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Persistence in Tillage Decisions

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Two Analysis Frameworks

- Equilibrium Modeling of Practice Adoption
  - Typical of ex-ante benefit analysis
  - Supply curves or hurdle rates applied to land allocation models
- Econometric Estimates of Treatment Effects
  - Typical of ex-post benefit analysis
  - Average Treatment Effect of the Treated usually static, but increasingly focused on dynamic effects

Cost Effectiveness

The stochastic and dynamic approach of the econometric framework can lead to very different conclusions about the cost-effectiveness of payments for environmental services.

In this presentation, we will look at this framework applied to conservation tillage.

Research Questions

- Do temporary program payments result in persistent practice adoption?

- Why does persistence matter? A simulation exercise for soil carbon benefits
- Is persistence a general property of no-till adoption? Analysis of Survey Data
- Do we observe post-program persistence in residue levels? Analysis of Satellite and Conservation Program Data

The No-Till Farming Practice

- Conventional tillage eliminates prior crop residue before planting.
- No-till farming involves planting without tillage and leaves crop residue in place (see photo).

Photo by Lynn Belts, USDA NRCS (https://photogallery.sc.egov.usda.gov/res/sites/photogallery/)

Program Participation and No-Till

Overall adoption of No-Till

1990: 20 million acres (Source: CTIC cited in Hill)

1994: 39 million acres (Source: CTIC)

2012: 96 million acres (Source: USDA Census of Ag.)

1996 to 2016: About 4 million acres enrolled in no-till through USDA EQIP. (Exact acreage is difficult to establish in early years.)

Other factors driving the expansion:

- Seed technology (herbicide resistance)
- Planter technology (seeders and drillers)
- Conservation compliance rules for highly erodible land

Literature

- Persistence in consumer preferences (Keane, 2013)
- Long-term tillage sequences (Wade and Claassen, 2017)
- Crop choice and Markov models (Hua et al, 2005; Ji et al., 2015; Wang et al. 2015)
- **Soil carbon and permanent adoption of no till (Antle et al, 2007; Feng et al. 2006)**

The Modeling Literature

- A closer look at Antle et al. 2007 shows key assumptions of the modeling approaching using an ecosystem service supply curve.
  – Greater adoption is costly (the supply curve slopes up)
  – All adoption is additional (any additional adoption above the baseline occurs because of payments)
  – Elimination of payments leads to return to the baseline (there is no persistence)

A Simulation of Soil Carbon Sequestration Costs

- Long-run no-till can remove carbon (CO2) from the atmosphere and sequester it in the soil.
- Soil carbon sequestration faces two challenges:
  - Additionality: The proportion of sequestered carbon that would not have occurred otherwise.
  - Permanence: The carbon must stay in the soil and not be released by future tillage operations.
- How much persistence is needed for no-till payments to be cost-effective sequestration?

Estimating the Cost of Effective Carbon Sequestration

- We examine how persistence and other factors change the average cost of carbon sequestration in a stylized conservation program.
- Key assumptions:
  - Contracts: Annual payments for 3 years of no-till
  - Saturation: Total sequestration over twenty years
  - Baseline: Transition from conventional tillage
  - Additionality: Based on literature for no-till
  - Impermanence: No sequestration for non-persistence

Variation in the Cost per Ton of CO2

Conventional to No-Till Conversion Scenario				
CO2 sequestered		25.67		
Additionality		47%		
		Annual Payment Per Acre		
Permanence		$15	$23	$40
	10%	$37.30	$57.19	$99.46
	50%	**$7.46**	**$11.44**	**$19.89**
	80%	**$4.66**	**$7.15**	**$12.43**

Total CO2 sequestered in tons per acres. Costs in dollars per ton of carbon dioxide equivalent. Only one value is below the current social cost of carbon estimate based on domestic damages (EPA 2018). Bold values are below the former estimate of $42 per ton of CO2 (EPA 2016). Some analysis suggest SCC estimates above $100 (Howard 2015)

Comparison to Modeling Studies

- Contract length:
  - Prior research (e.g.: Antle et al. 2007): 20-year contracts, which have little precedent in existing programs.
  - Current simulation: 3 year contracts (e.g. EQIP).
- Sequestration
  - Prior research: Annual sequestration over life of contract, no modeling of post-contract.
  - Current simulation: Persistence beyond contract.

Findings from Survey Analysis

- Persistence is a feature of No-Till across survey years (observations are “field-years”).
  - No-till: 64 – 90 %
  - Mixed tillage: 43 – 71 %
  - Till: 90 – 96 %
- Prior research suggests that about 10 to 15 percent of the cross-sectional variation is explained by soil and climate (Wade and Claassen 2017, forthcoming).

Survey Evidence on Persistence

- The USDA ARMS Phase 2 survey provides data on long-term no-till adoption.
  - Nationally representative, field-level
  - Targeted crop varies by survey year
  - Captures up to five years of crop history and no-till history for each field
- These data can be used to look at tillage persistence in general. Detailed data on prior conservation program participation are not available for Phase 2.

