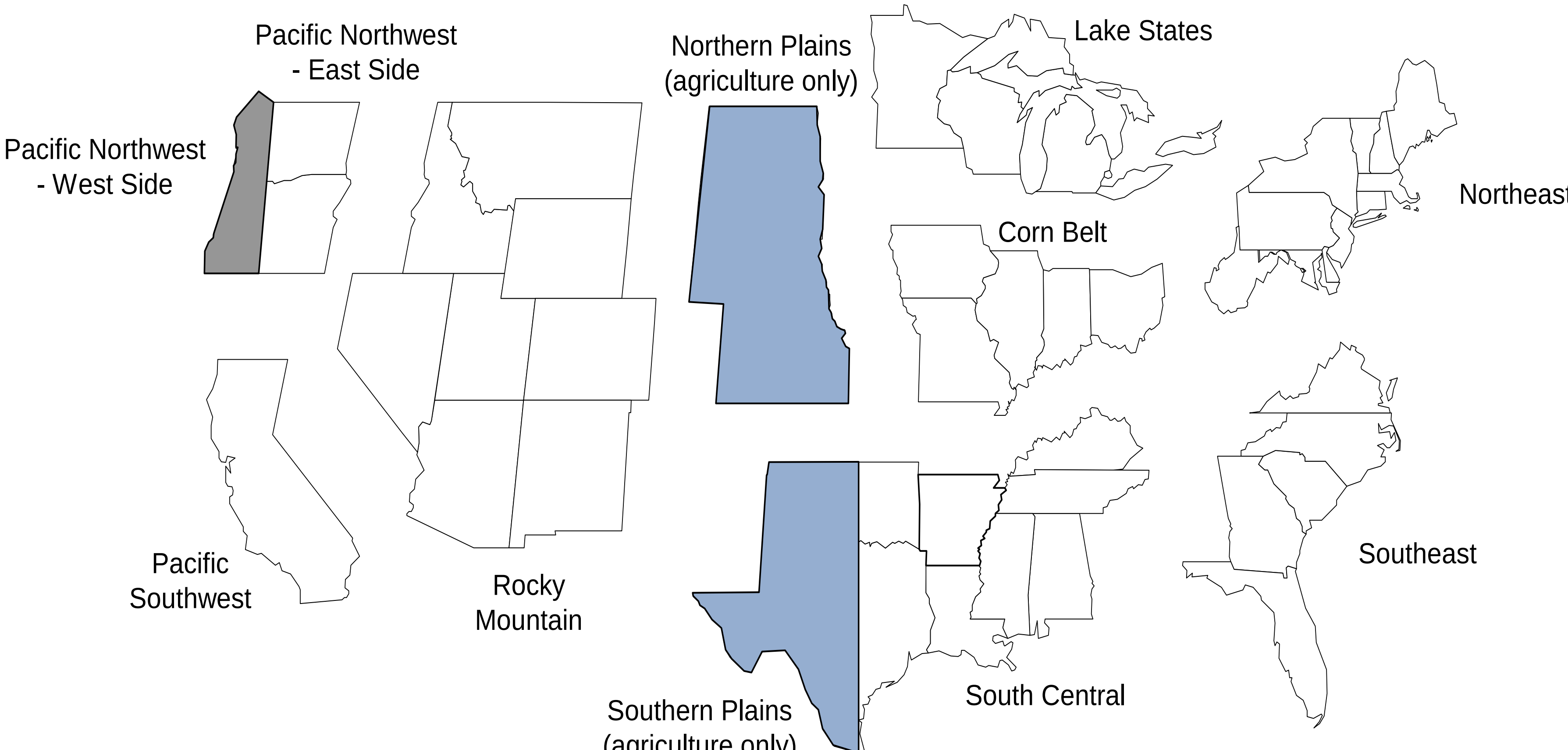
Some Modeling Details

Regions In Forestry



How is land currently characterized by bio-physical models and IAMs?

