Agricultural and Carbon Sequestration FASOM and IAM Models

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Paper/Study Objectives

- **Address questions in conference document**
- **Discuss insights from studies done on ag and forestry that could influence IAM work**
- **Reveal some information on project direction**

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

Reporting on FASOM – Forest and Agriculture Sector Optimizing Model – GHG version which is a 2 sector economic model (Not either an IAM or a biophysical)

Land Characterization depends on sector

Differs somewhat in ag and forestry

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

In Forestry

Land is represented by array

INVENT(cohort,reg,CLS,OWNER,SPECIES,SITE,MIC)

Which now has 7430 cases and we pick up a 100+ more with afforestation

Dimensions

Cohort tree ages

0-100+ years in 5 year ages

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

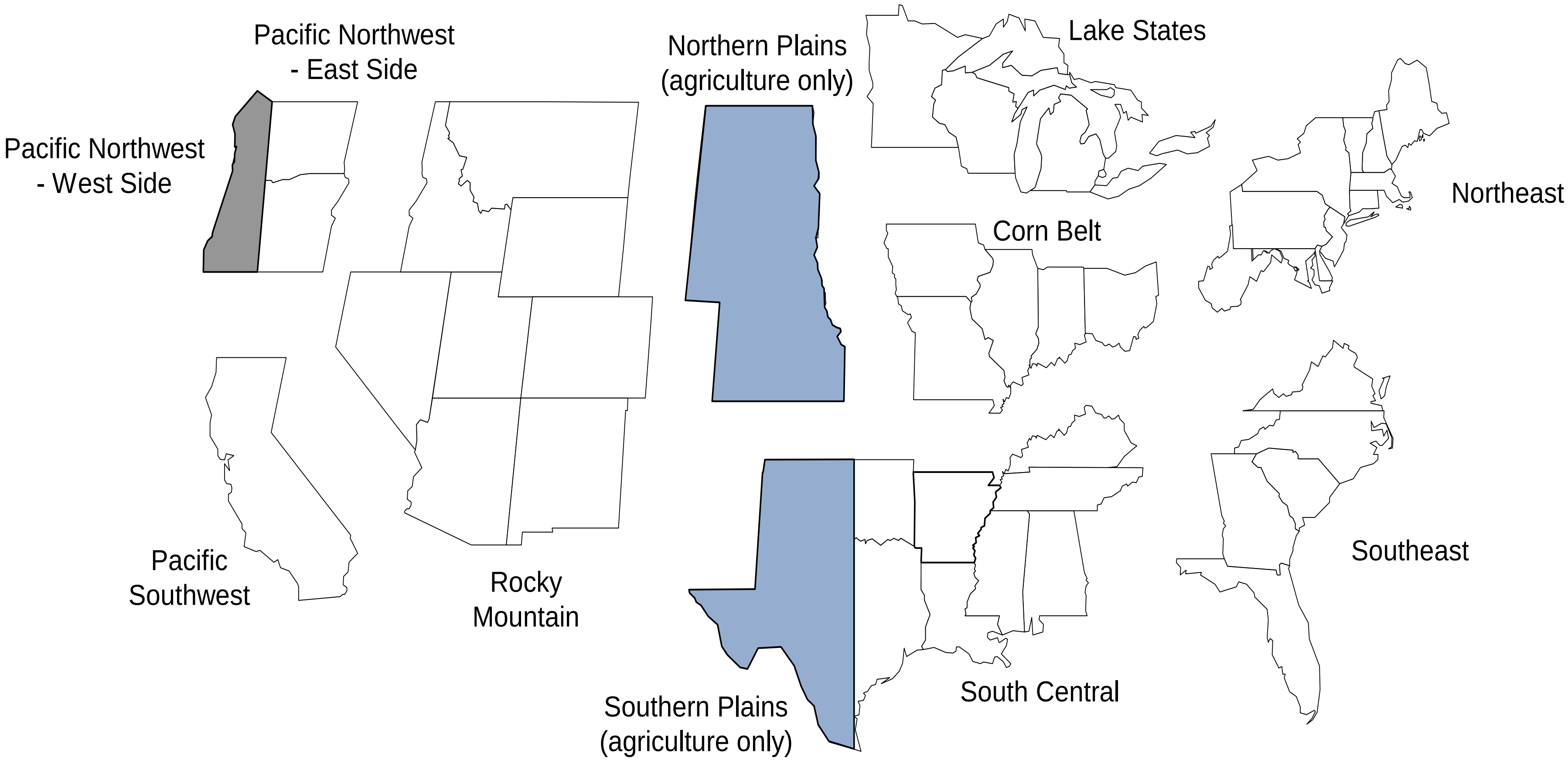
In Forestry

Regions

CB	Corn Belt
GP	Great Plains (no forestry)
LS	Lake States
NE	Northeast
RM	Rocky Mountains
PSW	Pacific Southwest
PNWW	Pacific Northwest west side (no ag)
PNWE	Pacific Northwest east side
SC	South Central
SE	Southeast
SW	South West (no forestry)

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

In Forestry



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

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
NF	National forest lands
OG	Other governmental lands

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

In Forestry

Species types of forest stands specifying rotation

(30 but really 3)

plnt_pine_plnt_pine	plnt_pine_nat_pine	plnt_pine_oak_pine
plnt_pine_up_hard	plnt_pine_bot_hard	nat_pine_plnt_pine
nat_pine_nat_pine	nat_pine_oak_pine	nat_pine_up_hard
nat_pine_bot_hard	oak_pine_plnt_pine	oak_pine_nat_pine
oak_pine_oak_pine	oak_pine_up_hard	oak_pine_bot_hard
up_hard_plnt_pine	up_hard_up_hard	bot_hard_plnt_pine
bot_hard_bot_hard	doug_fir_doug_fir	doug_fir_oth_swds
doug_fir_hard	oth_swds_doug_fir	oth_swds_oth_swds
oth_swds_hard	hard_doug_fir	hard_oth_swds
hard_hard	soft_soft	soft_hard

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

In US Forestry

Site **land quality**

HIMELO

Mic **management applied (25 types)**

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

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

In Forest trade Manufacture and Markets

No Land Modeling

CBCC	**Canada British Columbia for product manufacture**
CINT	**Canada Interior for product manufacture**
CEST	**Canada East for product manufacture**
North	**Northern US for product manufacture**
Northeast	**Northeastern US for product manufacture**
Northcentral	**North Central US for product manufacture**
South	**Southern US for product manufacture**
Southeast	**South Eastern US for product manufacture**
Southcentral	**South Central US for product manufacture**
West	**Western US for product manufacture**
Canada	**Canada as a whole for demand and exports**
Canada_East	**Eastern Canada for log supply**
Canada_West	**Western Canada for log supply**
Overseas	**Overseas for log supply and exports**

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

Forest products

SWSAWTLOG	HWSAWTLOG	SWPULPLOG	HWPULPLOG
SWFUELLOG	HWFUELLOG	SWSAWLOG	HWSAWLOG
SWPLOG	HWPLOG		
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			

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

In US Agriculture

AGTILLAGEFORUSE(periods,allreg,landtype,tltech)

Periods Years

2000-2100 in 5 year intervals

Land type

W3-8Land	wetlands
LOEILand	lo erodable crop land
MDEILand	medium erodable crop land
SVEILand	Severely erodable crop land
Pasture	Pasture land
AUMS	AUM grazing land
CRP	CRP (Conservation Reserve Program)

