Policies to Improve Water Quality: In-stream versus Edge-of-Field Assessment

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It is now widely recognized that identical conservation practices put in place on two different tracts of land can have widely divergent water quality effects. Proximity to surface water, differing hydro-geologic settings, variation in rainfall, and other factors contribute to these differences. Despite this recognition, policy assessments have largely been based on edge-of-field models, stopping short of linking conservation practices to ambient water quality.

In this project, we consider the water quality consequences of conservation policies in the Upper Mississippi River Basin (UMRB). We integrate economic models with two biophysical models: one that predicts edge-of-field erosion reductions and one that predicts changes in ambient water quality levels. Our analysis preserves the micro-level heterogeneity of individual landowners' behavior while at the same time incorporating complex watershed biophysical relationships at the watershed and large landscape levels.

Policy Scenario

We consider a scenario in which corn and soybean producers are offered a conservation practice subsidy policy based loosely on a combination of the Conservation Reserve Program and the newly adopted Conservation Security Program. Specifically, we assume that farmers can choose to enroll in a program that would pay a fixed per acre subsidy to retire land from production OR in a program that pays a fixed per acre subsidy to implement conservation tillage practices. The farmers choose between the two programs by maximizing the difference between the subsidy offered and the producer's opportunity cost. If neither subsidy exceeds the corresponding opportunity cost, the farmer does not change farming practices. We assume that the farmer receives the tillage subsidy even if he or she has already implemented conservation tillage practices as a reward for good stewardship. To provide a more complete picture, we estimate the transfer component of the policy examined.

The integrated modeling framework is used to address two policy questions:

1. What are the water quality benefits, measured as erosion reductions, from a conservation policy that offers fixed per acre payments for retirement of land from active production or for adoption of conservation tillage?
2. How do the spatial configurations of environmental benefits differ when measured in-stream versus at the edge-of-field?

Upper Mississippi River Basin (UMRB)

- covers 189,000 square miles (or 492,000 km^2) in seven states in the central U.S.,
- is comprised of 14 U.S. Geological Service (USGS) four-digit watersheds (shown on the map) or 131 USGS eight-digit watersheds,
- is dominated by agriculture: cropland and pasture together account for nearly 67% of the total area (NAS),
- contains more than 1,200 stream segments and lakes that appear on the U.S. Environmental Protection Agency listing of impaired waterways,
- has lakes with the highest concentrations of phosphorous found in the world (Downing),
- is estimated to be the source of nearly 40% of the Mississippi nitrate load discharged in the 1980-1986 period (Goolsby et al.).

Both conservation tillage and land retirement have the potential to reduce sediment loading but at rates and costs that vary considerably across space. To take into account the cost variability, we let the subsidies differ by the USGS four-digit watersheds: the conservation tillage subsidy is set at each watershed's median of conservation tillage adoption costs, and the land retirement subsidy is set at the 20th percentile of land retirement costs in the watershed. Using the combined models, we predict which of the more than 37,500 cropped National Resources Inventory (NRI) points (Nusser and Goebel) in the region will adopt conservation tillage, which will retire their land from production, and which will remain in conventional tillage.

Economic Modeling

To simulate the effects of the conservation policy, we model a producer's choice when he or she has three alternatives: produce with conventional tillage practices, produce with conservation tillage and receive the tillage subsidy, or retire land from production in exchange for the retirement subsidy.

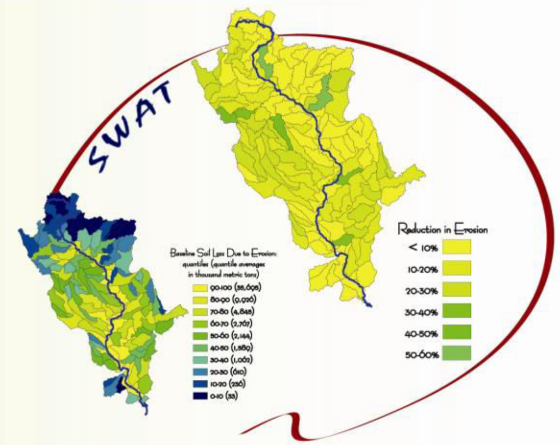
To estimate the opportunity cost of land retirement, we calculate a set of piece-wise linear functions that relate the yield potential to the cash rental rate for each NRI point in the study. Separate functions are estimated for each state and, where possible, for each sub-region. To estimate the opportunity cost of conservation tillage adoption, we employ a discrete choice model that assumes a producer will adopt when the net return to conservation tillage exceeds that of conventional tillage plus a risk premium. Separate adoption models were estimated for each of the 14 four-digit USGS watersheds in the UMRB.

