FROM THE MARKET TO THE FIELD: THE IMPACT OF AGRICULTURAL AND ENERGY LINKAGES ON FARMERS' CHOICES

Silvia Secchi
Associate Professor, Geography & Environmental Resources
Director, Environmental Resources & Policy Ph.D. Program
Southern Illinois University Carbondale
ssecchi@siu.edu

Acknowledgements

- This work is supported by:
  - USDA National Institute of Food and Agriculture/Agriculture and Food Research Initiative, Award number 2016-67024-24755.
- It builds on work previously supported by
  - A EPA Region 7 Cooperative Agreement
  - USDA ERS Cooperative Agreements 58-6000-0-0056 and 58-6000-9-0083 .
  - USDA National Institute of Food and Agriculture/Agriculture and Food Research Initiative, Award number 2010-65400-20434.
- Collaborators
  - Rebecca Dodder, EPA ORD
  - Amani Elobeid, Iowa State University
  - P. Ozge Kaplan, EPA ORD
  - Lyubov Kurkalova, NCA&T State University
  - Simla Tokgoz, IFPRI

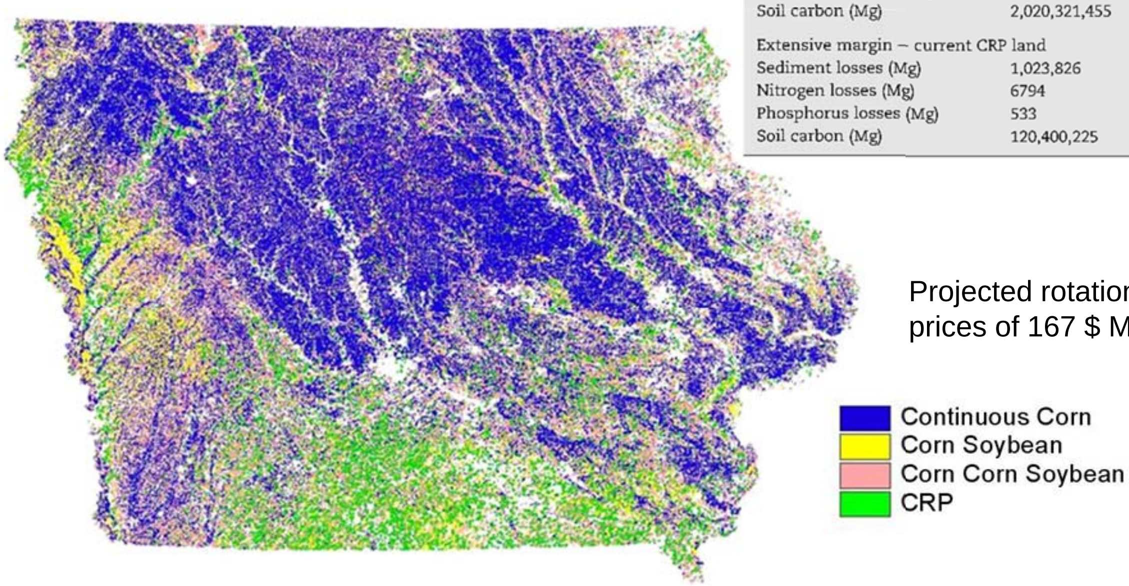
Integrated economic-environmental modeling

Table 2 – Historical and projected land use on the basis of corn prices.

Rotation area	Historic baseline	Corn price 108 $ Mg^{-1}	Corn price 142 $ Mg^{-1}	Corn price 167 $ Mg^{-1}
Intensive margin – current cropland (km^2)				
Corn-soybean	64,389	92,066	38,618	10,717
Corn-corn-soybean	12,944	0	42,784	13,974
Continuous corn	2556	0	10,664	67,375
Extensive margin – current CRP land (km^2)				
CRP	7087	4189	2492	2027
Corn-soybean	0	2898	2952	1050
Corn-corn-soybean	0	0	1501	1561
Continuous corn	0	0	142	2449

Table 3 – Historical and projected environmental indicators on the basis of corn prices.

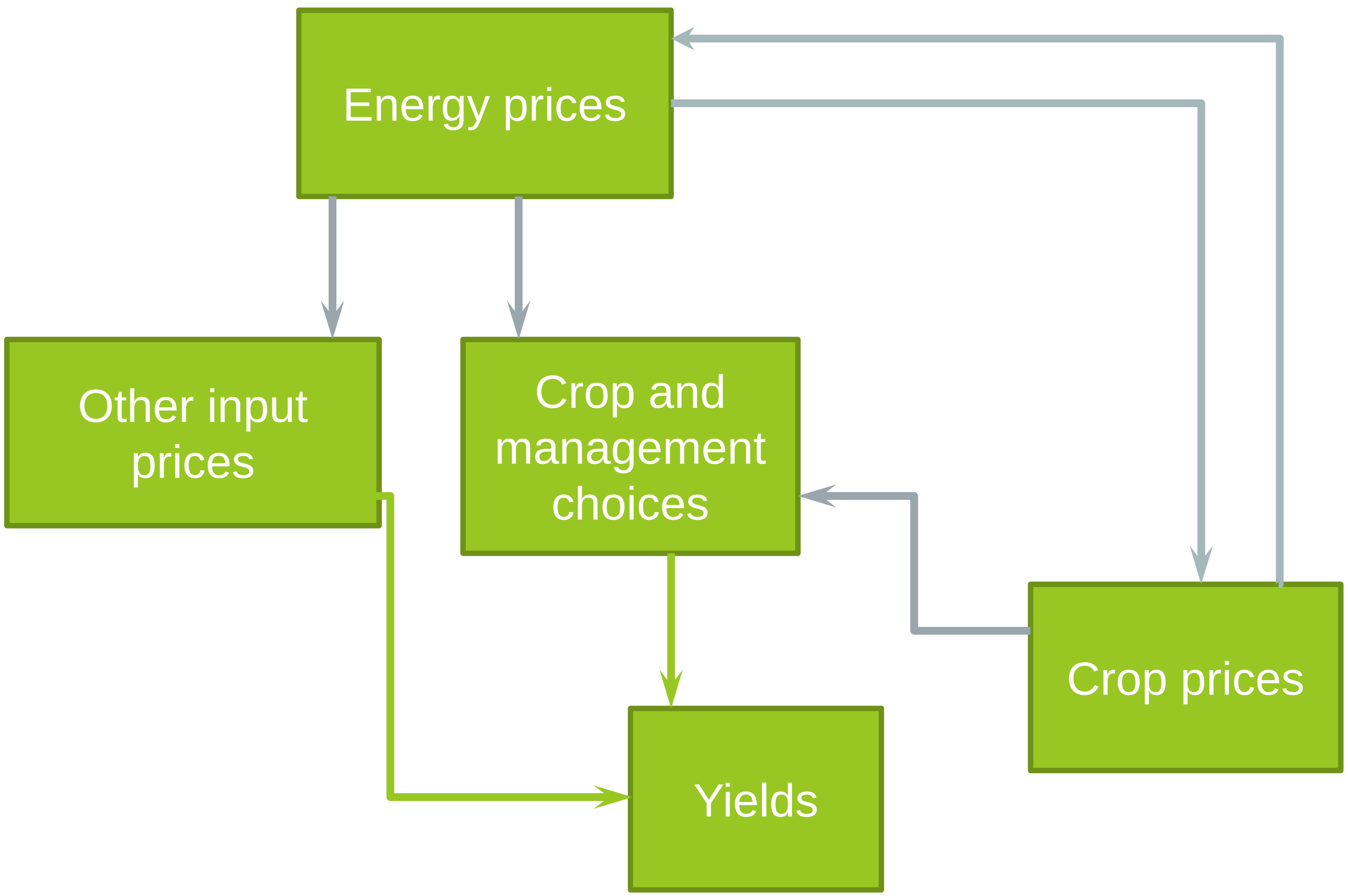
	Historic baseline	Corn price 108 $ Mg^{-1}	Corn price 142 $ Mg^{-1}	Corn price 167 $ Mg^{-1}
Intensive margin – current cropland				
Sediment losses (Mg)	20,041,671	36,413,102	45,601,316	64,457,979
Nitrogen losses (Mg)	545,136	609,732	741,057	934,464
Phosphorus losses (Mg)	19,120	28,020	31,680	34,546
Soil carbon (Mg)	2,020,321,455	1,978,707,457	1,956,628,896	1,935,990,115
Extensive margin – current CRP land				
Sediment losses (Mg)	1,023,826	1,646,552	3,579,939	6,633,448
Nitrogen losses (Mg)	6794	20,861	39,096	57,428
Phosphorus losses (Mg)	533	1167	2175	2862
Soil carbon (Mg)	120,400,225	113,303,996	108,297,841	104,843,115