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

In US Agriculture

TLTECH   tillage types

Vent   Conventional Tillage
Cons   Conservational Tillage
Zero   Zero Tillage

Plus duration

years 0 to 30 crop has been in this tillage type

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

Primary Commodities

Cotton	Corn	EthlCorn	Soybeans
SOFT	HRWW	DURW	HRSW
Sorghum	Rice	Oats	Barley
Silage	Hay	Alfalfa	Sugarcane
Sugarbeet	Potatoes	Fallow	Tomatofrsh
Tomatoproc	Orangefrsh	Orangeproc	Grpfrtfrsh
Grpfrtproc	SwitchGras	HybrPoplar	Willow

Sheep	CowCalf	BeefFeed	Dairy
HogFarrow	FeedPig	PigFinish	OthLvstk
StockSCav	StockHCav	StockSYea	StockHYea
VealCalf	Turkeys	Broilers	Eggs
Beefcows			

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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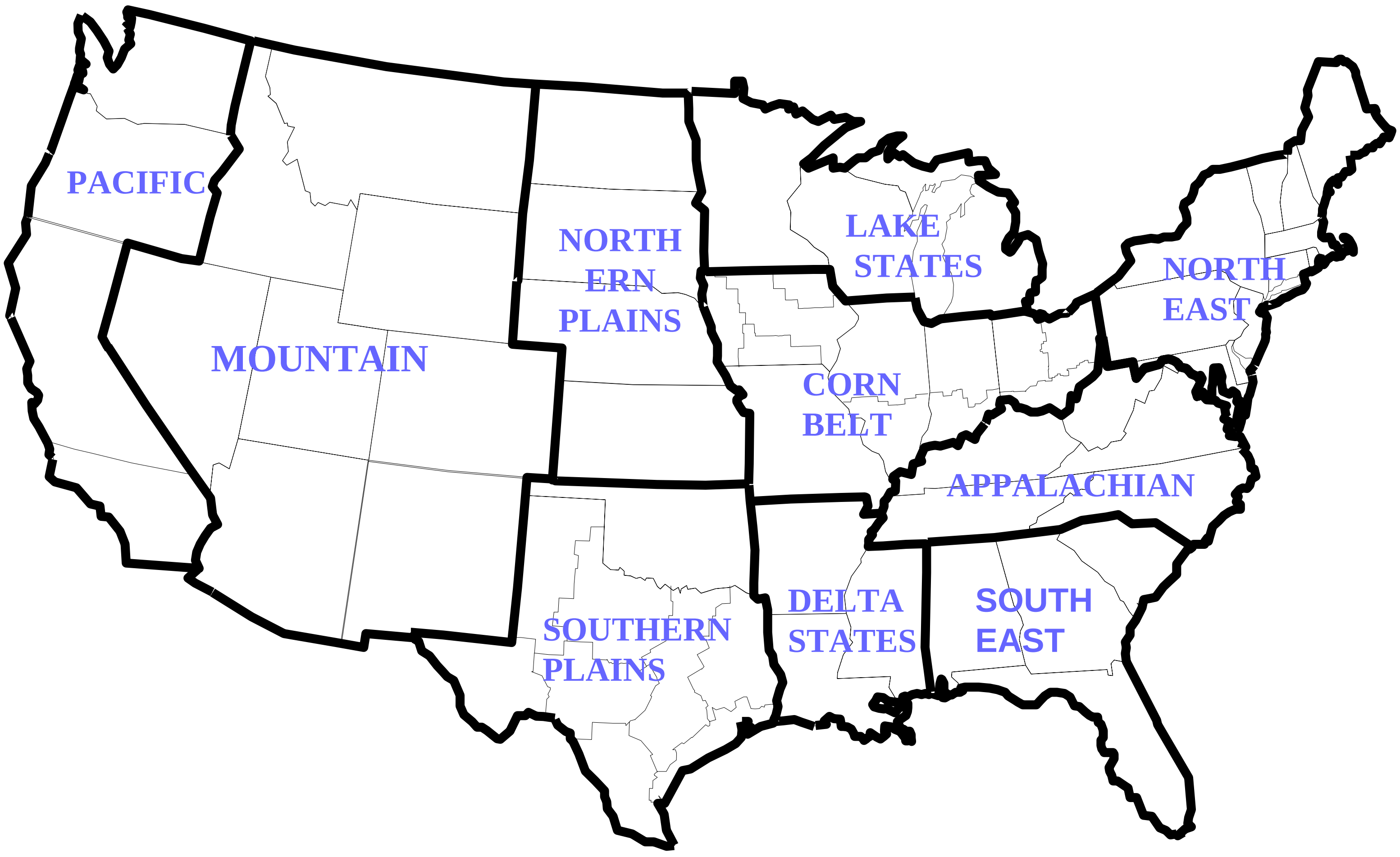
In US Agriculture