Limitation of the Survey Analysis

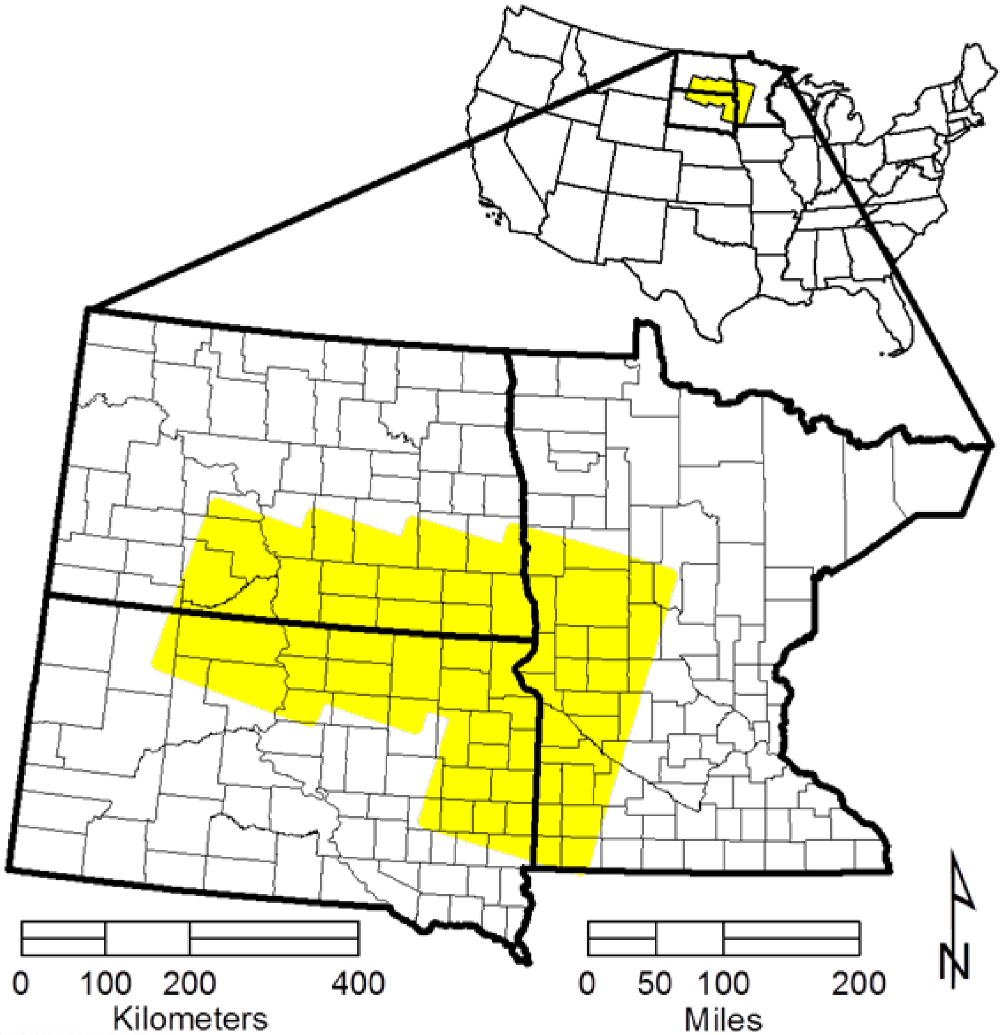
The main limitation of the ARMS survey for evaluating the persistence from program payments comes from three data limitations:

- Five years of tillage adoption is not sufficient time when contracts are three years.
- The survey cannot be adequately linked to data on prior program participation.
- The sample size is small given the likelihood of program participation (statistical power).

Satellite Data Analysis

- USDA ARS and partners have developed methods to estimate residue from multi-spectral satellite image (Daughtry 2006)
- Residue estimates can be used to infer tillage decisions or worked with directly.
- For this project, we developed residue estimates for fields in the Northern High Plains from 2007 to 2016.

Study area focused on the boundaries between SD/ND and SD/MN – 150,000 sq km



Summary of Contracts and Residue (Percent of Field Covered)

	Fields with Contracts			Two-year Average Residue			
				In Contract		Not in Contract	
Year	Before	During	After	Mean	N	Mean	N
2007	337	99	0	.	.	.	.
2008	264	136	8	31.60	111	31.23	246,786
2009	236	143	44	35.34	116	32.78	258,245
2010	131	151	133	37.55	120	32.18	265,533
2011	106	136	175	37.04	108	32.00	271,785
2012	73	129	229	37.82	98	34.39	275,202
2013	45	67	322	.	.	.	.
2014	20	81	331	.	.	.	.
2015	0	63	373	32.36	59	32.30	321,072
2016	0	13	423	43.30	10	32.54	322,283
	1212	1018	2038	35.63	622	32.50	1,960,906

Increases in Residue (%) Persist After Contracts Conclude

	Contract Fields		All Fields	
Variable	(1)	(2)	(3)	(4)
Constant	33.596	31.192	32.503	31.386
	(0.345)	(0.419)	(0.000)	(0.014)
During	2.794	2.586	2.794	2.547
	(0.504)	(0.578)	(0.503)	(0.502)
After	2.727	2.699	2.727	2.458
	(0.514)	(0.912)	(0.514)	(0.514)
2009		3.45		1.454

Dependent variation: two-year average of estimated percent residue. All models estimated with field-level fixed effects. A Hausman test (with non-robust errors) rejects a random effects model with p=0.001. Robust standard errors in parentheses Models (1) and (2) are look at change in residue on fields that have contracts. Models (3) and (4) add the comparison of non-contract fields. Models (2) and (4) add year fixed effects.

Discussion

- Survey data reveal considerable general "structural" persistence in tillage decisions.
- Satellite-based estimates show that program payments are associated with persistent (but modest) increases in residue.
- Obstacles to causal estimates of persistence from program payments include data limitations and controlling for participation endogeneity.
- Higher levels of persistence can make no-till contracts a cost-effective form of sequestration.

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