Projected rotations on the intensive and extensive margin at corn prices of 167 $ Mg^{-1}

Secchi et al. 2011 – Biomass & Bioenergy

The market(s)

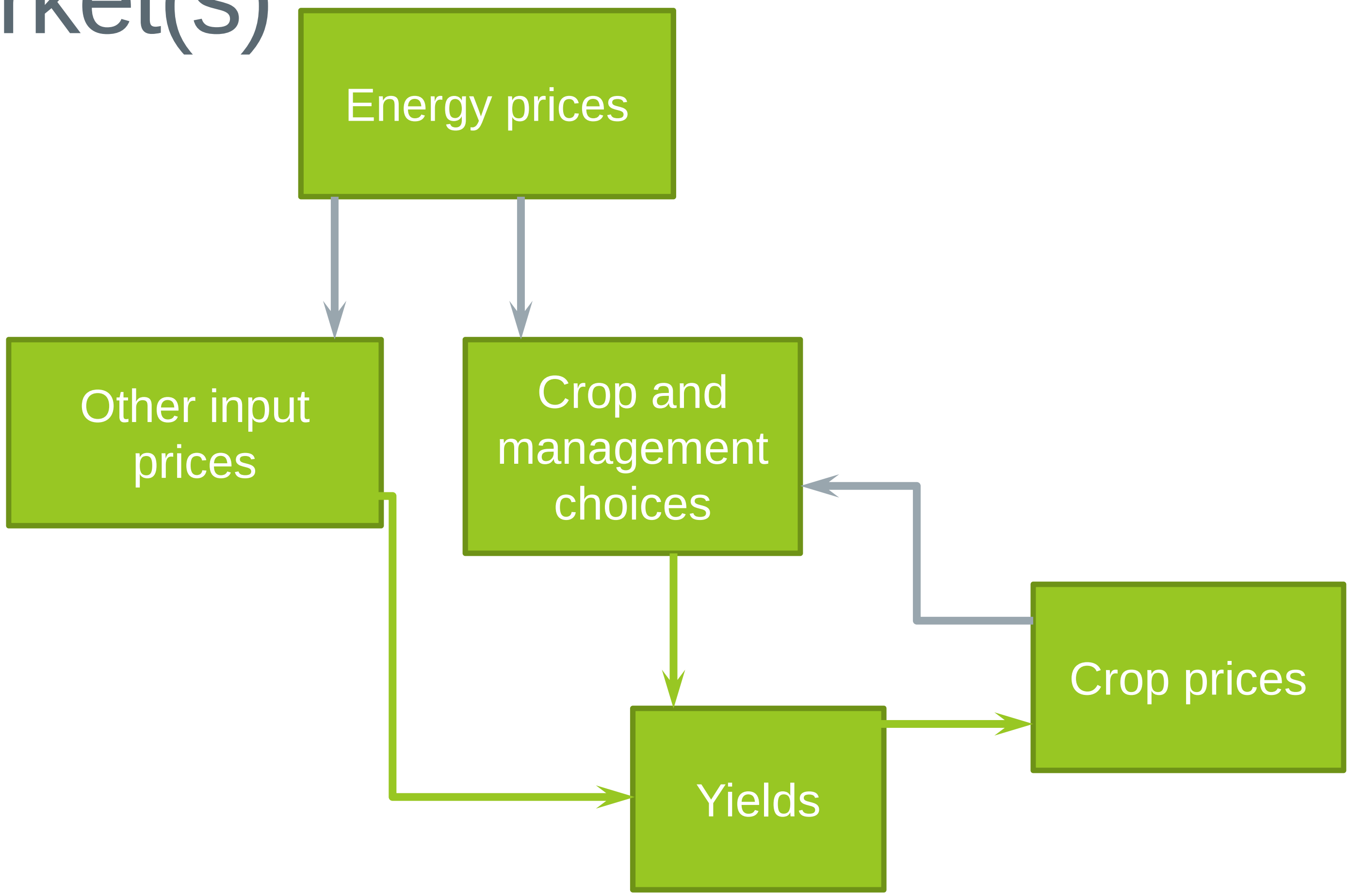


Energy prices
Other input prices
Crop and management choices
Crop prices
Yields

Why is the link increasingly important?

- The historical approach had difficulty capturing the impact of biofuels on supply of and demand for energy substitutes and the resulting feedback to agricultural markets.
  - Biofuel production can move energy prices, and if higher biofuel volumes lower fuel prices, two countervailing effects occur.
    - Lower fuel prices reduce the cost of agricultural production (input cost reduction effect)
    - Lower fuel prices make biofuels less competitive (substitute output price reduction effect).
- The net impact will depend on the relative size of each of these effects.

The market(s)



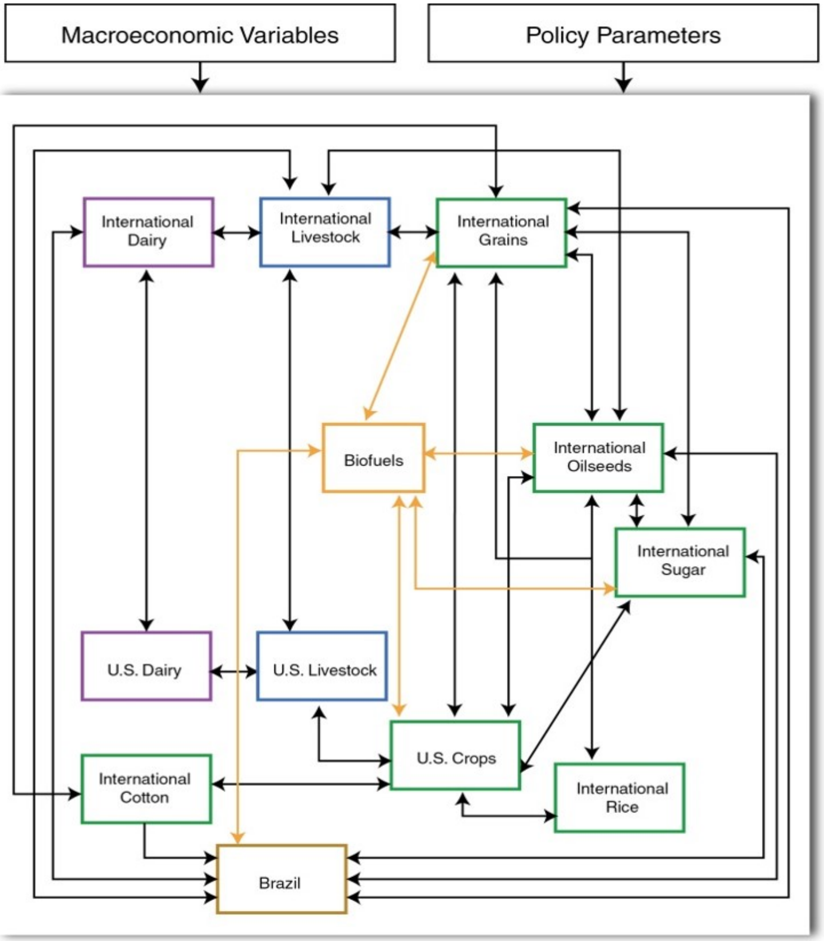
Energy prices
Other input prices
Crop and management choices
Crop prices
Yields

The market(s)

