CSiTE Task 2.4
Economic Methods

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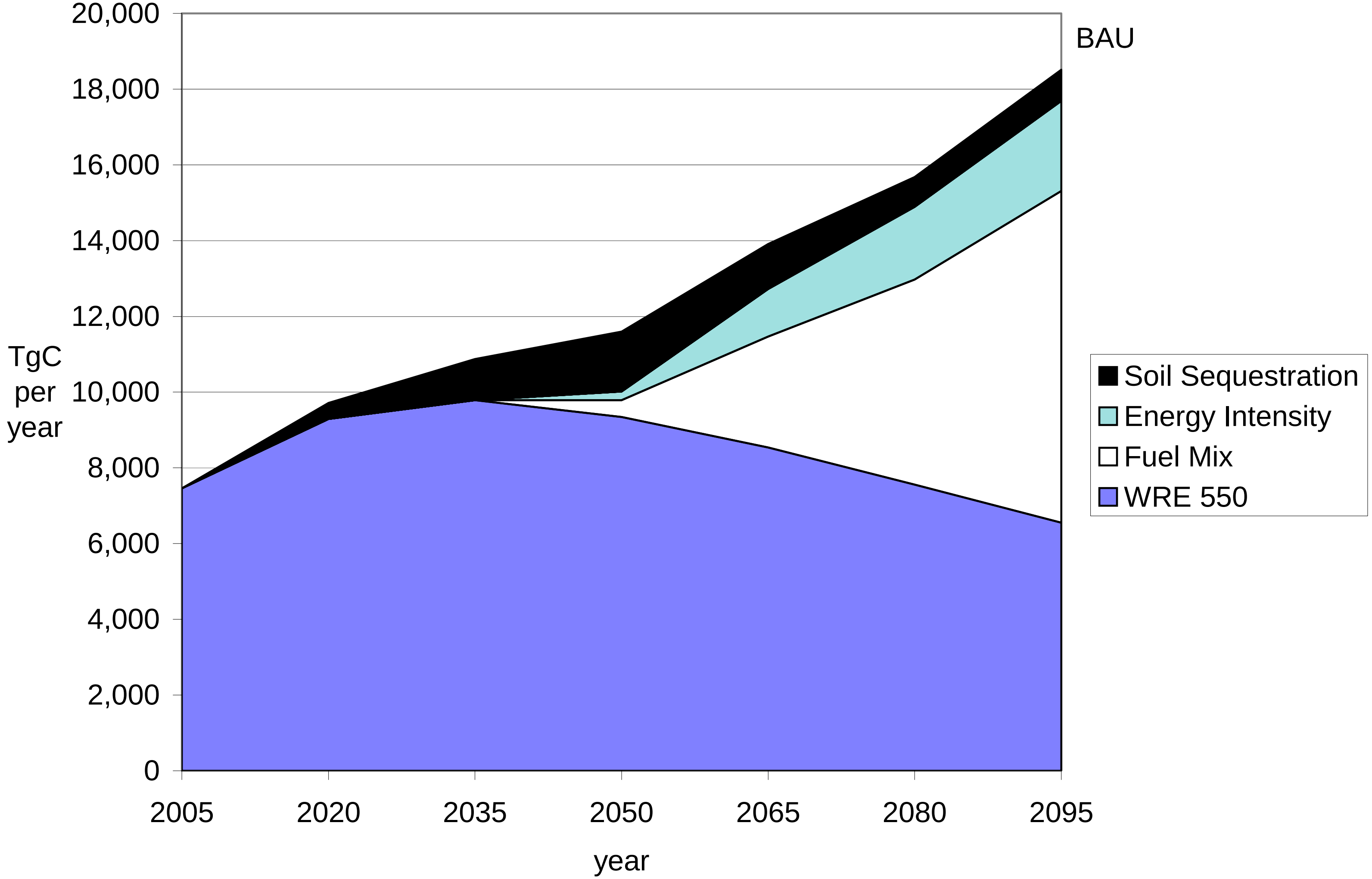
Outline

