Modeling Global cropland net greenhouse gas dynamics and mitigation costs

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DOE Sequestration Conference
Washington, DC
10 May 2006

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Project motivation

- Agriculture's significant GHG emissions role
- Potential cost-effective mitigation options
- Analyses of agriculture's **relative** global mitigation role – relative across options, regions, and time
- Need for **globally consistent** abatement cost estimates –biophysical dynamics, economic variables, methodology, b/w baseline and management alternatives
- Complicating biophysical characteristics: multiple GHG fluxes, spatial heterogeneity, dynamic responses
- Non-CO2 mandate

Outline

- Project overview – GHG mitigation on croplands, rice paddies, and livestock emissions
- Cropland GHG mitigation
  - Methods – models & data, regions, resolution
  - Physical effects
  - Economic costs
- Conclusion & future opportunities

Advancing understanding of mitigation costs – Enhanced international Ag abatement curves

Biophysical Modeling

DNDC model for Asian rice systems

DAYCENT model for world croplands

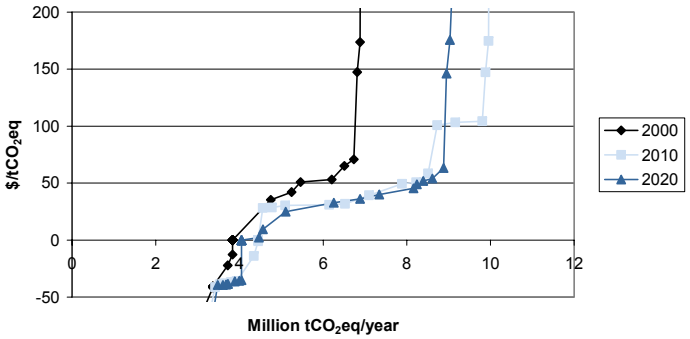
Lit sources for livestock options

Components

Biophysical
Δ GHGs
Δyields/productivity
Δ fertilizer inputs

Economic
Ag commodity and input prices (current and projected)
Δ labor
Δ capital costs
Input cost shares

Abatement cost curves for 2000, 2010 and 2020



Global market effects

IFPRI's IMPACT model for global ag markets → Sensitivities of static costs to market effects

Product: regional abatement curves

The set of international GHG abatement curves for 2000, 2010 and 2020

Croplands

- 36 regions
- Wheat, maize, soybeans
- Irrigated and rainfed
- 6 management options
- N2O and soil C

Rice paddies

- 12 Asian regions
- Irrigated and rainfed
- 6 management options
- CH4, N2O, soil C