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

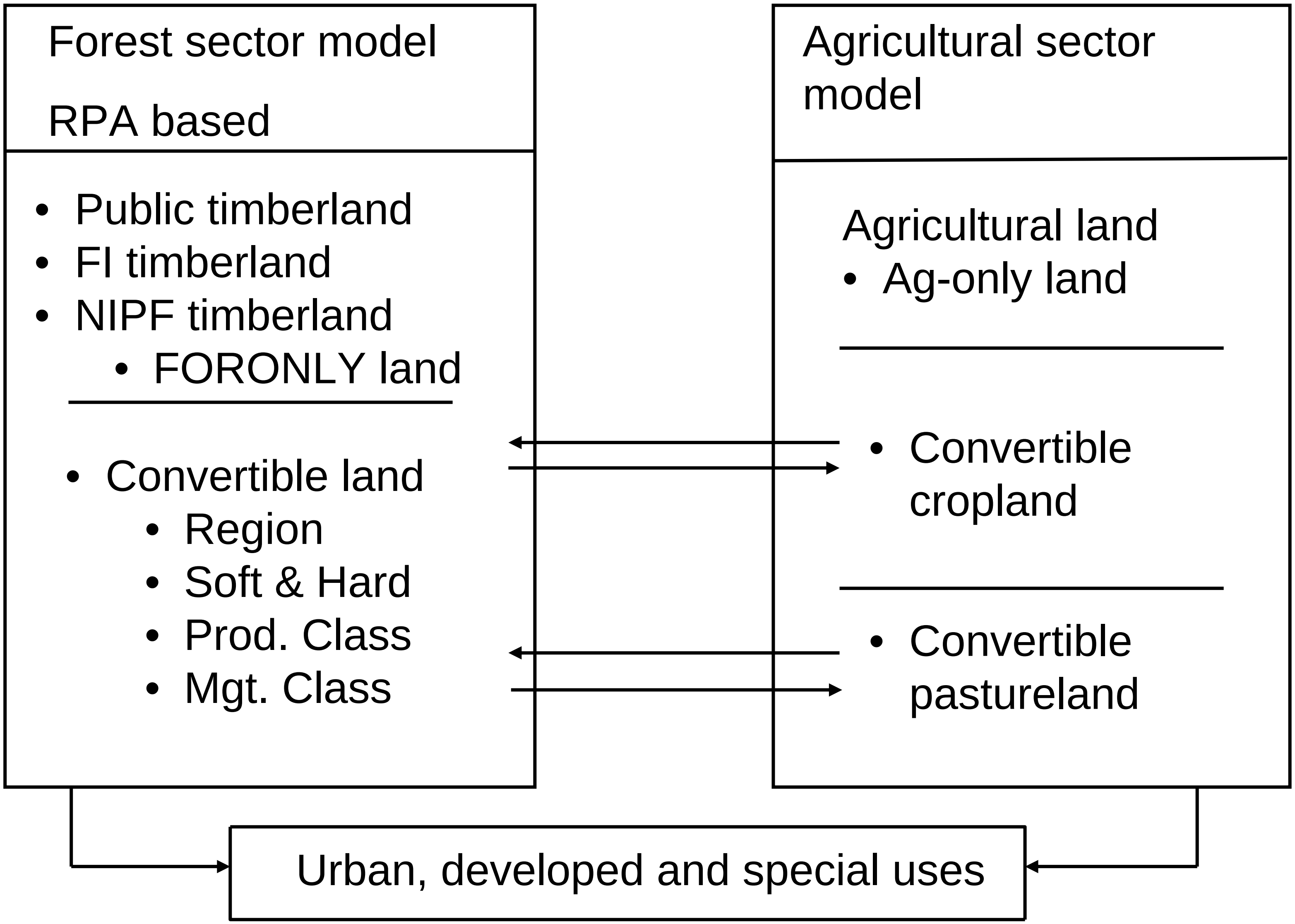
Constrained Optimization Problem

- 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

Condensed Tableau

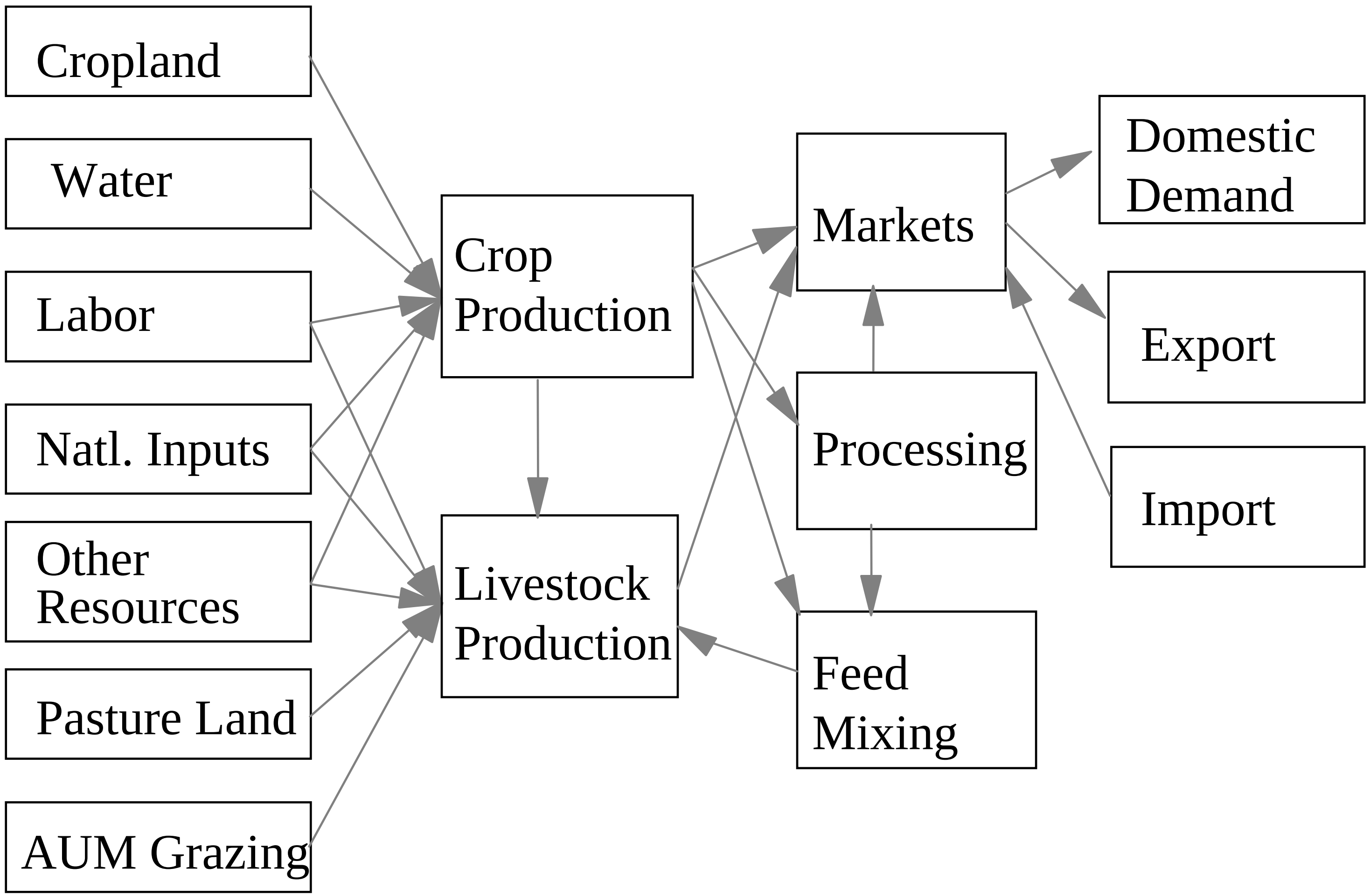
	FOREST SECTOR		LAND TRANSFER		AGRICULTURE SECTOR			CARBON	
	FOREST CONSUMPTION	FOREST PRODUCTION	LAND FROM FOREST TO AG	LAND FROM AG TO FOREST	AG PRODUCTION	AG CONSUMPTION	AG INPUT SUPPLY	GHG INCENTIVE	
OBJECTIVE – NPV VALUE MAX	+INTEGRAL UNDER DEMAND	-COST	-TRANSFORM COST		- COST	+INTEGRAL UNDER DEMAND	- 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

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



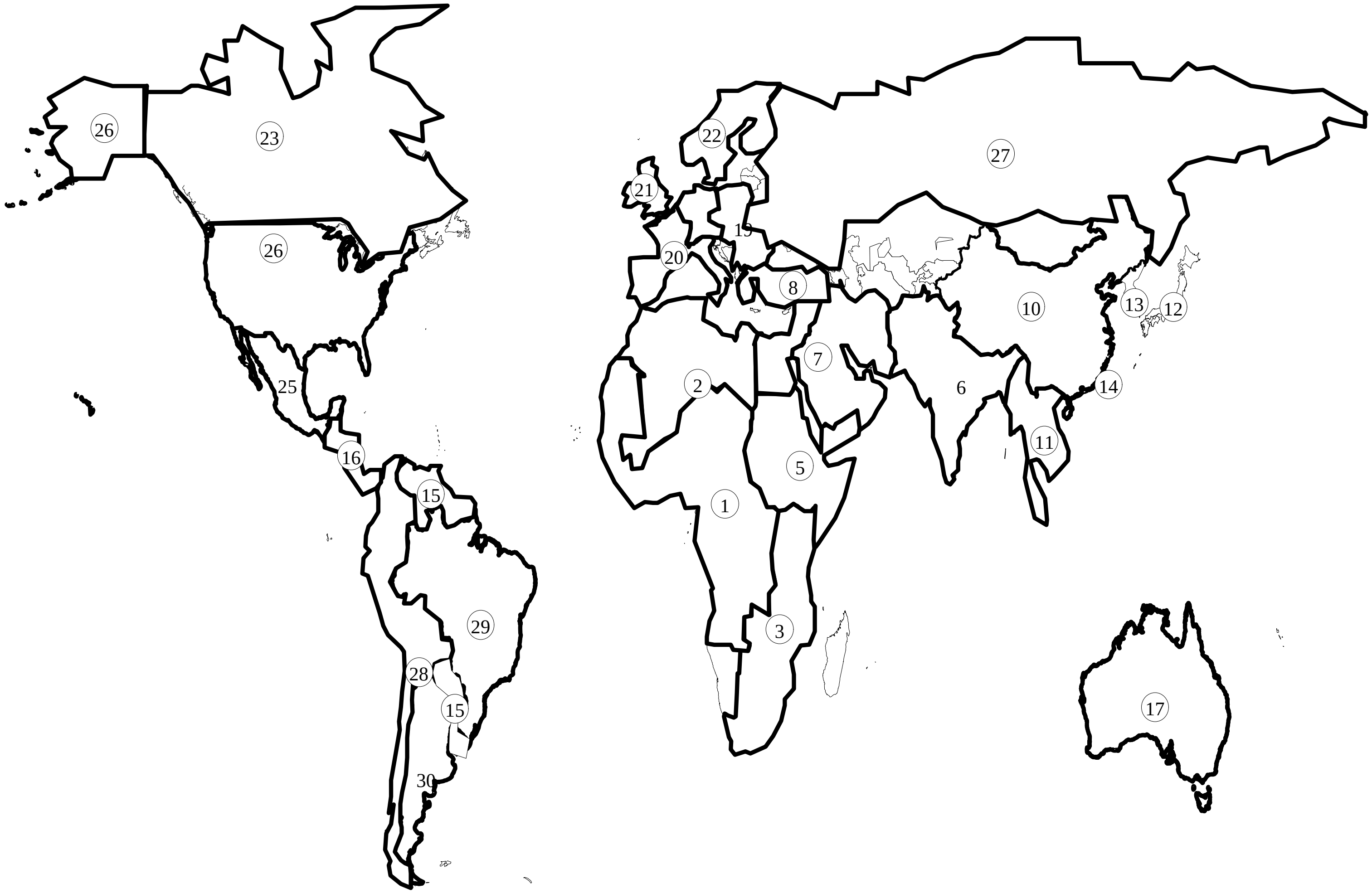
How are land-use and terrestrial GHG mitigation decisions currently modeled