In US Agriculture

Subreg

Alabama	Arizona	Arkansas	CaliforniN	CaliforniS
Colorado	Conn	Delaware	Florida	Georgia
Idaho	IllinoisN	IllinoisS	IndianaN	IndianaS
IowaW	IowaCent	IowaNE	IowaS	Kansas
Kentucky	Louisiana	Maine	Maryland	Mass
Michigan	Minnesota	Mississipp	Missouri	Montana
Nebraska	Nevada	NewHampshi	NewJersey	NewMexico
NewYork	NorthCarol	NorthDakot	OhioNW	OhioS
OhioNE	Oklahoma	Oregon	Pennsylvan	Rhodeislan
Southcarol	Southdakot	Tennessee	TxHiPlains	TxRolingPl
TxCntBlack	TxEast	TxEdplat	TxCoastBe	TxSouth
TxTranspec	Utah	Vermont	Virginia	Washington
Westvirgin	Wisconsin	Wyoming		

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Forest products

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In Forestry

Cls	Land suitability
FORONLY	Forested land suitable only for forest uses
FORCROP	Currently forested land that was once crop land
FORPAST	Currently forested land that was once pasture
CROPFOR	Afforested land that came from crop land
PASTFOR	Afforested land that came from pasture land

Owner

FI	Forest industry lands
OP	Other private ownership

A Supplementary Appendix
Some Modeling Details

In US Agriculture

TLTECH tillage types

Vent Conventional Tillage
Cons Conservational Tillage
Zero Zero Tillage

Plus duration

years 0 to 30 that crop has been in this tillage type

A Supplementary Appendix
Some Modeling Details

In US Forestry

Site land quality

HI ME LO

MgtIntensity management applied (25 types as opposed to 4)

trad_plnt_pine	lo	plnt_med
plnt_hi	short_rotswds	reserved
Passive	affor	nat_regen
Plant	plant+	affor_cb
plnt_lo_thin	plnt_med_thin	plnt_hi_thin
nat_regen_thin	plant_thin	
part_cut_lo	part_cut_hi	part_cut_hi+
natregen_partcut_md	natreg_pcut_hi	lo_part_cut
ntregen_partcut_lo		

Supplementary Appendix
Some Modeling Details

In Forestry

Species types of forest stands specifying rotation

(10 as opposed to 2)

BOT_HARD	HARD	UP_HARD
DOUG_FIR	NAT_PINE	OAK_PINE
OTH_SWDS	PLNT_PINE	PLT_PINE
SOFT		

Tree age

0-4 to 95-99 in 5 year increments plus 100+

used to be 10 year age classes

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

FASOMGHG Dimensions (II)

- **Temporal**
  - 100 year horizon
  - Decadal time step
  - Dynamically optimal: economic agents are forward-looking
  - Biophysical data from USDA RPA assessment:
    - capture non-linear, time-dependent processes of:
      - soil carbon accumulation,
      - forest growth, and
      - CO_2 releases through forest product decay

Foreign Regions in FASOMGHG

Agricultural GHG Accounting — Saturation

- Assume soils stop sequestering carbon after 30 years.
- Assume linear approach to saturation.
- Model separates tillage from production, then keeps vintage information on how long tillage practice has been used.
- Assume carbon increments occur in the first three decades, then stop.
- Model separates carbon by crop under given tillage system, from the average carbon under that tillage system.
- Explicit saturation discounts not needed, since we formally use a NPV framework.