- Motivation
- Research Objectives
- Integration into CSiTE mission
- Collaborations
- Approach
- Results
- Key publications

Motivation (1)

- Framework Convention on Climate Change (FCCC): stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate
- Carbon sequestration in soils can contribute to this goal

Simulating Global Carbon Emissions



Motivation (2)

- Opportunities for soil carbon sequestration should be compared to
  - Other opportunities in agriculture such as biomass fuels
  - Carbon mitigation opportunities in energy system
- An economic framework, linked to key scientific findings and biophysical models, is needed
- Full accounting is needed of costs and careful consideration of amount of credits
- Full GHG accounting needed

Research Objectives (1)

- Development of methods for the full appraisal of the cost of sequestering carbon in terrestrial ecosystems
- Development of methods to address the ways carbon sequestration in terrestrial ecosystems contribute, relative to other options, towards stabilization of the atmosphere
  - Desirability relative to other agricultural options (forest sequestration, biofuels, livestock emissions, etc.)
  - Role of CO_2 and Non-CO_2 greenhouse gases
  - Desirability relative to other energy system options

Research Objectives (2)

- Development of methods for factoring in the spatial heterogeneity of land in the analysis of the questions above
- Determination of the dominant potential strategies for reducing net greenhouse emissions in agriculture and forestry with dominance defined over time, space and carbon equivalent price level

Integration into CSiTE Mission

- Carbon coefficients (Task 2.2) for converting economic activity to carbon emissions
- For alternative crop management practices, biophysical models (Task 2.3) inform economic models (Task 2.4) on the physical tradeoffs among:
  - Crop yield
  - Carbon sequestered
  - Emissions of nitrous oxide and methane
  - Requirements for other inputs to production, especially water and fertilizer
  - Environmental co-benefits

External Collaborations

- Stanford Energy Modeling Forum
- Consortium for Agricultural Soil Mitigation of Greenhouse Gases (CASMGS)
- Battelle/EPRI Global Energy Technology Strategy program
- EPA/DOE/USDA policy groups
- Non-CO2 network
- EU and Japanese research teams
- Agricultural Modeling Forum

Approach

- U.S. Agriculture and Forestry Model
  - Bruce McCarl runs the Forest and Agriculture Sector Optimizing Model (FASOM) covering agricultural and forestry supply and demand in the United States.
  - FASOM simulates production of 22 traditional crops, 3 biofuel crops, and 29 animal products in 63 U.S. regions. plus 8 forest commodities in a 100 year simulation.
- Methods developed to link backward from FASOM to CSiTE's crop simulation (CENTURY, EPIC) modeling system.
  - Brings in spatial dimension
  - Allows one to develop data on new approaches/possibilities
- Methods developed to link forward from FASOM to PNNL's energy-economy modeling system.
  - Allows direct comparison of agricultural mitigation options with options from the energy system.
  - Portrays interactions between agriculture and forest activities, especially through land competition.