Sector Scope



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

Foreign Regions in AG Part of FASOMGHG



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

Activity and GHG Coverage

Strategy	Basic Nature	CO2	CH4	N2O
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

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

	Temp	Rainfall	CO2	SeaLevel	ExtremeEvnts
Plants					
Crop and forage growth	X	X	X		X
Crop /forage water need	X	X	X		X
Soils					
Soil moisture supply	X	X			X
Irrigation demand	X	X	X		X
Soil fertility	X	X	X		
Animals					
Performance	X	X			X
Pasture/Range Carry cap	X	X	X		`
Irrigation Water Supply					
Evaporation loss	X	X			X
Run-off/general supply	X	X			X
Non-AG competition	X	X	X		
Other					
Water borne transport		X		X	X
Port facilities		X		X	X
Pest and diseases	X	X			
Insurance	X	X			X

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

A House of Cards

Climate Scenarios	**– GCMs**
Crop Simulation	**– Regional crop yields (dry and irr)**
	– Regional irrigated crop water use
Forest Simulation	**– Yields by region, year and species**
Hydrologic simulation	**– Irrigation water**
Livestock sim /experts	**– Livestock performance,**
Grass simulation	**– Livestock pasture usage,**
	Animal unit month grazing supply
Other studies	**– International supply and demand**
Regression	**– Pesticide usage**
	Non Ag water use
	Extreme event effects
Adaptation obs/expert	**– Crop mix shift**
	Varieties
Economics	**– FASOM sector model**

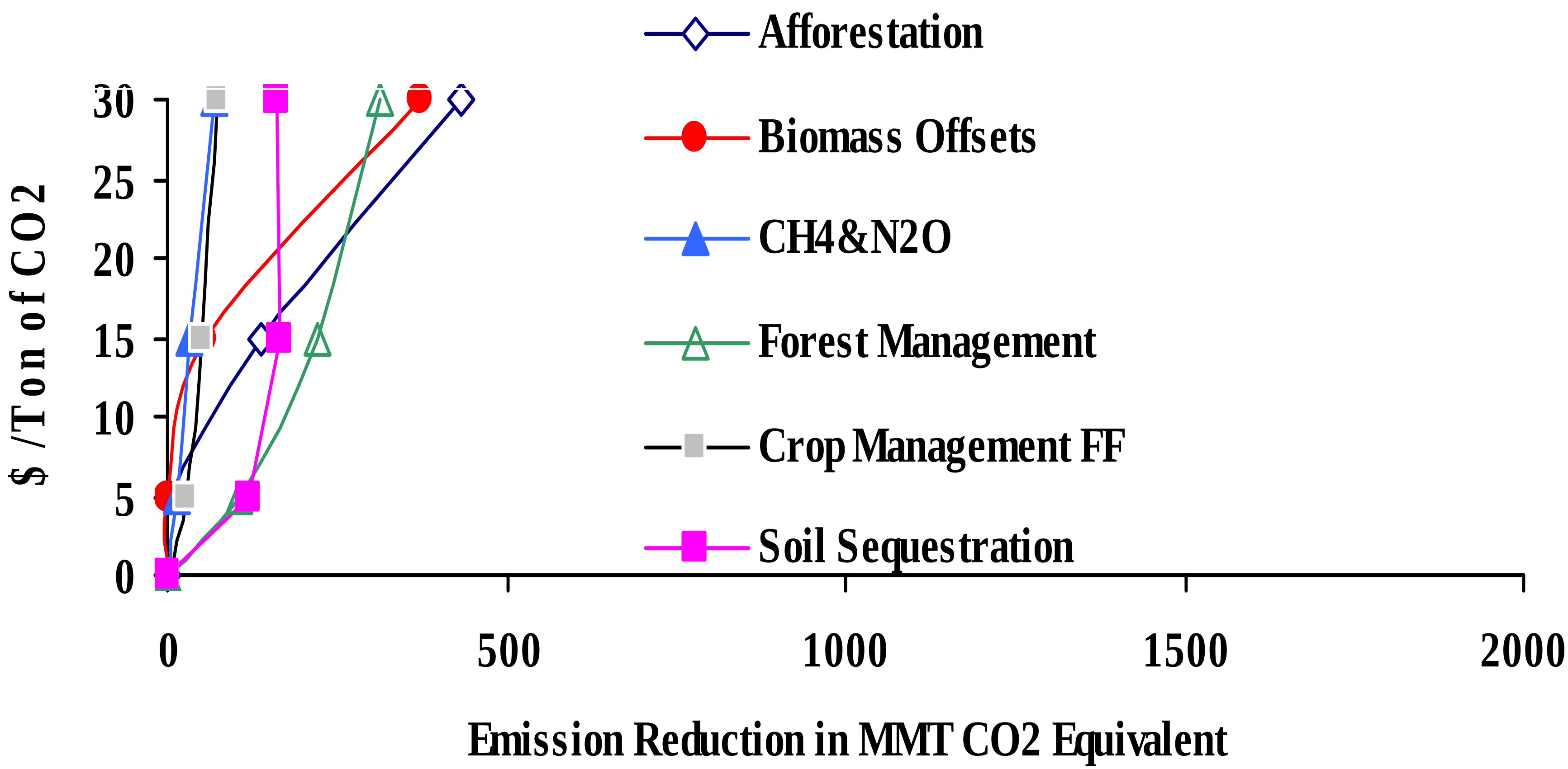
What other issues should IAM modelers consider?

Undesirableness of sequestration only modeling
Dynamics
Substitution with traditional production
– short and long run
Regional heterogeneity
Fungibility
Co-benefits
Adapting price expectations
Policy scope and applicability

What other issues should IAM modelers consider?