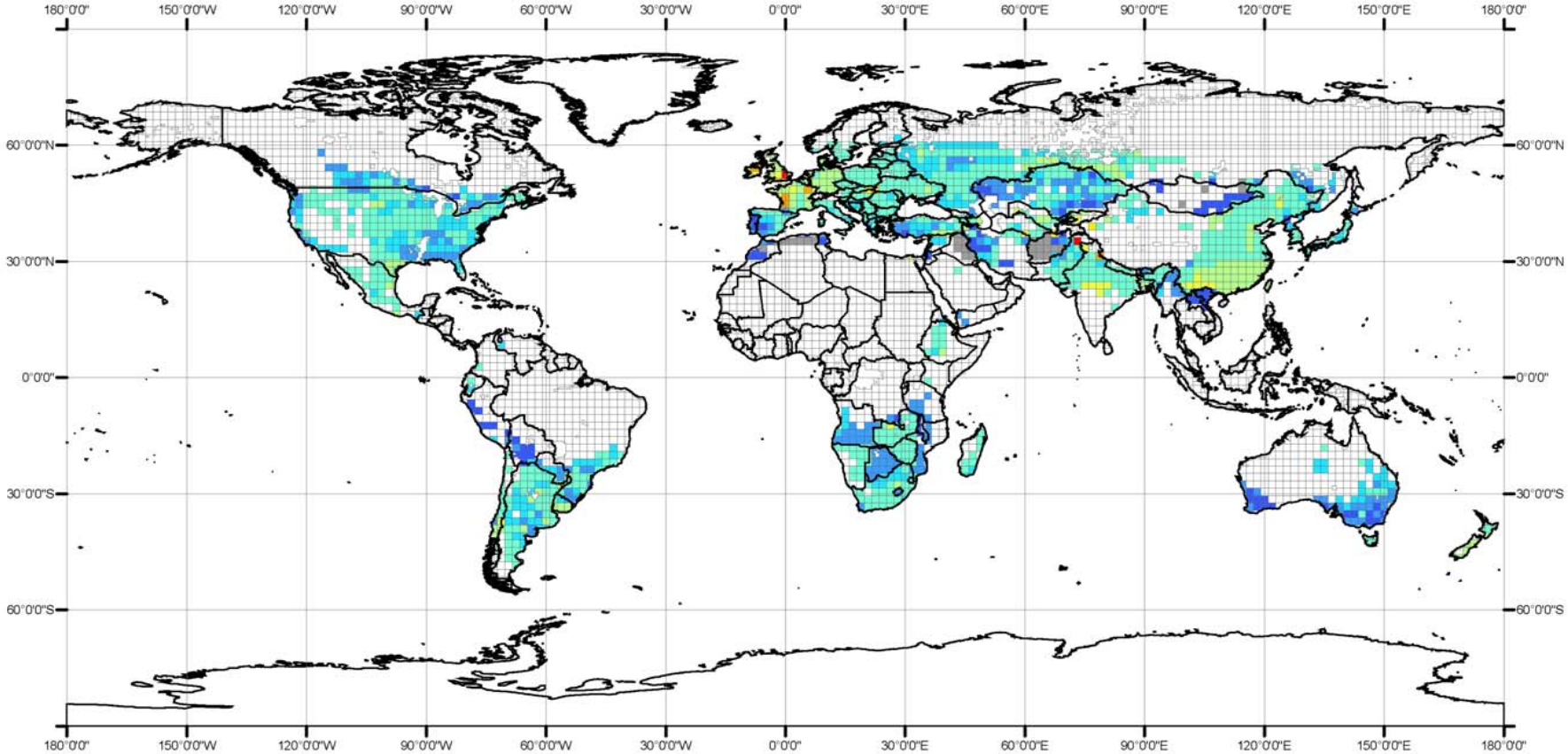
Livestock

- 36 regions
- Cattle (beef and dairy) & hogs
- Management options: 6 for enteric, 8 for manure
- CH4 and N2O

World croplands: application of DAYCENT

- DAYCENT
  - Process-based model w/ daily time step
  - Inputs: soil properties, crop type, daily climate data, management practices, synthetic & organic N additions
  - Outputs: N_2O, SOC, yields
  - Now used for majority of ag soil N_2O in annual *Inventory of U.S. Greenhouse Gas Emissions and Sinks* reported by EPA
- Global datasets of weather (NOAA), soils (FAO), cropland area (IGBP, GLC) mapped to 2° x 2° resolution
- Maize, wheat & soybean systems, under both irrigated & rainfed conditions (then weighted according to IFPRI %'s by crop, region, over time)
- Synthetic fertilizers: historic rates (FAO, IFA); projected rates (FAO yield/fertilizer relationships w/ IFPRI yields)
- Organic fertilizers: historic rates (FAO, IPCC); projected (EPA)