Activity and GHG Coverage

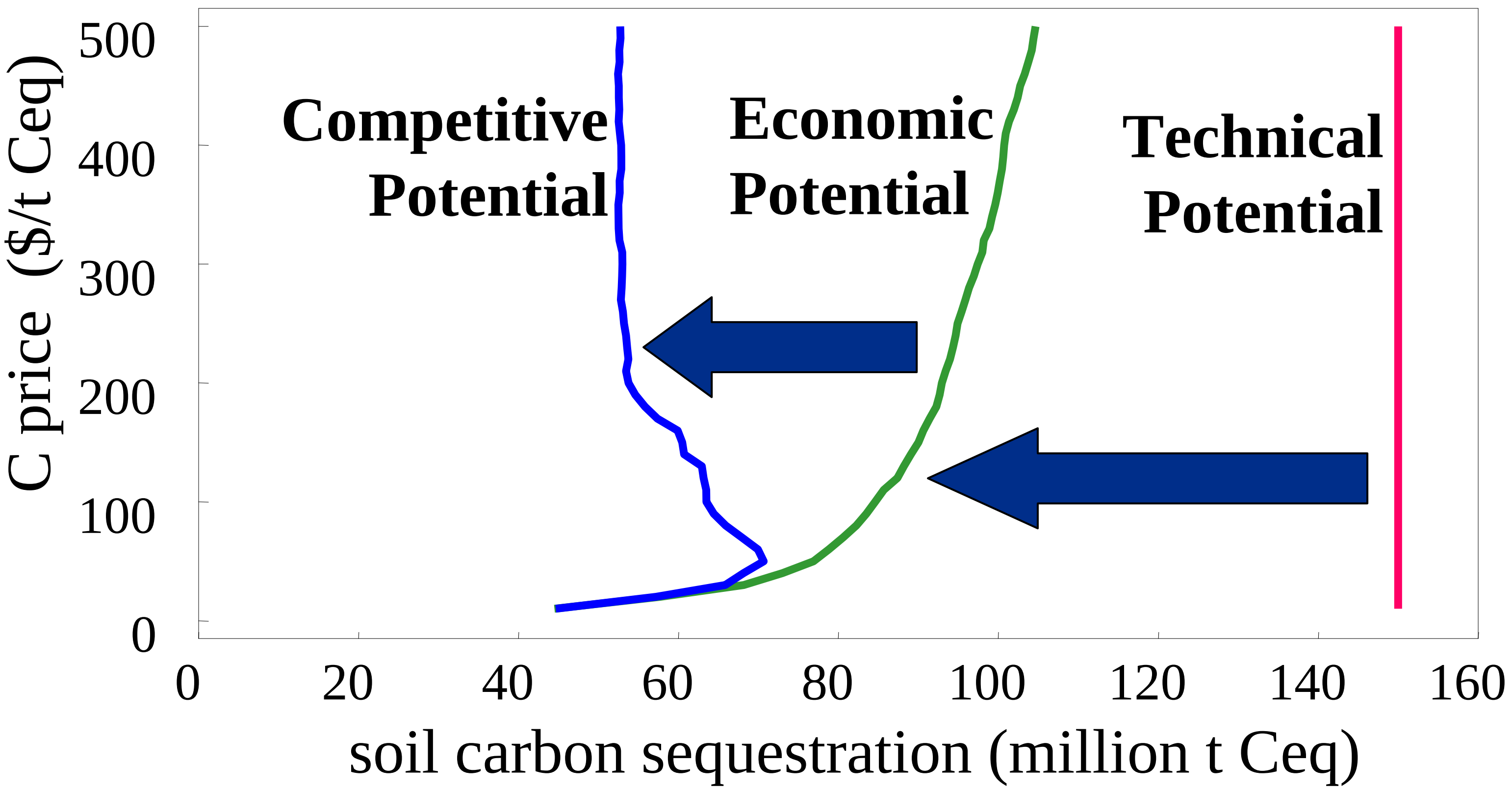
Strategy	Basic Nature	CO_2	CH_4	N_2O
Afforestation	Sequestration	X		
Existing timberland/reforestation	Sequestration	X		
Deforestation	Emission	X		
Biofuel Production	Offset	X	X	X
Crop Mix Alteration	Emiss, Seq	X		X
Crop Fertilization Alteration	Emiss, Seq	X		X
Crop Input Alteration	Emission	X		X
Crop Tillage Alteration	Sequestration	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

Results (U.S. agriculture and forestry)