Energy prices

Crop prices

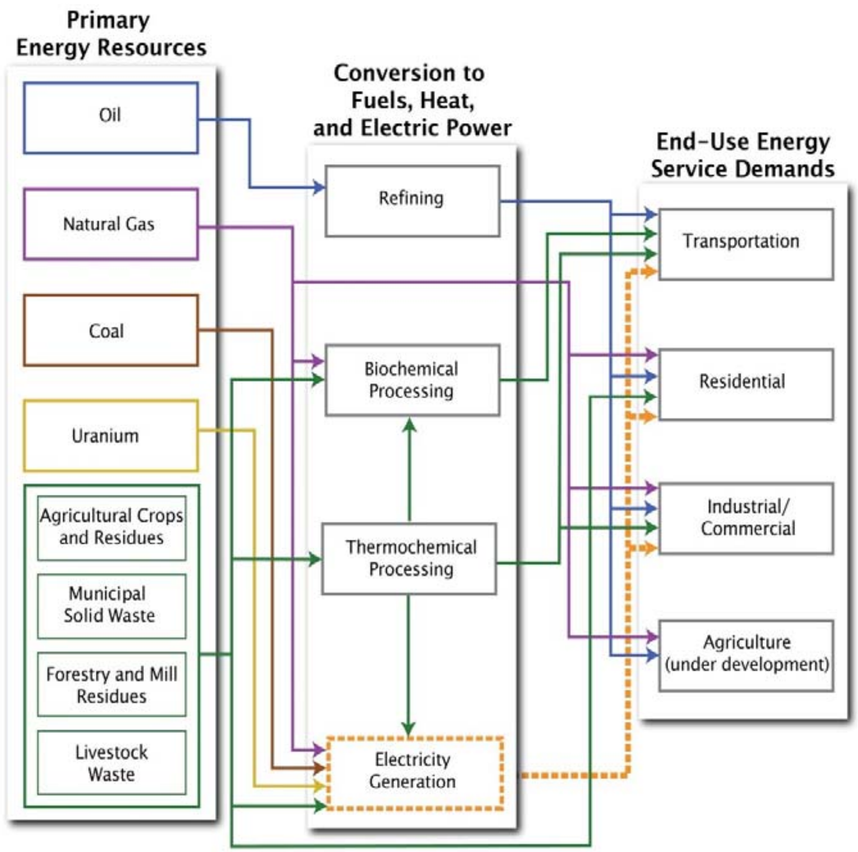
The market(s)



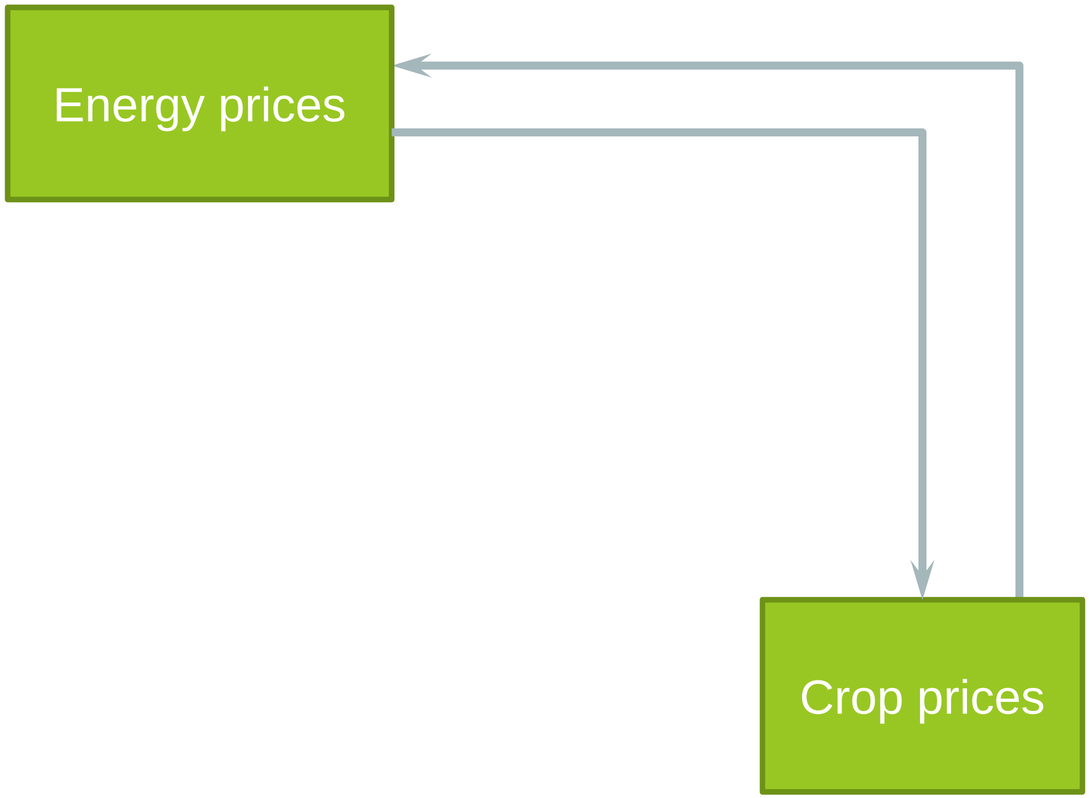
Crop prices

The market(s)

Energy prices



The market(s)



Modeling logic differences

- Optimization models like MARKAL are prescriptive: given assumptions about the energy system, MARKAL determines what a rational planner seeking to minimize total system costs should do over the model's time horizon.
  - MARKAL uses a less conservative time horizon (2050), compared to CARD (2024.
- The different modeling logics reflect both the different historical rationales for the two models and the different structures of the energy and agricultural industries.
- The energy sector relies very heavily on physical capital, and is sensitive to new technologies. Given public support of new technologies has long term ramifications, an optimization approach and long-term horizons are helpful for policy planning.

Macro-level Model Linkages

- The linking of the two modeling systems allows for the endogenizing of variables that would otherwise be exogenous to each model.
- Variables such as ethanol and biodiesel production are endogenous in both models and remain so during iterations.
- The models are iteratively updated to achieve convergence on ethanol and biodiesel production.

Macro-level Model Linkages

- The linking of the two macro-level models was performed in two steps:
  1) Data and information exchanges included coordination of historical data on agricultural crops and biofuels in the CARD model database, coordination of ethanol production costs, ethanol volumes, energy prices, and technological assumptions such as conversion rates from the MARKAL database, and biofuel by-product yield rates from the CARD model.
  2) A "joint" baseline was created by linking the models. As the feedback between the models was endogenized, the joint baseline was different from the two individual baselines.

Macro-level Model Linkages

- Linking the CARD and MARKAL models to allow feedback between the agricultural and energy sectors includes harmonizing data inputs and assumptions in both modeling systems.
- Variables that MARKAL treats as exogenous inputs but are endogenous variables to CARD include corn and soybean production, and input and output prices in the ag sector.
- Variables that CARD treats as exogenous but are endogenous variables to MARKAL are production costs for the corn ethanol market, and energy prices.

Pre- and Post-Linkage Results

	Initial Baseline			Post-linkage (Converged) Baseline		
	Corn	Soybeans	Wheat	Corn	Soybeans	Wheat
Planted area (M ac)	114	68	61	95	74	59
Production (M bu)	18,916	3,164	2,358	15,818	3,349	2,417
Domestic use (M bu)	16,259	2,441	1,356	13,164	2,416	1,327
Feed & residual[a]	6,155	2,247	214	5,389	2,234	168
Fuel alcohol	8,579			6,320		
HFCS	581			535		
Food & other	915		1,056	896		1,075
Seed	28	194	86	24	183	84
Exports (M bu)	2,605	731	1,117	2,662	939	1,203
Ending stocks (M bu)	1,212	221	332	1,493	250	631
Farm price ($/bu)	4.37	10.81	5.86	4.28	9.96	6.37
Var. prod.n costs ($/ac)	301	140	126	320	141	134

Elobeid et al. 2013 Environmental Modeling & Software

Pre- and post-linkage results

- The integrated models produced different results than the individual models.
- Endogenizing the exogenous variables by linking the models is critical by providing important feedbacks between the two systems.
- Keeping the energy sector exogenous in the CARD model tends to overestimate the ethanol supply and demand levels as well as ethanol prices.
- Consequently, there is higher demand for corn as a feedstock for ethanol production, which increases corn prices and bids land away from competing crops.

Scenario analysis

- Oil and gas price shock
- Crop production affected by the changes in energy prices
  - diesel fuel to power planting and harvesting machinery,
  - LP gas to dry harvested crops,
  - nitrogen fertilizer (derived from natural gas) to supply crop nutrients
- Increases in energy prices act as fertilizer, fuel and LP gas taxes, reducing the net returns to farming for energy and/or fertilizer intensive crops
- Impact on conservation tillage

Scenario analysis - baseline versus scenarios for 2025/2026.