DAYCENT - NCEP Global Simulation
Wheat N_2O Emissions: 1991 - 2000



DAYCENT Simulation
grams / meter^2

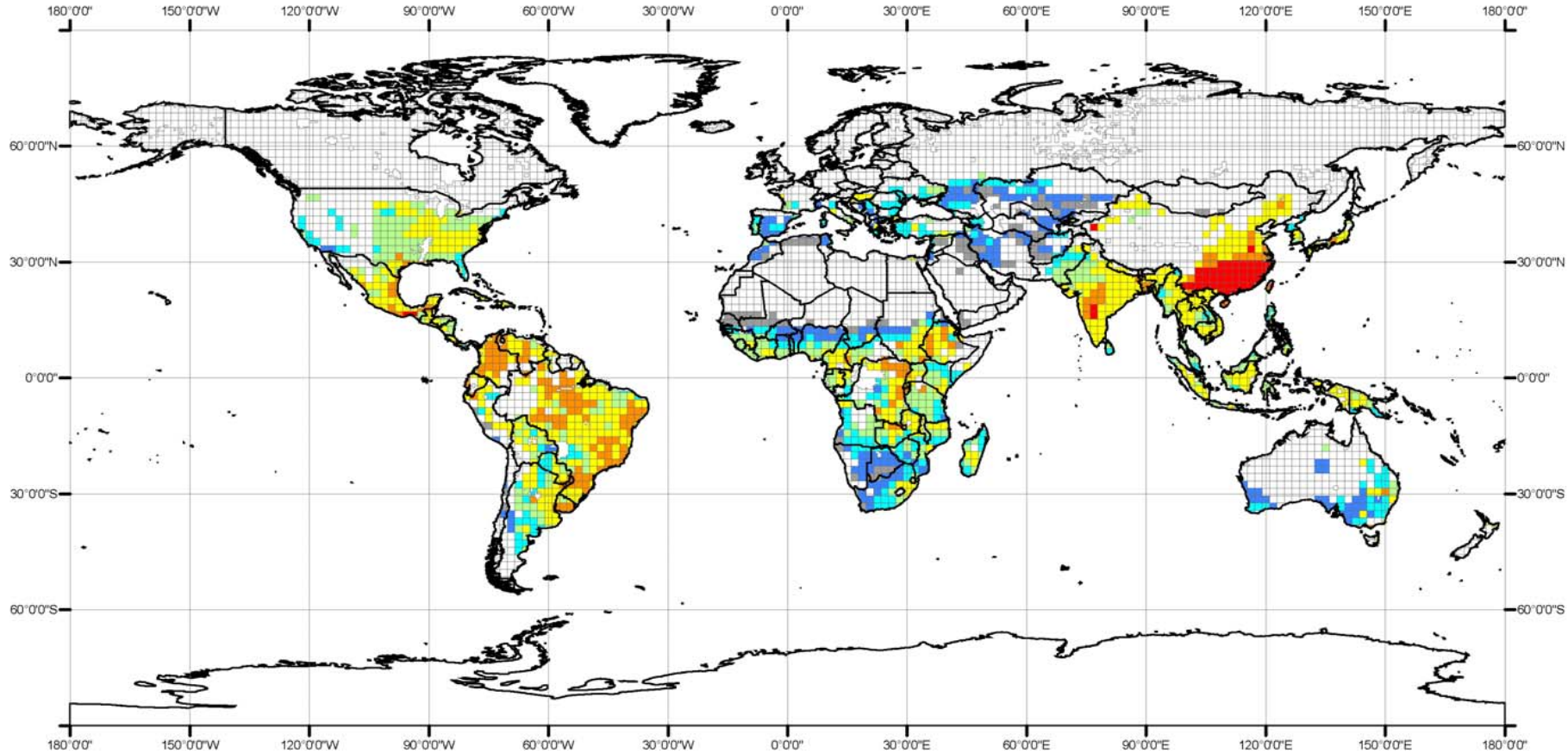
- 0.003900 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.200
- 0.200 - 0.300
- 0.300 - 0.400
- 0.400 - 0.500
- 0.500 - 0.600
- 0.600 - 0.700
- 0.700 - 0.830

N
W E
S

2 - Degree Resolution (approx.)

0 2,000 4,000 6,000 8,000 Kilometers

DAYCENT - NCEP Global Simulation
Soybean N_2O Emissions: 1991 - 2000



DAYCENT Simulation
grams / meter^2

0.0035 - 0.025	0.025 - 0.050	0.100 - 0.200
	0.050 - 0.075	0.200 - 0.300
	0.075 - 0.100	0.300 - 0.488

N
W E
S

2 - Degree Resolution (approx.)