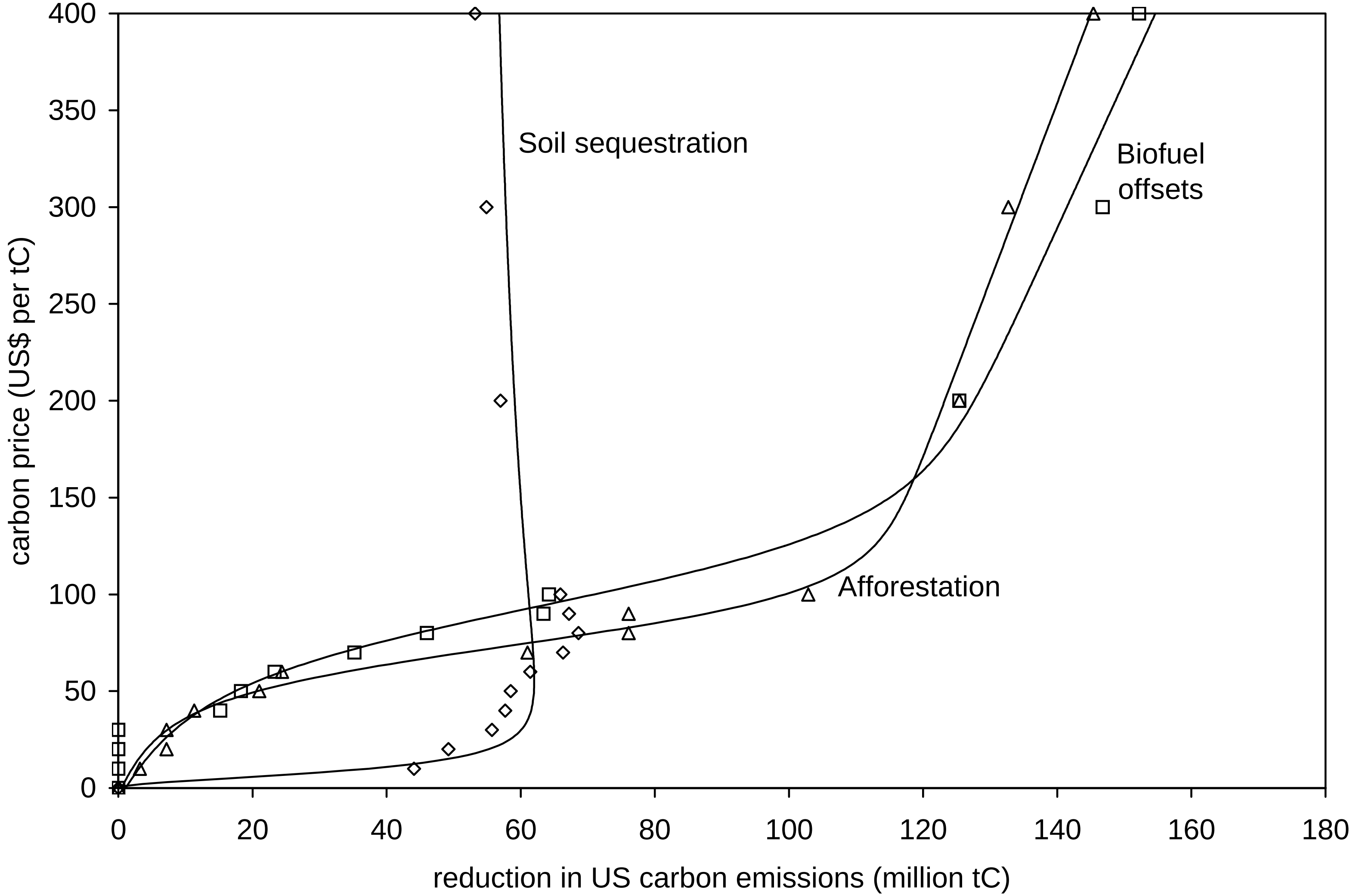
- Methods linking EPIC, CENTURY, and FASOM were developed and used to simulate reductions in net greenhouse gas emissions as a function of carbon price for key activities:
  - Soil sequestration
  - Biofuel offsets
  - Afforestation
  - Reductions in emissions of methane and nitrous oxide
  - Environmental co-benefits

Potential for Sequestration

Example: U.S. ag soil potential:



