Linking the Economic Costs and Water Quality Benefits of Conservation in Agricultural Lands: An Iowa Assessment

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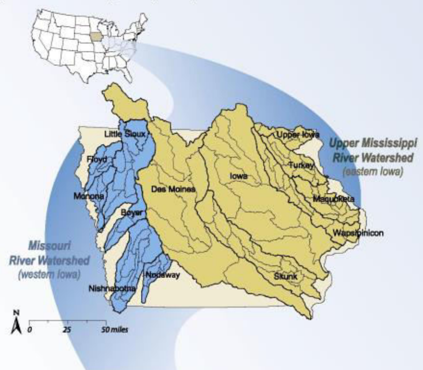
ABSTRACT

An economic and environmental analysis of mitigating cropland nonpoint source pollution was performed for Iowa. The net present value of implementing a set of conservation practices in a 10-year program period was estimated to range from $2.4 billion to $4.3 billion, depending on whether only new adopters or old and new adopters were paid and whether low or high cost estimates were used. The corresponding reductions in sediment, nitrates, total N, and total P across the 13 watersheds were predicted to range from 6 to 65%, 6 to 20%, 15 to 30%, and 28 to 59%.

INTRODUCTION

The USEPA is required to perform a periodic national Clean Watersheds Needs Survey in response to directives that were established in the 1972 U.S. Clean Water Act. As part of this process, an economic and environmental assessment of abating nonpoint source pollution in Iowa was conducted for the Iowa Department of Natural Resources (IDNR) by using economic models and cost data, and the Soil and Water Assessment Tool (SWAT) model (Arnold et al., 1998). The study required (1) calibration and validation of SWAT, (2) selection of conservation practices, and (3) estimation of the total costs and environmental impacts of implementing the conservation practices. The economic analysis was performed for the entire state. The SWAT simulations were run for 13 major watersheds in Iowa that together cover 87% of the state. Full details of the study are presented in Kling et al. (2005).

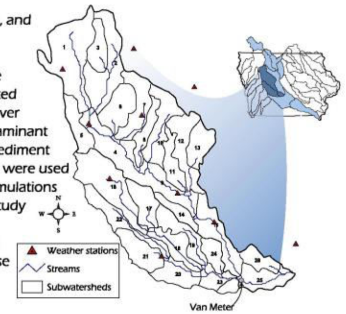


Characteristics of the 13 study watersheds

Watershed	# of 8-digit watersheds	# of sub-watersheds	Drainage area (km^2)	Major land use (%) Cropland	Grassland	Forest	Urban
Floyd	1	5	2,376	84	13	0	3
Monona	1	5	2,452	78	19	2	1
Little Sioux	2	10	9,203	86	13	1	0
Boyer	1	5	2,820	68	26	4	2
Nishnabotna	3	11	7,718	84	15	1	0
Nodaway	1	7	2,051	52	41	5	3
Des Moines	9	9	37,496	71	16	6	7
Skunk	3	12	11,246	69	25	5	1
Iowa	9	9	32,796	77	12	4	8
Wapsipinicon	2	11	6,582	77	19	3	1
Maquoketa	1	10	4,827	56	32	10	3
Turkey	1	9	4,400	56	25	16	3
Upper Iowa	1	7	2,569	51	26	19	3

SWAT CALIBRATION

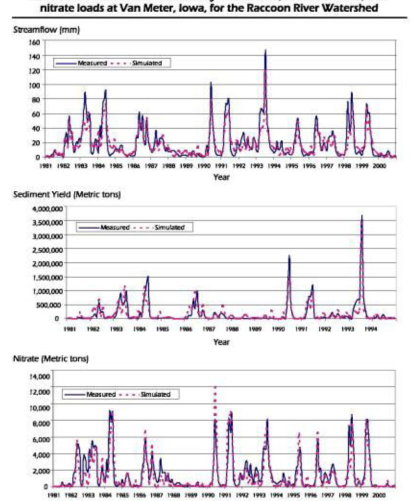
A SWAT calibration and validation exercise was performed for the Raccoon River Watershed. Calibration was carried out for 1981-89 and validation was performed for 1990-2000 (streamflow and nitrate) or1990-94 (sediment) by comparing predicted values with measured data collected at Van Meter. Graphical comparisons, and r^2 and Nash-Sutcliffe modeling efficiency (E) statistics, show that the model realistically tracked most of the Raccoon River stream flows and contaminant losses. The calibrated sediment and nitrate parameters were used directly in the SWAT simulations performed for the 13 study watersheds; additional stream flow calibration was performed for these watersheds.



Predicted versus measured statistics for the Raccoon River calibration and validation

Indicator	Calibration Period (1981-89) Annual R^2	Annual E	Monthly r^2	Monthly E	Validation Period (1990-99) Annual r^2	Annual E	Monthly r^2	Monthly E
Stream flow	0.96	0.95	0.78	0.77	0.93	0.87	0.86	0.82
Sediment	0.90	0.88	0.46	0.44	0.96	0.83	0.91	0.90
Nitrate	0.92	0.82	0.78	0.75	0.77	0.70	0.79	0.75

Simulated versus measured monthly stream flow, sediment loads, and nitrate loads at Van Meter, Iowa, for the Raccoon River Watershed