	Baseline	High energy prices scenario	% change
Corn M acres	92.5	95.7	3.46
Soybeans M acres	73.5	72.0	-2.16
Corn price $/bu	4.76	4.99	4.74
Soybean price $/bu	11.07	11.21	1.29
Variable production expenditures Corn $/ac	405.21	416.30	2.74
Variable production expenditures Soybeans $/ac	165.36	166.02	0.40
Nitrogen fertilizer price PPI (90-92=100)	399.83	434.86	8.76

Dodder et al. 2015 Energy Economics

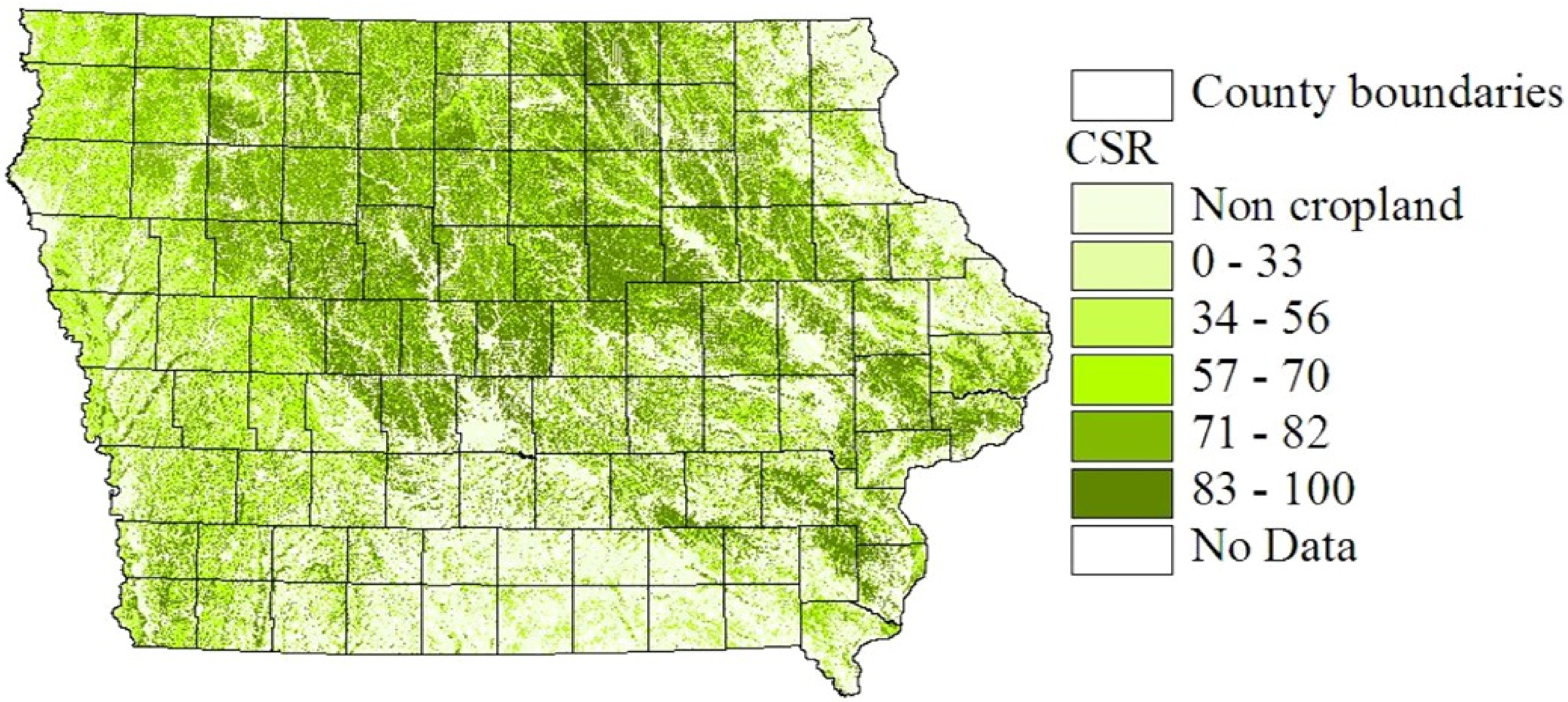
Land Based carbon offsets

- Rationale:
  - A relatively low cost climate mitigation strategy,
  - Known technology – bridge role
  - Potentially high co-benefits
- Payments for Continuous No Till (CNT) are appropriate for heavy production regions such as the Corn Belt.
  - No till can be monitored with remote sensing

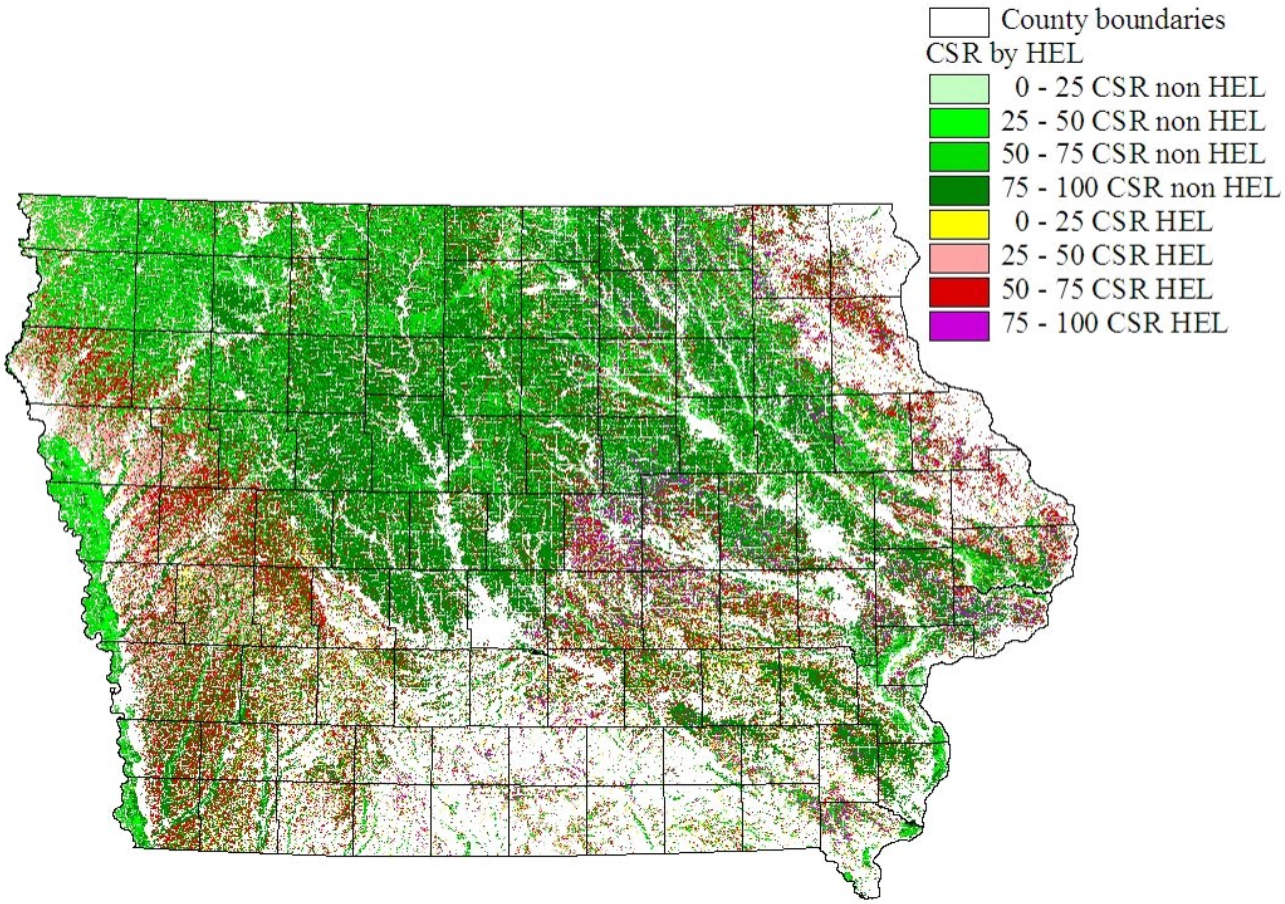
Crop choice modeling

- Soil productivity is measured by the Corn Suitability Rating (CSR), an index from 0 to 100.
- Environmental vulnerability of cropland is measured by the HEL code.
  - USDA Natural Resource Conservation Service classifies cropland as HEL if the potential of a soil to erode, considering the physical and chemical properties of the soil and climatic conditions where it is located, is eight times or more the rate at which the soil can sustain productivity.
- While most of Iowa cropland is of high productivity, most of the cropped HEL is of medium productivity.
- 2009 land use baseline