Examined validity of various estimates of potential



Reduction in U.S. net carbon emissions from three activities simulated in FASOM

Projects: Discounts and Costs

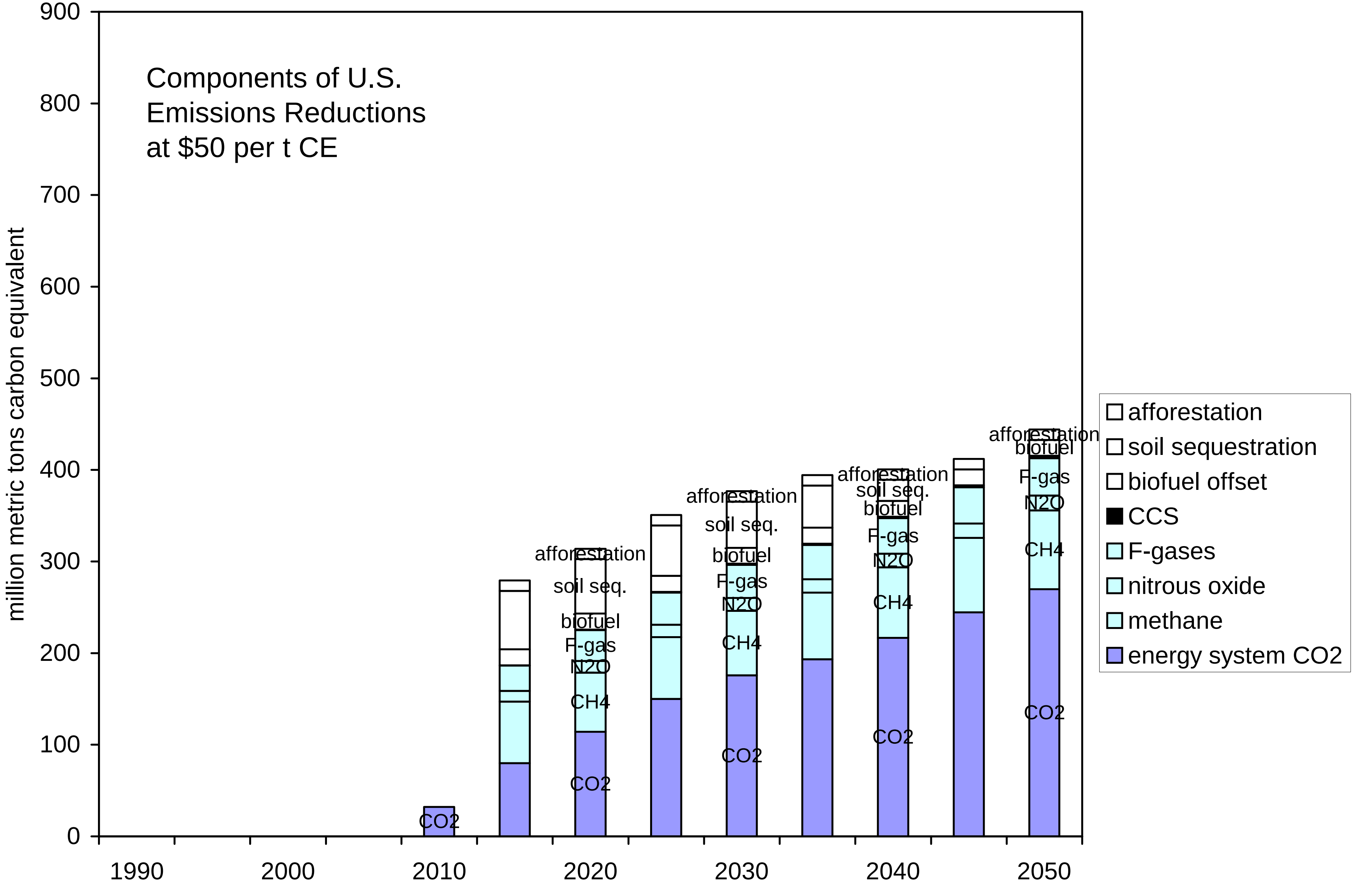
- *Additionality*: credit only for sequestration that would not otherwise have occurred
- *Uncertainty*: variability of sequestered quantity due to climate and other factors
- *Leakage*: market conditions may induce emission increases elsewhere
- *Permanence*: potential for volatility, required maintenance costs, or need to recontract for offsets after a lease expires
- *Transactions costs:* money spent to make projects happen
- *Extra incentive costs*: money to overcome risk aversion, education and reluctance to adopt

Results (comparison with non-terrestrial mitigation options)