Undesirableness of sequestration only modeling

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



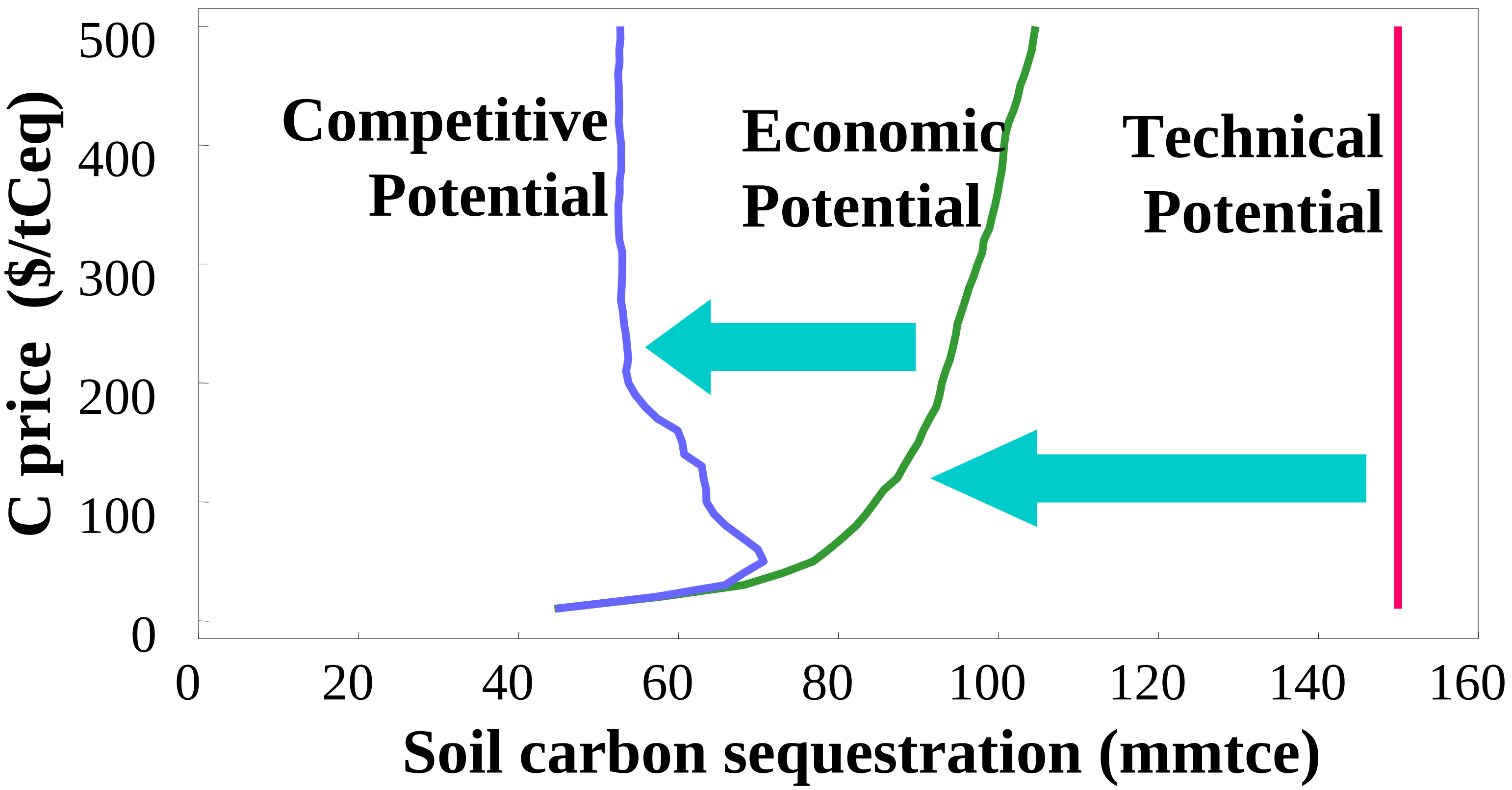
•Small importance of CH4 and N2O

•Different strategies dominate at different price levels

What other issues should IAM modelers consider?

Undesirableness of sequestration only modeling

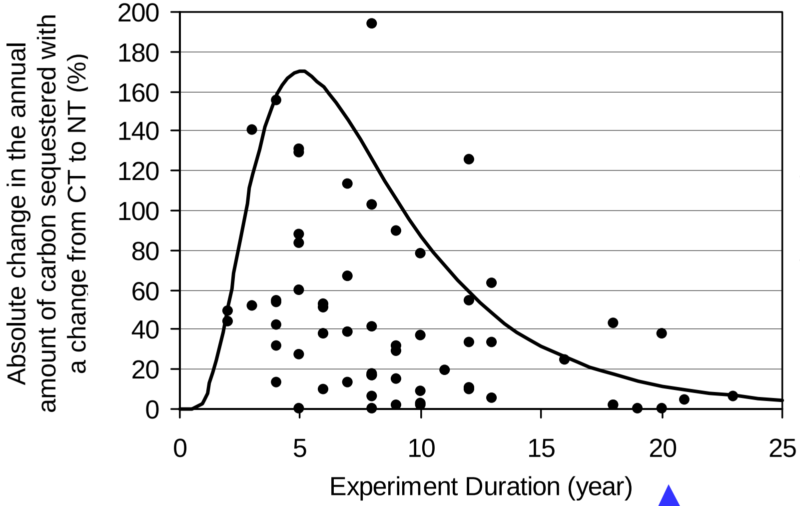
Example: U.S. ag soil potential:

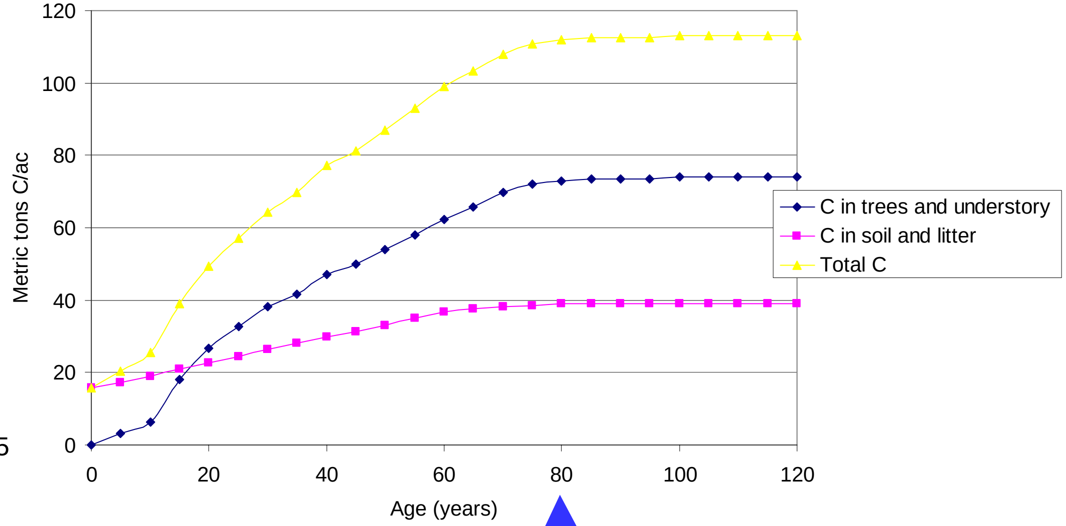


What other issues should IAM modelers consider? Dynamics

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

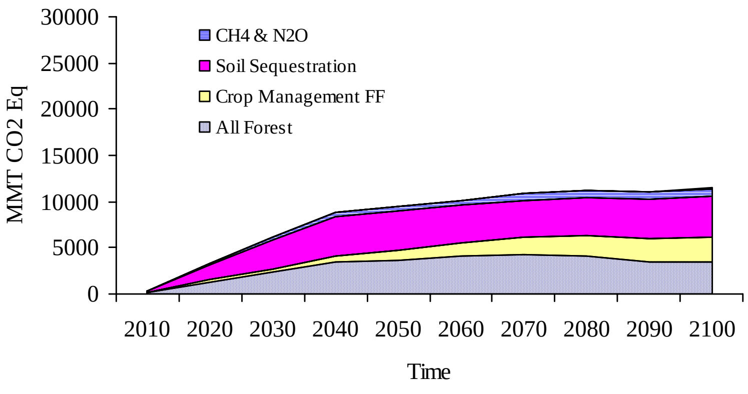
Carbon Accumulation on an Afforested Southeastern Pine Stand, to Saturation -- Birdsey