Crop choice modeling



Crop choice modeling



Assumptions

- Farmers participate in the offset program if it offers as much as the crop rotation that maximizes their net returns
  - N application rate is variable
  - Optimal N depends on soil productivity, prices and yield drags
  - 6 year contracts

Optimization problem

- For each tillage system T used (conventional-1, mulch-2, or no-till-3), the farmer maximizes over the nitrogen rate N
- $\max_N \left(P^C_{2020} Y^C_{2020} - \bar{F}^{C,T}_{2020} - P^N_{2020} N_{2020}\right) = \pi^{C,T}_{2020}$
- $Y^C_{2020} = \alpha_C \tau_k \left(\beta^T_{0,k} + \beta^T_{1,k} N_{2020} + \beta^T_{2,k} N^2_{2020}\right)$
- Y^C is the corn yield,
- The subscript k stands for the crop grown in previous year: corn ($k = C$) or soybeans ($k = S$),
- α_C is the parcel-specific corn yield multiplier,
- τ_k is the previous crop- and tillage-specific corn yield multiplier,
- $\beta^T_{0,k}$, $\beta^T_{1,k}$ and $\beta^T_{2,k}$ are the previous-crop and tillage specific parameters of the yield function
- $\bar{F}^C_{2020}$ are the fixed costs of production for corn for that year

Optimization problem

- For soybeans, there is no maximization since there is no nitrogen application, so profit is
- $\pi_{2020}^{S,T} = P_{2020}^{S} Y_{2020}^{S} - \bar{F}_{2020}^{S,T}$
- $Y_{2020}^{S} = \alpha_S$
- Y^S is the soybean yield,
- α_S is the parcel-specific soybean yield multiplier,
- $\bar{F}_{2020}^{C,T}$ are the costs of production for soy for that year for tillage system *T*

Optimization problem

- Since farmers are comparing rotations, we find the one that maximizes the (expected) PV of profits over six years
- Rotation and management choices are:
  - CC conventional
  - CS conventional
  - CCS conventional
  - CS low till
  - CS mix till
- These are the most common rotations in the state by far
- One off ex ante choice on the basis of expected prices – no renegotiation allowed
  - Penalties for early withdrawal assumed high
  - Monitoring (e.g. via remote sensing) assumed widespread and cheap

Optimization problem

- For CC conventional the PV of profits is:
- $\Pi^{CC,1} = \pi_{2020}^{C,1} + \frac{\pi_{2021}^{C,1}}{(1+r)} + \frac{\pi_{2022}^{C,1}}{(1+r)^2} + \frac{\pi_{2023}^{C,1}}{(1+r)^3} + \frac{\pi_{2024}^{C,1}}{(1+r)^4} + \frac{\pi_{2025}^{C,1}}{(1+r)^5}$
- For CS conventional:
- $\Pi^{CS,1} = \pi_{2020}^{C,1} + \frac{\pi_{2021}^{S,1}}{(1+r)} + \frac{\pi_{2022}^{C,1}}{(1+r)^2} + \frac{\pi_{2023}^{S,1}}{(1+r)^3} + \frac{\pi_{2024}^{C,1}}{(1+r)^4} + \frac{\pi_{2025}^{S,1}}{(1+r)^5}$

Optimization problem

- Inputs from the coordinated CARD-MARKAL modeling system
- $\max_{N}\left(P^{C}_{2020}Y^{C}_{2020} - \bar{F}^{C}_{2020} - P^{N}_{2020}N_{2020}\right) = \pi^{C,T}_{2020}$
- $\pi^{S,T}_{2020} = P^{C}_{2020}Y^{S}_{2020} - \bar{F}^{S,T}_{2020}$

Optimization problem & carbon offsets

- Compare the rotation that maximizes the (expected) PV of profits over six years with the profit from CS low till plus offsets to construct conservation tillage supply curves

- Compare
- $Max\ (\Pi^{CC,1}, \Pi^{CS,1}, \Pi^{SC,1} \ldots \Pi^{CCS,1} \ldots \Pi^{CS,4})$

- With CS no till plus the payment ω :

- $\Pi^{CS,3} = (\pi^{C,3}_{2020} + \omega) + \frac{(\pi^{S,3}_{2021}+\omega)}{(1+r)} + \frac{(\pi^{C,3}_{2022}+\omega)}{(1+r)^2} + \frac{(\pi^{S,3}_{2023}+\omega)}{(1+r)^3} + + \frac{(\pi^{C,3}_{2024}+\omega)}{(1+r)^4} + \frac{(\pi^{S,3}_{2025}+\omega)}{(1+r)^5}$

- Classic "practice" approach

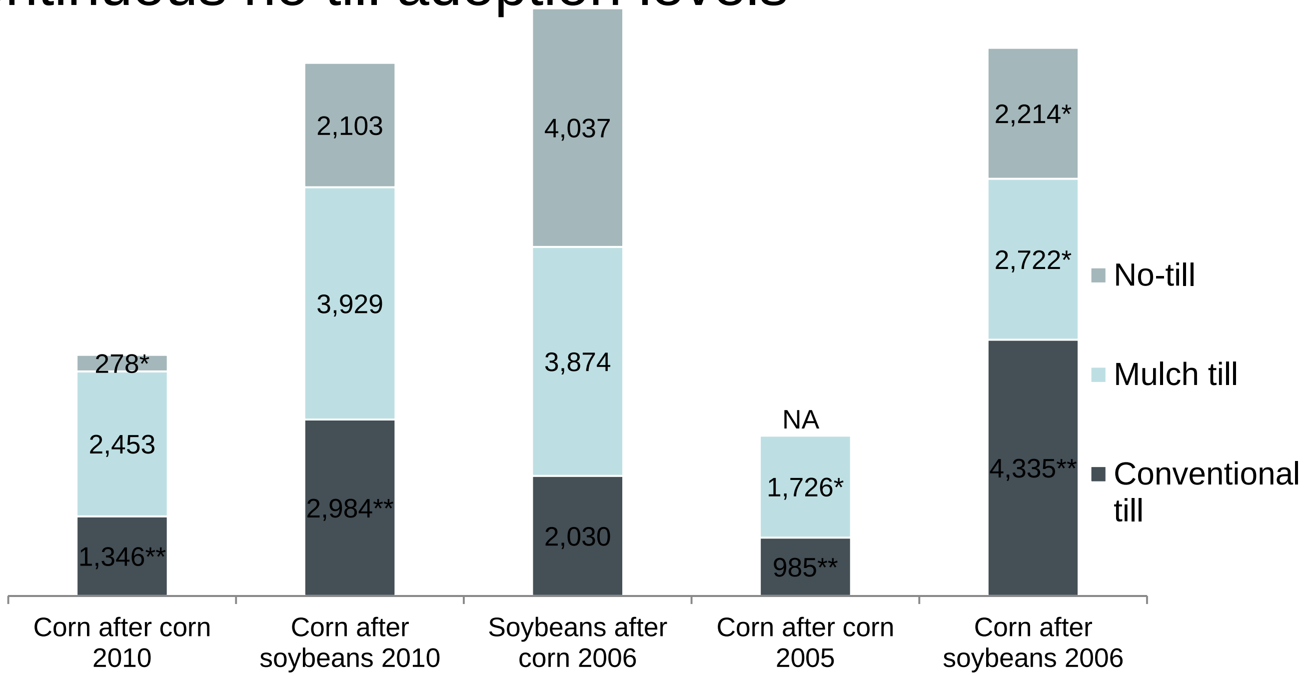
Baseline CNT adoption

- Approximately 35.5 % of U.S. cropland planted to eight major crops had no till operations in 2009
- However, when looking at multiple years of no-till, just 13% of acres in the Upper Mississippi River Basin were in no-till every year over the 3-year survey period - Horowitz et al. (2010), based on NRI-CEAP surveys from 2003-2006

Baseline CNT adoption

- Little information on conservation tillage adoption
  - Small samples
  - No long term recall questions
  - No annual surveys
- Can only infer continuous no till adoption levels

ARMS results on tillage practices in Iowa by crop and previous crop, thousand ac



*- The estimate is statistically unreliable due to the combination of a low sample size and high sampling error.
** - The estimate is a combination of two estimates, with at least one of the estimates categorized as *.
NA - Estimate does not comply with ERS disclosure limitation practices, is not available, or is not applicable..