0 2,000 4,000 6,000 8,000 Kilometers

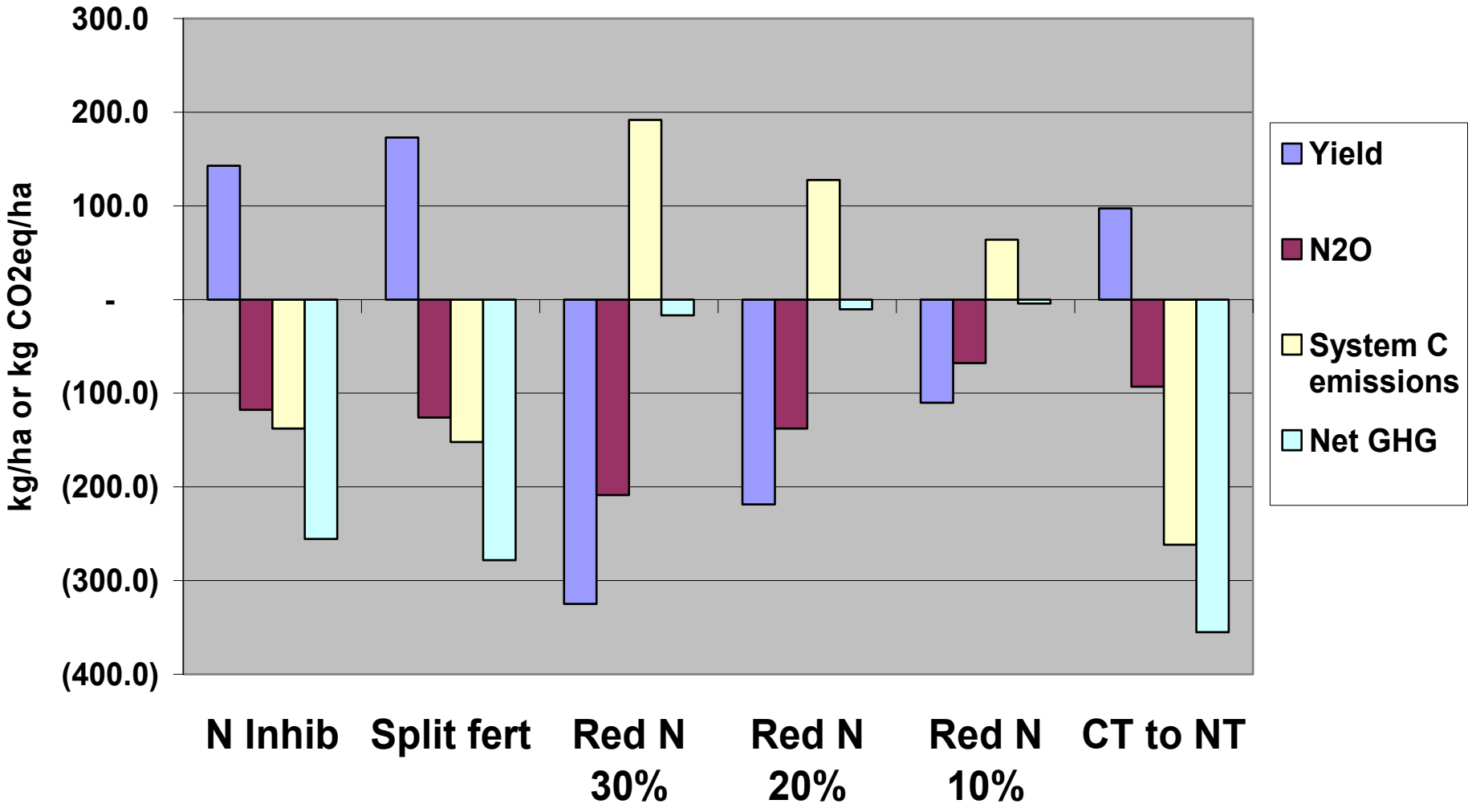
GHG mitigation options chosen for croplands

- Precision or split fertilization
- Reduce baseline synthetic nitrogenous fertilizer application rate by
  - 10%
  - 20%
  - 30%
- Nitrification inhibitors
- Conversion from conventional tillage to no-till

Biophysical responses
e.g., Argentina rainfed wheat CT to NT

Changes associated with conversion from conventional tillage to no-till for rainfed wheat in Argentina						
		2000	**2005**	**2010**	**2015**	**2020**
		Change (%)	**Change (%)**	**Change (%)**	**Change (%)**	**Change (%)**
Yield (kg/ha)		86 (4%)	92 (4%)	97 (4%)	109 (5%)	120 (5%)
GHG emissions (kg CO2eq/ha)						
	System carbon	-231 (n/a)	-246 (n/a)	-262 (n/a)	-276 (n/a)	-290 (n/a)
	Direct N2O	-77 (-15%)	-84 (-14%)	-90 (-14%)	-93 (-13%)	-96 (-13%)
	Indirect N2O	-3 (-1%)	-3 (-1%)	-3 (-1%)	-4 (-1%)	-5 (-1%)
	Total	-311 (-39%)	-333 (-37%)	-355 (-36%)	-373 (-36%)	-391 (-35%)