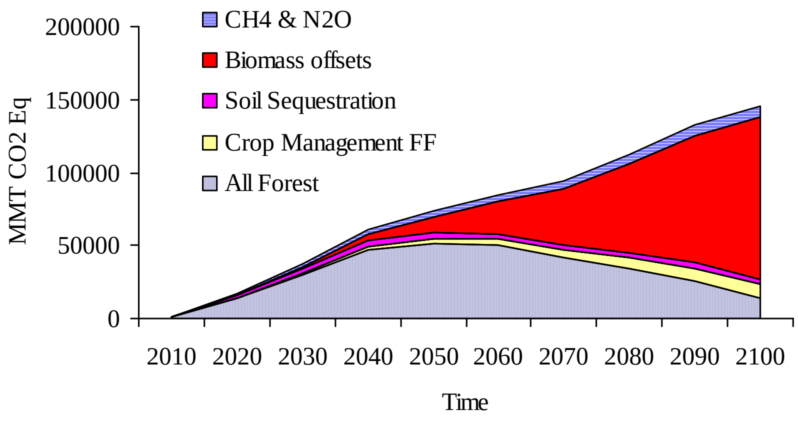


What other issues should IAM modelers consider?

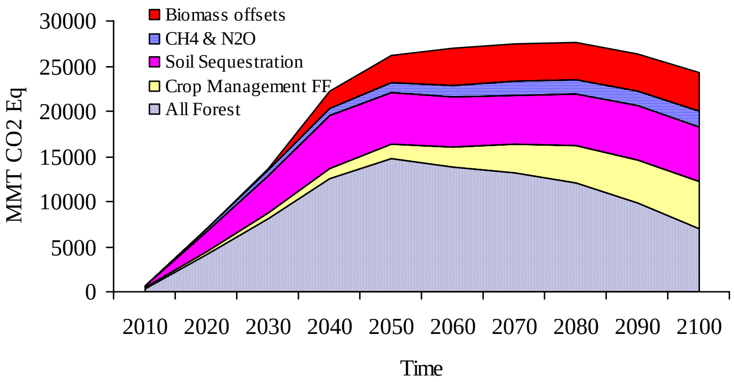
Dynamics



Cumulative Contribution at a $5 per tonne CO2 Price



Cumulative Contribution at a $50 Price



Cumulative Contribution at a $15 Price

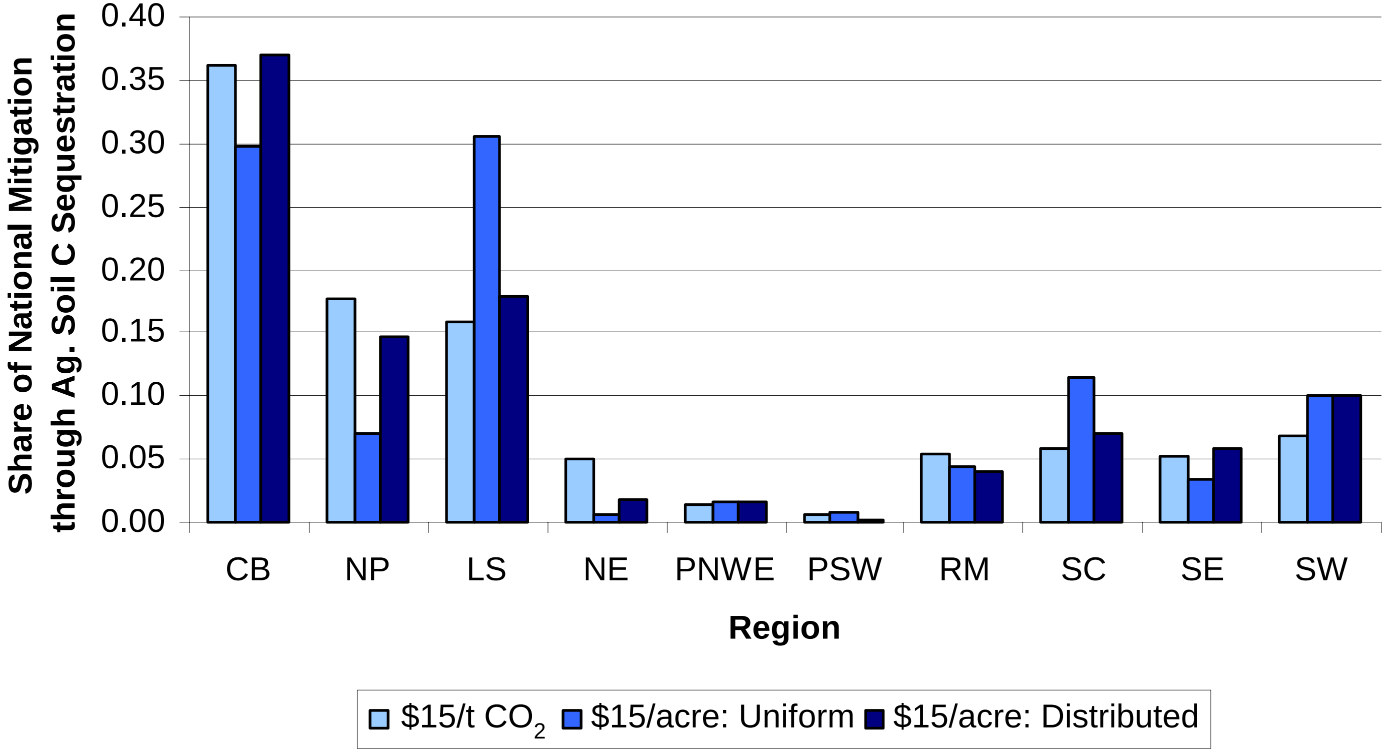
Note

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.

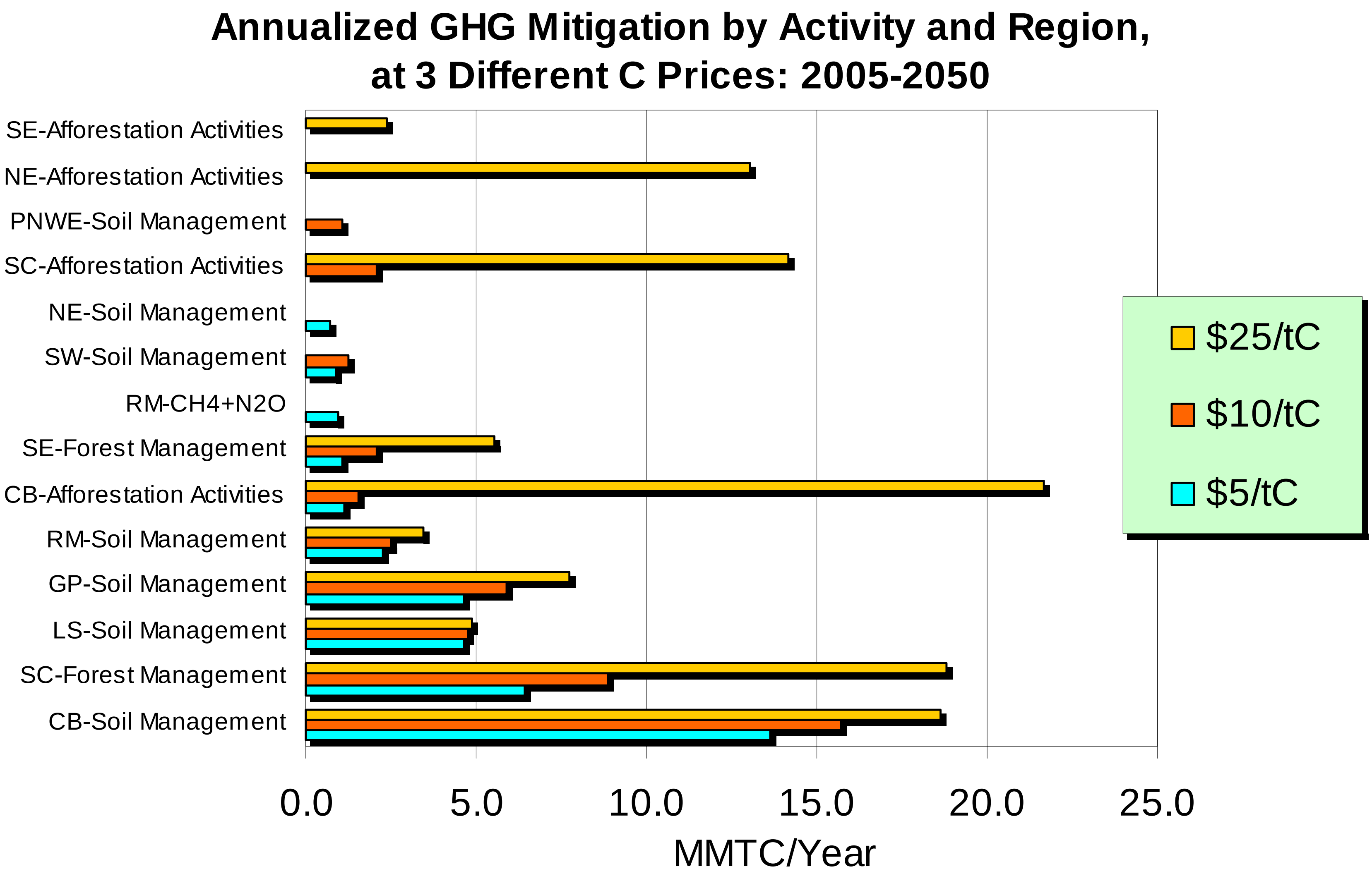
What other issues should IAM modelers consider?
Regional heterogeneity