Randomizing the model

- To capture the variability of costs faced by farmers, the differential costs of no till were randomized.
  - Range of +/-$40 from the deterministic costs
  - Chosen to mimic historical land use/ calibrate to the data
  - Randomization by crop, land productivity and year

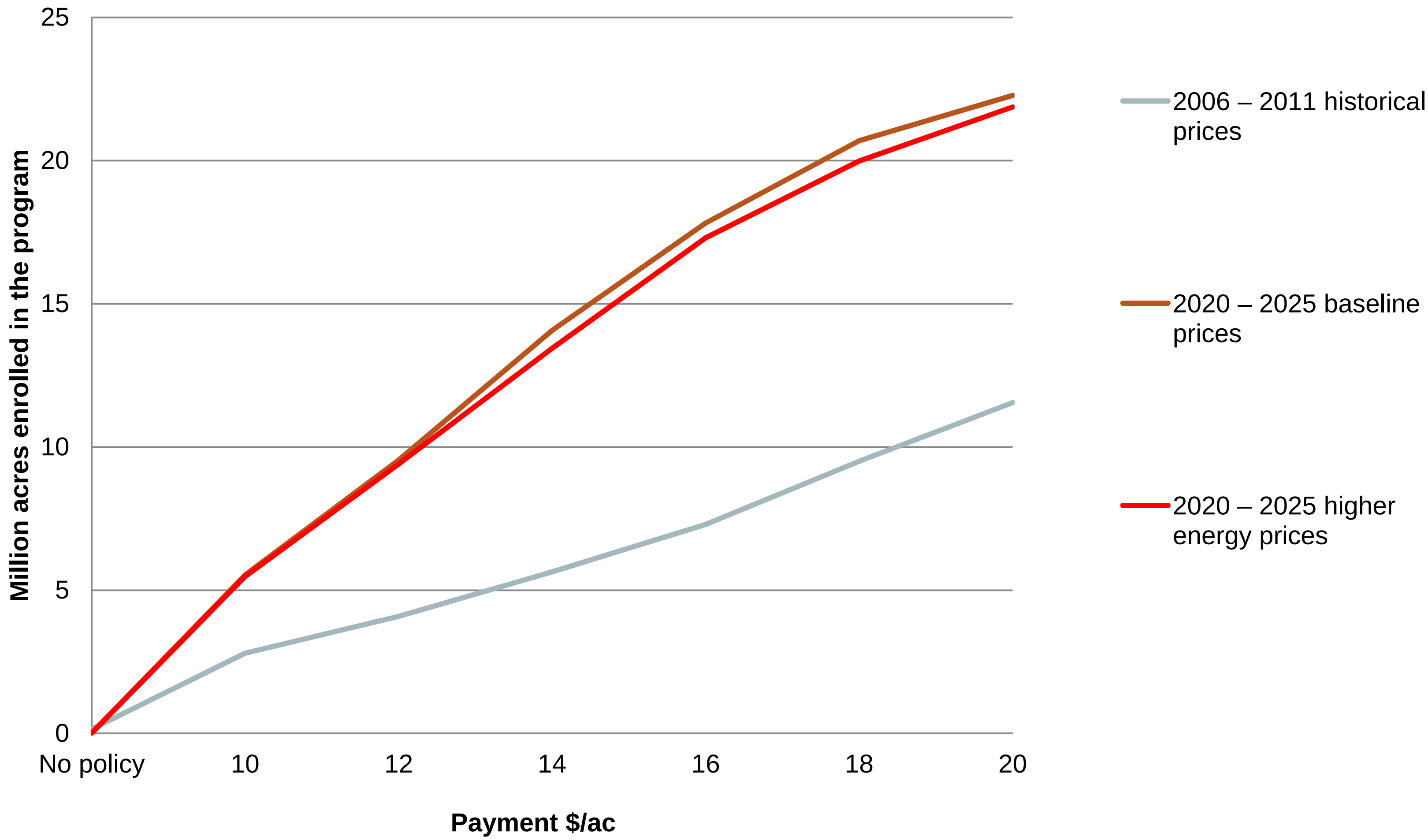
  - $\max_{N}\left(P_{2020}^{C}Y_{2020}^{C} - \bar{F}_{2020}^{C,3} - P_{2020}^{N}N_{2020} - \gamma_{2020}^{C}\right) = \pi_{2020}^{C,3}$
  - $\pi_{2020}^{S,3} = P_{2020}^{C}Y_{2020}^{S} - \bar{F}_{2020}^{S,3} - \gamma_{2020}^{S}$

  - Each land productivity class (100), crop (2) and year (6) simulated 100 times – 120,000 simulations

Randomizing the model

	CC thousand ac	CS no till thousand ac	CS mixed till thousand ac	CS mulch till thousand ac
2006-2011 historical prices	2,455	150	17	21,037
2020-2025 baseline prices	3,377	11	0	20,271
2020-2025 higher energy prices	4,832	4	0	18,823

Supply curves



Conservation Compliance

- To receive subsidized crop insurance, farmers growing crops in Highly Erodible Land (HEL) have to follow conservation compliance practices, no till being one of the primary practices
- Very contentious part of the farm bill
- Not clear at this point if HEL land cropped under no till will be eligible for land-based offsets or if this will be considered double dipping

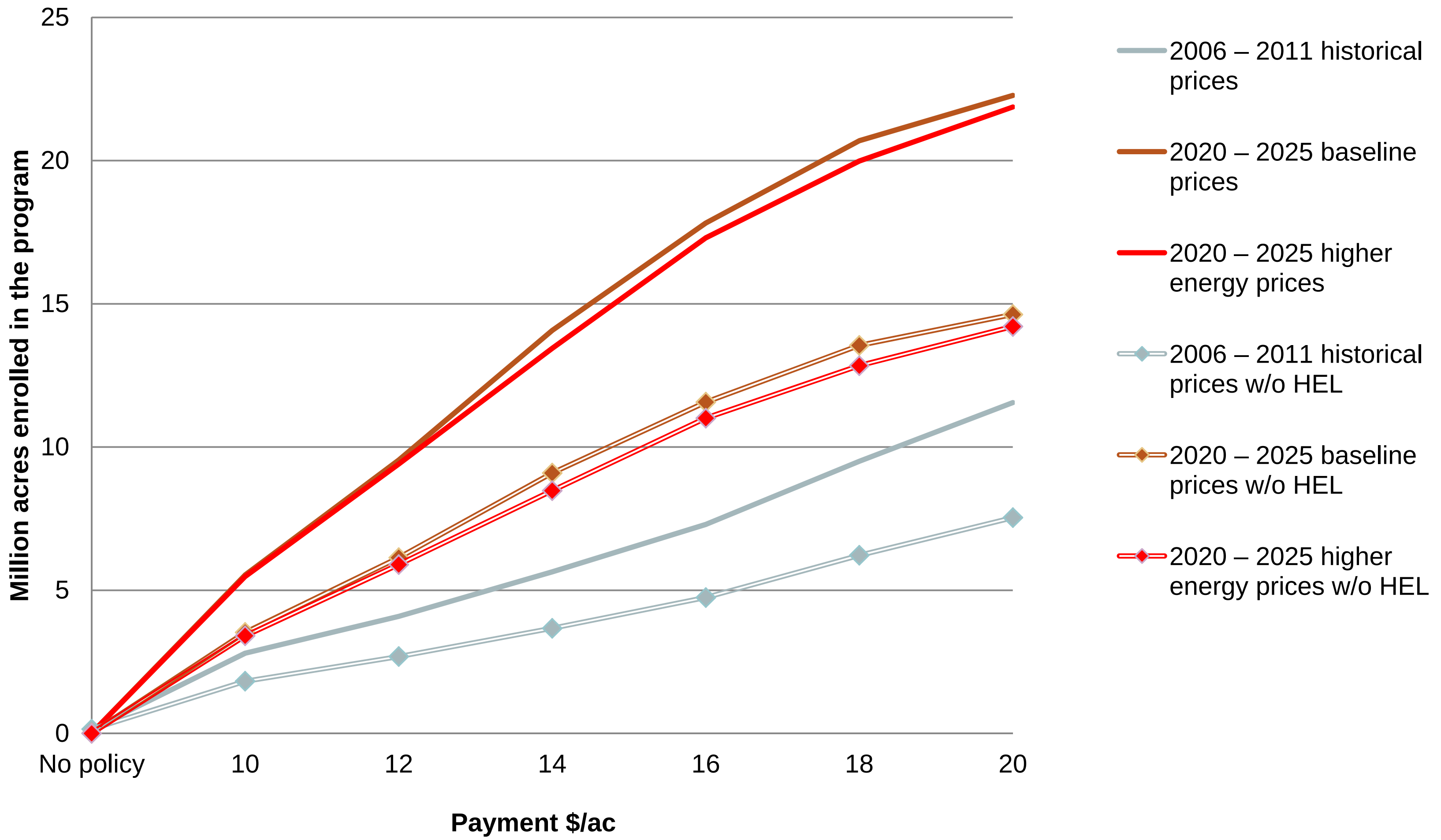
Conservation Compliance

- Conservation compliance not well enforced.
- In 2003, a GAO's nationwide survey found that:
  - Almost half of NRCS' field offices do not implement the conservation provisions as required
  - Sample selection bias - NRCS disproportionately emphasizes tracts with low noncompliance, such as permanent rangelands
  - FSA often waives noncompliance determinations without adequate justification