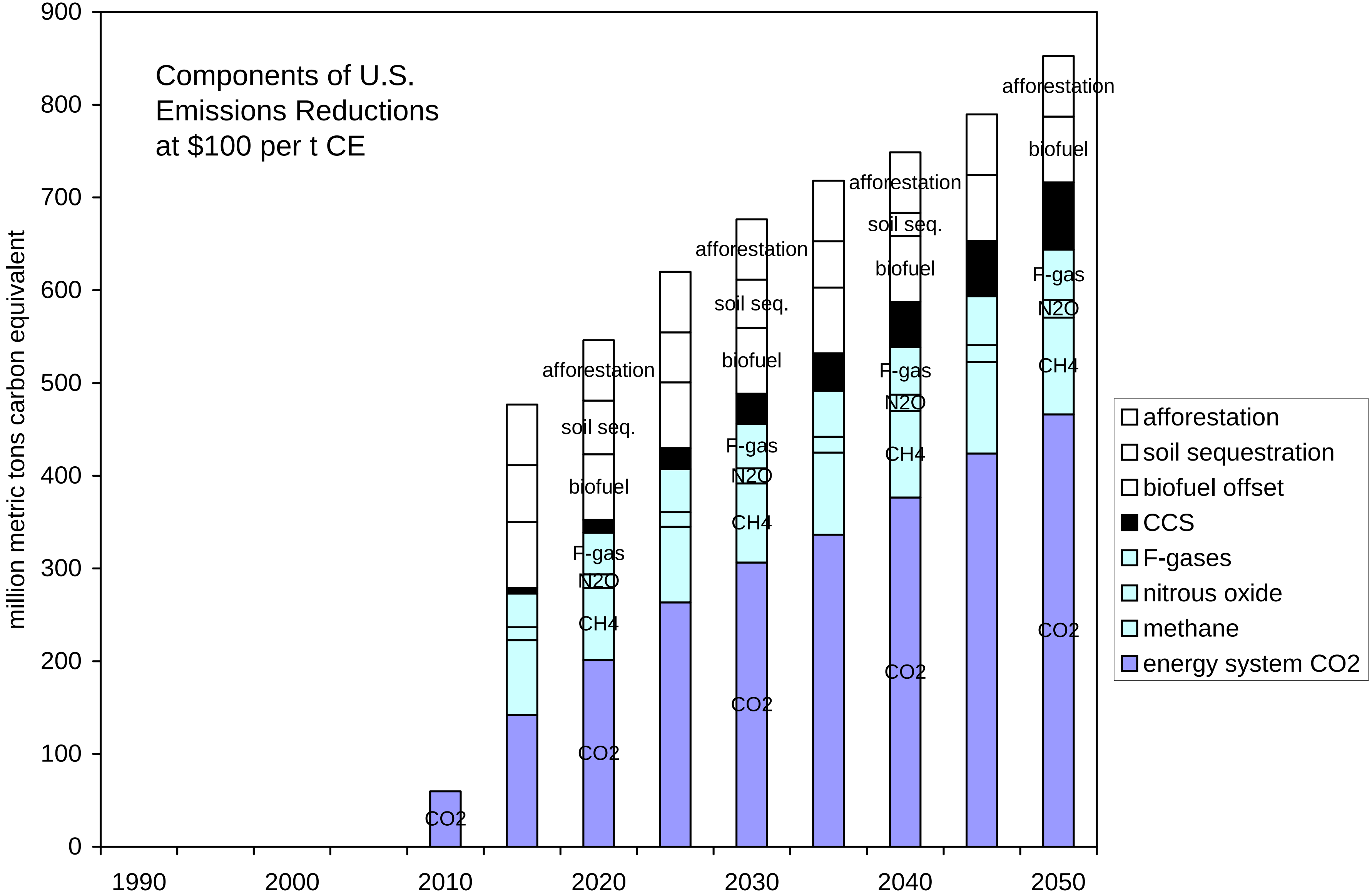
- No single model can simulate all activities and processes
- Develop strategy to determine relative contribution of mitigation options at various carbon prices
  - Marginal abatement cost curves from FASOM reflect spatial heterogeneity across U.S.
  - Dynamics of carbon accumulation
  - Dynamics of capital stock turnover in the energy system
- Simulate a full suite of mitigation options in the United States at $50 and $100 per ton of carbon