Regional Shares of Agricultural Soil Carbon Sequestration



What other issues should IAM modelers consider?

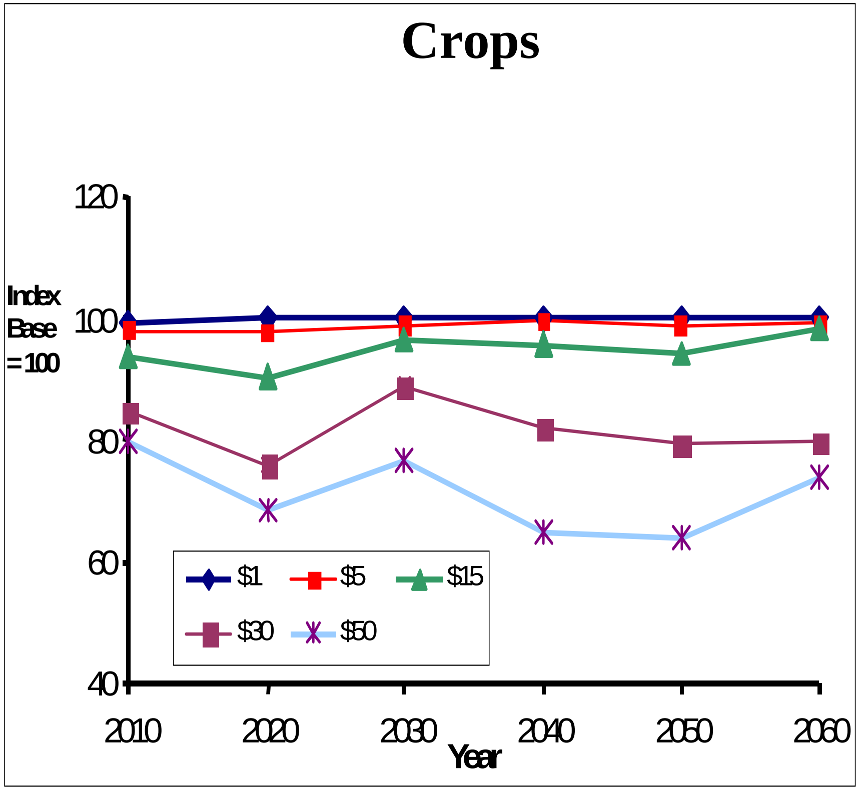
Regional heterogeneity

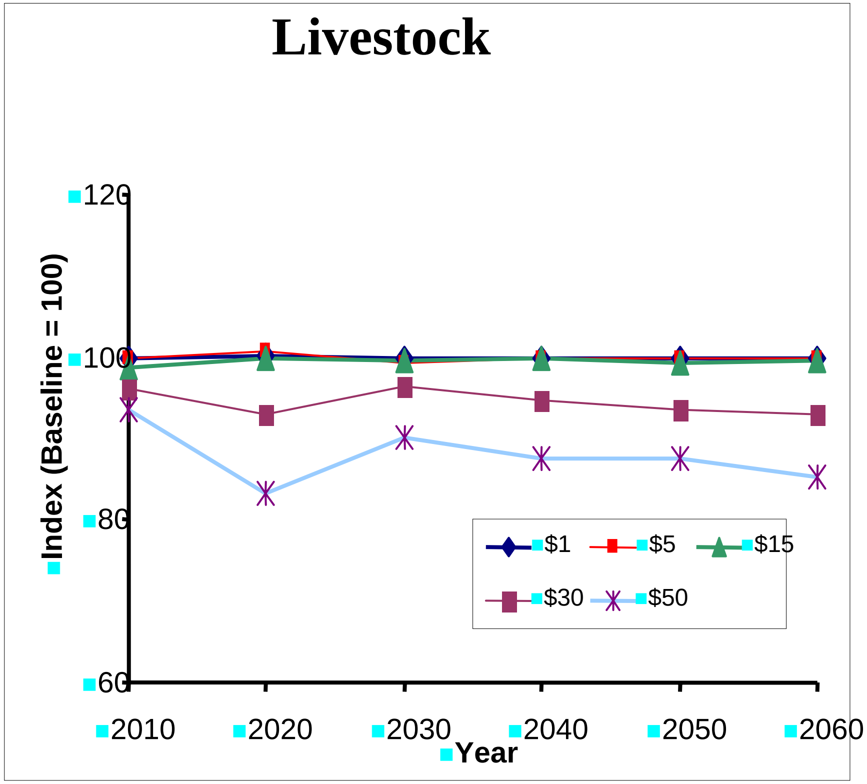


What other issues should IAM modelers consider?