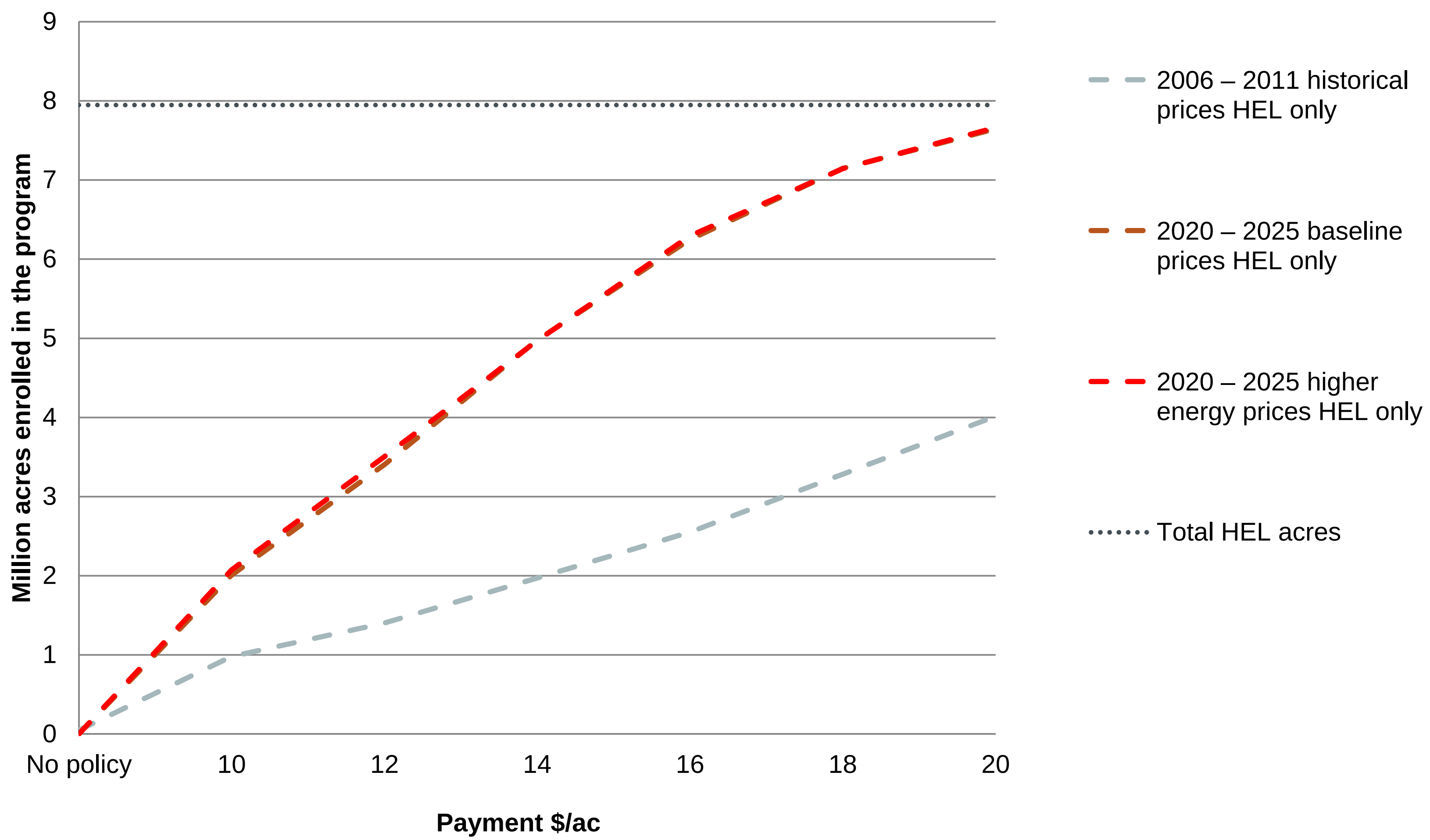
Conservation Compliance

- Two possible program configurations:
  - Payments exclude HEL – CC stays in force
  - Payments to HEL only – targeting if CC disappears