Full Suite of Mitigation Options

- Energy System
  - CO_2 emissions from energy combustion; carbon capture and storage (CCS) from electricity generation
  - Battelle-PNNL Second Generation Model
- Non-CO_2 Greenhouse Gases
  - Methane, Nitrous Oxide, F-gases
  - Energy Modeling Forum (EMF-21) baselines and marginal abatement cost curves
- Terrestrial Offsets
  - Soil sequestration, Afforestation, Biofuel Offsets
  - Agricultural Sector Options (McCarl, B.A. and Schneider, U.A. 2001. "Greenhouse Gas Mitigation in U.S. Agriculture and Forestry." Science 294, 2481-2482.)



Components of U.S. Emissions Reductions at $50 per t CE
million metric tons carbon equivalent
900
800
700
600
500
400
300
200
100
0
1990
2000
2010
2020
2030
2040
2050
CO2
CH4
N2O
F-gas
biofuel
soil seq.
afforestation
afforestation
soil sequestration
biofuel offset
CCS
F-gases
nitrous oxide
methane
energy system CO2



Components of U.S.
Emissions Reductions
at $100 per t CE
million metric tons carbon equivalent
900
800
700
600
500
400
300
200
100
0
1990
2000
2010
2020
2030
2040
2050
afforestation
soil seq.
biofuel
F-gas
N2O
CH4
CO2
afforestation
soil sequestration
biofuel offset
CCS
F-gases
nitrous oxide
methane
energy system CO2

Strategic Comparison across Mitigation Options

- Soil carbon
  - Cost-effective in short term at low carbon prices
  - Saturates after 20 or 30 years
- Biofuels
  - Needs $40 or so carbon price
  - Market penetration needs growth and capital stock turnover
  - Never saturates
- CO_2 Capture and Storage
  - Cost-effective at higher carbon prices
  - Limited in short term by turnover of existing capital stock
  - Large future potential
- Non-CO_2 greenhouse gases
  - Cost-effective at low carbon prices
- Energy efficiency
  - Increases along with carbon price
  - Limited in short term by turnover of existing capital stock

Key Publications

- McCarl, B. and Schneider, U.(2001).“Greenhouse Gas Mitigation in U.S. Agriculture and Forestry.” Science 294, 2481-2482.
- McCarl, B. Schneider U., Murray, B., Williams, J. and Sands, R. (2001). “Economic Potential of Greenhouse Gas Emission Reductions: Comparative Role for Soil Sequestration in Agriculture and Forestry.” Proc. of First DOE National Conf. on Carbon Sequestration, May 14-17, 2001, Wash. D.C.
- Sands, R, McCarl, B., Gillig, D. and Blanford, G.(2002). “Analysis of Agricultural Greenhouse Gas Mitigation Options within a Multi-Sector Economic Framework.” Proceedings Sixth Int. Conference on Greenhouse Gas Control Technologies, Oct. 1-4, Kyoto, Japan. (http://www.rite.or.jp/GHGT6/oral4.html#L4).
- McCarl, B., Kim M., Lee H., Murray B., Sands R., and Schneider U. "Insights from Agricultural and Forestry GHG Offset Studies that Might Influence IAM Modeling," in Integrated Assessment of Human Induced Climate Change, edited by Schlesinger, Kheshgi; Smith; de la Chesnaye; Reilly, Wilson and Kolstad, EMF book, 2005.

Significance & Summary

- Two broad classes of mitigation options in terrestrial ecosystems
  - Management of existing land use
  - Land use change
- Potential reductions in greenhouse gas emissions are large enough to matter in national-scale analysis at a reasonable cost
- Special features of terrestrial ecosystems require development of economic models, methods, and links between models
  - Geographical heterogeneity
  - Permanence, saturation, leakage, etc.
  - Economic drivers of land use change