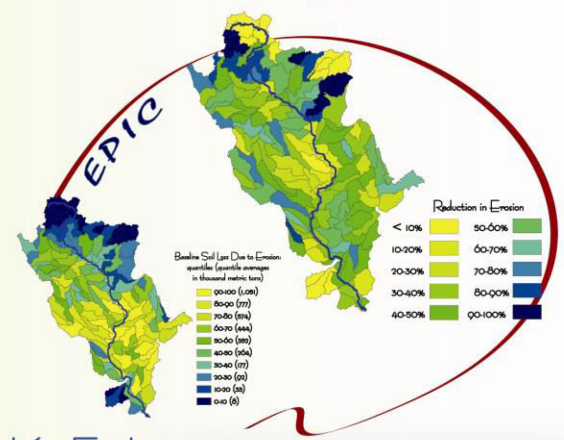
Biophysical Models: SWAT and EPIC

For our analysis, we use two models, one of which gives field-level effects while the other shows watershed-level impacts. The watershed-level model is represented by the Soil and Water Assessment Tool (SWAT) model (Arnold et al.) and the field-level model is represented by the Environmental Policy Integrated Climate (EPIC) model (Williams).

Both models can simulate a high level of spatial details, operate on daily time-step and can perform long-term simulations. However, the models differ markedly in the environmental analysis they provide and in the nature of policy assessments they facilitate. The difference resides in the fact that a field-scale model simply adds up predicted environmental changes at the field level with no consideration of interactions between fields. Watershed-based models, on the other hand, focus on the environmental outcomes at comparatively fewer points, and because they treat watersheds as systems with interacting components, they are highly non-linear.

The baseline erosion figures (shown in the adjacent panel) from EPIC indicate that the watersheds with the highest sediment loss are located primarily in the lower part of the watershed. In contrast, the in-stream SWAT results indicate that the watersheds with more sediment lost at their outlets are clustered around the Mississippi. This difference occurs because of the fundamental nature of in-stream versus edge-of-field measurements (rivers flowing into the Mississippi tend to transport significant sediment) and illustrates the importance of choosing an appropriate model for policy analysis.





Key Findings

The use of an in-stream versus edge-of-field assessment tool predicted starkly different erosion reductions. The EPIC model predicts much larger percentage reductions than does SWAT over most of the watersheds. Thus, using EPIC as a policy assessment tool may indicate larger policy impacts than would SWAT.

The policy implications associated with in-stream versus edge-of-field may differ markedly. An important and evolving policy tool is the targeting of watersheds. These results suggest that the choice of assessment tool will identify different watersheds for such targeting.

Scenario Results

The table below summarizes the results of the scenario by four-digit watershed. Overall, the subsidies average $44/acre for adoption of conservation tillage and $92/acre for land retirement. As columns 2-4 indicate, the policy is highly effective in increasing conservation tillage adoption and inducing land retirement in the region, with the rates of land use change varying significantly across the watersheds. Not unexpectedly, the policy is expensive, with the overall cost exceeding $1.8 billion. However, the largest share of the program cost, over 71% of the total expenditure, is an income transfer, given by the sum of producer surpluses retained by the farmers whose opportunity costs fall below the subsidies.

USGS watershed	Pre-policy conservation tillage adoption rate	Post-policy conservation tillage adoption rate	Post-policy land retirement rate	Program cost (mil$)	Transfers as percentage of program cost
0701	0.15	0.58	0.14	26.8	52.3%
0702	0.16	0.51	0.14	107.7	41.5%
0703	0.14	0.50	0.14	3.8	51.8%
0704	0.38	0.53	0.25	34.3	39.0%
0705	0.22	0.57	0.11	5.4	52.3%
0706	0.78	0.86	0.09	56.6	66.9%
0707	0.37	0.66	0.23	18.8	61.2%
0708	0.69	0.81	0.09	188.8	53.0%
0709	0.58	0.79	0.05	272.8	85.2%
0710	0.46	0.69	0.10	102.3	44.9%
0711	0.49	0.72	0.07	26.4	61.6%
0712	0.52	0.74	0.02	413.0	85.4%
0713	0.45	0.72	0.05	526.4	75.3%
0714	0.46	0.72	0.04	76.1	77.1%
UMRB	0.49	0.71	0.09	1859.1	71.5%

Caveats

Note that there are some important measurement differences across the two models, which may account for some of the disparities in results. Additionally, ongoing calibration and model testing may also result in some differences between these preliminary findings and final results. Please visit our web site to learn more! *www.card.iastate.edu\waterquality*

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