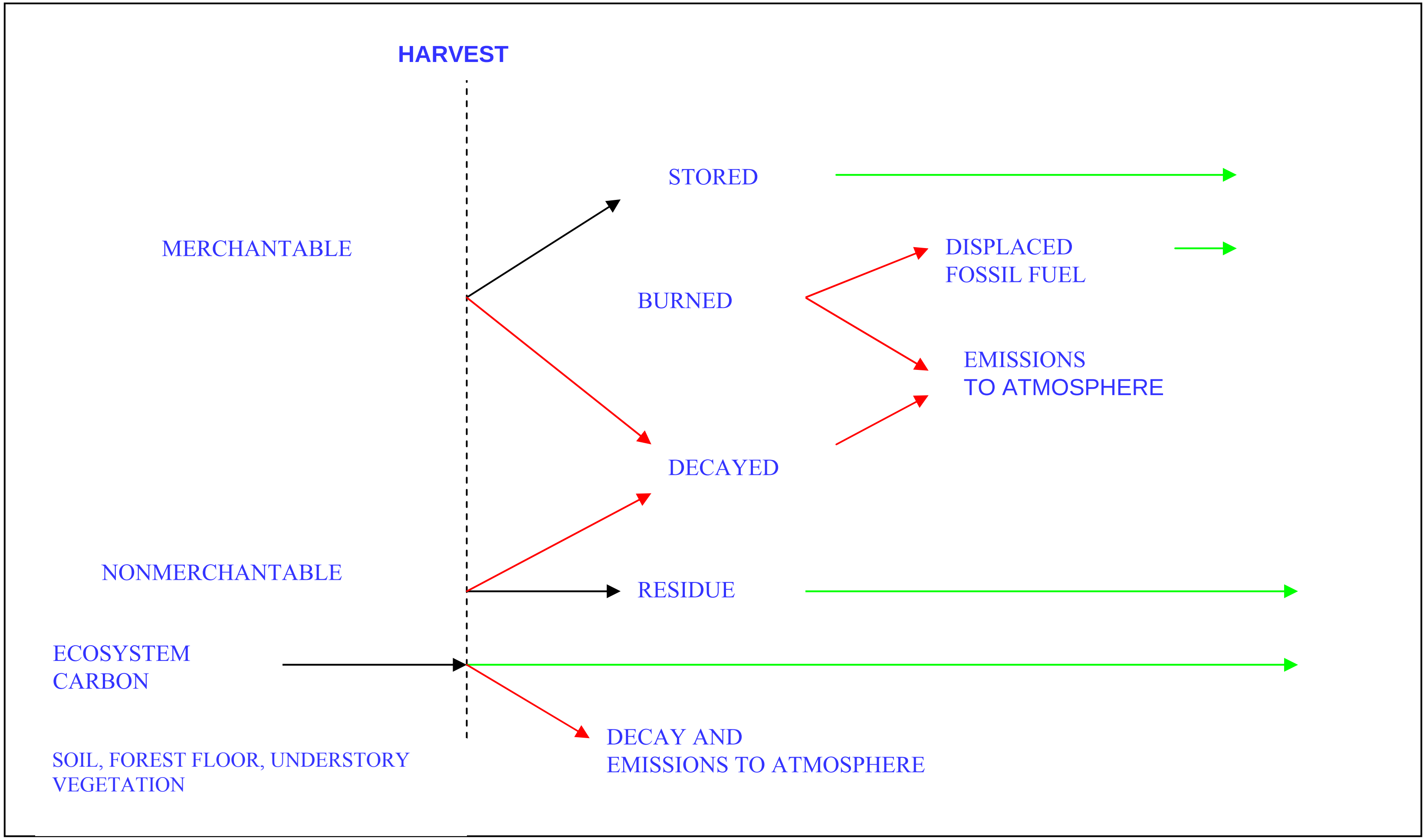
Biofuels

- Two opportunities — Ethanol and biofuel for power plants
- Biomass production for power plant use in FASOM required several new production possibilities be added:
  - Diversion of mill residues from traditional pulp and paper or other uses;
  - Collection of logging residue or harvest of whole trees for chipping, and shipment to a power plant;
  - Production and hauling of switch grass and short rotation woody crops for biomass
  - Treatment of power plant use of biomass to the point where the energy in biomass is on an equivalent basis with the energy from coal; (100 mega watt plant) Ira Shavel, Mark Shenckel and Bob Shackleton made up numbers for this)
  - Treatment of the possible use of wood chips from short rotation woody crops for pulp and paper production.
- Each is covered in http://ageco.tamu.edu/faculty/mccarl/papers/679.pdf
- Turnure, J. T., S. Winnett, R. Shackleton, and W. Hohenstein. Biomass Electricity: Long-Run Economic Prospects and Climate Policy Implications. unpublished paper U.S. Environmental Protection Agency, Office of Policy Analysis, Washington, DC, 1995.

Merchantable Timber Volume Yields & Forest Inventory

- Timber inventory strata by:
  - Region (9)
  - Ownership (2)
  - Forest type (4 classes describing species composition, either softwoods or hardwoods, in the current and preceding rotation)
  - Site productivity (3 levels for potential wood volume growth)
  - Timber management intensity (4)
  - Suitability for conversion (3)
  - 10-year age classes (10)
- Each stratum is represented by the number of timberland acres and the growing stock volume per unit area

Forest Carbon Accounting after Harvest



How are land-use and terrestrial GHG mitigation decisions currently modeled

- Constrained Optimization Problem
- Objective Function: Maximize NPV of sum of producers' and consumers' 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

How should land potential and land-use responses (impacts) to climate change be modeled?

A House of Cards

Climate Scenarios	– GCMs
Crop Simulation	– Crop yields (dry and irr), water use Carbon sequestration
Forest Simulation	– Yields by region, year and species Product fate Carbon sequestration
Hydrologic simulation	– Irrigation water
Livestock sim /experts	– Livestock performance,
Grass simulation	– Livestock pasture usage Animal unit month grazing supply Carbon sequestered
Other studies	– International supply and demand
Regression	– Pesticide usage, Non Ag water use Extreme event effects
Adaptation obs/expert	– Crop mix shift Varieties
GHG Mitigation	– Methane from rice, enteric, manure, others N2O from fertilizer, manure, other sources Biomass yields and processing
Economics	– FASOM sector model