Substitution with traditional production
– short and long run

Production Quantity Index over Time

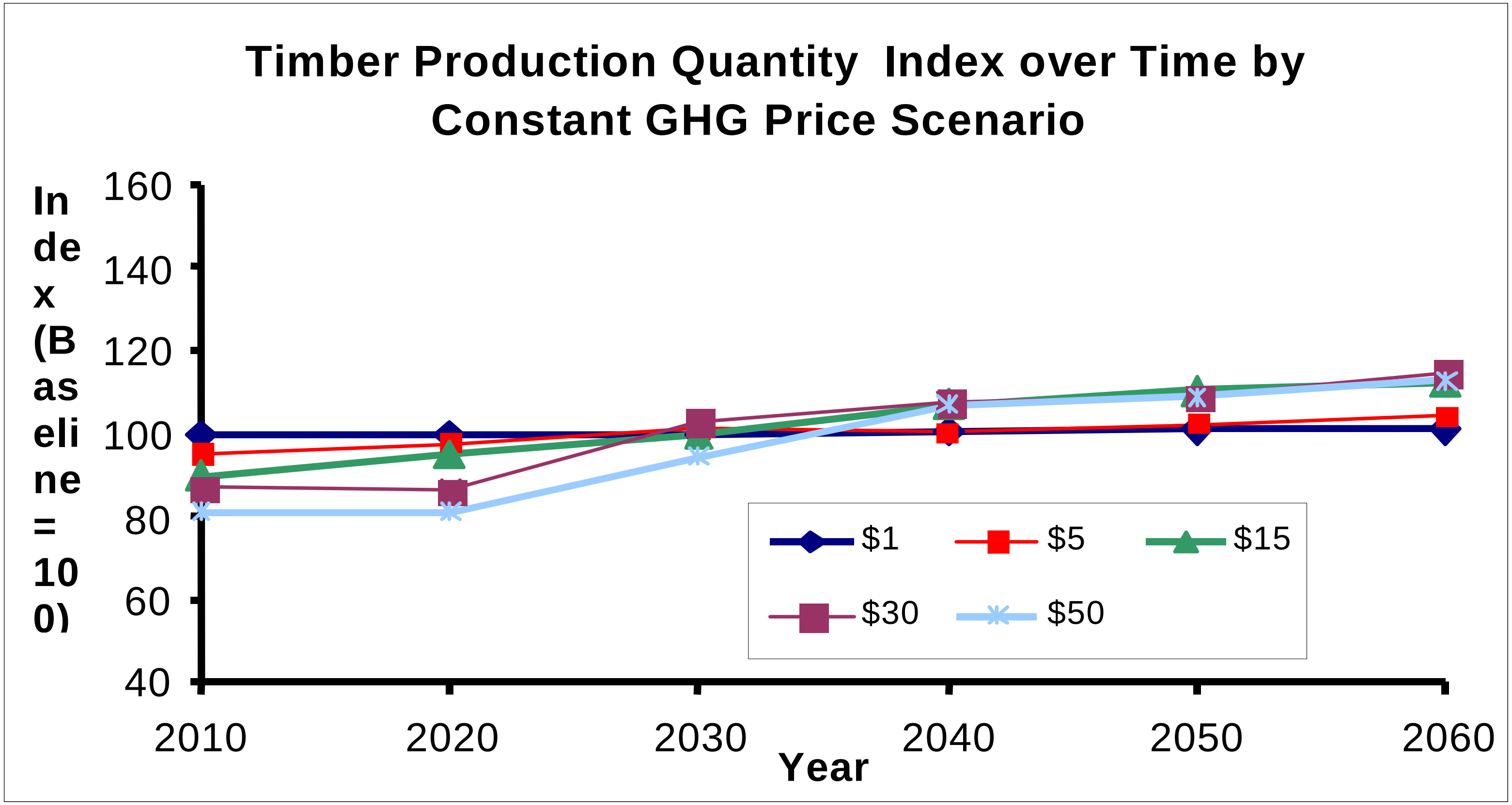




Substitutes

What other issues should IAM modelers consider?

Substitution with traditional production – short and long run



Near term Substitutes, Long Run Complement

What other issues should IAM modelers 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 other issues should IAM modelers consider? Fungibility

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

Where

Buyback is amount when lease expires

MainCost is amount paid to maintain stands or practices

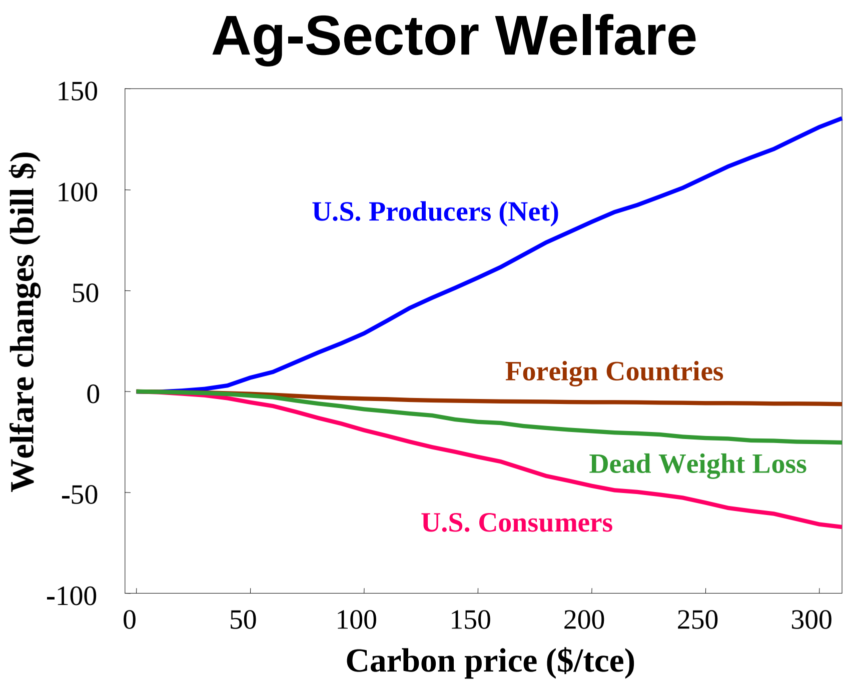
What other issues should IAM modelers consider? Fungibility

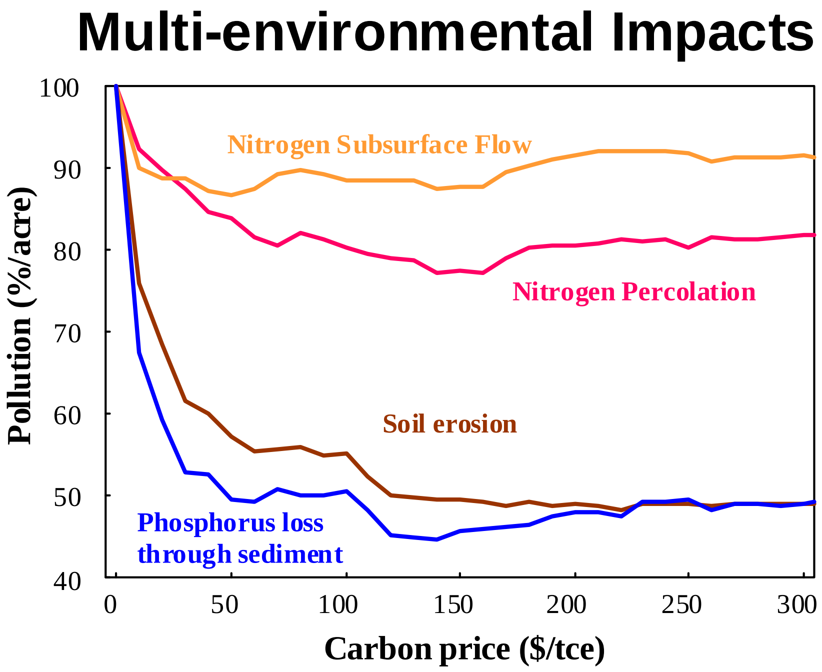
Beaumont through Columbus Texas area has historically produced rice. In 1985, 600,000 acres. In 2000, 214,000 acres. Policy, environment and markets are applying pressure. Today, many rice producers are in quest of new opportunities. Trees, other crops and pasture provide possible alternatives to some.

	Perm	Add	Leak	Uncer	All	Salable
Rice to crops	30%	12%	32%	21%	67%	**33%**
Rice to pasture	50%	4%	17%	21%	69%	**31%**
Rice - trees(pulp)	30%	1%	16%	21%	54%	**46%**
Rice - trees (saw)	10%	1%	16%	21%	41%	**59%**

What other issues should IAM modelers consider?

Co-benefits





Gain here but lose in energy sector

Probably should ignore for now

What other issues should IAM modelers consider?

Avoiding perfect Price foresight

Depicting anticipated possibly regionalized policy scope and applicability

Using response functions from FASOM type models

Now upgrading to avoid foresight and be more dynamic