Responses to cropland management alternatives
e.g., Argentina rainfed wheat 2010



Ranking of mitigation responses - Argentina rainfed maize, soybean, and wheat; 2010

	Management option	System Carbon	N2O	Net GHG	Yield
		kg CO2/ha	*kg CO2eq/ha*	*kg CO2eq/ha*	*kg/ha*
Wheat	Nitrogen inhibitor	3	4	3	2
	Split fertilization	2	3	2	1
	Reduce fertilizer 30%	6	1	4	6
	Reduce fertilizer 20%	5	2	5	5
	Reduce fertilizer 10%	4	6	6	4
	CT to NT	1	5	1	3

Ranking of mitigation responses - Argentina rainfed maize, soybean, and wheat; 2010

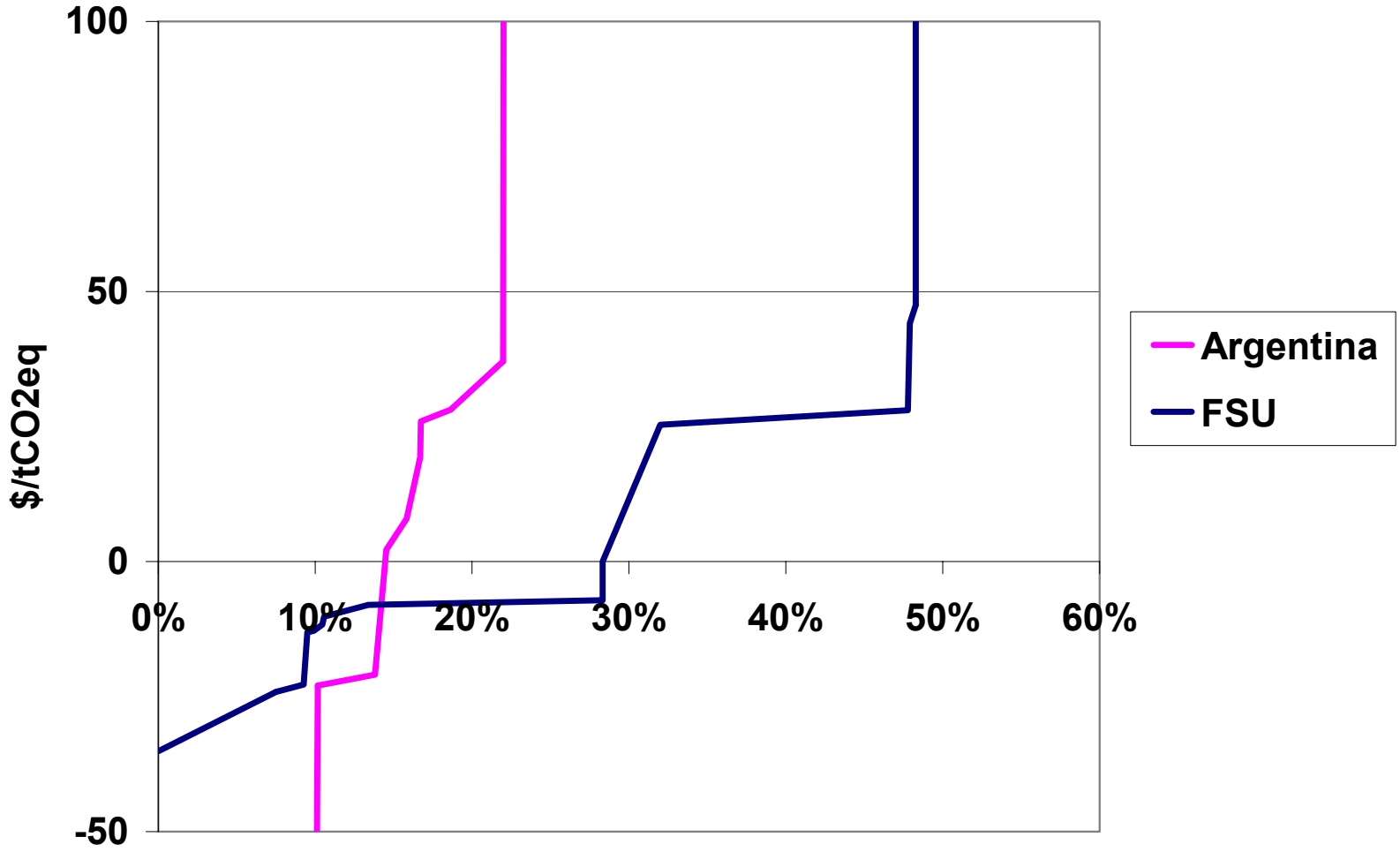
	Management option	System Carbon	N2O	Net GHG	Yield	Abatement Cost	Regional cost
		kg CO2/ha	*kg CO2eq/ha*	*kg CO2eq/ha*	*kg/ha*	*$/tCO2eq*	*$/tCO2eq*
						(out of 6)	*(out of 36)*
Wheat	**Nitrogen inhibitor**	3	4	3	2	3	20
	Split fertilization	2	3	2	1	2	14
	Reduce fertilizer 30%	6	1	4	6	n/a	n/a
	Reduce fertilizer 20%	5	2	5	5	n/a	n/a
	Reduce fertilizer 10%	4	6	6	4	n/a	n/a
	CT to NT	1	5	1	3	1	9
Maize	**Nitrogen inhibitor**	3	4	2	2	3	19
	Split fertilization	2	6	3	3	2	16
	Reduce fertilizer 30%	6	1	6	6	n/a	n/a
	Reduce fertilizer 20%	5	2	5	5	n/a	n/a
	Reduce fertilizer 10%	4	5	4	4	n/a	n/a
	CT to NT	1	3	1	1	1	3
Soybean	**Nitrogen inhibitor**	2	1	2	2	5	22
	Split fertilization	3	4	3	3	6	23
	Reduce fertilizer 30%	6	3	4	6	2	6
	Reduce fertilizer 20%	5	5	5	5	4	8
	Reduce fertilizer 10%	4	6	6	4	3	7
	CT to NT	1	2	1	1	1	1