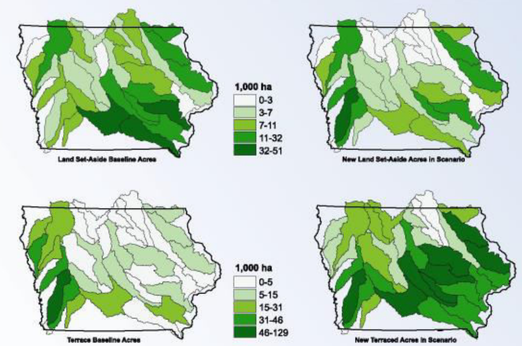


SIMULATION METHODOLOGY AND ESTIMATION OF COSTS

The USDA-NRCS 1997 National Resources Inventory (NRI) database (http://www.nrcs.usda.gov/technical/NRI/) was a key source of land use, soil type, and baseline conservation practice data for the SWAT simulations and economic analysis. A policy scenario was evaluated using a conservation practice algorithm that was selected in consultation with the IDNR. This scenario resulted in a significant increase in the statewide area that would be treated with the conservation practices. The costs were determined based on available data obtained from USDA and Iowa state agency sources, and/or computed with discrete choice economic models; a range of cost estimates was found for some of the practices. The effect of contouring, terraces, and grassed waterways in SWAT was primarily accounted for by adjusting the MUSLE support practice (P) factor.

Conservation Practice Algorithm

- **Step 1.** Retire all cropland within 100 ft. of a waterway
- **Step 2.** Retire more cropland until 10% is retired statewide, based on the NRI Erosion Index.
- **Step 3.** Terrace remaining cropland with slopes above 7% in western Iowa (Figure 1) and 5% for the remainder of Iowa
- **Step 4.** Implement contouring on all remaining cropland with slopes above 4%.
- **Step 5.** Install grassed waterways (GWs) on remaining cropland with 2 to 4% slopes
- **Step 6.** Implement conservation tillage (20% no-till and 80% mulch-till) on all non-retired cropland with slopes ≥ 2%
- **Step 7.** Nutrient management (NM): assume fertilizer rates are reduced on all corn acres by 10%

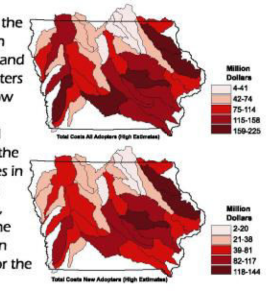


Net increase in land set-aside, conservation tillage (CT), contours, grassed waterways (GW), terraces, and nutrient management (NM) in the scenario by watershed

Watershed	New Set-Aside (acres)	New CT (acres)	New Contour (acres)	New GW (acres)	New Terrace (acres)	NM (acres)
Floyd	5,600	170,500	65,400	197,400	26,700	243,900
Monona	26,100	111,100	43,000	47,400	36,400	222,400
Little Sioux	47,200	454,100	83,100	508,600	97,300	691,400
Boyer	46,300	296,000	38,800	64,200	109,600	233,900
Nishnabotna	129,600	776,600	41,500	121,000	212,700	631,400
Nodaway	16,700	133,800	22,200	46,600	46,100	136,200
Des Moines	98,200	847,700	199,100	1,688,200	559,400	2,635,500
Skunk	63,200	569,000	86,600	447,200	353,100	968,700
Iowa	90,800	1,409,300	302,400	2,157,800	713,900	2,898,700
Wapsipinicon	29,300	314,900	56,900	485,400	111,400	703,100
Maquoketa	42,400	301,800	33,200	241,600	182,800	468,900
Turkey	38,100	249,000	27,100	291,900	192,700	410,800
Upper Iowa	18,800	149,100	15,700	72,200	67,600	116,400

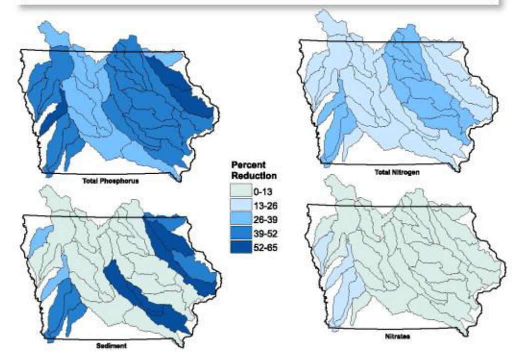
RESULTS

The projected upper and lower bound estimates of the total annual costs of implementing the conservation practices over a 10-year program period were $2.4 and $4.3 billion, depending on whether only new adopters or old and new adopters were paid and whether low or high cost estimates were used. The costs varied significantly among watersheds. Land set-aside and terraces were the most expensive practices, due to the high cost of these practices. The predicted decreases in sediment, nitrates, total N, and total P across the 13 watersheds were predicted to range from 6 to 65%, 6 to 20%, 15 to 30%, and 28 to 59% respectively. The impacts of the scenario on the pollutant losses again varied significantly among watersheds, especially for the estimated reductions in sediment losses.



Program costs by practice ($ millions)

Acreage category	Land Set-Aside Costs	CT Costs	Contour Costs (high)	GW Costs (high)	Terraces	NM	Total Costs (high)
New acreage	315	150	42	142	1,712	121	2,482
Existing acreage	640	324	73	40	709	0	1,786
Total acreage	955	474	115	182	2,421	121	4,268



CONCLUSIONS

The results of this study suggest that the costs of reducing nonpoint source pollution in Iowa could be very high, and that additional research is needed to accurately estimate such costs at both state and national levels. The modeling system used for this analysis proved to be a generally robust tool for estimating the costs and environmental impacts of mitigating cropland nonpoint source pollution in Iowa. This initial analysis does not begin to address all the potential practices that could be used to improve water quality, such as wetlands and riparian buffers. Thus it is probable that the algorithm does not result in the most cost-efficient set of conservation practices or the most effective approach for reducing pollutant loads. There is also a lack of clarity regarding what the desired target pollutant levels should be in streams, which needs to be addressed for future studies.

REFERENCES

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