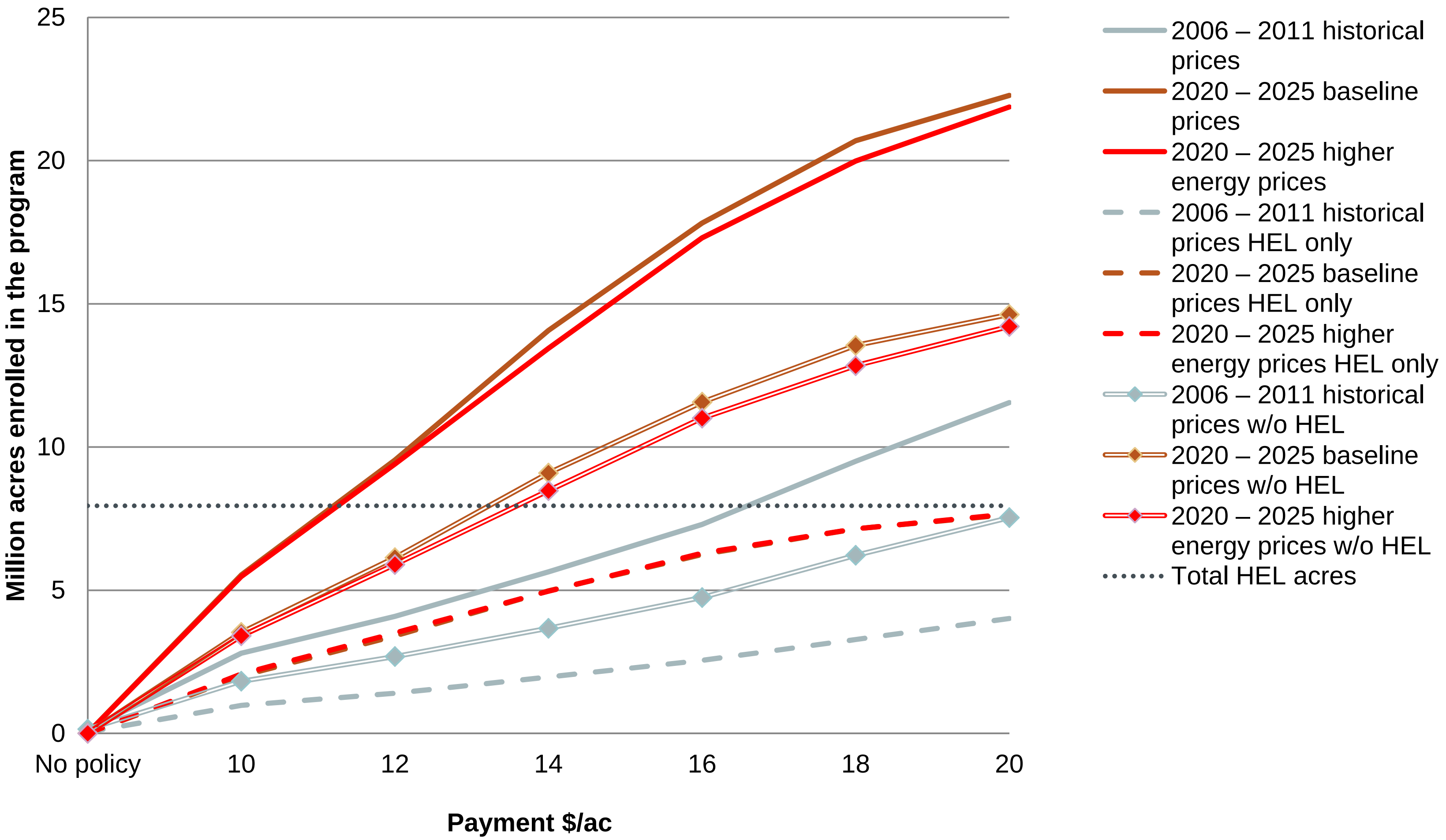
Supply curves w/o HEL



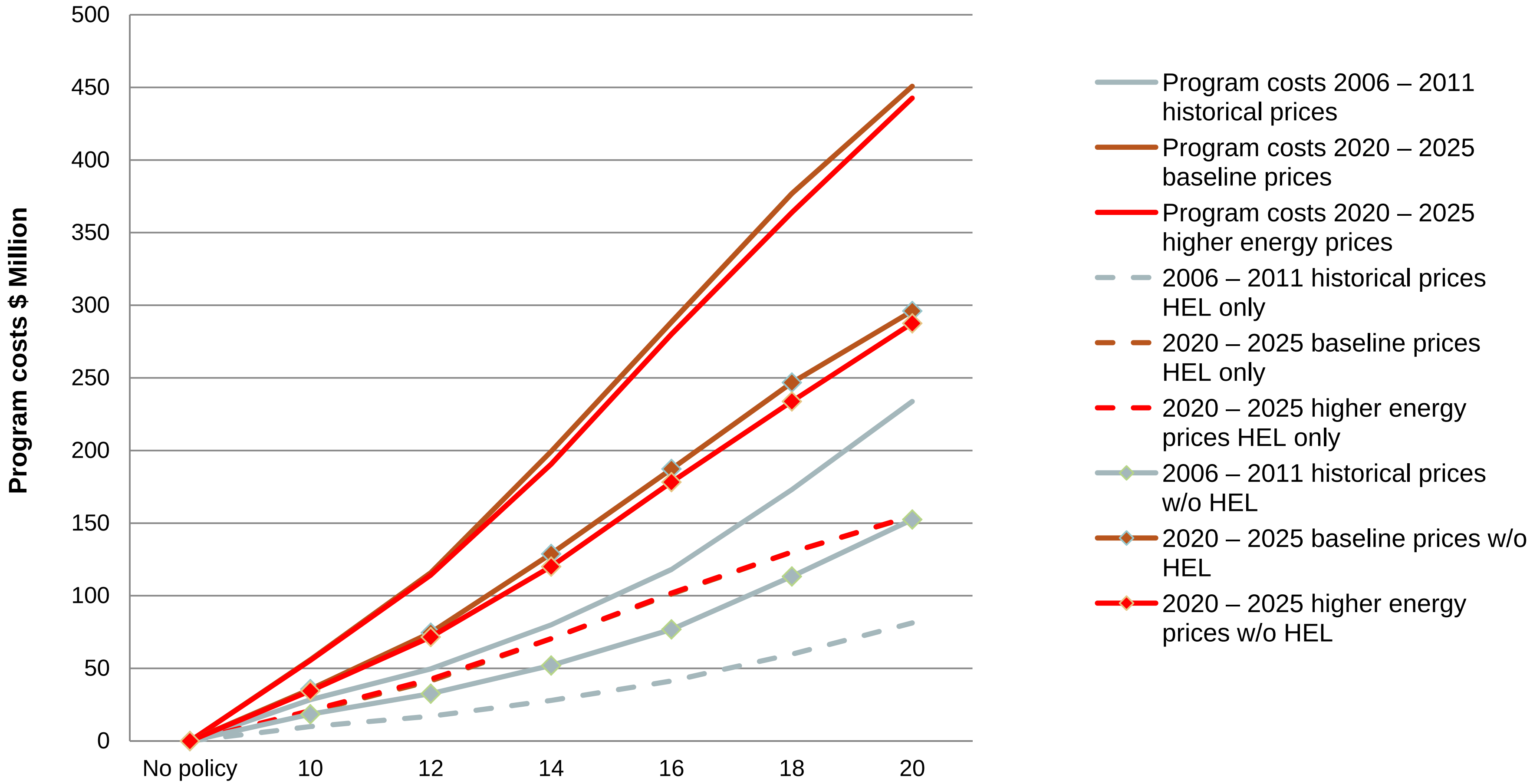
Supply curves HEL only



Supply curves



Program costs



How inefficient are practice-based programs?

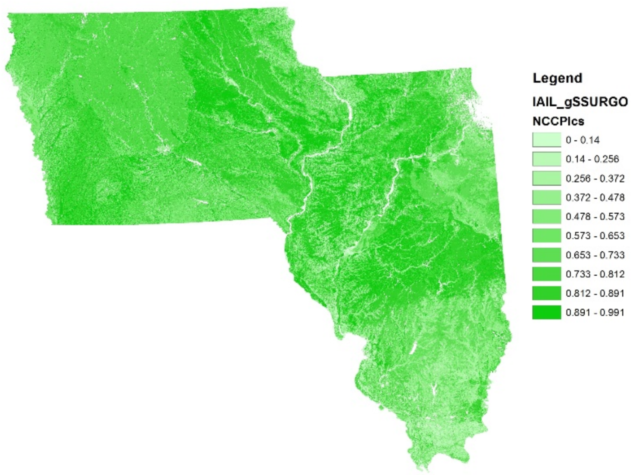
	Historical prices			Baseline			High energy prices		
Payment per ac	Total payments $ million	Total WTA $ million		Total payments $ million	Total WTA $ million		Total payments $ million	Total WTA $ million	
No policy	0	0		0	0		0	0	
10	28	21	73%	56	29	51%	55	28	51%
12	50	33	67%	116	54	47%	114	54	48%
14	80	50	62%	199	90	45%	190	88	46%
16	118	70	59%	288	132	46%	280	130	46%
18	173	96	56%	377	178	47%	364	174	48%
20	234	127	54%	451	225	50%	443	220	50%

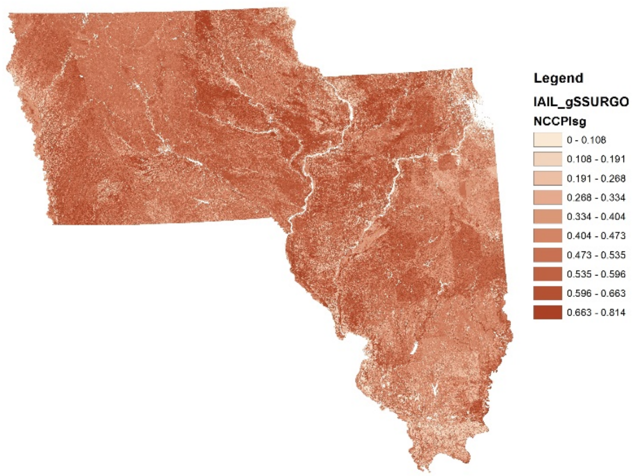
How much carbon is that?

	Carbon sequestered ton/ac	Annual cost per ton of carbon sequestered	Tons of carbon sequestered millions	Additional acres enrolled '000s	PV of the cost per ton of carbon over 20 years	PV of the cost per ton of carbon over 6 years
Historic	2	2.33	6	2,599	62	25
	4	1.17	12		31	13
	7	0.78	17		21	8
Bsl	2	2.25	1	490	60	24
	4	1.13	2		30	12
	7	0.75	3		20	8
Higher energy prices	2	2.22	1	521	59	24
	4	1.11	2		30	12
	7	0.74	3		20	8

Extensions in the works

- Performance vs. practice based payments using EPIC to model carbon sequestration levels
- CSR is an Iowa only soil productivity measure – we can extend this to the whole country using the NCCPI





Conclusions

- Program configuration matters - linkages with CC provisions and commodity title of the farm bill crucial to the results
- Since opportunities costs are key, the linkages with the CARD-MARKAL prices give more realistic foundation to scenario analysis
- The “process” aspects of this project are transferable
  - Strengths and weakness of single models
  - Policy relevant and realistic research questions