n/a = commodity currently not grown or positive change in emissions

Comparison of Argentina to FSU
e.g., rainfed maize, soybean, and wheat; 2010

		Argentina			FSU	
	Management option	Abatement Cost	Regional cost		Abatement Cost	Regional cost
		$/tCO2eq	*$/tCO2eq*		*$/tCO2eq*	*$/tCO2eq*
Wheat	Nitrogen inhibitor	3	20		3	13
	Split fertilization	2	14		1	6
	Reduce fertilizer 30%	n/a	n/a		n/a	n/a
	Reduce fertilizer 20%	n/a	n/a		n/a	n/a
	Reduce fertilizer 10%	n/a	n/a		n/a	n/a
	CT to NT	1	9		2	11
Maize	Nitrogen inhibitor	3	19		3	15
	Split fertilization	2	16		1	7
	Reduce fertilizer 30%	n/a	n/a		n/a	n/a
	Reduce fertilizer 20%	n/a	n/a		n/a	n/a
	Reduce fertilizer 10%	n/a	n/a		n/a	n/a
	CT to NT	1	3		2	10
Soybean	Nitrogen inhibitor	5	22		n/a	n/a
	Split fertilization	6	23		n/a	n/a
	Reduce fertilizer 30%	2	6		n/a	n/a
	Reduce fertilizer 20%	4	8		n/a	n/a
	Reduce fertilizer 10%	3	7		n/a	n/a
	CT to NT	1	1		n/a	n/a

Abatement cost schedules
e.g., Argentina and FSU; 2010



Concluding remarks

The set of international GHG abatement curves for 2000, 2010 and 2020

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Forthcoming EPA report:
U.S. EPA (2006) Global Mitigation of Non-CO2 Greenhouse Gases (draft)

Concluding remarks

- **Future opportunities**
  - Biophysical modeling of marginal effects
  - Fuller set of Ag net GHG management options
  - New sub-regional survey data

Thank you!!

Key References

DNDC model description

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DAYCENT model description

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Spin off paper

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Forthcoming EPA mitigation report

U.S. EPA (2006) Global Mitigation of Non-CO_2 Greenhouse Gases (draft)